Chapter 5

SUMMARY AND CONCLUSION

The present research work was undertaken to ascertain the most promising hybrid (s) for yield and component traits, find out the important yield contributing trait, estimate the heritability and extent of heterosis, work out the nature and identify the potential parental lines and cross combinations for genetic improvement in bitter gourd. All the experiments were conducted at R&D Farm, Lal Teer Seed Limited, Gazipur, Bangladesh during the period 2016 to 2019 year. The experiments were comprises of twenty seven inbred lines of bitter gourd to characterize the inbred lines, selection of parent through line X tester analysis, correlation coefficient, path analysis, heritability, combining ability and heterosis of yield and yield related traits were studied in F_1 generations from 7X7 diallel cross. The experiments were laid out in Randomized Complete Block Design with three replications. The data were recorded on first female flower open, node number, number of branches per plant, days to first harvest, number of fruits per plant, single fruit weight, fruit length, fruit diameter, number of seeds per fruit, 100 seed weight and finally yield per plant. Data on eleven characters were analyzed for interpretation. The results obtained are presented and discussed as below

5.1 Evaluation of inbred lines under study

5.1.1 Mean performance of parents

Analysis of variances for yield and different yield contributing traits showed that the inbred lines differed significantly for the traits (Table 4.1.1.1). This indicated that the materials were genotypically divergent that might used in hybridization programs and this will produce wide variability with high heterotic effect. The mean data for all the characters showed appreciable differences. The mean values of different inbred lines for eleven characters are shown in Table 4.1.1.2. The inbred line BT-1 showed the lowest mean value for days to female flower opening (28.23) followed by BT-15 (28.63). BT-5 was the most in advance regarding first harvestable fruit (38.80 days) followed by BT-4 (39.37 days), BT-1 (40.20 days). The highest average single fruit weight was recorded in BT-1 (251.17 g) followed by BT-15 (236 g). Maximum fruit length was observed in BT-19 (31.24 cm) followed by BT-01 (30.40 cm), BT-07 (27.37 cm). The inbred line BT-22 produced the highest number of fruits per plant (37.20) followed by BT-18 (26.13). The highest yield per plant was 3.69 kg in BT-1 followed by BT-15 (3.37 kg), BT-07 (3.23 kg), BT-12 (3.12 kg), BT-08 (3.01 kg) and BT-18 (3.01 kg).

These inbred lines can be used in hybridization program for the development of high yielding hybrid varieties.

The phenotypic coefficient of variation was marginally higher than the corresponding genotypic coefficient of variation indicating the influence of environment in the expression of the character under study. The range of variation was high in days to female (28.23-37.27) flower's opening, node number (16.30-28.42), number of branches per plant (6.43-21.13), days to first fruit harvest (38.80-49.23), single fruit weight (82.8-251.2). Fruit length (13.60 - 31.24 cm) and diameter (4.700-7.800 cm), number of fruits per plant (10.30-7.2), number of seeds per fruit (17.73-39.90), 100-seed weight (9.23 - 18.03g) and yield per plant (1.32 -3.69 kg) suggested to give priority on these characters for selection. Genotypic co-efficient of variations were also high for these maximum traits, indicated a wide variability among the inbred lines and offered better scope for selection.

5.1.2 Selection of yield contributing traits based on trait association

Assessing the interrelationship for yield and yield contributing characters is a prerequisite for any crop improvement program. The present investigation revealed that genotypic correlation coefficient was higher in magnitude than respective phenotypic correlation coefficient for most of the characters which may be attributed to the masking effect of the environmental factors in revealing the true association.

The correlation study revealed that yield per plant was significant and positively correlated with number of fruits per plant, single fruit weight, fruit length and fruit diameter at phenotypic and genotypic levels respectively. At the genotypic level, yield per plant was also strongly and positively correlated with all the characters and at phenotypic level. It denoted the importance of these characters in fruit yield in bitter gourd. However, days to female flower opening, node number, branch per plant and 100 seed weight had significant and negative relationship with yield per plant at genotypic and phenotypic levels. The findings suggested that selection for higher yield per plant of bitter gourd could be done through indirect selection of higher fruit weight, number of fruits per plant and fruit size.

Path analysis, however, at the genotypic level revealed that the single fruit weight contributed maximum positive direct effect (0.932) on fruit yield followed by number of fruits per plant (0.816). Though days to female flower opening showed higher positive association with yield per plant, but single fruit length had positive direct effect on yield. The results as a whole indicated that the single fruit weight and number of fruits per plant were important for fruit yield since they had maximum direct contribution on fruit yield. The residual effects of genotypic and phenotypic path analysis were 0.051 and 0.061 respectively, revealed higher genetic based relationship of the traits with fruit yield and suggested lower percent of environmental influence on the selected eleven characters of bitter gourd.

Heritability (h^2b) as well as genetic advance as per cent of mean was high for these traits. However, genotypic co-efficient of variation (GCV) was lower than the corresponding phenotypic co-efficient of variation (PCV) for all the cases which indicated considerable influence of environment. All the characters namely, days to first female flower opening, node number, number of branch per plant, fruit length, single fruit weight, fruit diameter, number of seed per plant, 100 seed weight and yield per plant showed high heritability which ranged from 64.20 to 91.01% and higher genetic advance ranged from 28.62 to 65.89 which indicated that these characters were less influenced by environment confirming additive gene action, and therefore, selection of these characters would be more effective for yield improvement of bitter gourd. High GCV and high heritability indicated that the traits offer adequate scope for effective selection for improvement and easily transferable to hybrid in bitter gourd.

5.2 Selection of parents based on genetic background utilizing Line x Tester analysis

All inbred lines that were used in the research showed differences with respect to the traits used in the experiment (Table 4.2.1.1 & 4.2.1.2). This case showed that there was a significant variation among the lines, testers and hybrids. Hence, it is possible to calculate the general combining abilities in the population. BT-1 possessed the highest ranked for fruit length followed by BT-19 and BT-12, it also stood second rank for average fruit weight on the basis of general combining ability (Table 4.2.2.1). BT-12 showed the highest ranking for first female flower opening followed by BT-9 and BT-17. BT-15 possessed the highest ranked for number of branches per plant and average fruit weight, it also stood second rank for fruit diameter and yield per plant. Rest of the characters showed moderate values. BT-22 showed the highest rank for number of fruits per plant followed by BT-11 and BT-8. BT-2 stood the highest rank for number of seed per fruit followed by BT-5 and BT-25. BT-18 possessed the highest rank for hundred seed weight followed by BT-16 and BT-15. But it also produced the highest 100 seed weight which was due to bigger size of seed. BT-14 showed the highest rank for yield per plant followed by BT-15 and BT-13. Yield is the ultimate goal for any crop production. The highest yield was in BT-1 inbred lines on the basis of mean performance followed by BT-15 and BT-7 (Table 4.2.2.2). The single fruit weight possessed the highest weight in BT-1 followed by BT-15, BT-12, BT-6 and BT-7 respectively. It also scored highest in first female flower opening followed by BT-15, BT-05 and BT-23. The highest fruit per plant was in BT-22 inbred lines followed by BT-18, BT-11 and BT-04 respectively (Table 4.2.2.2).

In case of parent selection, the highest and lowest GCA have been considered to know the behavior or of gene action. Parent selection is an important step in any breeding program. In the present study, out of 27, 7 different inbred lines were selected on the basis of combining ability utilizing line X tester analysis and mean value (Table 4.2.1.3). Parents having the highest mark were given the lowest rank. Ranking helped in selection parent from different inbred lines. The dissimilarity among the seven selected parents was quite high. BT-1, BT-7 was selected due to the highest ranking (203 and 144 respectively) within the inbred lines. BT-18, BT-13 was selected due to the lowest ranking (90 and 104 respectively) within 27 inbred lines. Finally, BT-1, BT-4, BT-7, BT-13, BT-15, BT-18 & BT-19 were selected on the basis of ranking for 7 × 7 diallel crossing programs (Table 4.1.2.7). So, utilizing this genetic potentiality of the selected seven parents could be evaluated by combining ability.

5.3 Genetic analysis of parents based on diallel analysis

Plant breeders use diallel analysis as an aid in selection and to investigate genetic properties of parents and their crosses. Diallel cross provides information on average performance of individual lines in crosses known as general combining ability (GCA). It also gives information about the performance of crosses relative to the average performance of parents involved in the cross known as specific combining ability (SCA). Significant GCA and SCA effects provide information to help determine the efficacy of breeding for improvements in given traits and they can be used to identify lines to serve as parents in a breeding program for trait improvement. The choice of appropriate parental inbred lines for crossing is the first and foremost step in the development of new crop cultivars. General combining ability effects are important indicators of the potential value of inbred lines, while sca is used to designate capability of the hybrids. The following parents are used for combining ability in this study: BT-01, BT-04, BT-07, BT-13, BT-15, BT-18 and BT-19.

Analysis of variance

The analysis of variance for diallel analysis revealed that significant differences for all the characters among inbred lines and hybrid. Combining ability along with genetic parameters for eleven characters were estimated. The significant ($P<0.05$ and $P<0.01$) mean sum of squares due to general and specific combining ability (GCA and SCA) for these characters indicated both additive and as well as non-additive types of gene actions for the expression of these characters. The GCA variance was significant for all the traits except number of branches per plant, first harvest and number of seeds per fruit. Significant SCA variance was observed for all the measured variables. Therefore, in the present investigation additive and non-additive gene actions were found to influence the performance of the hybrid except number of branches per plant, first harvest and number of seeds per fruit for which only non-additive gene actions were predominant. Both additive and non-additive effects influenced the performance of the hybrid in all these traits. The non-additive effects played a more important role than additive effects for yield and yield components in bitter gourd during identifying the outstanding hybrids.

GCA effect of the parents

Out of seven parental lines, BT-01 had negative estimates and was the best general combiner for first female flower opening among all the inbred lines. Therefore, this parent might be used in the breeding program for developing early flowering, i.e., early fruiting varieties. The parent BT-07 was the highest and negative GCA effect for the node number. Earliness for days to first harvest is most important character in bitter gourd. Parents BT-15, BT-18, BT-07, BT-19 and BT-BT-13 showed favorable significant negative GCA effects for earliness for harvest. The positive GCA effects for number of fruits per plant and yield per plant indicated that the concerned parent had the ability to produce more fruits with higher yield per plant. Out of 7 parental lines, BT-18 and BT-19 found good general combiner for number of fruits per plant and expressed positive GCA effects. Among the parental lines, BT-15 was good general combiner having positive GCA effect for single fruit weight and fruit diameter. Hence, BT-15 was the good general combiner to use in crossing to improve the average single fruit weight. The BT-19 showed highest positive GCA effect indicating that it was the best general combiner for fruit length among the parental lines. The highest general combiner for number of seed per fruit was found in BT-13. The parent BT-15 had also significant general combining ability for 100 seed weight. So, considering most of the characters, BT-07 was the best general combiner under study followed by BT-15, BT-18, BT-19, BT-01, BT-13 and BT-04 could be used in hybridization program for identifying the best cross combinations to develop hybrid variety in bitter gourd.

SCA effect of the crosses

The sca effects of almost all the crosses for all traits under study were significant, but BT-01 X BT-18, BT-04 X BT-18, BT-13 X BT-19, BT-15 X BT-18 and BT-18 X BT-19 crosses were significant for all the traits. Among these hybrids BT-07 X BT-15 was the best specific combiner for first female flower opening and first harvest. The crosses BT-07 X BT-18 exhibited highest significant negative sca effect for node number. The cross BT-18 X BT-19 showed the highest positive significant sca effects for the number of branches per plant, fruit diameter and number of fruits per plant. Out of 21 cross combinations BT-01 X BT-19 showed the highest significant and positive sca effect for single fruit weight and fruit length. The cross-combination BT-04 X BT-18 provided maximum value of the parameter for number of seed per fruit and the cross BT-04 X BT-13 showed the highest significant and positive effect for 100 seed weight. BT-18 X BT-19 was the best specific combination due to highest positive sca effects for the yield per plant.

Specific combining ability indicated that the cross-combination BT-18 X BT-19 had significant effects for the different important characters including number of branches per plant, single fruit weight, fruit length, fruit diameter, yield per plant and suitable for early female flower opening, node number and early harvest. The combination BT-07 X BT-15 was suitable for early female flower opening, node number, early harvest, single fruit weight, fruit length, fruit diameter, 100 seed weight and yield. The best combinations were BT-18 X BT-19 and BT-07 X BT-15 thus; these combinations could be used for exploitation of heterosis. The success in breeding depends mainly on the choice of superior parents for hybridization and the information on nature and combining ability of the parents.

Reciprocal effect of the crosses

Among the 21 reciprocal hybrids, 11 showed negative specific combining ability effects in desirable direction for day to first female flower opening, ten hybrids for node number at first female flower appeared, four hybrids for primary branches per plant, thirteen hybrids for days to first fruit harvest, five hybrids for fruit per plant, nine hybrids for single fruit weight, ten hybrids for fruit length, twelve hybrids for fruit width, eight hybrids for seed per fruit, nine hybrids for 100 seed weight and seven hybrids for fruit yield. Crosses BT-07 X BT-01, BT-19 X BT-13, BT-04 X BT-01 and BT-18 X BT-07 were recorded to be the most promising combinations for fruit yield. Such results indicated that these crosses could be exploited for heterotic effects through nuclear inheritance only. These reciprocal effects indicated to some extent the effect of cytoplasmic genes controlling the expression of the characters.

5.4 Evaluation of experimental hybrids through heterosis study

Heterosis were estimated for individual crosses (i.e., 42 hybrids) against yield and yield contributing characters over mid parent (average), better parent (heterobeltiosis) and check variety (standard heterosis). The heterosis expressed in all the traits were considerable. Most of the hybrids were significantly superior as compared to their respective parents in most of the traits. Both positive and negative heterosis were found for different characters of the F_1 hybrids and reciprocal F_1's. A high degree of heterosis was observed for most of the characters under investigation.

Mid parent heterosis

The highest and desirable heterosis over mid parent for days to female flower opening was observed in the cross BT-01 X BT-07 (-13.81%) followed by BT-07 X BT-13 (-12.56%), BT-07 X BT-18 (-9.89%) and BT-19 X BT-07 (-8.53%); for node number at which first female flower opening the combination BT-07 X BT-18 showed maximum heterosis (-44.00%) over mid parent in desirable direction followed by BT-07 X BT-18 (26.30%) and BT-13 X BT-18 (25.24%); for number of branch per plant it was 58.25% in BT-15 X BT-13 followed by BT-15 X BT-07 (57.34%) and BT-18 X BT-19 (55.19%); days to first fruit harvest the combination BT-07 X BT-18 showed the maximum highly significant heterosis (-16.26%) over mid parent followed by BT-18 X BT-15 & BT-13 X BT-18 (-10.57%) ; for number of fruits per plant it was 85.53% in BT-18 X BT-19 followed by BT-19 X BT-18 (78.86%), BT-18 X BT-15 (69.60%); single fruit weight it was 35.74% in BT-18 X BT-19 followed by the crosses BT-07 X BT-18 (20.91%), BT-19 X BT-18 (18.87%) and BT-19 X BT-13 (18.52%). The crosses of BT-15 X BT-07 (17.69%) and BT-18 X BT-13 (13.66%) also gave good results considering average fruit weight; for the fruit length it was 8.79% in BT-19 X BT-01 followed by 7.70% in BT-07 X BT-13, 6.64% in BT-07 X BT-19, 6.10% in BT-01 X BT-19; for fruit diameter it was 33.12% in BT-18 X BT-19 followed by 24.77% in BT-13 X BT-18, 24.10% in BT-19 X BT-18 ; for number of seed per fruit it was -54.19% in BT-13 X BT-18 followed by -48.04% in BT-04 X BT-15 and -47.12% in BT-13 X BT-01; for hundred seed weight it was 39.74% in hybrid BT-15 X BT-04 followed by 32.02% in the cross BT-18 X BT-15 and 31.68% in BT-15 X BT-01; for yield per plant it was 137.83% in hybrid BT-18 X BT-19 followed by 130.24% in the cross BT-19 X BT-18, 92.69% in BT-18 X BT-13, 79.92% in BT-18 X BT-15 and 70.47% in BT-15 X BT-07. So, considering the significant level of mid parent heterosis for all the characters the selected crosses BT-18 X BT-19, BT-18 X BT-13, BT-18 X BT-15 and BT-15 X BT-07 could be worthful.

Better parent heterosis

The highest and desirable heterosis over better parent was found for days to female flower opening in the cross BT-01 X BT-07 (-18.15%) followed by BT-07 X BT-13 (-12.65%), BT-07 X BT-18 (-12.42%) and BT-15 X BT-07(-11.46%). Heterobeltiosis for node number at which first female flower open, maximum significant heterosis percentage (-51.73) was recorded in F1 BT-07 X BT-18 whereas minimum percentage of heterosis (-5.45) was observed in hybrid BT-01 X BT-18; for number of branch per plant it was 55.17% in BT-18 X BT-07 followed by BT-15 X BT-13(52.60%) and BT-18 X BT-19(46.63%); for days to first fruit harvest it was -17.71% in BT-07 X BT-18 followed by -14.69 in BT-18 X BT-15, -12.53% in BT-07 X BT-15; for number of fruit per plant it was 56.96% in BT-13 X BT-19 followed by 48.85% in BT-18 X BT-19 and 44.68% in BT-19 X BT-15; for single fruit weight it was 21.66% in BT-18 X BT-19 followed by 17.91% in BT-19 X BT-13 and 10.45% in BT-15 X BT-07; for fruit length it was7.33% in BT-19 X BT-01 followed by 4.67% in BT-01 X BT-19, 3.45% in BT-18 X BT-04; for fruit diameter it was 24.67% in BT-18 X BT-19 followed by 23.63% in BT-13 X BT-18, 21.34% in BT-18 X BT-13 and 13.71% in BT-07 X BT-18; for number of seed per fruit it was -58.24% in BT-13 X BT-01 followed by -56.96% in BT-13 X BT-18, -52.73% in BT-04 X BT-01 and -51.20% in BT-13 X BT-19; for hundred seed weight it was 26.23% in the cross BT-15 X BT-01 followed by 23.02% in the cross BT-15 X BT-04, 19.80% in BT-01 X BT-15 and 11.82% in BT-15 X BT-07; for yield per plant it was 118.21% in the cross BT-18 X BT-19 followed by 111.24% in BT-19 X BT-18, 73.84% in BT-18 X BT-13, 70.32% in BT-18 X BT-15 and 66.86% in BT-15 X BT-07. Considering the significant level of better parent heterosis the selected crosses BT-18 X BT-19, BT-18 X BT-13, BT-18 X BT-15 and BT-15 X BT-07 could be considered worthful.

Standard heterosis

The significant negative standard heterosis was found in only four crosses for days to female flower opening. It was ranged from -7.89% in BT-01 X BT-07 to -0.36% in BT-15 X BT-07. The highest standard heterosis -42.65% was found in BT-07 X BT-18 for node number at which first female flower open followed by BT-07 X BT-13 (29.38%) and BT-07 X BT-01 (28.44%); for number of branch per plant it was 13.27% in BT-18 X BT-19 followed by BT-15 X BT-04 (17.54%) and BT-15 X BT-13 (11.37%); for number of fruit per plant it was 52.55% in BT-18 X BT-19 followed by BT-19 X BT-18 (47.06%) and BT-18 X BT-15 (40.00%). The highest significant positive heterosis showed 32.10% for single fruit weight in BT-15 X BT-07 followed by 19.54% in BT-19 X BT-01 and 16.00% in BT-15 X BT-19 over check commercial variety (Tia F_1). These crosses also showed significant positive effect for seed characters. The highest standard positive heterosis was found 26.53% in BT-19 X BT-01 followed by 23.40% in BT-01 X BT-19 and 17.92% in BT-07 X BT-19 for the fruit length. For the fruit diameter it was 18.78% in BT-13 X BT-15 followed by 15.96% in BT-15 X BT-18, BT-04 X BT-13, BT-13 X BT-04 and 15.49% in BT-18 X BT-15. The crosses BT-15 X BT-07 and BT-18 X BT-19 also showed significant positive heterosis on check variety. The highest positively significant standard heterotic effect for the yield per plant was found 30.14% in BT-18 X BT-19 followed by 25.98% in BT-19 X BT-18, 13.71% in BT-18 X BT-15 and 11.40% in the cross BT-15 X BT-07. These crosses also showed positive standard heterosis for seed characters.

Considering the significant level of standard heterosis for the traits the four crosses viz BT-18 X BT-19, BT-15 X BT-07, BT-19 X BT-18 and BT-18 X BT-15 were selected. These crosses may be utilized to develop hybrid variety. Since earliness and desirable fruit shape are the important considerations for choice of elite high yielding F1 hybrids, the decision for final selection of a hybrid for commercial cultivation should also take into account the earlier two factors *i.e* earliness and fruit shape *i.e*., high fruit yield. Considering yield and yield contributing traits of the studied cross combinations, BT-18 X BT-19 and BT-15 X BT-07 revealed significantly higher heterosis and earliness which led to conclude that these two combinations could be the most promising hybrids (F_1) which can be utilized for commercial purpose.

Conclusions

Yield improvement is the prime need in bitter gourd breeding in Bangladesh. Genetic potentiality can be exploited by recombining the genes which increased yield in generally associated with vigor of the hybrid. However, not all crosses produce progenies which show hybrid vigor and all hybrids do not express same level of heterosis. This information can only be gained by crossing between the superior inbred lines in a definite pattern followed by evaluating which combinations would give the best offspring. Different sets of dominant alleles could be selected for the same trait in different inbred lines which would result cumulative better effect in the heterozygote hybrid compared to the homozygous inbred. Correlation coefficient study suggested that high number of fruits per plant, single fruit weight, fruit length, fruit diameter and earliness of female flower opening and node number at which first female flower open could be considered as selection criteria for higher yield per plant of bitter gourd. Thus, days to first opening of female flower, number of fruits per plant, single fruit weight and fruit diameter had positive direct effect on yield of bitter gourd. Path coefficient analysis showed that number of fruits per plant had maximum direct effect on yield per plant followed by single fruit weight, fruit diameter and days to first female flower opening. However, line X tester analysis helps to select the superior inbred for the construction of a hybrid. Therefore, crosses should be made between the better parents selected on the basis of ranking. Considering the genetic information of yield and yield related traits, proper breeding method should be taken to develop high yielding bitter gourd variety. Wide range of genetic diversity for fruit morphology and other characters were observed in twenty-seven bitter gourd inbred lines. Relatively higher GCV and high heritability coupled with high genetic advance of different yield contributing characters indicated the better response in selecting the characters for yield improvement in bitter gourd. Out of twenty-seven, seven different inbred lines were selected on the basis of ranking of inbred lines. To select homozygous parents from the inbred lines, ranking was done on the basis of general combining ability through line X tester method and mean performance of the inbred lines. The parents BT-15, BT-07, BT-18, BT-19, BT-13, BT-01 and BT-04 are selected as the best parents for hybridization to develop hybrid varieties. Combining ability analysis showed both additive and non-additive gene actions for the expression of different characters. Positive association between parental means and their general combining ability (GCA) indicated that four inbred lines of bitter gourd were better parents considering all important economic traits for the crossing programs. High sca effects may arise not only in crosses involving H^+ X H^+ combinations but also in those involving H^+ X M^+. Even L^+ X M^+ cross combinations or L^+ X H^+ crosses can also lead to high sca values. Thus, in practice some of the low combiners should also be accommodated in hybridization program.

A total of forty-two experimental hybrids have been produced through a full diallel fashion, so interested bitter gourd breeders could receive both the inbred lines and hybrids for further investigation. High heterosis and sca effects for yield and yield contributing traits were present. Considering the desired significant performance for yield and yield contributing traits of bitter gourd two hybrids viz. Peea G X Polo VLG (BT-15 X BT-07), Sakura LG X Prince XL (BT-18 X BT-19) were identified as the best performer as well as also possessed attractive fruit as per present market demand. These Test hybrid-1 F_1 (BT-15 X BT-07) and Test hybrid-2 F_1 (BT-18 X BT-19) have been registered as HSTU-1 (Registration number: 1(27)/293/ 2020) and HSTU-2 (Registration number: 1(27)/294/ 2020) respectively; can be used for commercial utilization.