Research Highlights

2016-2017

Variety improvement

The main objective of the Plant Breeding Division, BARI is to develop high yielding maize varieties as well as minor cereal crops varieties (barley, millets and sorghum) with a view to enhance maize and minor cereal crops productivity in Bangladesh. Development of climate resilient maize variety has been given the highest research priority under the content of global climate change. Emphasis has also been given to develop nutrition enrich maize varieties. Molecular research is going on to identify abiotic as well as multi stress tolerance mechanism. The performance of newly developed maize hybrids from national and international sources specially CIMMYT are being evaluated under different growing environments across the country and promising hybrids superior to the standard check varieties are selected. In addition, research thrust has been put forward towards developing new hybrids, inbred development and seed production.
Development of drought and salt tolerant barley (hulled and hull-less) as well as millets are also emphasized. Priority has also been given to disseminate and popularize developed technologies among farmers and private agencies through block demonstration, farmers training, workshop, field days, publications etc.

A. Collection, characterization & maintenance of germplasm

Maintenance and seed increase of promising inbred lines of maize

Inbred lines represent a fundamental resource for producing maize hybrids. The quality of hybrid seed greatly depends on field production methods, both in adherence to quality assurance standards and implementation of appropriate agronomic management. Inbred lines are the result of repeated self-pollination of particular maize populations to produce a plant that essentially has a fixed and uniform genetic composition.
One hundred sixty five exotic inbred lines of field corn from the International Maize and Wheat Improvement Center (CIMMYT) were maintained through selfing carefully by hand pollination. Total 1188 number of selfed ears were harvested from different inbred lines and preserved separately for future breeding program.

B. Development of source population & inbred lines

Development of base population in maize (2 sets)

The source population development is very important for the development of elite inbred lines. Elite inbred lines are important for the development of superior hybrids in maize. For making our own source of germplasm, a mixture of 39 top yielding commercial maize hybrids of 6^{th} cycle were planted in two sets (two groups) in isolation condition. Each of the groups contained 100 selected selfed ears which were selected in previous year. The desirable selfed bulk seeds from each set were selected based on two groups, viz. (i) medium height and high yield goal and (ii) dwarf, earliness and medium yield goal. For next cycle of selection and inbred development from desirable plants, finally 100 selfed ears were selected separately from each of the two groups based on the specific objective and preserved them carefully for next year selection.

Recycling for development of maize inbred lines (1 set)

Extraction of superior inbred lines through recycling is a common technique in maize breeding. Seeds of commercial hybrid IM8119 field corn were grown to advance from S_0 to S_1 generation. The selected plants were selfed by hand pollination carefully. Finally 120 selfed ears of S_1 were selected, dried properly and kept separately in store for advancing S_2 lines in the next rabi season.

Advancing S_1 to S_7 generation of field corn, popcorn, baby corn and sweet corn (24 sets)

Inbred line development from commercial hybrids following selfing is an common technique in maize breeding. The balanced bulk selfed seeds of S_1 sweet corn (20 S_1 lines of Dream sweet, and 12 S_1 lines of Dream sweet 3) were advanced to S_2 generation. Among them 78 and 22 selfed ears were selected from Dream sweet and Dream sweet 3, respectively & preserved separately for advancing them to next generation and used them for testcross hybrid production.

The balanced bulk seeds of S_2 baby corn (Baby star, 20 lines) and field corn (IM 8013, 30 lines) were advanced to S_3 generation. Variations were found among the S_2 lines for different traits. The selected S_2 plants in each line of each set were selfed and finally 115 and 87 selfed S_3 ears of Baby star and IM 8013 were preserved for advancing them to S_4 generation and development of test cross hybrid.

Nine sets of S_3 lines (Set I: Early and dwarf line, Set II: Medium height and high yield, Set III: Swiss pop corn, Set IV: Titan, Set V: 9120, Set VI: Multi parent synthetic line-Ishurdi, Set VII: Multi parent synthetic line-Barisal, Set VIII: Multi parent synthetic line- Gazipur) were advanced to S_4 generation following ear to row method. Variations were found among the lines for different traits. The selected S_4 selfed ears were stored separately for advancing them to S_5 generation following ear to row method in the next rabi season.

Three sets of field corn hybrids viz. Arun (15 lines), 981(25 lines) and Pinnacle (30 lines) and one set of popcorn variety viz. Popcorn Nepal (21 lines) were advanced to S_5 generation in order to develop superior inbred line(s) following ear to row method. Variation was found among the S_4 lines of each set for different traits studied. Selected S_4 plants were selfed and S_5 seeds were collected for advancing them to S_6 generation.

The S_5 lines of two field corn hybrids 981 (30 lines) and Pioneer (40 lines) were advanced to S_6 generation following ear to row method. The plants were seemed to be mostly uniform in height. Selected S_5 plants were selfed and finally 184 and 175 ears for 981 and Pioneer were preserved for next generation advancing.

Three sets of S_6 lines of field corn varieties viz. 7074, 981 and Local Germplasm (LG) and two sets of popcorn varieties PCB10 and Thai pop corn were advanced to S_7 generation in order to develop superior inbred lines following ear to row method. This is the final stage of inbred development through recycling. There was no variation among the lines in plant height and those were supposed to attain uniformity and homozygosity. These fully developed inbred lines would be used in hybrid development.

C. Evaluation of inbred lines

Study on genetic diversity in new maize inbred lines

To assess the divergence among 47 genotypes in maize, Mahalanobis D^2 statistics was applied based on 10 yield and yield contributing traits. The genotypes were grouped into 5 clusters, where cluster I was the largest containing 16 genotypes followed by cluster IV with 11 genotypes, cluster V with 9 genotype and cluster II and III with 7 and 4 genotype, respectively. The maximum inter cluster distance was observed between cluster II and cluster III (D^2=8.05); and cluster II and cluster IV (D^2=8.05) indicating wider genetic diversity among genotypes in these groups and lowest between cluster I and cluster V (D^2=3.94). While, Intra cluster D^2 value was maximum in cluster II (0.46). Cluster I exhibited highest mean values for most of the traits. The crosses involving parents/inbred lines from most divergent clusters were selected which could be intercrossed to obtain high heterotic expression.

Evaluation of inbred lines of field corn through line × tester method (6 sets)

In set I, twenty selected inbred lines of field corn were crossed with 2 testers (CML161 and CML 165) as male parent in a Line × Tester mating design and the resulting 40 crosses along with the parents and three checks (BHM9, 981 and BHM5) were evaluated in a alpha lattice design with two replications at Gazipur. Among the lines VL109279 and CLQRCYQ74 and tester CML165 were good general combiners for grain yield and some of the important yield contributing characters. Line VL109579 and CML171 were good general combiners for earliness and short stature, respectively. CML 165 was good combiner for yield. Three crosses viz. CML 163 × CML 161, CML 171 × CML 161 and CML 193 × CML 165 showed high SCA effects with high standard heterosis (16.7-27.5%) & high mean performances (11.2-12.7 t/ha) for yield which could be used for commercial hybrid development after verification.

In set II, another twenty selected different lines of field corn were crossed with 2 testers (CL02450 and CML 451) in a Line × Tester mating design to generate 40 crosses. All the crosses along with the parents and standard checks (BHM9, 981 and Sunshine) were evaluated in a alpha lattice design with two replications at Gazipur. The parents CML 430, CML 429, CML 223 and CML 451(tester) could be used in hybridization program as donor. Better performing two crosses (CML 287 × CML 451 and CML 431 × CLO2450) showed high heterosis over standard check and also had high mean yield (10.4-11.4 t/ha) were selected to evaluate in multilocation trial.

In set III, 30 selected of Pinacle S_3 lines of field corn were crossed with two different testers (BIL 28 and BIL79) in two isolations to generate test crosses (rabi 2015-16). The test crosses and their parents were evaluated along with three cheeks (BHM9, 981 and Sunshine) in a alpha lattice design with two replications at Regional Agricultural Research Station, Jessore, to test combining ability and heterosis for particular traits of economic importance in rabi 2016-17. The best GCA was observed for PNL/S_3-4. Seven crosses (PNL/S_3-4, PNL/S_3-7, PNL/S_3-12, PNL/S_3-14, PNL/S_3-15 crossed with BIL-28; PNL/S_3-4 and PNL/S_3-24 crossed with BIL-79) showed higher kernel yield ranged from 9.74-12.18 t/ha.

In set IV, 30 S_3 selected lines of field corn were crossed with two different testers (BIL28 and BIL79) in two isolations to generate test crosses in rabi 2015-16. The test crosses and their parents were evaluated with three cheeks BHM9, 981 and Sunshine in a alpha lattice design with two replications at Regional Agricultural Research Station, Jessore, to test combining ability and heterosis for particular traits of economic importance in rabi 2016-17. The best GCA was observed for 981/S_3-24. Kernel yield ranged from 7.22 to 13.87 t ha^{-1}. Maximum yield was for 981/S_3-12 (13.87 ton/ha), using BIL-28 as a tester. A total of 22 test crosses showed kernel yield higher than mean of checks (11.03 ton/ha).

The experiment was conducted with 17 inbred lines of field corn crossed with 4 testers (Set V) in a Line × Tester mating design and the resulting 68 crosses with the parents were evaluated along with three cheeks (BHM9, 981 and Sunshine) in a alpha lattice design with two replications at Gazipur. The inbred parents 7074/S_6-15, B-3, A-6, F-7-1 and F-10 were found as the good general combiner for yield. Two crosses 7074/S_6-15×BIL 28 and 7074/S_6-5×BIL 28 showed high mean yield (11.47-11.56 t/ha), significant positive sca and significant higher positive standard heterosis (10.2% and 9.3%) were identified as the best combinations.

In set VI, 41inbred lines of field corn were crossed with 2 testers (BIL 110 and BIL157) in a Line × Tester method and the resulting 82 crosses along with the parents and three standard checks (BHM9, 981 and Sunshine) were evaluated in a alpha lattice design with two replications at Gazipur. Eight lines viz. A-21-2, A-3, F-2, F-4, F-13, F-19, F-21-2 and F-31-1 were found good general combiner for grain yield. Better performing 3 crosses A-21-2×BIL 110, 7074/S_6-6×BIL 110 and F-2×BIL 157 showed significant positive SCA, significant positive heterosis (8.5%-16.9%) for yield and also high

mean yield (11.38-12.27 t/ha) were selected as the best combinations. These crosses could be utilized for commercial hybrid after verification under wider agro ecological zones of Bangladesh.

Study of combining ability and heterosis in field corn (2 sets)

In set I, Seven inbred lines of field corn were crossed in all possible combinations (excluding reciprocals) and the resulting 21 F_1's along with 3 commercial hybrids viz. BHM9, Sunshine and 981 were evaluated following alpha lattice design with 3 replications at Gazipur. Parents P_4 and P_7 were the best general combiner for high yield; P_1 and P_2 for dwarf & earliness. Two crosses ($P_3 \times P_7$ and $P_4 \times P_7$) showed high mean yield (9.61-11.08 t/ha). These two crosses also showed significant positive sca and positive standard heterosis for yield. The hybrids need to be further evaluated for confirmation.

In set II, 8 diverse inbred lines of field corn were crossed in all possible combinations (excluding reciprocals) and the resulting 28 F_1's along with 2 commercial hybrids viz. BHM7 and 981 were evaluated in a alpha lattice design with two replications at Gazipur. Parent P_4 and P_6 was the best general combiner for high grain yield and parent P_7 and P_8 for earliness and dwarf plant type. The highest heterosis was exhibited by the cross $P_2 \times P_4$ (10.83%) followed by $P_6 \times P_7$ (9.72%). Three crosses $P_2 \times P_4$, $P_6 \times P_7$ and $P_4 \times P_6$ showed high mean yield(11.82-13.02 t/ha) as well as higher heterosis and sca effects can be utilized for developing high yielding hybrids as well as for exploiting hybrid vigour.

D. Evaluation of single cross & three way cross hybrids

Evaluation of early, short stature and high yielding single cross field corn hybrids

Twenty single cross of field corn hybrids were evaluated along with four commercial checks BHM 9, 981, Pioneer 3396 and Sunshine in RCBD with two replications at Gazipur. Significant differences were observed among the genotypes for all the characters studied. Two hybrids BMZ 25 × Ki 21 and BMZ 68 × CML 487 showed high mean yield (10.05-10.72 t/ha) with low plant height. These hybrids were found promising and selected for further evaluation at different locations.

Evaluation of promising field corn & baby corn hybrids at different agro-ecological regions of Bangladesh (5 sets)

In set I, eleven promising crosses of field corn and four checks (BHM9, 981, Sunshine and BHM5) were evaluated at five locations viz. Gazipur, Hathazari, Rahmatpur, Burirhat, and Jessore in RCBD with three replications. The AMMI (additive main effects and multiplicative interaction) model was used to analyze the genotype-environment interaction over five locations. Considering yield potentiality and stability parameter hybrids, E1 (11.87 t/ha) and E2 (11.11 t/ha) showed higher yield as well as stable across locations and were selected for further verification.

In set II, 13 single crosses and two checks (BHM9 and 981) were evaluated in RCBD with 3 replications at five locations namely Gazipur, Ishurdi, Rahmatpur, Jessore and Rangpur to assess genotype-environment interaction (GEI) and stability for selection of the best hybrid. Gazipur, Ishurdi and Jamalpur were poor and Rangpur and Barisal were good environments for maize production. Among all the hybrids, A-9×B-19 showed the highest yield (12.04 t/ha) and was found stable across the locations.

In set III, seven baby corn hybrids were evaluated at six environment viz. Barisal, Gazipur, Hathazari, Jamalpur, Jessor and Rangpur along with two commercial check varieties namely Baby Star and MSC 001. The AMMI (additive main effects and multiplicative interaction) model was used to analyze the genotype-environment interaction over six locations. Barisal was the most suitable and Hathazari was

the poorest environment for baby corn cultivation. Among the hybrids, BCP 271-18×BCP 271-6 and BCP 271-18×BCP 271-16 had higher number of cobs per plant and hybrids BCP 271-13×BCP 271-7 (637 g) and BCP 271-20×BCP 271-19 (657 g) had high green fodder per plant and were found stable over the environments.

In set IV, Thirteen maize hybrids along with five check varieties (BHM 9, 981, Sunshine, Pioneer and Kaveri 60) were evaluated for genotype environment interaction (GEI) and stability for the selection of promising one(s) in six different locations namely Gazipur, Jamalpur, Hathazari, Rahmatpur, Burirhat, and Jessore in RCBD with 2 replications. The AMMI (additive main effects and multiplicative interaction) model was used to analyze the genotype-environment interaction over six locations to select the hybrid having higher yield and other potential attributes. Among the hybrids, 9MS/S7-9×BIL-114 was high yielder (11.12 t/ha) and was stable across the locations.

In set V, twenty five hybrids including 4 checks (BHM9, Pioneer3396, Sunshin and 981) were evaluated in Alpha lattice design with 3 replications at five locations namely Gazipur, Rangpur, Jamalpur, Barisal and Jessore to assess genotype-environment interaction (GEI) and stability for selection of the best hybrid. Rangpur, Jamalpur and Gazipur was poor but Barisal and Jessore were rich for hybrid maize production. Among the tested hybrids, E16 (10.7 t/ha) and E21 (10.79 t/ha) were high yielder and stable across five environments.

Evaluation of short stature maize hybrids in different locations

Seventeen promising field corn hybrids along with three commercial check varieties (BHM 9, 981 and Sunshine) were evaluated at five different locations namely Gazipur, Rangpur, Jamalpur, Barisal and Jessore in RCBD with 3 replications. The AMMI model (additive main effects and multiplicative interaction) and GGE Biplot were used to analyze the genotype-environment interactions over five locations to select the hybrids having higher yield and other potential attributes. Rangpur was found highly suitable for hybrid maize cultivation followed by Jamalpur. F-14×M-14, F-30×M-10 and $P_3 \times P_7$ were stable but low yielding. Among the hybrids, F-30×M-15(11.75 t/ha), F-14 ×M-2(10.67 t/ha) and F-14×M-4 (10.54 t/ha) exhibited high yield as well as stable across environments.

E. Maize Biotechnology: Molecular breeding

Role of trehalose in maize under salinity and low P stress

In this study, the level of oxidative stress and the participation of antioxidant and glyoxalase systems were investigated in seedlings of two maize genotypes BARI Hybrid Maize-7 (BHM-7) and BARI Hybrid Maize-9 (BHM-9) subjected to salinity and low P stress and addition of trehalose (Tre) was done to unveil the oxidative stress tolerant role Tre under salinity and low P. Addition Seven days old seedlings were imposed to 12 dSm^{-1} salinity and low P (10 ppm) for 5 days. Growth parameter as well as reactive oxygen species (ROS), lipid peroxidation (as melondialdehyde, MDA), methylglyoxal (MG), lipoxigenase (LOX) and enzymatic antioxidant and glyoxalase activities were investigated in fully expanded leaves. Salinity reduced the shoot length, root length and root volume in both genotypes. However, low P increased the root length and volume in both genotypes. In case of salinity plus low P stress, remarkable inhibiton was observed for these parameters in both genotypes. Addition of 100µM Tre in growing media increased all of the growth parameters. Salinity and low P increased all of the ROS, MDA, LOX activity and MG enormously in both genotypes. Application of Tre in the growing media lessened the oxidative damage in both genotypes by reducing the components. Under salinity, Increased SOD and POD activities were observed in both genotypes. Addition of trehalose did not increase the activity. Like salinity, low P stress also increased SOD activity in both genotypes, but addition of Tre further increased the activity over low P stress. The treatment Salinity+low P also reduced the SOD activity by 29% and 28% in BMH-7 and BMH-9, respectively. Notably, addition of Tre in this stress treatment maintained higher SOD activity in both genotypes. However, CAT is seemed not to important H_2O_2 scavenger. Increased activities of GPX and APX suggested being important scavenger in maize. Tre treatment further increased the activity

in both genotypes. Like salinity, low P also increased the activity in both genotypes. However, in case of double stress, the activity drastically decreased. Addition of Tre restored the activity higher in both genotypes. Increased GR and DHAR activity under salinity signified their role in maintain GSH and ASA in maize. However, MDHAR activity decreased under salinity suggesting its interaction with ROS. The treatment Low P and double stress decreased the activities of GR, MDHAR and DHAR. Application of Tre increased the activities in both genotypes suggesting its restoring role of GSH and ASA in maize. Gly-I activity varied with genotype. In BHM-7, the activity decreased under stress and addition of Tre increased the activity. On the other hand, in BHM-9, salinity increased the activity, but low P decreased the activity. Tre supplement increased Gly-I activity indicated its importance in MG detoxification. On the other hand, higher activity of GST under the stresses with or without Tre in both genotypes could play detoxification and leaf senescence role in maize under stress.

F. Stress Breeding-Abiotic stress tolerant variety development

Screening of drought tolerant maize inbred lines at seedling stage under pot condition

An experiment was carried out with 29 CIMMYT maize genotypes in the green house of plant breeding division planted in pot (7″×3″). Pots were arranged using randomized complete block design with two replicates. Three seeds were sown in each pot and later thinned to one per pot. Each replicate was under two different treatments, treatment 1 (T1= Non stress / control; water was applied as and when required) and treatment 2 (T2= Drought stress / water stress; throughout the growing period). Pots were evaluated to identify best genotype(s) with very good performance at low moisture condition. Results were analyzed by using balanced two factor factorial analysis of variance, principal component analysis and biplot analysis for selection of tolerant genotypes. Highly significant differences among accessions for all the characters were found under water stress condition. First two principal factors showed more than one Eigen value under water stress condition. First two factors contributed 73.92% and 83.05% cumulative variability in stress condition. Leaf number, shoot fresh weight, shoot dry weight, plant fresh weight and plant dry weight were proved the most effective selection indicators against drought stress at early growth stage. Genotype E2, E11, E14, E18, E19 and E23 were better performer under drought stress.

Evaluation of maize hybrids in optimal and saline condition

Eight selected inbred lines were crossed in all possible combinations (excluding reciprocals) and resulting 28 F_1's along with 2 commercial hybrids viz. BHM9 and 981 were evaluated in RCB design with two replications in two different environments viz. Gazipur and Benarpota, Satkhira. Among the parents, P_1, P_3 and P_5 were good combiner for earliness, whereas P_2 and P_3 were shorter ear height. For hybrid, earliness was found in the crosses $P_1\times P_3$ & $P_1\times P_5$; and the crosses $P_2\times P_5$. $P_1\times P_3$, $P_2\times P_3$, $P_2\times P_6$, $P_3\times P_5$, $P_6\times P_7$ and $P_6\times P_8$ produced short statured plants. Considering earliness, plant height, ear height and yield $P_2\times P_3$, $P_2\times P_5$ and $P_6\times P_8$ were selected for further trial in multilocations.

Evaluation of single cross maize hybrids under saline condition

Forty two single cross hybrids of field corn along with six checks (BHM-9, 981, Sunshine, Pioneer3396, Kaberi 50 and Pacific 999 Super) were evaluated in RCB design with three replications at Benerpota, Satkhira under saline condition. None of the hybrid produced higher yield compared to the best check Kaveri50. Considering earliness, plant height, ear height and yield hybrids $L_1\times T_2$, $L_3\times T_1$, $L_3\times T_2$, L5×T3, $L_6\times T_3$, $L_{10}\times T_1$ and $L_{11}\times T_3$ were selected to evaluate in the next year.

Evaluation of selected promising maize hybrids for saline areas (2 sets)

In set I, ten previously screened single cross field corn hybrids along with four commercial checks Sunshine, 981, BARI hybrid maize BHM 9 and BHM 12 were evaluated at ARS, Benarpota, Satkhira during rabi 2016-17 following alpha lattice with three replications. Considering high yield, percent heterosis and overall performance four hybrids; B-18× BIL-113,

$P_7 \times Q_2$, A-12-1×M-16 and BHM 12 (BARI released hybrid variety used as check) were found promising for grain yield, yield components and selected for further evaluation at different saline prone locations.

In set II, 14 hybrids including 2 checks (BHM-9 & 981) were evaluated in three saline areas viz. Satkhira, Khulna and Coxbazar in RCB design with 3 replications. The AMMI model (additive main effects and multiplicative interaction) was used to analyze the genotype-environment interactions over three locations to select the hybrid having higher yield and other potential attributes. Cox's bazar was found rich for hybrid maize production under saline condition whereas Satkhira was poor. Hybrids E5 (6.77 t/ha) & E11(6.44 t/ha) were high yielder but unstable. Hybrid E14 (6.40 t/ha) was high yielder and also stable across three environments.

Phenotyping of the HTMA hybrids under optimal temperature at Gazipur (10 sets)

The experiment composed of 10 sets of trials and a total of 345 maize hybrids from CIMMYT, India including six check varieties viz. BHM 9, 981, 942, NK 40, Pioneer 30V92 and Kaveri-50 were studied under HTMA project at the BARI Gazipur during the Kharif I season, 2016 to observe the performance of the hybrids under optimal temperature. Among the tested hybrids considering grain yield and other contributing characters the following hybrids, viz. VH131167 (8.64 t/ha), ZH15445 (8.08 t/ha), ZH15419 (7.50 t/ha) and ZH141592 (7.08 t/ha) in trial AHSIII-19; entry ZH1610 (7.15 t/ha) in trial AHSIII-29; entries VH131167 (9.10 t/ha), ZH137177 (7.99 t/ha) and ZH137413 (7.46 t/ha) in trial ASHII-19 ; entries ZH15432 (7.62 t/ha) and ZH138069 (7.14 t/ha) in trial ASHII-29; entries ZH16835 (7.98 t/ha) and ZH15266 (6.80 t/ha) in trial DEIIYW-25; ZH138088 (9.07 t/ha), VH112881 (8.82 t/ha), ZH138088 (8.36 t/ha), ZH138077 (7.56 t/ha) and VH112881 (7.09 t/ha) in trial TWH-15 were selected for further evaluation in wide agro-ecologies.

Phenotyping of the HTMA hybrids under optimal temperature at Barisal (5 Sets)

A total of 160 maize hybrids from CIMMYT, India were evaluated under HTMA project including six check varieties viz. 981, 942, NK 40, Pioneer 30 V 92, Kaveri 50 and BHM 9 were studied at RARS, Rahmatpur, Barisal during the Kharif-1 season of 2016 to observe the performance of the hybrids under optimal temperature. Considering plant height, ear height, earliness and yield entry ZH16822 in trial 16S_DEIIYW-16; entry ZH169, ZH138098, ZH15440 and ZH15439 in trial 16S_AHSIII-112; entry VH112944, ZH15433 and ZH1610 in trial 16S_AHSIII-212; entry ZH15302 and ZH1680 in trial 16S_ASHII-112 and entry ZH141592 in trial MLT 151 were found promising and selected for further evaluations in across agro ecologies.

Phenotyping of HTMA hybrids under heat stress at Ishurdi (8 sets)

The experiment composed of 8 sets of trials and a total of 285 hybrids from CIMMYT, India including six check varieties viz. BHM9, 981, 942, NK40, 30V92 and Kaveri 50 were evaluated at the Regional Agricultural Research Station, Ishurdi, Pabna during the kharif-1 season of 2016 to observe the performance of the hybrids under heat stress. Highest and lowest temperature was observed 38.0ºC and 29.9ºC, respectively, during the silking and early grain filling stage. Among the hybrids considering yield and other secondary traits contribute to heat stress tolerance the best hybrids were VH131167(8.07 t ha^{-1}) and ZH15439 (7.30 t ha^{-1}) in trial AHSIII-111; VH112944 (6.66 t ha^{-1}), ZH1612 (6.27 tha^{-1}), ZH1610 (6.18 tha^{-1}) and ZH15381 (6.07 tha^{-1}) in trial AHSIII-211; ZH15416 (7.23 t ha^{-1}), VH112859 (7.05 t ha^{-1}) and ZH15286 (6.93 tha^{-1}) in trial ASHII-111; ZH137413 (7.23 t ha^{-1}), ZH16840 (8.89 t ha^{-1}), ZH16856 (8.89 t ha^{-1}) and ZH16879 (8.07 t ha^{-1}) in trial DMIIYW-16; ZH16849 (6.34 t ha^{-1}) in trial DMIIYW-26; ZH15445 (8.48 t ha^{-1}), ZH138077 (8.03 t ha^{-1}), VH121076 (7.79 t ha^{-1}) and ZH111755 (7.66 t ha^{-1}), in trial TWH-16; ZH15381 (7.74 tha^{-1}) in trial MLT-141. These hybrids need to be evaluated further in across agro-ecologies.

Phenotyping of HTMA hybrids under heat stress at Jessore (12 sets)

A total of 855 CIMMYT, India developed hybrids including six checks were evaluated in 12 sets of trials at the Regional Agricultural Research Station, Jessore during the kharif-1 season of 2016 to evaluate the performance of test cross hybrids under heat stress. Highest and lowest temperature was observed 38.0ºC and 28.6ºC respectively, during the silking and early grain filling stage. Among the hybrids considering yield and other yield contributing traits including heat stress tolerance the best hybrids were entry VH12242 (10.20 t ha^{-1}) in trial 16S_AHSIII-110; entries ZH1611 (9.54 t ha^{-1}), ZH15433 (9.80 t ha^{-1}) and VH112944 (10.33 t ha^{-1}) in trial 16S_AHSIII-210; entries ZH141592 (9.37 t ha^{-1}), ZH1679 (10.42 t ha^{-1}) and VH131167 (10.64 t ha^{-1}) in trial 16S_AHSII-110; entry ZH15432 (10.05 t ha^{-1}) in trial 16S_ASHII-210 and entries ZH16273 (9.58 t ha^{-1}) and ZH16300 (9.80 t ha^{-1}) in trial 16S_DHTC-34; entry ZH16386 (9.74 t ha^{-1}) in trial 16S_DHTC-44 and entry ZH169 (10.83 t ha^{-1}) in MLT-139. These hybrids need to be evaluated further in across agro ecologies.

G. Production of New Hybrids

Production of single cross field corn hybrids through diallel mating design, line × tester method and North Carolina design II fashion

In hybrid maize development program, documentation of outstanding single cross combination having high heterotic effect is one of the important aims and goals. There are various ways to develop different types of hybrids in maize. Combining ability analysis is one of the powerful tools in identifying the better combiners. Diallel mating design, line × tester method and North Carolina design II fashion provides an opportunity to evaluate the genotypes during development of inbreds. These designs are most suitable to find out additive and dominant genetic variances, heterotic hybrids and heterotic partners of inbred lines.

Total four sets of crosses following 8×8 and 7×7 diallel fashion (excluding reciprocal) were made at Gazipur, Rahmatpur and Jamalpur and produced total 22.88 kg F_1 seeds. Through line × tester method two sets of pop corn produced 4 kg F_1 seeds. Total 8.62 kg F_1 seeds were produced by 7×7 North Carolina Design II method. These F_1 seeds will be evaluated in the next rabi season to select promising one(s).

Production of promising selected hybrids, modified single cross hybrids and stress tolerant experimental hybrids of short statured, lodging tolerant, excess soil moisture and saline tolerant of field corn, pop corn and baby corn

Seven sets of single crosses produced total 22.1 kg field corn, 6.1 kg popcorn and 5.4 kg baby corn F_1 seeds. Two sets of modified single cross produced 13.96 kg and 2.85 kg F_1 field corn and popcorn seeds, respectively. Total 9.8 kg stress tolerant experimental hybrids of short stature, lodging tolerant, excess soil moisture and saline tolerant of field corn seeds were produced.

H. Maintenance & seed increase of parental lines and hybrid seeds

Maintenance and seed increase of parental lines of BARI maize hybrids

Seed production of parental lines of selected BARI maize hybrids and promising BARI maize hybrids

In maize breeding program, maintenance of parent lines is pre-requisite for maintaining the quality of the respective inbred lines. It is very important to increase large scale seed production of the parental lines for large scale hybrid (F_1) seed production to meet the local demand. Total 3645 kg seeds of twelve parental lines (BIL 28, BIL79, BIL 157, BIL 210, BIL 211, BIL 212, BIL 213, BIL 214, BIL

215, BIL 216, BIL 217 and BIL 218) of BARI released maize hybrids were produced in isolation at different locations during 2016-17.
BARI developed a number of promising hybrids. It is necessary to increase large scale hybrid (F_1) seeds production to utilize in demonstration and adaptive yield trial across countryside. Total 606 kg seeds of promising BARI maize hybrids (HTMA 19, HTMA 21 & $P_1 \times P_7$) were produced in isolation at different locations during 2016-17 for further use.

Seed production of BARI hybrid maize

Seed is the most important raw material for crop production. To popularize the released varieties, seed production is a pre-requisite for demonstration at farmer's field. So, the experiment was undertaken to increase seed stock of the BARI released hybrid varieties of maize to be used for demonstration and future use.
Total 2672 kg F_1 seeds of 7 hybrids BHM7, BHM8, BHM9, BHM12, BHM13 BHM14 and BHM15 were produced at different RARS & HQ in isolation condition maintaining 4:2, female and male plant ratio during rabi 2016-17.

I. Maintenance & seed production of open-pollinated varieties

Maintenance & seed production of BARI composite maize varieties

Normally composite varieties are lower yielder than hybrid maize variety. Inspite of this, its advantage over hybrid is that, farmers can keep their own seed and low inputs requirement in cultivating the crop.
Total 932 kg seeds of three BARI OPV's (BARI Sweet Corn 1, BARI Khoibhutta and BM7) were produced at different locations in isolation by open pollination maintaining 2:1 ratio of females and males.

J. Barley and Millets Improvement Program

Hybridization of barley

Hybridization is one of the major techniques to create variability and to integrate one or more desirable characters from different sources (e.g. wild relatives, local cultivars) into an individual (existing popular variety).
Nine parental lines were crossed with three testers to develop early, high yielding hull-less barley variety. Among 27 crosses, 25 crosses produced seeds which will be used for confirmation trial in next year.

Evaluation and selection in different filial generation

Success of a hybridization program depends on carefully handling of segregating materials. It is often desirable to discard poor cross combinations in early generation, so that adequate attention can be paid to really potential combinations. The main objective of handling segregating generations is to grow and select the desirable families and individual plants in different filial generation for further evaluation.
In different segregating generation, selection was done based on earliness, short stature, hull-less and high yield. In F_1 generation, 1 plant from 1 cross, in F_3 generation 50 plants from 2 crosses, in F_4 generation 17 families, in F_5 generation 4 families & in F_6 generation 3 families were selected.

Preliminary, advanced and regional yield trial of hull-less barley

Through preliminary yield, six barley genotypes along with one check variety (BB-7) were evaluated in three different locations namely Gazipur, Ishurdi and Jamalpur in RCBD with 3 replications. The AMMI model (additive main effects and multiplicative interaction) was used to analyze the genotype-environment interactions over three locations to select the barley genotypes with higher yield and

other potential attributes. Considering earliness, yield and yield contributing characters 2 barley genotypes performed superiorly and Ishurdi was proved as the best environment for barley cultivation.

Four genotypes along with one check variety of barley were assessed in advance yield trial for genotype environment interaction (GEI) and stability for selection of the best barley lines at three different locations namely Gazipur, Jamalpur and Ishurdi. The AMMI (additive main effect and multiplicative interaction) model was used to estimate the genotype-environment interaction over three locations to select the barley lines having higher yield and other potential attributes. Check entry BARI Barley-7 exhibited higher yield and as well as stable over all environments. Genotype INBONL-21/15 and Atabapha12 were high yielding for specific location.

Regional yield trials ensure the varietal suitability for specific location. Five barley lines including one check viz. BB-7 were evaluated across three different locations viz. Jamalpur, Gazipur and Ishwardi to find out the suitable genotypes. From the overall mean yield and other desirable characters the entry BHL-10 was found suitable across locations.

International barley trials

Iinternational naked barley yield trial (INBYT-HI) and observation nursery (INBON)

Twenty five barley genotypes of international naked barley yield trial were evaluated at Gazipur to find out the suitable genotypes for large plot yield trial. Among the genotypes, entry 21 was early (94 days). Entry 23 exhibited the highest yield (2.95t/ha) followed by entry 6 (2.47 t/ha), entry 8 (2.01t/ha), entry 7 and 11 (1.93 t/ha).
International naked barley observation nursery was conducted at Gazipur. Ninety four hull-less barley lines received from ICARDA along with one standard check BARI Barley-7 was evaluated to select better performing hull-less barley lines. There were 50 lines with two rows and 44 lines with six rows among the genotypes. Considering earliness, yield and yield contributing characters 6 lines were selected from the 94 barley lines for preliminary yield trial.

International barley observation nurseries-high input

Barley is an important cereal crop used as human food, feed for animals, malt, and beverage. ICARDA has developed many new improved barley varieties, genotypes and advanced lines which are adapted to many different environments. Every year they are evaluating the developed lines to test their better performance across the world. Last year ICARDA provided some advanced barley lines to identify suitable lines under Bangladesh condition.
One hundred and twelve barley entries including one check (BB-6) were evaluated at Gazipur to select better performing barley lines. Considering earliness, yield and yield contributing traits (line 3, 4, 5, 11, 43, 46, 57, 58, 76, 77, 87, 94, 101, 107, 108 and 109) were selected for future breeding program.

Adaptive trials with BARI barley varieties and advanced lines in southern belt and barind areas

Two sets of 4 BARI barley varieties (BARI barley-4, BARI barley-5, BARI barley-6 and BARI barley-7) and one advanced lines (BHL-15) were evaluated at Harodda, Vorma and Satkhira to observe the performance of BARI barley varieties in dry and saline areas. The highest grain yield (2.58 t/ha) was recorded in BARI barley-5 and lowest grain yield (1.82 t/ha) recorded in BARI barley-4 in set-I. The highest grain yield (2.41 t/ha) was recorded in BARI barley-5 and lowest (1.74 t/ha) in BARI barley-4 in set-II. The lowest level of soil salinity was recorded in sowing time (4.12 dS/m) and the highest level of salinity (10.76 dS/m) was recorded at the harvesting stage in set-I and

the lowest level of soil salinity was recorded in sowing time (4.25 dS/m) and the highest level of salinity (11.05 dS/m) was recorded at the harvesting stage in set-II.

Four BARI barley varieties viz. BARI barley-4, BARI barley-5, BARI barley-6 and BARI barley-7) and three advanced lines (BHL-15, BHL-17 and BHL-21) were tested in saline areas of Noakhali. Among the tested varieties highest yield was found in BARI barley 7 (1.40 t/ha) followed by BHL-15 (1.39 t/ha) and BARI barley 6 (1.38 t/ha). The yield of barley varieties were low in comparison to their yield potentially might be due adverse effect of salinity during reproductive stage. At this stage rain was occurred several times with small amount which stimulated salinity progression when temperature raised.

Seven BARI barley varieties that BARI barley-1, BARI barley-2, BARI barley-3, BARI barley-4, BARI barley-5, BARI barley-6 and BARI barley-7 were evaluated at MLT site Koyra, Khulna during rabi season 2016-17 to test the seven BARI barley varieties. Among the tested varieties BARI barley-5 produce the highest yield (2.13 t/ha) and lowest yield was produced by BARI barley-3 (1.74 t/ha).

Three advance lines viz. BHL-19, BHL-25 and BHL-26 and two barley varieties namely BARI Barley-5, BARI Barley- 6 as check were evaluated at the farmer's field of FSRD site, Kadamshahar, Godagari, Rajshahi with a view to select high yielding barley advance lines for drought areas. Out of five barley varieties/lines BHL-19 gave the highest grain yield (2.19 t ha^{-1}) followed by BARI Barley-6 (2.08 t ha^{-1}). The lowest grain yield was produced by BHL-25 (0.98 t ha^{-1}). Considering the yield and yield contributing characters BHL-19 is the suitable one for Barley production in High Barind Tract.

Adaptive trials with BARI kaon varieties in southern belt and hilly areas

Two sets of three kaon varieties (BARI kaon-1, BARI kaon-2 and BARI kaon-3 (dwarf variety) were evaluated Benarpota, Satkhira to observe the performance of BARI kaon varieties in dry and saline areas. The highest grain yield was (2.77 t/ha) recorded in BARI kaon-3 and lowest (2.45 t/ha) in BARI kaon-1 in set-I. The highest grain yield (2.54 t/ha) was recorded in BARI kaon-3 and lowest (1.54 t/ha) in BARI kaon-1 in set-II. The lowest level of soil salinity was recorded in sowing time (4.00 ds/m) and the highest level of salinity (10.82 dS/m) was recorded at the harvesting stage in set-I and the lowest level of soil salinity was recorded in sowing time (4.05 dS/m) and the highest level of salinity (11.00 dS/m) was recorded at the harvesting stage in set-II.
Three BARI kaon varieties (BARI kaon-1, BARI kaon-2, BARI kaon-3) were evaluated at Kyamlong para hill valleys in Bandarban to compare the performance of BARI developed kaon varieties. Among BARI kaon-2 gave the highest yield (1.86 t/ha) followed by BARI kaon-1 (1.75 t/ha).

Breeder seed production of barley and millets

Barley and Millets (kaon, cheena) are considered as minor cereals of Bangladesh. Minor cereals are consider as a short-season, early maturing annual grain crop with some degree of tolerance to drought and salinity, which allows its production in a wide range of climatic zones including both irrigated and dry land production areas. But only a few released varieties of barley and millets are available in the country. To maintain the varietal purity and maintenance breeder seed production is the pre-requisite for suitable crop production.
Total 408 kg breeder seed were produced from 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 and 130 kg breeder seed of Kaon and Cheena were produced at four locations during 2016-17.

Advanced yield trial of foxtail millet

Four genotypes along with one check variety of foxtail millets viz. BARI Kaon-2 was assessed for genotype environment interaction (GEI) and stability for selection of the best foxtail millet lines in three different locations namely Gazipur, Jamalpur and Ishurdi. The AMMI (additive main effect and

multiplicative interaction) model was used to analyze the genotype-environment interaction over three locations to select the barley genotypes having higher yield and other potential attributes. Among the tested foxtail millet lines Ise-1820 exhibited higher yield and as well as stable over all environments. Genotype Ise-710 and BK-2 were high yielding for specific location.

Preliminary yield trial of finger millet

Millets are considered as minor cereals of Bangladesh. It can be cultivated easily with low input in the char areas of Bangladesh. Millets can play partial role in fulfilling the food crisis of our country. But only a few released varieties of millets are available in the country. Therefore the improvement of yield potentiality and adaptability were major objectives of finger millet breeding program.

Seven finger millet lines were evaluated across two location viz. Jamalpur and Rangpur to find out the suitable genotypes for large plot yield trial. From the overall mean yield and other desirable characters the entry Ie-501and Ie-2619was found comparatively suitable across locations.

Maintenance and seed increase of pearl millet, sorghum and proso millet germplasm

Germplasm are the main building blocks of variety development. Maintaining seed purity by rouging off type, diseased and weak plants is most important in plant breeding. Again, availability of enough seed is pre requisite to conduct various breeding program to develop superior variety.
Total 4.1 kg seeds were produced from 9 selected pearl millet germplasm for next year trial. From seven selected sorghum germplasm total 18.2 kg seeds were produced. Total 13.07 kg seeds were produced from 21 exotic and locally developed proso millet lines for future breeding program.

J. Technology Transfer Activities

Farmers, Government and NGO personnel were trained to make them familiar with the new maize varieties, modern crop management practices, seed preservation techniques and mechanization in maize cultivation. Training program for farmers, extension officers, young scientists, maize field staffs, NGO personnel and others were conducted through audio-visual aids, demonstrations, lectures, training classes, field days etc. by maize staffs.

During 2016-17 Plant Breeding Division of BARI arranged 2 batches training for SAAO, SSA, SA (60 persons), 35 batches training for farmer (1050 persons), 1 batch biometric training for scientist (30 persons), 1 batch molecular breeding training for scientists, NGOs and seed companies (30 persons), hybrid maize production for Upazilla and district level officers of DAE and scientists 4 batches (120), hybrid maize seed production and parent lines maintenance for BADC officers, NGOs and seed companies 4 batches (60 persons). A training on 'Digital data capture and processing' was jointly organized by PBD, BARI and CIMMYT under Heat Tolerant Maize for Asia (HTMA) project where 40 participants had taken part from BARI and 5 leading seed companies (BRAC, ACI, Lal Teer, Supreme seed and Krishibid Group). This division also arranged ten training program on minor cereal production for SAAO, SA and SSA (300 persons) and Farmers for 30 batches (900 persons).
A group of scientists and DAE personnel visited the demonstrations and seed production plots several times and were impressed to see the plots. A good number of visitors both from home and abroad and students from different college and universities visited the experimental field and laboratory of PBD. Research activities of PBD were presented to them during their visit. Five field days were organized by PBD, Gazipur in seed production and block demonstration plots at Comilla, Faridpur, Kishorgonj, Khulna and Sherpur where about 300 farmers and local representatives were present. Plant Breeding Division also executed 2 field days on kaon at Munshigonj and Sherpur where 120 farmers and local representatives were present. Plant Breeding Division also arranged on-farm demonstration trials at Comilla, Faridpur, Kishorgonj, Khulna, sherpur, Patuakhali and Rajshahi.