VARIABILITY AND INTERRELATIONSHIP AMONG THE VARIETIES OF Bt AND CORRESPONDING NON-Bt BRINJALS (*Solanum melongena* L.)

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CERTIFICATE

This is to certify that thesis entitled, **"VARIABILITY AND INTERRELATIONSHIP AMONG THE VARIETIES OF Bt AND CORRESPONDING NON-Bt BRINJALS (*Solanum melongena* L.)"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University Dhaka, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in GENETICS AND PLANT BREEDING, embodies the result of a piece of bona fide research work carried out by Mahfuza Akther, Registration No. 10-03791 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has been duly acknowledged.

Dated: June, 2015
Place: Dhaka, Bangladesh

Prof. Dr. Md. Sarowar Hossain
Supervisor

Dedicated to
My Beloved Parents

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ABSTRACT

An experiment was conducted during the period from November 2015 to April 2016 in rabi season in the experimental area of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka to find out the variability and interrelationship of yield and yield contributing traits in Bt Brinjal *(Solanum melongena* L.*)* along with parents. The result indicated that different brinjal genotypes differed significantly regarding all the characters studied. Minimum differences of genotypic and phenotypic variances and coefficient of variation as well as high heritability coupled with high genetic advanced in percent of mean were observed for all the traits of different brinjal genotypes indicated additive gene effects of these traits. Fruit diameter of different brinjal genotypes had a high degree of significant positive association with yield per plant and high positive direct effect indicated that these characters had the major contribution towards the yield per plant. Regarding fruit diameter and yield per plant, the genotype BARI Bt Begun 4 performed best. BARI Bt Begun 3 and BARI Bt Begun 2 produce higher yield next to the genotype BARI Bt Begun 4. Based on the comparison of eight brinjal varieties, BARI Bt Begun 4 was found to be the highest yielder followed by BARI Bt Begun 3 and BARI Bt Begun 2. The other varieties showed much less yield compared to the formers. As no insecticide was used to study the resistance capacity of the brinjal genotypes against Lepidopteran insects like fruit and shoot borer, all Bt Brinjal varieties showed much higher yields compared to their non Bt Brinjal parents.

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SOME COMMONLY USED ABBREVIATION

FULL WORD	ABBREVIATION
Agro-Ecological Zone	AEZ
And others	*et al.*
Accessions	ACC
Bangladesh Agricultural Research Institute	BARI
Bangladesh Bureau of Statistics	BBS
Centimeter	cm
Co-efficient of Variation	CV
Etcetera	etc.
Figure	Fig.
Genotype	G
Genetic Advance	GA
Genotypic Co-efficient of Variation	GCV
Genotypic Variance	σ^2_g
Gram	g
Heritability in broad sense	h^2b
Journal	J.
Kilogram	Kg
Meter	m
Mean Sum of Square	MSS
Millimeter	mm
Muriate of Potash	MP
Number	No.
Percent	%
Phenotypic Co-efficient of Variation	PCV
Phenotypic variance	σ^2_p
Randomized Complete Block Design	RCBD
Replication	R
Research	Res.
Sher-e-Bangla Agricultural University	SAU
Standard Error	SE
Square meter	m^2
Triple Super Phosphate	TSP

CHAPTER I

INTRODUCTION

Brinjal *(Solanum melongena* L.*)* is one of the important vegetable crops grown in all parts of Bangladesh (Rashid, 1995). Brinjal also known as Eggplant or Melongene or Aubergene is one of the most important and popular Solanaceous crops under the botanical name *Solanum melongena* L. (2n = 24) grown in Bangladesh. There are three main botanical varieties under the species melongena (Choudhury, 1976). It has a positive role in both summer and winter to fulfill the market demand of vegetables of Bangladesh. Yield potentiality of the varieties cultivated in Bangladesh is less and choice of brinjal size, shape, and skin colour varies in different locations. Improvement in fruit yield, colour, and insect resistances will certainly enhance the production and consumption of the crop. Genetic variability of brinjal has been studied by various workers in India (Misra, 1961; Thakur *et al.*, 1968) and also in Bangladesh (Basar, 1999; Chowdhury, 2005). For improvement programme, the information about variability is a prerequisite. The phenotypic variability among a collection of genetic stocks gives an indication of potential genotypic variability, however, the quantitative characters are greatly influenced by the environment. Therefore, information of the extent of variability available in some important economic traits and their heritability will be helpful to the breeders to formulate sound breeding programmes. Hence, the present study was undertaken to evaluate yield performance, to estimate the extent of variability, heritability and expected genetic advance of sixteen exotic and local eggplant germplasm.

Asia has the largest eggplant production, which comprises more than 90% of the world production area and 87% of the world production (Choudhary and Gaur, 2009). It is the second most important vegetable crop next to potato in Bangladesh in respect of total acreage and production. It is cultivated on about 15% of total vegetable cultivated land and contributes about 8% to total vegetable production (BBS, 2011). In Bangladesh, more than 60 different types of vegetables of indigenous and exotic origin are grown. Total vegetable growing area in the country is about 885 thousand acres (2.47 acre is equal to a hectare) in 2009-2010 of which 60% are cultivated during winter. Depending on yield, size, shape as well as consumer's preference a number of brinjal genotypes are being cultivated throughout the country. In rabi (winter) 2009-2010 the total area covered by brinjal cultivation was 28.74 thousand hectares with the production of 216 thousand metric tons and in kharif (summer), the hectares and production was 17.81 thousand and 125 thousand metric tons respectively (BBS 2010). Brinjal is grown round the year though bulk of its production is obtained during winter season in Bangladesh. Due to its quality, diversified use, lower market price and year round availability, it has become the widely consumed vegetable in Bangladesh. As it is the major native vegetable of our country, lots of variability is available throughout the country. A number of wild types are also found here and there throughout the country.

Brinjal is grown across Bangladesh round the year. It is cultivated on small, family- owned farms where sale of its product serves as a ready source of cash income throughout the year. It is rich in protein, calorie, riboflavin, calcium and iron. A number of cultivars are grown throughout the country depending on yield, size and shape as well as consumer's preference. The actual area under brinjal cultivation is not available due to its seasonal nature of cultivation. In Bangladesh total cultivated area of kharif and rabi brinjal reported to be 22,221 hectares and 42,836 hectares of land respectively (BBS, 2000) and total production was 3,78,000 metric tons (BBS, 2002). The wide range of variability was observed in respect of morphological traits, but till date very few systematic assessment of genetic diversity on this crop has been done. Brinjal has been a popular vegetable in our diet since ancient times. It is liked by both poor and rich. Contrary to the common belief, it is quite rich in nutritive value and can be compared with tomato (Choudhury, 1976).

But their productions are hampered due to the infestation of different insects like root and shoot borer, spider mites and diseases like wilt, phomopsis blight, etc. Ultimately the control approach based entirely on toxic pesticides and chemicals is not working properly in the field. On the other hand, the chemicals and pesticides led to higher costs of production, environmental pollution, destruction of natural enemies, development of pesticide resistance etc. We need it to bring down the cost of cultivation. Sixty to 70% of planted brinjal is lost to pests during cultivation. Farmers use insecticides and sprays that are harmful to the soil as well as to the laborer's working on farms. Brinjal has no natural resistance to the stem borer (pest). Hence, there is a need to have a variant that is resistant to the pest. The alternative technology is to use the pest resistant gene of *Bacillus thuringiensis* (Bt). Through this technology, cost and pollution can be reduced and the produce will be bountiful. Moreover, the technology is ready to deliver the product now. On October 30, 2013 with approvals from the Ministries of Environment and Forests (MoEF) and Ministry of Agriculture (MoA), the Bangladesh Agricultural Research Institute (BARI) received permission to release four varieties of Bt brinjal in time for the 2013–2014 growing season that are named as BARI Bt Begun 1 (Bt Uttara), BARI Bt Begun 2 (Bt Kajla), BARI Bt Begun 3 (Bt Nayantara), and BARI Bt Begun 4 (Bt ISD006).

The Bt brinjal is a suite of transgenic brinjals created by inserting a crystal protein gene (*Cry1Ac*) from the soil bacterium *Bacillus thuringiensis* into the genome of various brinjal cultivars. *Bacillus thuringiensis* microbial formulations have been shown to be very specific to target insect pests. Bt is a trait and not a variety of Brinjal and it is important to point this out because people tend to confuse trait and variety. This Bt trait is added to existing varieties of Brinjal by back-crossing. For example, there are hundreds of varieties of Bt-Cotton in India, just as there are many non-Bt varieties as well. Bt brinjal provides an effective environmentally friendly and economically sustainable solution to tackle crop losses resulting from fruit and shoot borer infestation. The cry1-Ac protein produced in Bt brinjal is similar in structure and activity to that found in nature and is already available and used commercially in the form of Bt-based bio-pesticides, often used by organic growers. However, pesticidal sprays are only effective during a brief window then the larvae hatches from the egg and bores into the fruit or shoot of the brinjal plant. Once the larvae takes refuge within the fruit they are safe from surface sprays however intensive they may be, and are free to destroy the crop from within. Bt brinjal, in which the cry1-Ac gene is genetically engineered into the brinjal, ensures a built-in resistance against the fruit and shoot borer larvae.

Tests have shown that Bt brinjal’s effectiveness is 100% pest mortality in shoots and fruits, compared to 30% or less with conventional pesticide treated varieties. Because of this quality Bt has been used for pest control in agriculture since the 1920s. Bt brinjal looks and has the same nutrient composition as the conventional brinjal except for the additional Bt protein that renders it resistant to the fruit and shoot borer. It retains the same nutritional value as non-Bt brinjal and feeding tests with different animal groups that included fish, chicken, rabbit, goat, rats and buffalo revealed no toxicity or new allergenic compounds. It is considered environmentally friendly and is used widely by organic farmers since it is harmful only to a small class of insects and does not have any effect on other insects or animals or human beings. What scientists have done is that they have isolated the gene responsible for producing the Bt-toxin in the bacterium and have incorporated this gene into the brinjal genome. With this modification the plant itself produces it own Bt-toxin. As a result brinjal growers can use much less pesticides, thus potentially saving them time and money while also and reducing their crop losses. Since chemical pesticides are reduced it has environmental benefits as well.

Considering the above facts, the present study has been under taken to fulfill the following objectives:

- to study the variability and the yield potentiality of different genotypes
- to compare the Bt brinjal with the parent varieties
- to categorize the brinjal materials on the basis of defense mechanism against insect pests including fruit and shoot borer

CHAPTER II

REVIEW OF LITERATURE

Eggplant is one of the most important vegetable crops grown in all parts of Bangladesh. In Bangladesh research effort on variability studies of eggplant seems to be poor. In order to increase desired genotypes in breeding progenies, superior parents with high breeding values are needed. Variability and genetic diversity are the fundamental law of plant breeding which is a major tool being used in parent selection for efficient hybridization programme. Therefore, relevant information available in the literature pertaining to the comparative studies of the Bt Brinjal and the parents were reviewed in this section. Moreover, literatures related to the efficient multivariate techniques for diversity analysis were also reviewed in the following headings.

- **Morphological characters**
- **Yield and its contributing characters**
- **Infestation and diseases**
- **Qualitative characters**

2.1 Morphological characters:

Chadha and Saimbhi (1977) investigated with 29 genotypes of brinjal for the varietal variation in flower type and showed that all the varieties per lines bear flower cluster along with a solitary flower and the fruiting habit in a variety was not directly related to the occurrence of different flower types in cluster.

Chowdhury *et al.* (2007) conducted an experiment in the Olericulture Division of Horticulture Research Centre (HRC) of Bangladesh Agricultural Research Institute (BARI) during the winter season 2003-04,) to evaluate and compare aubergine genotypes Uttara, BL-081, B-009, BL-SA-02, Nayantara, BL-097, BL-102, BL-113, BL-114, ISD-006, BL-072, EG-195, BL-095, BL-081, BL-099 and Kazla representing samples from the different districts of Bangladesh. Various morphological and yield contributing characters of these aubergine genotypes were observed. Significant variations for most of the morphological characters were observed among the aubergine genotypes. The results revealed that the maximum number of fruits per plant was obtained from the line BL-099 (43.67). The maximum fruit weight (410.9 g), fruit weight per plant (4.79 kg) and fruit breadth (8.71 cm) were recorded from the line ISD-006. The longest fruit was recorded from the line B-009 (30.22 cm).

Golani *et al.* (2007) observed twenty-three genotypes of brinjal (aubergine) during the late kharif season of 2001/02-2003/04 in Junagadh, Gujarat, India to determine the nature and magnitude of genetic divergence and genetic variability for fruit yield and its contributing characters: plant height, plant spread, fruit length, fruit girth and 10-fruit weight. The population was grouped into 6 clusters. Cluster I comprised 6 genotypes, followed by clusters II and III, each with 5 genotypes, while cluster VI was a solitary cluster. The clustering pattern indicated that there was no association between the geographical distribution of the genotypes and genetic divergence. However, the shape and colour of fruits and the genotypes played a major role in the grouping of the genotypes into various clusters. The maximum intercluster D2 value was reported between clusters II and III. The genotypic coefficient of variation, heritability and genetic advance as percentage of mean were high for fruit length, fruit girth and 10-fruit weight, indicating additive gene action, which contributed to maximum divergence and played a major role in the improvement of brinjal yield.

Kushwah and Bandhyopadhya (2005) observed variability and correlation analyses for 13 traits (number of days to 50% flowering, number of flowers per cluster, number of fruits per cluster, number of days to first picking, number of pickings, fruit length, fruit diameter, fruit weight, number of fruits per plant, leaf area, number of leaves, plant height, and fruit yield per plant) of aubergine which were conducted in Tehri Garhwal, Uttaranchal, India during the kharif of 2000. Highly significant variation among the genotypes was recorded for all traits. High phenotypic and genetic coefficients of variation, and high genetic advance were recorded for fruit weight, number of flowers per cluster, and fruit diameter. Except for leaf area and number of leaves, high heritability estimates were recorded, suggesting that selection for the remaining characters would be effective. At the genetic level, the number of fruits per plant, fruit diameter, and number of pickings showed a significant positive correlation with yield per plant. At the phenotypic level, fruit yield was positively correlated with the number of pickings, fruit diameter, and number of fruits per plant, but was negatively correlated with the number of days to first picking. Fruit weight and diameter were negatively correlated with the number of fruits per plant, fruit length, number of fruits per cluster, and number of flowers per cluster.

Lenuta and Nedelea (2010) most important breeding objectives are complex traits consisting of multiple components. In that direction, in eggplant yield can be decomposed into several yield components as well as branches number per plant, fruit number per plant, fruit weight. The aim of this paper was to evaluate the variability and breeding potential of different eggplant cultivars for some yield traits. A significantly bigger fruit comparing to the control was observed for the following varieties: Baluroi and Long purple, which may be successfully used in plant breeding programs to improve the fruit weight. Given the variability of fruit length and diameter, the choice of the genitors in the eggplant improvement programs the market requirements should be considered. The existing variability within the studied assortment allows the use of considered varieties within eggplant breeding programs taking in consideration the increased yield that is attainable for certain varieties on the ground of contrasting traits.

Mehrotra and Dixit (1973) observed a wide range of phenotypic variation for fruit yield, fruit length and plant height in 45 varieties per lines of eggplant. High heritability accompanied by high estimates of genetic advance expressed as a percentage of the mean was observed for plant height and bottom girth of the fruit.

Mohanty (2001) conducted an experimented on 15 aubergine genotypes during the kharif seasons of 1994, 1995 and 1996 in Orissa, India to determine genotype environment interaction. Genotype environment interaction was significant for average fruit weight, number of fruits per plant, and yield. Phenotypic coefficient of variation was high for number of fruits per plant (42.0%) and average fruit weight (38.9%), while it was moderate for number of branches per plant, yield and plant height. High magnitude of genotypic coefficient of variation was observed for number of fruits per plant (40.2%) and average fruit weight (36.9%) whereas it was moderate for number of branches per plant (25.6%). The estimates of heritability in the broad sense ranged from 62.9% for plant height to

91.6% for number of fruits/plant. High estimates of genetic gain were obtained for number of fruits per plant (77.26%) and average fruit weight (72.06%) while it was moderate for number of branches per plant (47.43%). The phenotypic and genotypic path coefficient studies showed that average fruit weight had the highest positive direct effect on yield followed by the number of fruits per plant.

Muniappan *et al.* (2010) carried out an experiment on the genetic divergence was to assess the variability, association, direct and indirect effects of eight morphological characters in thirty four eggplant (*Solanum melongena L.*) genotypes. High PCV and GCV were recorded by the characters viz., number of branches per plant, fruit length, fruit breadth, number of fruits per plant, average fruit weight, and fruit yield per plant. All the characters were accompanied by high heritability and high genetic advance excepting days to 50 per cent flowering. The characters were mostly controlled by additive gene action, hence it could be inferred that simple selection will be effective for these characters. The characters such as number of branches per plant, fruit breadth, number of fruits per plant and average fruit weight exhibited positive and significant association with fruit yield per plant. Path analysis indicates that number of fruits per plant and average fruit weight had high directs the effects and were the major factors that determine fruit yield per plant.

Naik *et al.* (2010) conducted an experiment at Olericulture Unit, Kittur Rani Channmma College of Horticulture, Arabhavi, Gokak, Belgaum, and Karnataka during kharif season of 2004-05 to evaluate 61 genotypes using randomized block design. The observations on 24 characters were recorded. High heritability values and high percentages of genetic advance were recorded fruits length, number of fruits per cluster, number of fruits per plant, total yield per plant, yield per plot, yield per hectare which indicated that there were more number of additive factors for these characters and improvement in yield could be brought about by selection, based on phenotypic observations.

Panda *et al.* (2005) observed genetic parameters for 13 traits (number of days to first flowering, number of flowers per inflorescence, number of primary branches per plant, plant height, fruit length, fruit diameter, number of marketable and unmarketable fruits per plant, total number of fruits per plant, weight of marketable and unmarketable fruits, total weight of fruits per plant, and early yield per plant) during the winter of 2001-02 and autumn-winter of 2002-03 in 5 round-fruited aubergine cultivars (Pant Rituraj, PB-60, PB-61, PB-62 and T-3) and 10 crosses (produced by diallel crossing between these cultivars) grown in Pantnagar, Uttaranchal, India. Heritability in the narrow sense was highest for number of days to first flowering, whereas the genetic advance was greatest for weight of marketable fruits per plant. The number of flowers per inflorescence, number of marketable fruits per plant, fruit diameter, and total number of fruits per plant were characterized by high genetic advance and high heritability; thus, selection would be suitable for the improvement of these traits. The analysis of the genetic component of variation revealed over dominance for plant height, number of marketable fruits per plant, and total weight of fruits per plant, and partial dominance for number of days to first flowering, fruit diameter, number of unmarketable fruits per plant, and total number of fruits per plant. Fruit length and number of flowers per inflorescence showed complete dominance. The results suggested that heterosis breeding will be effective for the improvement of plant height, number of marketable fruits per plant, and total weight of fruits per plant, whereas combination breeding will be suitable for the improvement of the other traits.

Prasad *et al.* (2006) conducted a field experiment in Raipur, Chhattisgarh, India during the kharif season of 2002-03 on genetic variability in 52 aubergine genotypes. Moderate to high estimates of genotypic coefficient of variation, heritability and genetic advance was recorded for average fruit weight, fruit yield, fruit girth, number of fruits per plant and fruit length. Low estimates of genotypic coefficient of variation and genetic advance were recorded for number of days to 50% flowering, fruit set and number of primary branches. Moderate estimates of genotypic coefficient of variation, genetic advance and heritability were recorded for plant height and number of days to first flowering and fruit set.

Rajesh *et al.* (1998) stated the information on heritability and genetic variance derived from data on 16 characters in 40 diverse cultivars grown during 1993-94 and 1994-95. Plant spread, days to 1st flowering, flowers per plant, fruits per plant and fruit yield per plant gave comparatively lower values of heritability indicating environmental influence of these characters. The highest estimate for genetic advance was noted for fruit weight.

Reena and Mehta (2009) carried out an investigation to study genetic variability in 20 genotypes of brinjal. Phenotypic coefficient of variation was greater than genotypic coefficient of variation for all the characters. Both phenotypic coefficient of variation as well as genotypic coefficient of variation was high for seed pulp ratio, weight of fruit and number of fruits per plant. High heritability and moderate genetic advance were observed for plant height, fruiting span and number of fruits per plant suggesting that selection based on phenotypic performance of these traits is possible. Good variation was also observed for the morphological characters investigated. Genotypes PB-64, D-77-19, PB-67 and JB-15 were found least susceptible to discolouration. It is an important character that should be considered in breeding programme for developing variety having good consumer preference.

Rylski *et al.* (1984) showed that percentage of fruit set is found where the stiga is above the stamens. In short-styled flowers the androecium is fertile but the stiga is smaller with underdeveloped papillae and lower sugar content than that in long-styled flowers. There is no pollen germination on the stiga or penetration of pollen tube into short styles.

Singh *et al.* (2010) carried out an experiment with 99 genotypes (76 F1s, 19 lines and 4 testers) of brinjal to assess the character association and contribution of quantitative trait towards yield. Yield per hectare was positively correlated with number of flowers per plant, number of fruits per plant, fruit length, fruit weight, fruit volume, number of fruit picking, plant height, plant girth, leaf area and plant spread (in both direction) while days to first fruit harvest and per cent of plant wilted showed significant negative association with fruit yield. The path analysis suggested that fruit weight and fruit per plant had high direct effect on fruit yield. However, the indirect contribution of fruit diameter, leaf area and plant spread (in both direction) were appreciable to affect fruit yield in brinjal.

Tambe *et al.* (1993) studied the diversity using D2 analysis among 25 diverse varieties per lines of brinjal. The 25 genotypes were grouped into 5 clusters with substantial genetic divergence between them. They reported that geographical distribution did not necessarily follow clustering pattern.

2.2 Yield and its contributing characters:

Aramendiz *et al.* (2009) studied the phenotypic, genotypic and environmental correlations between six characters of 24 cultivars of eggplant (*Solanum melongena*) in the research centre of Turipana of Corpoica. A completely randomized block design was used with three repetitions and experimental units of 10 m^2. The analyses showed that genetic correlations were of higher or equal magnitude to the phenotypic correlations, while the environmental ones had low effects on the results. The number of fruits and the yield showed a positive and highly significant ($r=0.56$, $P<0.01$) genetic correlation. A negative and highly significant ($r = -0.68$, $P<0.01$) genetic correlation was observed between fruit length and fruit strength. No correlation was detected between yield and fruit weight ($r = 0.04$). Fruit number and fruit weight showed a negative and highly significant genetic correlation ($r = -0.63$, $P<0.01$). It is suggested that the number of fruits per plant could be used as a selection criterion to obtain high yield eggplant cultivars.

Bhutani *et al.* (1977) studied genetic variability in 17 brinjal varieties per lines of diverse origin. The number of marketable fruits per plant and the total number of fruits per plant both had high genetic coefficient of variation and high estimates of heritability and genetic advance.

Das *et al.* (2002) carried out an investigation with 11 genotypes of aubergine under three fertility levels. The pooled data revealed that characters like average fruit weight, wilt incidence, fruits per plant, plant height, fruit yield per plant, leaf width, leaves per plant, leaf length and stem girth showed high heritability values. Considering the three genetic parameters namely genotypic coefficient of variability, heritability and genetic advance together, it was evident that phenotypic selection would be more effective for characteristics like average fruit weight, fruit yield per plant, fruits per plant and wild incidence than other characteristics.

Gopimony *et al.* (1984) studied the analysis of data on total fruit yield per plant and 11 related traits from 27 *Solanum melongena* verities per lines revealed that the phenotypic coefficient of variation ranged being highest for yield and single fruit weight, heritability and genetic advance being highest for single fruit weight and over all mean. The association of high heritability and genetic advance shown by yield, single fruit weight and fruit diameter was taken as an indication of additive gene effects.

Jadhao *et al.* (2009) studied the Correlation and path analysis of 50 F4 progenies and six parents of brinjal (*Solanum melongena L.*) for eleven yield contributing characters. The phenotypic coefficient of variation was greater than the respective genotypic coefficient of variation for all the characters studied. The yield contributing characters viz., plant height, number of branches per plant, days to last picking, fruit weight and number of fruits per plant showed positive significant correlation with fruit yield per plant. Path coefficient analysis revealed that plant height, number of branches per plant, days to Initiation of flowering, days to first picking, days to last picking, fruit length and fruit weight showed positive direct effect on fruit yield per plant indicating these characters had direct relation with yield, so while seeking improvement in yield attributes, these characters may get priority.

Muniappan *et al.* (2010) reported the number of fruits per plant had positive correlation with fruit length, fruit width and individual fruit weight. Fruit length had negative correlation with fruit width. There was positive insignificant correlation between fruit length with individual fruit weight. Number of fruits has positive correlation with fruit yield. Individual fruit weight was positively correlated with plant height, number of primary branches per plant, number of secondary branches per plant, number of fruits per plant, but insignificant with fruit length and fruit width.

Naliyadhara *et al.* (2007) carried out an experiment on evaluation of 21 genotypes of brinjal during late kharif season that revealed that PCV was slightly greater than GCV for all the traits. High heritability with moderate to high GCV and genetic gain was observed for all the characters except fruit yield which could be improved by simple selection methods. The genotypic correlation coefficients were higher than corresponding phenotypic one for most characters reflecting predominant role of heritable factors. Fruit yield displayed significant and positive genotypic and phenotypic correlations only with 10-fruits weight. Path coefficient studies explained that fruit length, 10-fruits weight and plant spread exerted higher positive direct effect on fruit yield suggesting to give emphasis on such fruits while imposing selection for fruit yield of brinjal.

Prabhu and Natarajan (2007) evaluated thirteen diverse genotypes for estimating the range of variability, heritability and genetic advance of growth and yield attributes in aubergine. The high genotypic coefficient of variation expressed by yield contributing traits such as number of fruits per plant, mean fruit weight and fruit borer infestation. Higher values of genetic advance as percent over mean along with higher estimates of heritability were observed for all characters except earliness. This will be useful to get desired improvement in the yield of aubergine genotypes.

Randhawa *et al.* (1993) studied 22 genotypes of brinjal on 24 quantitative characters for deriving information on yield co-relation and observed that fruits per plant and number of branches per plant had the highest direct effect on yield.

Sarma *et al.* (2000) evaluated thirty four genotypes of brinjal (*Solanum melongena*) of diverse origin in plots at Jorhat. Analysis of data on yield and its components grouped the genotypes into 10 clusters using Mahalanobis's D2 statistic. Fruit circumference and average fruit weight were the main characters affecting grouping of genotypes. Eco-geographic diversity of the genotypes was not related to genetic diversity.

Sharma and Swaroop (2000) conducted a field experiment on genetic variability in terms of mean, genotypic and phenotypic coefficient of variances, heritability, expected genetic advance and expected genetic advance as per cent of mean, correlation and path coefficient for yield per plant and its attributing traits in 27 genotypes. Considerable variation was observed in all the characters. The phenotypic coefficient of variation was higher than genotypic coefficient of variance in all the characters. The genotypic coefficient of variation estimates was high for number of fruits per plant, mean fruit weight and yield per plant. Heritability estimates were high for length of fruits, number of fruits per plant, mean fruit weight and yield per plant. In spite of high heritability values for most traits, the expected genetic advance as percentage of mean ranged from 11.47 to 95.36. Genotypic correlation was higher in magnitude over phenotypic correlation. Most of the characters were positively correlated with yield except for days to 50% flowering. Path coefficient analysis revealed that number of fruits per plant, mean weight of fruits and diameter of fruits had maximum direct effect at genotypic level and hence direct selection could be made for these characters for improving the yield, while maximum direct effect at phenotypic level was showed by number of fruits per cluster, plant height, number of fruits per plant, mean weight of fruits and diameter of fruit. The number of fruits per cluster showed maximum indirect positive effect on yield. Number of flowers per cluster, number of branches per plant, plant height and length of fruit had positive indirect effect towards yield per plant via number of fruits per plant and hence simultaneous selection for these characters can be made for the improvement of yield.

Sherly and Shanthi (2008) carried out an investigation with 24 genotypes of brinjal for variability, heritability and genetic advance. The study indicated that high estimates of phenotypic and genotypic coefficients of variation were observed for fruit length, number of fruits per plant, fruit weight and fruit yield per plant. High heritability coupled with high genetic advance was registered for all the characters except total number of harvest and ascorbic acid. These characters can be effectively improved through selection.

Suneetha and Kathiria (2006) studied the combining ability for 9 traits (fruit yield per plant, days to first picking, plant height, plant spread, 1000-seed weight, fruit dry matter, total soluble sugars, total phenols and leaf area per plant in 10x10 diallel (excluding reciprocals) of aubergine during late summer in Gujarat, India. Analysis of variance for combining ability revealed significant mean squares due to both general (gca) and specific combining ability (sca) for fruit yield, yield components, quality and physiological characters. KS 224, PLR 1, Morvi 4-2 and JBPR 1 appeared to be good general combiners for fruit yield per plant. In addition, KS 224 was a good combiner for total phenols, whereas PLR 1 and Morvi 4-2 were good combiners for total soluble sugars. These parents also recorded high per se performance for the traits. Among the hybrids, 22 crosses exhibited significant and desirable sca effects for fruit yield per plant. Of these, 9 crosses also exhibited high per se performance. KS 224 x PLR 1, involving both good combiner parents, recorded the highest fruit yield per plant and exhibited desirable sca effects and per se performance for most traits. Six other crosses also recorded significant and desirable sca effects and per se performance for fruit yield and quality traits.

Suneetha *et al.* (2006) investigated the manifestation of hybrid vigour in 45 aubergine hybrids for yield, yield components, quality and physiological characters during the summer season in Gujarat, India. Hybrids were found to be high yielding, relatively late and tall with greater plant spread and leaf area per plant, compared to their parents. Existence of significant levels of heterobeltiosis and commercial heterosis for all the traits in the material studied was also observed from the significant mean squares recorded for parents vs. hybrids and control vs. hybrids components of variation in the ANOVA. Furthermore, the expression of heterosis was maximum over better parent for total soluble sugars, and for leaf area per plant over the control, GBH 1. Total phenols had also recorded high levels of heterosis (>70%) over both better parent and the control. Heterobeltiosis and standard heterosis more that 20% were also recorded for the number of days to first picking, 100-seed weight and fruit yield per plant. The existence of such high levels of heterosis for fruit yield, yield components, quality and physiological characters in aubergine hybrids during summer indicated the potential of hybrid cultivation during off-season. Among the hybrids, PLR 1 x JBPR 1, a relatively early and dwarf hybrid was identified as a potential hybrid combination for fruit yield per plant, while the hybrid JB 64-1-2 x AB 98-13 was identified as a promising hybrid for both, fruit yield and quality for cultivation during off-season.

Vedivel and Bapu (1990) studied nineteen genotypes of eggplant including 7 from foreign sources, which were grown in a Randomized Block Design for observation on growth and yield related traits. Plant height, fruit weight and fruit per plant exhibited high genotypic variance. High heritability coupled with high genetic gain from fruit yield per plant, fruit per plant and length indicated the predominance of additive gene effects.

2.3 Infestation and diseases:

Abrol and Singh (2003) stated that fruit and shoot borer (FSB) is a small larva that bores inside shoots and bores into petioles and midribs of large leaves and tender shoots, causing shoot tips to wilt. Later on, they also bore into flower buds and fruits. Attributable to its infestation, it affects the quality and quantity of fruits. Affected fruits are difficult to sell on the market (unless the price is discounted heavily) and contain significantly less vitamin C.

Alam *et al.* (2003) observed that the full-grown larvae come out of the infested shoots and fruits and for pupate in the dried shoots and leaves or in plant debris fallen on the ground within tough silken cocoons. There were evidences of presence of cocoons at soil depths of 1 to 3 cm. FAO (2003) made a study which stated that the full-grown larvae pupate on the surface they touch first. The pupal period lasts 6 to 17 days depending upon temperature.

Rahman (2006) stated that it is 7 - 10 days during summer, while it is 13 - 15 days during winter season. The color and texture of the cocoon matches the surroundings making it difficult to detect.

Braham and Haji (2009) conducted an experiment to determine the use of insecticides based on different chemistry and found that varying modes of action is an important component of an IPM strategy. Hence, insecticides continue to be an integral component of pest management programs due mainly to their effectiveness and simple use. Use of pesticide was not suggested at first hand but judicious use as last option of pest management was suggested globally.

Chakraborti and Sarkar (2011) stated that eggplant fruit and shoot borer, *Leucinodes orbonalis Guenee* is the key pest of eggplant inflicting sizeable damage in almost all the eggplant growing areas. Dutta *et al.* (2011) also observed that it is most destructive, especially in south Asia. Baral *et al.* (2006) studied its feeding inside fruit; the fruits become unmarketable and yield losses up to 90 percent. Sharma (2002) stated that it also reduces the content of vitamin C in fruit up to 80 percent. Gapud and Canapi (1994) observed that many farmers leaving growing eggplant because of this pest. Therefore, pertinent literatures were gleaned and overviews prepared for the management of the *L. orbonalis* with consideration of supporting literature helpful for management.

Crawford *et al.* (2003) and Quasem (2003) conducted detailed socioeconomic studies along with large scale trials of Bt Brinjal and indicated the potential of Bt Brinjal to increase farmers' welfare through insecticide reductions and an increase in marketable yields of brinjal fruits. Different studies were conducted separately by different universities (like the University of Hohenheim by Stuttgart, Germany and the Singapore Management University) to demonstrate the socioeconomic impact of Bt Brinjal. They found that Bt technology has a significant potential to increase farmers' welfare through insecticide reductions and sizeable increases in marketable yield. The most destructive insect pest of eggplant in the Philippines and other Asian countries is the fruit and shoot borer (FSB). Eggplant yield losses from 51 to 73% due to FSB have been reported in the country.

Donegan *et al.* (1995) reported an important aspect of the risk assessment of transgenic plants on soil ecosystem from residual plant material following harvesting and tillage. In their experiments, they suggested that apart from Bt toxin production, genetic manipulation or tissue culturing of the plants may have produced a change in plant characteristics that can influence growth and species composition of soil micro-organisms. But they did not observed any toxic effect of Cry protein on microorganism of the soil.

Kale *et al.* (1986) reported that the susceptible varieties showed higher shoot infestation as compared to resistant varieties. Chandha (1993) conducted an experiment with resistant varieties and found that low fruit infestation. Long narrow fruited variety suffered less because of low egg laying preference compared to short and wide fruited. Because of antibiosis, resistant varieties resulted low larval survival and weight gain of pupae significantly lower.

Kolady and Lesser (2005) observed that in India, 43 percent of brinjal farmers suffered from health hazards due to various complexities related to pesticide application.

Mall *et al.* (1992) studied the main problem with growing brinjal by a dozen of insect pest species, among which the most serious and vicious one is the brinjal shoot and fruit borer (FSB).

Meah *et al.* (2007) observed more than 60 cultivars of eggplant are grown in Bangladesh which shows a wide variation in fruit shape, size, colour and their reaction to disease and insects. The disease can effectively be controlled by spraying fungicides which provokes environment pollution. Islam, (2006) observed the hazards of chemical use, searching the source of resistance revealed the existence of variation in eggplant cultivars of Bangladesh against *P. vexans*.

Neupan (2000) evaluate that the cultural practice, i.e. pruning of infested twigs and branches prevents the dissemination of *L. orbonalis*. Ghimire *et al.* (2001) observed that the periodic pinching per pruning of wilted damaged shoot, their collection and burying or burning helps to reduce pest infestation. Talekar (2002) stated that pruning will not adversely affect the plant growth as well as yield. It is especially important in early stages of the crop growth and this should be continued until the final harvest. In addition, prompt destruction of pest damaged eggplant shoots and fruits at regular intervals, reduced the pest. Duca *et al.* (2004) reported that weekly removal of damaged fruits and shoots resulted in the highest weight of healthy fruits and lowest incidence of damaged fruits among the treatments.

Rahman (2000) and Wilson (2001) stated that the brinjal fruit and shoot borer (FSB) is the most destructive insect pest in South and South East Asia. To control this insect pest, farmers all over the world use large quantities of chemical insecticides singly or in combination to get blemish free fruits. In the district of Jessore, farmers spray pesticides 140 times during a cropping season of 180-200 days. As a result farmers suffer numerous health problems (including skin and eye irritation, nausea, and faintness), resulting from direct exposure to pesticide during handling and spraying. Alam *et al.* (2003) reported that in Bangladesh, almost all farmers experienced sickness related to pesticide application (e.g. physical weakness or eye infection or dizziness) and 3 percent were hospitalized due to complications related to pesticide use.

Sexena (1965) reported that the adult is a small white moth with 40-segented antennae and having spots on forewings of 20 to 22 mm spread. Young adults are generally found on the lower leaf surfaces following emergence or hiding under the leaves within the plant canopy. During day, they prefer to hide in nearby shady plots but at night all major activities, like feeding, mating and finding a place for egg-laying take place. Only dying adults can be found in an eggplant field. Mehto *et al.* (1983) observed that the adult gains full maturity in 10 to 14 days. Longevity of adults lasts 1.5 to 2.4 days for males and 2.0 to 3.9 days for females. The pre-oviposition and oviposition periods range 1.2 to 2.1 and 1.4 to 2.9 days, respectively. Kar *et al.* (1995) stated that the adult male dies after mating and the female moth dies after laying eggs. The overall life cycle completes in 22 to 55 days. It gives rise five generations a year and is active throughout the year. FAO (2003) showed the effect of climatic conditions in the life cycle of the *L. orbonalis* in eggplant. *L. orbonalis* is active in summer months, especially during the rainy season and less active from November to February. Peak populations are often reported in June-August. Development of the different stages of the insect takes longer during the winter months. *L. orbonalis* populations are reported to increase with average temperature, relative humidity and rainfall. As temperature increases and humidity decreases, fecundity increases and the duration of the life cycle decreases.

Singh and Kumar (2005) observed breeding activities in brinjal for the development of high-yielding, early, better quality and disease resistant varieties. The color of the fruit and size and shape, the proportion of seeds to pulp, short cooking time and lower solanine levels are important traits in assessing quality. As brinjal is susceptible to several pests and diseases such as wilt, Phomopsis, little leaf and root-knot nematodes and to insects such as shoot and fruit borer, jassids, epilachna beetle, etc. the development of pest resistant varieties is a major challenges. Plants are susceptible to both low and high temperature; therefore attempts are being made to develop chilling or frost- tolerant and heat-tolerant varieties.

Srinivasan (2008) conducted an experiment through the integrated pest management (IPM) strategy for the control of *L. orbonalis* consists of resistant cultivars, sex pheromone, cultural, mechanical and biological control methods. Successful adoption of IPM in eggplant cultivation increase profits, protect the environment and improve public health. The profit margins and production area significantly increased, whereas pesticide use and labor requirement decreased for those farmers who adopted the IPM technology. But, the efforts to expand the *L. orbonalis* IPM technology to other regions of South and Southeast Asia are underway.

2.4 Qualitative characters:

Advinus (2006) conducted a primary Skin Irritation test in Intox Pune with transgenic Bt Brinjal which contained cry1A(c) gene (*Solanum melongena L.)* on intact skin of rabbits. Total twelve rabbits were used in this study. Three rabbits were treated with transgenic vegetable, three with non-transgenic vegetable, three with non-transgenic vegetable (commercially available) and three remained untreated and served as control. The test article, transgenic or non-transgenic vegetable was moistened with water and applied directly on to the skin of three rabbits and was covered with gaze patch for 4 hours. The patches were removed at the end of 4 hours and skin reaction evaluated after 1, 24, 48 and 72 hours and scored according to Draize method. The results indicate that transgenic Bt Brinjal, non-transgenic vegetable and non-transgenic vegetable (commercially available) did not cause any skin reaction as observed at 1, 24, 48 and 72 hours after the patch was removed. No other signs of toxicity were seen in any of the treated animals. The irritancy index was zero (0.00) as determined from the scores of the skin reactions. Researcher concluded that on the basis of irritancy index, transgenic Bt Brinjal containing cry1A(c) gene *(Solanum melongena L.)* is classified as non-irritant to rabbit skin.

Anon. (2003a) oral toxicity study on Sprague Dawley rats in 2003 in INTOX Pune reveals that acute oral administration of Bt Brinjal expressing Cry1Ac protein to Sprague Dawley rats at the limited dose of 5000 mg per kg showed that Cry1Ac protein did not cause any toxicity and they conclude that Bt Brinjal is safe and nontoxic.

Anon. (2006b) made a study to determine the effect of Bt Brinjal on health of broiler chicken in Central Avian Research Institute (CARI) Izzat nagar demonstrated that Bt-Brinjal is as safe as non Bt-Brinjal in terms of responses of chickens fed with Bt Brinjal diets. Results of the study showed that body weight gain, food intake and food conversion ratio was not different between the birds who are feeding on Bt Brinjal than that of non Bt Brinjal. Various blood biochemical constitutions also did not differ statistically due to treatment of Bt and non Bt Brinjal diet. So they concluded that Bt Brinjal is as safe as non Bt Brinjal.

Anon. (2006c) Indian Institute of Chemical Technology (IICT) Hyderabad conducted a bio safety test on chemical fingerprinting of Bt and non-Bt Brinjal (alkaloids). The study involved isolation and identification of major alkaloids of fruit and roots of Bt and non Bt Brinjal hybrids. The results revealed that alkaloid profile from power samples of fruit and roots of Bt and non Bt Brinjal were the same with no significant variation in their relative abundances.

Arpaia (1996) tried to determine the possible hazard of CryIIIB protein of *Bacillus thuringiensis* on honeybees (*Apis mellifera L*). They supplied cry toxin to honey bees in supplementary syrup of *Apis mellifera L.* colonies. They took two different toxin concentrations which were about 400 and 2000 times higher than the expected protein content in pollen from Bt-transgenic plants. They sampled the hives every week to record larval of survival and pupil dry weight. Frames of bees were counted at the beginning and the end of the experiment as an index of colony strength. The results of the study did not show toxic effects on larvae. Pupal weight was not much affected by diet system. These results indicate that transgenic crops producing Cry IIIB toxin may represent a suitable environment for pollinators.

Basar (1999) conducted an experiment with 30 eggplant genotypes at the field of Genetic Resource' Centre in Bangladesh Agricultural Research Institute (BARI), Joydevpur, Gazipur to study their diversity based on qualitative and quantitative characters was observed for during November 1998 to March 1999. Significant variation in the characters number of flowers per inflorescence, number of fruits per plant, fruit length, fruit breadth, fruit weight among the eggplant genotypes.

Dong and Li (2007) stated that due to constant exposure to the toxin, an evolutionary pressure is created for resistant pests and the expression of the Bt gene can vary. For instance, if the temperature is not ideal, this stress can lower the toxin production and make the plant more susceptible to insects attack. More importantly, reduced late-season expression of toxin has been documented, possibly resulting from DNA methylation of the promoter. Tabashnik *et al.* (2008) reported that Bt-toxin resistance evolution in herbivore insects has been raised as a severe threat for the continuing success of Bt transgenic crops.

Herman *et al.* (2002) conducted an experiment in the laboratory to determine degradation rate of Bt proteins in the crop. They incorporated the Cry1F insecticidal crystal protein

(ICP) from *Bacillus thuringiensis* (Bt) into the genome of maize plants. They reported that after incorporation the plants were protected from attack by various Lepidopteran pests like the European corn borer, *Ostrini anubilalis* (Hubner). The stability of the Cry1F ICP in soil was assessed in laboratory study during the whole experiment. That indicates a continuous decline in Cry1F activity over time. This leads a positive impact on soil because after rapid degradation the Bt protein does not leach with groundwater and factors like sunlight destroy the Bt protein very rapidly. They concluded that Bt-toxin is environmental friendly insecticides because of two reasons, first it is target specific and second it decompose in non-toxic compounds when exposed to sunlight and safe for soil.

INTOX (2004) a mucous membrane irritation test on female rabbit in Indian Institute of Toxicology (INTOX) Pune in 2004 revealed that application of Bt Brinjal to the vaginal mucous membrane of the female rabbit did not cause any erythematic or edema as observed for 72 hours after application. Based on the average irritation index (0.0), Bt Brinjal was classified as non-irritant to mucous membrane in rabbit.

It was revealed by Ushakumiry *et al.* (1991) through the evaluation of fifty four diverse genotypes of brinjal for 10 yield components that phenotypic co-efficient of variation was higher than genotype co-efficient of variation for all the characters since they showed high heritability values. They concluded that there was enough scope for improvement of quantitative characters in brinjal by selection.

James (2006) reported that Bt is short for *Bacillus thuringiensis*, a natural bacterium in the genus Bacillus. One of the best modern agricultural defenses against plant-eating insects is *Bacillus thuringiensis* (Bt), which either can be applied to the surface of plants to provide temporary protection or can be genetically engineered into the plant to protect against insects throughout the lifespan of the plant.

Kaur *et al.* (1998) reported that cultivation of eggplant under net-house or poly-house is under practice in different part of the world. Further, he showed that cultivars BH-1, BH-2 and Punjab Barsati resulted in significantly higher.

Kumar (2002) reported that there is also another risk that, for example, transgenic maize will crossbreed with wild grass variants, and that the Bt-gene will end up in a natural environment, retaining its toxicity. An event like this would have ecological implications (Wu *et al.*, 2004), as well as increasing the risk of Bt resistance arising in the general herbivore population.

Mahyco (2004) study has been conducted by Mahyco research and life science centre, kallakal, Andhra pradesh to compare the chemical compositions in the fruit, leaf, stem and root tissues of Bt Brinjal and non-Bt Brinjal in terms of moisture, proteins, oil, ash, carbohydrates and calories for fruit tissue and nitrogen and crude fiber contents in leaf, stem and root tissues. They did not find any difference in chemical composition like moisture, protein or ash etc. in transgenic and non Bt Brinjal. They concluded that Bt Brinjal is as safe as non Bt Brinjal in term of all its chemical properties.

Mahyco (2009) carried out a 90 days Sub-chronic oral toxicity study on Sprague Daley rats which reveals that there is no adverse effect on body weight gain and average food and water intake of rat which consume Bt Brinjal for 90 days. The rats consumed about 1000 mg per kg body weight and found Bt Brinjal is non-toxic by oral route. This study also reveals that there were no biological differences between the allergic response to all transgenic and non-transgenic Brinjal hybrids.

MRC (2006) experiment conducted by Mahyco research and life sciences centre (MRC), Dawalwadi, Maharashtra for quantization of Cry1Ac insect control protein in various tissues of eight Mahyco Brinjal hybrids. This study reveals that the concentration of cry1Ac protein in various tissues (root, shoot, stem, leaf flower and fruit) was quantified. They observed that the level of concentration were sufficient for effective control of FSB (fruit and shoot borer) during the entire life of the Bt Binjal. The results of the study revealed that Bt protein was undetectable in the cooked fruits irrespective to the cooking method used (roasted, shallow, fried, deep fried or steamed). The first sampling time point was 5 minutes for roasted fruit and 1 minute for other form of cooking methods and it found safe for human consumption.

Shukla and Naik (1993) stated that brinjal is known to have ayurvedic medicinal properties and is good for diabetic patients. It has also been recommended as an excellent remedy for those suffering from liver complaints.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to find out the variability and interrelationship of yield and yield contributing traits in Bt Brinjal *(Solanum melongena L.)* along with parents. A brief description about the locations of the experimental site, characteristics of soil, climate, materials, layout and design of the experiment, land preparation, manuring and fertilizing, transplanting of seedlings, intercultural operations, data recording procedure, economic and statistical analysis etc. which are presented as follows:

3.1 Description of the experimental site

3.1.1 Experimental period

The experiment was conducted during the period from November 2015 to April 2016 (rabi season).

3.1.2 Site description

The present piece of research work was conducted in the experimental area of Sher-e-Bangla Agricultural University, Dhaka. The experimental site was at 90°22" E longitudes and 23°41" N latitudes at an altitude of 8.2 meters above the sea level. Experimental site is presented in Plate 1.

3.1.3 Climatic condition

The mean highest and mean lowest temperatures in the 6 months are 31.6 °C and 18.17 °C respectively. The monthly total rainfall, average sunshine hour, temperature during the study period was shown in Appendix I.

3.1.4 Soil characteristics of the experimental plot

The soil belonged to ‘The Madhupur Tract’, AEZ-28 (FAO, 1988). Top soil was silty in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 5.6 and had organic carbon 0.45%. The experimental area was flat having available irrigation and drainage system and above flood level. The selected plot was medium high land. The details have been presented in Appendix II

a. Just after transplanting

b. Regular watering after transplanting

c. Some days after transplanting

d. Flowering Begins

e. Fruiting begins almost al the plants

f. A photograph from regular field inspection

Plate 1(a-f). Field view of the experimental site

3.2 Experimental details

3.2.1 Materials

Few numbers of genotypes of brinjal collected from Bangladesh Agricultural Research Institute (BARI) was used in this experiment.

i. V_1 : BARI Begun 1 (Uttara)
ii. V_2 : BARI Begun 4 (Kajla)
iii. V_3 : BARI Begun 5 (Nayantara)
iv. V_4 : BARI Begun 6
v. V_5 : BARI Bt Begun 1 (Uttara)
vi. V_6 : BARI Bt Begun 2 (Kajla)
vii. V_7 : BARI Bt Begun 3 (Nayantara)
viii. V_8 : BARI Bt Begun 4 (ISD006)

3.2.2 Design and Layout of the experiment

The experiment was laid out in Randomized Complete Block Design (RCBD) with three (3) replications. Each replication contains 64 plants of both Bt and non-Bt brinjal. The spacing was 100 cm x 100 cm. Each plot was 4m length and 2 m breadth. Block to block distance was 1.5 m. The genotypes were randomly distributed to each row within each line.

3.3 Growing of crops

3.3.1 Raising of seedlings

Brinjal seedlings were raised in seedbeds of 3.0 m × 1.0 m size. The soil was well prepared and converted into loose friable and dried for seedbed. All weeds and stubbles were removed and well rotten cowdung was mixed with the soil. In each seedbed seeds were sown on 16th October 2015. After sowing, seeds were covered with light soil. Heptachlor 40 WP was applied @ 4 kg ha^{-1}, around each seedbed as precautionary measure against ants and worm. The emergence of the seedlings took place with 6 to 7 days after sowing. For healthy and uniform seedlings seedbeds were watering when necessary and removed weeds when emerged.

3.3.2 Land preparation

The plot selected for conducting the experiment was opened in the 1st week of November 2015 with a power tiller, and left exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain good tilth. Weeds and stubbles were removed, and finally obtained a desirable tilth of soil was obtained for transplanting brinjal seedlings. The experimental plot was portioned into unit blocks and blocks into unit plots in accordance with the design of the experiment. Cowdung and chemical fertilizers as indicated below in article 3.3.3 were mixed with the soil of each unit plot.

3.3.3 Application of manure and fertilizers

The sources of N, P_2O_5, K_2O and S as Urea, TSP, MP and Gypsum were applied respectively. For the experimental plot measuring $300m^2$, the entire amounts of TSP (4.5 kg), Gypsum (3 kg) and 10 kg of urea were applied during the final land preparation. The rest amount of urea was applied in three equal installments (1kg each) at 15 days after transplanting (DAT), during fruiting stage and middle point of brinjal harvesting with the amount was as per mentioned below. MP was applied in 50% at 15 DAT and during fruiting stage with the amount was as per mentioned below. Well-rotten cowdung300 kg was also applied during final land preparation. The amount of manures and fertilizers recommended by BARI (2011) shown in Table 1.

3.3.4 Transplanting of seedlings

Healthy and uniform brinjal seedlings were uprooted separately from the seed bed and were transplanted in the experimental plots in the afternoon of 15 November, 2015 with maintaining 100cm distance from row to row and 100 cm from plant to plant. This allowed an accommodation of 8 plants in each plot. The seedbed was watered before uprooting the seedlings from the seedbed so as to minimize damage to the roots. Seedlings were also planted around the border area of the experimental plots for gap filling.

3.3.5 Intercultural operations

Intercultural operations such as weeding, mulching, irrigation etc. were done when necessary for proper growth and development of the plants. But no insecticide or plant protection was used to study the resistance capacity of Bt brinjal against fruit and shoot borer. Extra soils were added around the root for proper rooting. Sticks were given to protect the plant from falling due to strong wind. Gap filling was done twice, firstly 11 days after transplanting and 2nd time 23 days after transplanting. Weeding was done for the first time 18 days after transplanting. Weeding was also done in several times by two weeks interval. In the early stage of transplanting watering was done twice a daily by water cane. In mature stage, flood irrigation was done to the field.

Table 1. The amount of fertilizers and manure recommended by BARI

Manures and fertilizers	Dose/ha	Application			
		Final land preparation	1st installment	2nd installment	3rd installment
Cowdung	10 tons	10 tons	--	--	--
Urea	375 kg	300 kg	25 kg	25 kg	25 kg
TSP	150 kg	150 kg	--	--	--
MP	250 kg	125 kg	50 kg	75 kg	
Gypsum	100 kg	100 kg	--	--	--

Table 2. The amount of fertilizers and manure applied for the experimental plot (300 m^2) as followed by BARI fertilizer recommendation

Manures and fertilizers	Total Amount that are applied for the land measuring $300m^2$	Application			
		Final land preparation	1st installment	2nd installment	3rd installment
Cowdung	300 kg	300 kg	--	--	--
Urea	13 kg	10 kg	1 kg	1 kg	1 kg
TSP	4.5 kg	4.5 kg	--	--	--
MP	8 kg	4 kg	2 kg	2 kg	
Gypsum	3 kg	3 kg	--	--	--

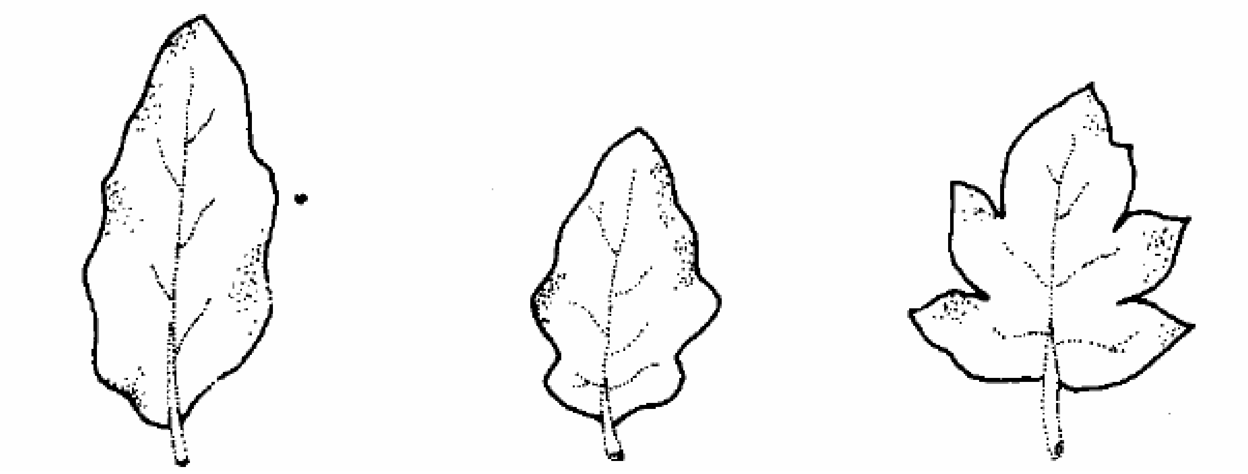
3.4 Data collection

The following data on days to first flowering, days to first harvesting, germination percentage, plant height, leaf length, leaf breadth, no. of branches per plant, fruit length, fruit diameters, fruit per plant, weight per fruit, yield per plant, no. of infested fruit were recorded at different stages.

3.4.1 Leaf blade color: Comparing with color chart

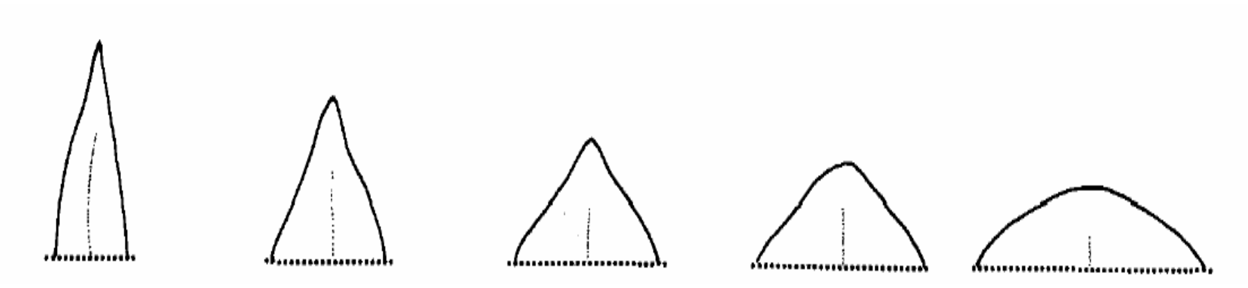
- Light green
- Green
- Dark green
- Greenish violet
- Violet

3.4.2 Leaf blade lobing: By visual observation as per the figure below:



Weak Intermediate Strong

3.4.3 Leaf blade tip angle: By visual observation as per the figure below



Very Acute Acute Intermediate Obtuse Very Obtuse

3.4.4 Corolla color: Comparing with color chart

- Greenish
- White
- Pale violet
- Light violet
- Bluish violet

3.4.5 Fruit colour: The fruit colour of 8 (eight) brinjal genotypes were recorded.

3.5.6 Fruit shape: By visual observation as per as the following shapes :

- Round
- Ovate
- Long
- Oblong

3.4.7 Days to first flowering

Days required for transplanting to initiation of flowering was counted from the date of transplanting to the initiation of flowering and was recorded. Data were recorded as the average of 5 plants selected from the inner rows of each plot.

3.4.8 Plant height (cm)

Plant height was measured from the ground level to the tip of the longest stem and mean value was calculated. Plant height was recorded during 1st flowering as the average of 5 plants to observe the growth rate of plants.

3.4.9 Number of branches per plant

The total number of branches per plant was counted from plant of each unit plot. Data were recorded during 1st flowering. Data were recorded as the average of 5 plants selected from the inner rows of each plot.

3.4.10 Length of leaf (cm)

The length of leaf was measured with a meter scale from one side in to another side in longitudinally of leaf blade of 5 fresh leaves from each plot and there average was taken and expressed in cm.

3.4.11 Breadth of leaf (cm)

The breadth of leaf was measured with a meter scale from one side in to another side of leaf blade of 5 fresh leaves from each plot and there average was taken and expressed in cm.

3.4.12 Number of fruits per plant

The number of brinjal fruits per plant was counted from plant of each unit plot and the number of brinjal per plant was recorded. Data were recorded as the average of 5 plants selected from the inner rows of each plot.

3.4.13 Weight of individual fruit (g)

Weight of individual fruit per plant was recorded in gram (g) from the five selected plants.

3.4.14 Fruit length (cm)

The Fruit length fruit was measured with a meter scale from the neck of the fruit to the bottom of 5 selected marketable fruits from each plot and there average was taken and expressed in cm.

3.4.15 Fruit diameter (cm)

Diameter of brinjal fruit was measured at the middle portion of 5 selected marketable fruits from each plot with a slide calipers and there average was taken and expressed in cm.

3.4.16 Number of infested fruit per plant

The number of infested fruit of both Bt and non Bt brinjal was counted from plant of each unit plot and the number of infested brinjal per plant was recorded. Data were recorded as the average of 5 plants selected from the inner rows of each plot.

3.4.17 Days to first harvest

Days required for transplanting to starting of harvesting was counted from the date of transplanting to the starting of 1st harvest of brinjal and were recorded. Data were recorded as the average of 5 plants selected from the inner rows of each plot.

3.4.18 Yield per plant (kg)

Yield of brinjal per plant was recorded as the whole brinjal fruit per plant harvested in different time and was expressed in kilogram. Data were recorded as the average of 5 plants selected from the inner rows of each plot.

3.5 Statistical analysis

The data obtained for different characters under the present trial were statistically analyzed to observe the genotype of brinjal in relation to yield contributing characters and yield and subsequently variability. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatment means was estimated by the Duncan Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

3.6 Estimation of variability

Genotypic and phenotypic coefficient of variation and heritability were estimated by using the following formulae:

- **Estimation of components of variance from individual environment**

Genotypic and phenotypic variance were estimated with the help of the following formula suggested by Johnson *et al.* (1955). This is estimated by using the following formula –

Genotypic variance, $\boldsymbol{\sigma}^2_{\mathbf{g}} = \frac{GMS-EMS}{r}$

Where,
GS = genotypic mean square
EMS = error mean square
r = number of replication

The phenotypic variance ($\boldsymbol{\sigma}^2_{\mathbf{ph}}$) was derived by adding genotypic variances with the error variance, as given by the following formula –

Phenotypic variance, $\boldsymbol{\sigma}^2_{\mathbf{ph}} = \sigma^2_g + EMS$

Where,
σ^2_g = Genotypic variance
EMS = Error mean sum of square

- **Estimation of genotypic and phenotypic correlation co-efficient**

The genotypic co-variance component between two traits and have the phenotypic covariance component were derived in the same way as for the corresponding variance components. The co-variance components were used to compute genotypic and phenotypic correlation between the pairs of characters as follows:

Genotypic Correlation (r_g) = $\frac{\mathrm{GCOV}xy}{\sqrt{\mathrm{GV}x\,.\,\mathrm{GV}y}}$

Where,
GCOV_{xy} = Genotypic co-variance between the traits x and y
GV_x =Genotypic variance of the trait x
GV_y =Genotypic variance of the trait y

Phenotypic Correlation (r_p) = $\frac{\mathrm{PCOV}xy}{\sqrt{\mathrm{PV}x.\ \mathrm{PV}y}}$

Where,
PCOV_{xy} =Phenotypic covariance between the traits x and y
PV_x =Phenotypic variance of the trait x
PV_y =Phenotypic variance of the trait y

- **Estimation of genotypic co-efficient of variation (GCV) and phenotypic co-efficient of variation (PCV)**

Genotypic co-efficient of variation (GCV) and phenotypic co-efficient of variation (PCV) were calculated following formula as suggested by Burton (1952):

Genotypic co-efficient of variation (GCV %) = $\sqrt{\frac{\sigma_g^2}{\bar{x}}} \times 100$

Where,
σ^2_g = Genotypic variance
$\bar{x}$ = Population mean

Phenotypic co-efficient of variation (PCV %) = $\sqrt{\frac{\sigma_{ph}^2}{\bar{x}}} \times 100$

Where,
σ^2_{ph} = Genotypic variance
$\bar{x}$ = Population mean

- **Estimation of heritability**

Heritability in broad sense was estimated (Lush, 1943) by the following formula as suggested by Johnson *et al.* (1955):

$$\text{Heritability, } h^2{}_b\% = \frac{\sigma^2{}_g}{\sigma^2{}_{ph}} \times 100$$

Where,

h^2b = Heritability in broad sense

σ^2_g = Genotypic variance

σ^2_{ph} =Phenotypic variance

- **Estimation of genetic advance**

The expected genetic advance for different characters under selection was estimated using the formula suggested by Lush (1943) and Johnson *et al.* (1955).

Genetic advance, $GA = K.\ h^2{}_b.\ \sigma_{ph}$

$$GA = K.\frac{\sigma^2{}_g}{\sigma^2{}_{ph}}.\sigma_{ph}$$

Where,

K = Selection intensity, the value which is 2.06 at 5% selection intensity

σ_{ph} = Phenotypic standard deviation

$h^2{}_b$ = Heritability in broad sense

$\sigma^2{}_g$ = Genotypic variance

$\sigma^2{}_{ph}$ = Phenotypic variance

- **Estimation of genetic advance in percentage of mean**

Genetic advance in percentage of mean was calculated by the following formula given by Comstock and Robinson (1952) :

$$\text{Genetic advance in percentage of mean} = \frac{\text{Genetic Advance (GA)}}{\text{Population mean } (\bar{x})} \text{ X } 100$$

CHAPTER IV

RESULT AND DISCUSSION

Performance of 8 genotypes of brinjal was investigated and the findings of present study have been discussed under different morphological characters. The result of the study showed marked variation in different characters and the variation of different characters are presented in the following Tables, Figures and Plates.

The data pertaining to Brinjal genotypes as well as yield and its contributing characters were computed and statistically analyzed and the results thus obtained are discussed below under the following heads:

1. Morphological Characterization
2. Performance of genotypes
3. Genetic parameters
4. Correlation co-efficient
5. Path coefficient analysis

4.1 Morphological characterization

4.1.1 Leaf blade color

Among the genotypes BARI begun-6 and BARI Bt Begun 4 produced green leaf and the rest of the genotypes produced purplish green colored leaf (Table 3a). Variation in leaves of different brinjal genotypes presented in Plate 2.

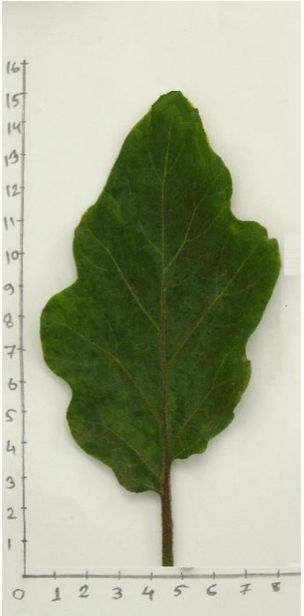
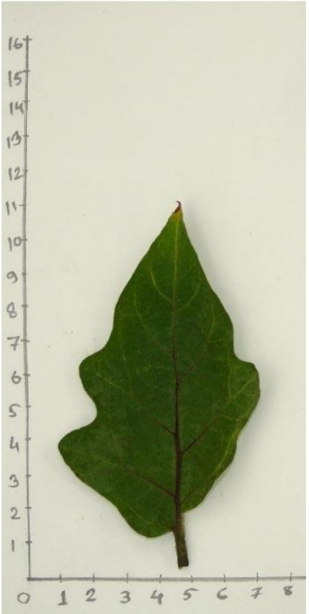
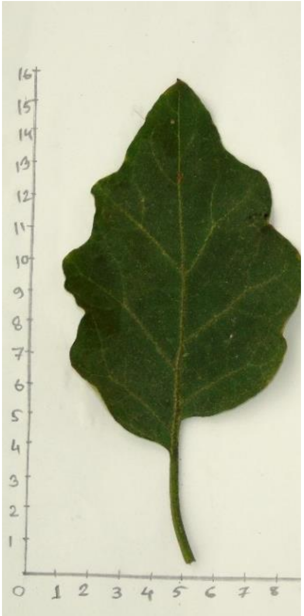
4.1.2 Leaf blade lobbing

Leaf blade lobbing is an important traits to choice a brinjal genotypes for future breeding programme. Leaf blade lobbing can help to a breeder to know the information on photosynthesis rate. Strong leaves can have a greater opportunity to get maximum sunlight than the weaker leaves. The strong leaves holder genotypes were shown better growth than the intermediate and weaker leaves holder genotypes. Here among the 8 genotypes all the genotypes were intermediate habit in their leaf blade lobbing (Table 3a).

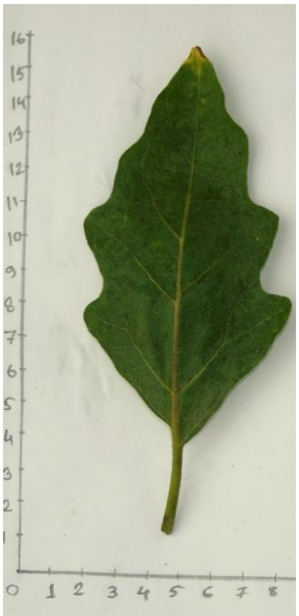
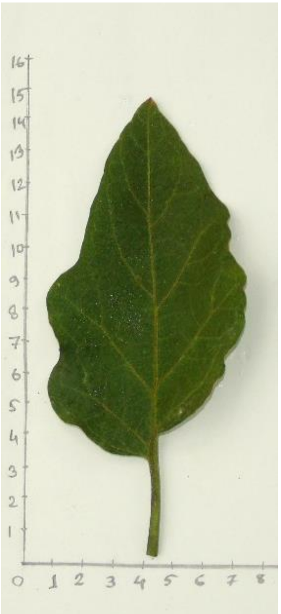
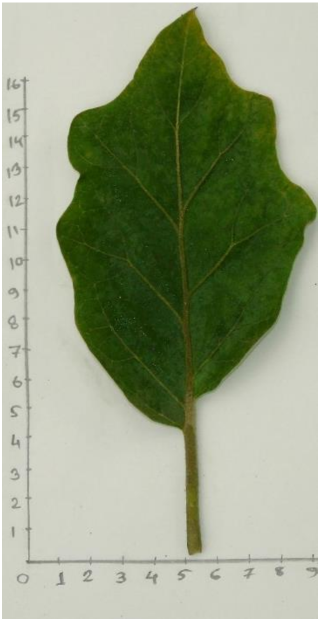
Table 3a. Characterization of 8 brinjal genotypes as per leaf characters

Genotypes	Leaf blade colour	Leaf blade lobing	Leaf blade tip angle
BARI Begun 1	Purplish green	Intermediate	Intermediate
BARI Bt Begun 1	Purplish green	Intermediate	Intermediate
BARI Begun 4	Purplish green	Intermediate	Acute
BARI Bt Begun 2	Purplish green	Intermediate	Acute
BARI Begun 5	Purplish green	Intermediate	Obtuse
BARI Bt Begun 3	Purplish green	Intermediate	Obtuse
BARI Begun 6	Green	Intermediate	Intermediate
BARI Bt Begun 4	Green	Intermediate	Intermediate

Leaf of different Brinjal Varieties


BARI Begun 1 **BARI Begun 4** **BARI Begun 5** **BARI Begun 6**


BARI Bt Begun 1 **BARI Bt Begun 2** **BARI Bt Begun 3** **BARI Bt Begun 4**

Plate 2: Variation in leaf among different brinjal genotypes

4.1.3 Leaf blade tip angle

Among the 8 genotypes BARI begun 4, BARI Bt begun 2 showed acute leaf blade tip angle while the genotypes BARI begun 5 and BARI Bt begun 3 showed obtuse tip angle and rest of the genotypes were intermediate habit in their leaf blade lobbing (Table 3a).

4.1.4 Corolla color

Wide variations were observed in corolla color of 8 genotypes. The genotypes of BARI Begun 4, BARI Bt Begun 2, BARI Begun 5 and BARI Bt Begun 3 are showed light violet corolla followed by BARI Begun 1, BARI Bt Begun 1, BARI Begun 6 and BARI Bt Begun 4 of bluish violet (Table 3b). Flowers of different brinjal genotypes presented in Plate 3.

4.1.5 Fruits colour

Fruit color is one of the important traits for consumer preference in brinjal marketing. Generally green and violet color fruits are common in the market. However, a lot of variations in fruit color were found and that could be classified in distinct groups: violet, whitish green, purple, white, light violet, milky white and blackish purple. The genotype BARI Begun 1 and BARI Bt Begun 1 produced purple fruit; Blackish purple were observed in BARI Begun 4, BARI Bt Begun 2, BARI Begun 5, BARI Bt Begun 3 and light green was observed in BARI Begun 6 and BARI Bt Begun 4 (Table 3b). This variation offered a good scope for breeding consumer preference attributes. Fruits color of different brinjal is presented in Plate 4.

4.1.6 Fruit shape

Fruit shape is an important consumer preference trait in brinjal marketing. Various types of brinjal were found according to their different shape. From the eight genotypes long, oblong and round shaped brinjal were observed. The genotypes BARI Begun 4 and BARI Bt Begun 2 produced long fruits, genotypes BARI Begun 1 and BARI Bt Begun 1 produced oblong fruits and genotypes BARI Begun 5, BARI Bt Begun 3, BARI Begun 6 and BARI Bt Begun 4 produced round fruits (Table 3b).

Table 3b. Characterization of 8 brinjal genotypes as per flower and fruit characters

Genotypes	Corolla colour	Fruit colour	Fruit shape
BARI Begun 1	Bluish violet	Purple	Oblong
BARI Bt Begun 1	Bluish violet	Purple	Oblong
BARI Begun 4	Light violet	Purple black	Long
BARI Bt Begun 2	Light violet	Purple black	Long
BARI Begun 5	Light violet	Purple black	Round
BARI Bt Begun 3	Light violet	Purple black	Round
BARI Begun 6	Bluish violet	Green	Round
BARI Bt Begun 4	Bluish violet	Green	Round

Flowers of different Brinjal Varieties

BARI Begun 1

BARI Begun 4

BARI Begun 5

BARI Begun 6

BARI Bt Begun 1

BARI Bt Begun 2

BARI Bt Begun 3

BARI Bt Begun 4

Plate 3: Variation in flower among different brinjal genotypes

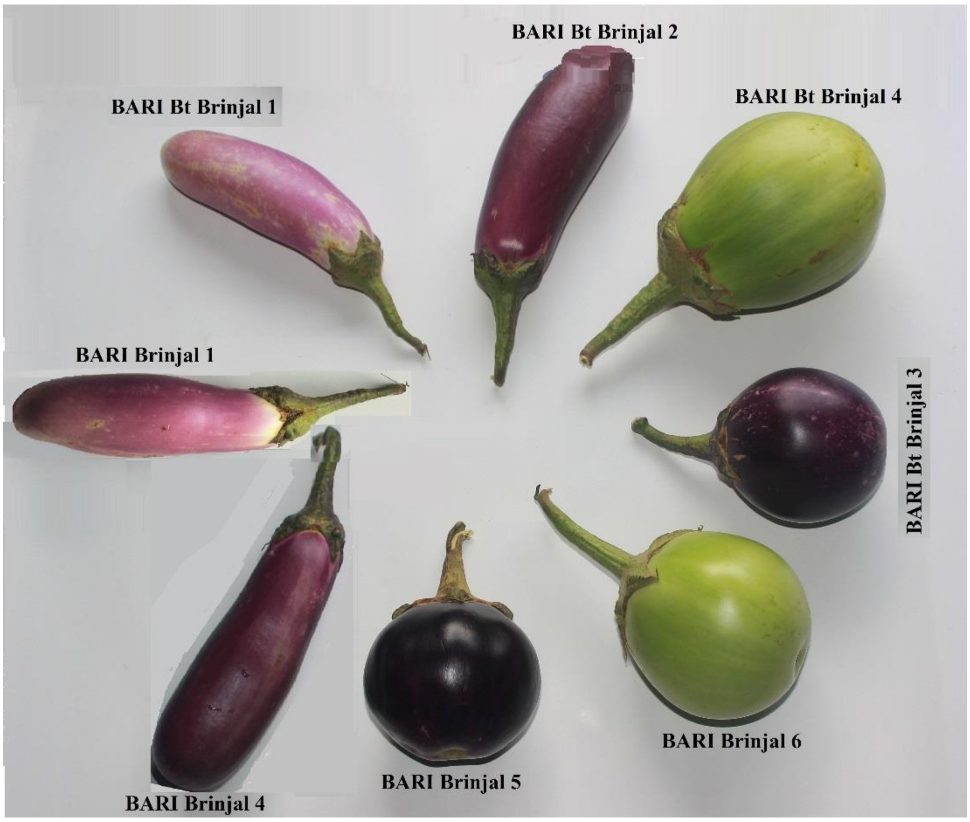


Plate 4: Variation in fruit shape & color among different brinjal genotypes

4.2 PERFORMANCE OF GENOTYPES

4.2.1 Days to first flowering

Wide range of variability was observed in respect of flowering time among the genotypes (Table 4). The maximum days required for 1st flowering (54.33) was recorded from BARI Begun 4, whereas the minimum days required for 1st flowering (49.33) was attained from BARI Bt Begun 3. The difference among the varieties might be related to the genetical characteristics of the lines, influence of day length and temperature. Sambandam (1960) studied the number of days required for flowering in different brinjal lines and concluded that the variation was due to the varietal characteristics.

4.2.2 Plant height (cm)

The plant height of different lines exhibited wide variation. The plant height was maximum (66.78 cm) in BARI Begun 6, which was identical (66.44 cm) with BARI Bt Begun 4. The shortest plant (58.00 cm) was found from BARI Bt Begun 1. The remaining varietieses were intermediate in this regard (Table 4). Statistically BARI Begun 6 produced tallest plants than rest of the line.

4.2.3 Number of branches per plant

Number of branches per plant is an important morphological character which is related to yield and number of fruit per plant. The number of branches each plant was recorded and their average mean was calculated (Table 4). It was observed that the maximum numbers of branches per plant (21.78) were produced by BARI Bt Begun 4 which were statistically better from the rest of the line. The least number of branches (17.78) recorded from BARI Begun 5. Variation of branches of different brinjal genotypes is presented in Plate 5.

Table 4. Mean performance of various growth parameter and yield components of eight Brinjal varieties

Sl No.	Genotypes	DFF	PH	BPP	LL	LB	FPP	FW	FL	FD	IFP	DFH	FYP
1	BARI Begun 1	52.55b	58.55bc	18.33c	13.83b	7.26c	30.11b	50.79e	13.38b	3.91d	68.13c	64.67a	1.51f
2	BARI Bt Begun 1	49.66c	58.00c	19.22bc	13.87b	7.31c	36.11a	51.35e	13.48b	4.38d	12.52de	64.45a	1.85e
3	BARI Begun 4	54.33a	59.78bc	21.11a	14.26b	8.06b	27.67c	60.92d	16.39a	4.14d	79.44a	62.78b	1.68ef
4	BARI Bt Begun 2	52.11b	60.22b	20.78ab	14.55b	8.20b	35.78a	62.55d	16.48a	4.24d	7.72f	62.11c	2.27c
5	BARI Begun 5	50.00c	59.33bc	17.78c	14.69b	8.05b	20.22e	108.73c	8.84e	6.56c	72.77b	62.44bc	2.21cd
6	BARI Bt Begun 3	49.33c	58.11c	18.45c	14.81b	8.32b	22.00d	111.10c	9.99d	6.96c	10.54ef	61.33d	2.47b
7	BARI Begun 6	49.67c	66.78a	20.22ab	17.70a	10.29a	9.67g	213.13b	9.72de	7.81b	65.76c	60.33e	2.06d
8	BARI Bt Begun 4	50.22c	66.44a	21.78a	17.73a	10.38a	12.89f	218.62a	11.72c	8.63a	15.65d	61.33d	2.81a

Values with same letter(s) are statistically identical at 5% level of probability.

DFF = Days of first flowering, PH = Plant height (cm), BPP = Branches per plant, LL = Leaf length (cm), LB = Leaf breadth (cm), FPP = Fruits per plant, FW = fruit weight g), FL = Fruit length (cm), FD = Fruit diameter (cm), IFP = Infested fruit per Plant, DFH = Days of 1st harvest and FYP = Fruit yield per plant (Kg).

Variation of Branches


BARI Begun 1


BARI Begun 4


BARI Begun 5


BARI Begun 6


BARI Bt Begun 1


BARI Bt Begun 2


BARI Bt Begun 3


BARI Bt Begun 4

Plate 5: Variation of branches of different brinjal genotypes

4.2.4 Length of leaf (cm)

The average marked difference on length of leaf of brinjal was observed among the genotypes (Table 4). The longest leaf (17.73 cm) was found from BARI Bt Begun 4, which was statistically identical (17.70 cm) BARI Begun 6, whereas the shortest leaf (13.83 cm) was recorded from BARI Begun 1.

4.2.5 Breadth of leaf (cm)

Breadth of leaf of brinjal varied significantly for different variety (Table 4). The highest breadth of leaf (10.38 cm) was attained from BARI Bt Begun 4, which was statistically identical (10.29 cm) with BARI Begun 6, whereas the lowest breadth of leaf (7.25) was attained from BARI Begun 1.

4.2.6 Number of fruits per plant

The number of fruits produced by different brinjal lines were recorded and presented in Table 4. It was revealed that the maximum numbers of fruits per plant (36.11) were produced by BARI Bt Begun 1 which were statistically superior to the rest of the varieties. BARI Bt Begun 2 produced second highest number of fruit per plant (35.78), which was also statistically different from the rest of the lines. The least number of fruits (9.67) produced by BARI Begun 6 while the other varieties took intermediate positions and they were statistically different among themselves (Figure 1).

4.2.7 Weight of individual fruit (g)

Different brinjal varieties under study showed variations in their fruit weight. The highest fruit weight (218.6 g) was obtained from BARI Bt Begun 4 which was statistically superior to the rest of the varieties while BARI Begun 6 produced the second highest fruit weight (213.1 g) (Table 4). The least individual fruit weight (50.79 g) was produced by BARI Begun 1 while the other lines took intermediate positions though there were statistical differences among themselves.

4.2.8 Fruit length (cm)

Fruit length showed statistically significant variation due to different variety (Table 4). The highest Fruit length (16.48 cm) was attained from BARI Bt Begun 2, which was statistically similar (16.39 cm) with BARI Begun 4, while the lowest length (8.85 cm) was found from BARI Begun 5. Fruit shape of different brinjal genotypes is presented in Plate 6.

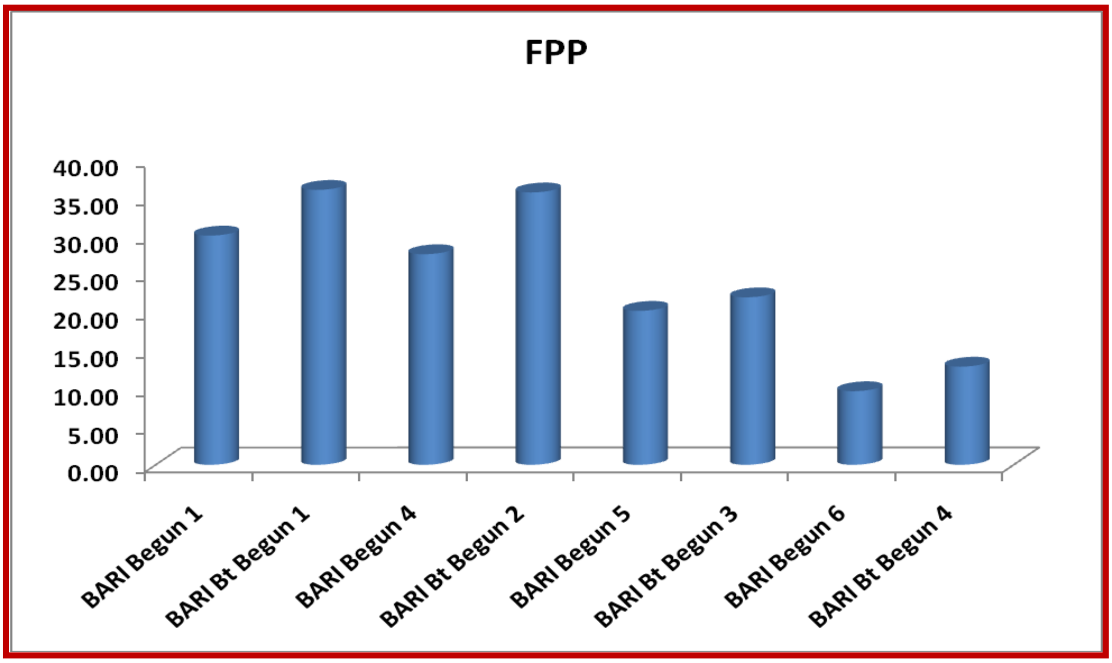
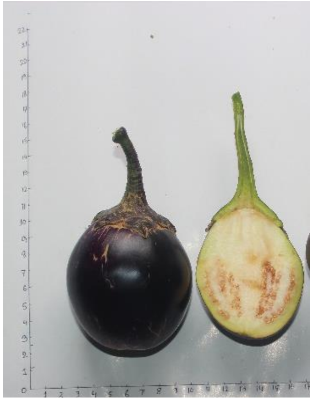


Fig. 1. Fruit per plant performance of eight Brinjal varieties

Fruits of different Brinjal Varieties

BARI Begun 1

BARI Begun 4

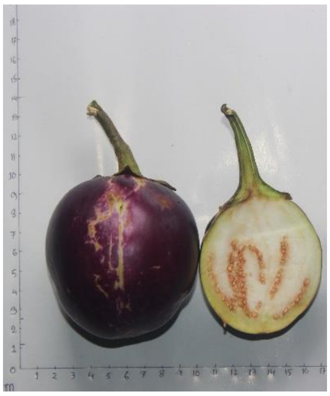


BARI Begun 5

BARI Begun 6

BARI Bt Begun 1

BARI Bt Begun 2



BARI Bt Begun 3

BARI Bt Begun 4

Plate 6: Fruit appearance of different brinjal genotypes

4.2.9 Fruit diameter (cm)

Statistically significant variation was recorded for different variety on diameter of brinjal (Table 4). The highest diameter of brinjal (8.33 cm) was recorded from BARI Bt Begun 4 and the lowest diameter (6.55cm) was found from BARI Begun 5.

4.2.10 Number of infested fruit per plant

Brinjal is mostly affected by shoot and fruit borer. It caused great harm to yield and reduced production of brinjal. So resistance is an efficient character of brinjal plant. Their rates of attack against different genotypes were significantly different. The attack of insect of brinjal depend on its morphological i.e. spinyness, hairiness, hardiness of fruit coat; physiological and genetical characteristics of plant. Number of infested fruits per plant of brinjal showed statistically significant variation from different variety (Table 4). From under study it was reveled that the maximum number of infested fruits per plant (79.44) was found from BARI Begun 4, whereas the minimum number (7.72) was recorded from BARI Bt Begun 2 (Fig. 2). Affected plant, shoots and infested fruits of different brinjal varieties is presented in Plate 7.

4.2.11 Days to first harvest

Statistically significant variation was recorded for different variety on days required for 1st harvest of brinjal (Table 4). The maximum days required for 1st harvesting (64.67) was recorded from BARI Begun 1, which was statistically identical (64.45) with BARI Bt Begun 1, whereas the minimum days required for 1st harvesting (60.33) was attained from BARI Begun 6. The difference among the varieties might be related to the genetical characteristics of the lines, influence of day length and temperature.

4.2.12 Yield per plant (kg)

Different variety showed statistically significant variation in terms of yield per plant of brinjal (Table 4). The highest yield per plant of brinjal (2.81 kg) was observed from BARI Bt Begun 4, while BARI Bt Begun 3 produced the second highest (2.47 kg) fruit yield per plant. The lowest yield per plant (1.51 kg) was recorded from BARI Begun 1 while the other varieties took intermediate positions and they were statistically different among themselves (Figure 3).

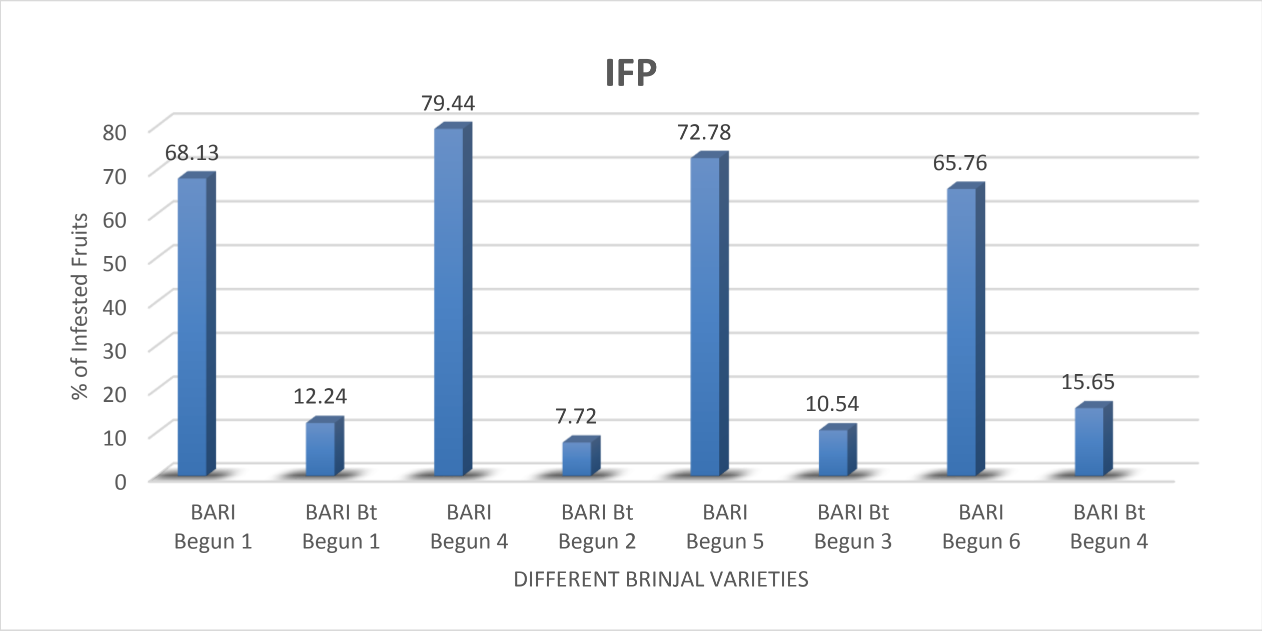
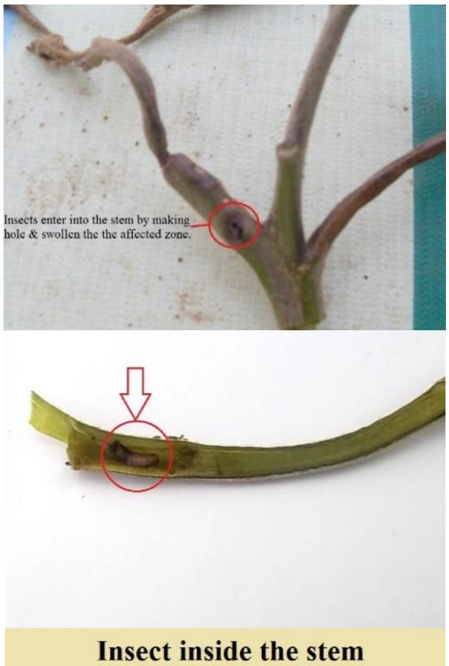


Fig. 2. Percent infested fruits of eight Brinjal varieties

Affected plant, shoots & infested fruits in different Brinjal Varieties

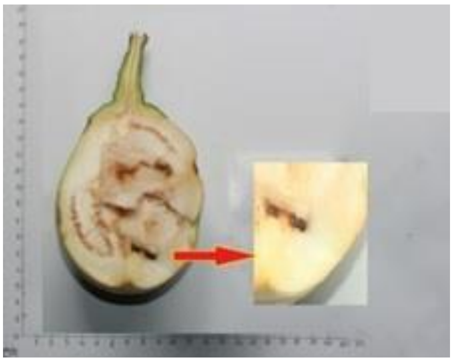
Affected plant



BARI Begun 1

BARI Begun 4

BARI Begun 5



BARI Begun6

BARI Bt Begun 1

Plate 7: Affected plant, shoots & infested fruits of different brinjal varieties

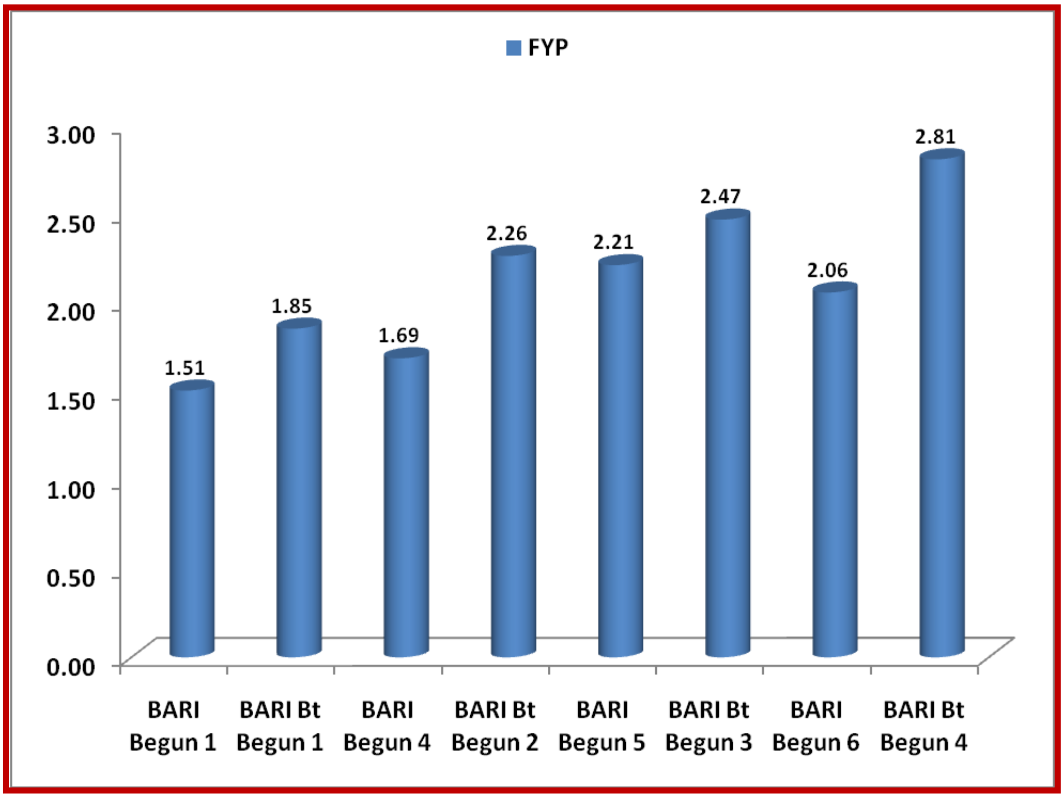


Fig. 3. Fruit yield performance of eight Brinjal vaieties

4.3 GENETIC PARAMETERS

The analysis of variances indicated the existence of highly significant variation among the genotypes studied. The mean sum of square, mean, range, variance components, genotypic and phenotypic coefficients of variations, heritability; genetic advance and genetic advance in percent of mean (GAPM) are presented in Table 5a and Table 5b. The results are discussed character wise as follows:

4.3.1 Days to first flowering

Analysis of variance for days to 1st flowering showed highly significant mean sum of square due to genotypic differences. The mean value with respect to this trait ranged from 49.33 (BARI Bt Begun 3) to 54.33 (BARI Begun 4) (Table 5a). The phenotypic variance (3.47) was higher than the genotypic variance (3.13). Narrow difference between the phenotypic coefficient of variation (3.66) and the genotypic coefficient of variation (3.47), which suggest that environment, has a little role on the expression of this trait (Figure 4). High heritability (90.02%) in days required for 1st flowering attached with low genetic advance (3.46) and low genetic advance in percent of mean (6.78) (Table 5b & Figure 5).

4.3.2 Plant height (cm)

Significant mean sum of square for plant height indicated considerable differences among the genotypes studied. The highest and lowest plant heights among the genotypes were 66.78 cm (BARI Begun 6) and 58.00 cm (BARI Bt Begun 1) respectively (Table 5a). The phenotypic and genotypic variances for this trait were comparatively low (13.67 and 12.69) (Table 5b). The phenotypic variance appeared to be higher than the genotypic variance, suggesting considerable influence of environment on expression of the genes controlling this trait (Figure 4). The phenotypic coefficient of variation (6.07) was higher than the genotypic coefficient of variation (5.85), which suggested that environment, has a little role on the expression of this trait. Heritability estimate was high (92.84) with low genetic advance (7.07) and moderate genetic advance in percent of mean (11.61) (Table 5b & Figure 5). Ram *et al.* (2007) reported high heritability coupled with high genetic advance indicating additive gene action was exhibited by characters plant height.

Table 5a. Estimation of genetic parameters in twelve characters of eight varieties in Brinjal

Parameters	Range	Mean	MS	CV (%)	SE
DFF	49.33-54.33	50.99	9.73**	6.12	2.55
PH	58.00-66.78	60.90	39.06**	10.26	5.10
BPP	17.78-21.78	19.71	6.48**	12.91	2.08
LL	13.83-17.73	15.18	7.72**	18.30	2.27
LB	7.25-10.38	8.48	4.37**	24.65	1.71
FPP	9.67-36.11	24.31	292.55**	70.37	13.97
FW	50.79-218.62	109.65	14590.39**	110.16	98.63
FL	8.85-16.48	12.50	26.00**	40.79	4.16
FD	3.91-8.63	5.83	10.60**	55.84	2.66
IFP	7.72-79.44	41.57	3138.46**	134.78	45.74
DFH	60.33-64.67	62.43	6.89**	4.21	2.14
FYP	1.51-2.81	2.11	0.54**	34.95	0.60

**, * indicates significant at the 0.01 and 0.05 level, respectively.

DFF = Days of first flowering, PH = Plant height (cm), BPP = Branches per plant, LL = Leaf length (cm), LB = Leaf breadth (cm), FPP = Fruits per plant, FW = fruit weight g), FL = Fruit length (cm), FD = Fruit diameter (cm), IFP = Infested fruit per plant, DFH = Days of 1st harvest and FYP = Fruit yield per plant (Kg), MS = Mean sum of square, CV (%) = Coefficient of variation, SE= Standard error.

4.3.3 Number of branches per plant

No. of branches per plant was significant indicating considerable differences among the genotypes studied. The maximum and minimum no. of branches per plant among the genotypes were 21.78 (BARI Bt Begun 4) and 17.78 (BARI Bt Begun 5) respectively with the mean value of 19.71 (Table 5a). The phenotypic and genotypic variances for this trait were comparatively 2.68 and 1.90 (Table 5b). The phenotypic variance appeared to be higher than the genotypic variance, suggested considerable influence of environment on the expression of the genes controlling this trait (Figure 4). The phenotypic coefficient of variation (8.31) was higher than the genotypic coefficient of variation (6.99), which suggested that environment, had a significant role on the expression of this trait. Estimated heritability was high (70.85%) with low genetic advance (2.39) and high genetic advance in percent of mean (36.89) (Table 5b & Figure 5).

4.3.4 Length of leaf (cm)

Mean sum of square for leaf blade length was highly significant due to genotypes of brinjal indicating existence of considerable difference for this trait. The maximum leaf length was found 17.73 in BARI Bt Begun 4 and the minimum was recorded 13.83 in BARI Begun 1 (Table 5a). The phenotypic variance (2.78) appeared to be higher than the genotypic variance (2.47) suggested considerable influence of environment on the expression of the genes controlling this trait. The genotypic co-efficient of variation (10.35) and phenotypic co-efficient of variation (10.98) were close to each other (Figure 4). Heritability (88.76) estimates for this trait was high, low genotypic advance (3.05) and genotypic advance in percent of mean (31.40) were found high (Table 5b & Figure 5). The high heritability along with high genetic advance in percentage of mean of length of leaf indicated the possible scope for improvement through selection of the character.

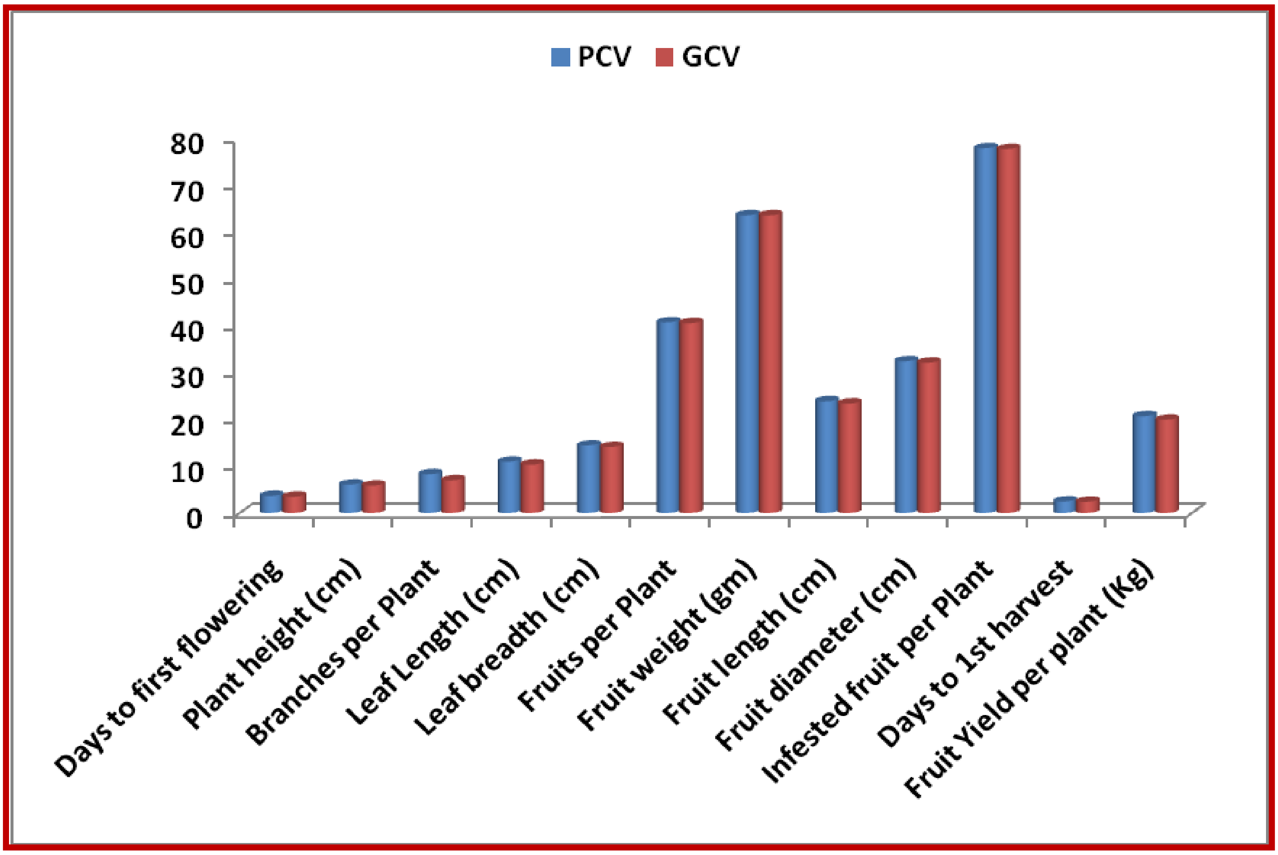


Fig. 4. Genotypic and phenotypic coefficient of variation in Brinjal

4.3.5 Breadth of leaf (cm)

The maximum leaf breadth was found 10.38 in BARI Bt Begun 4 and the minimum was recorded 7.26 in BARI Begun 1 (Table 5a). The phenotypic variance (1.50) appeared to be higher than the genotypic variance (1.44) suggested considerable influence of environment on the expression of the genes controlling this trait. The genotypic co-efficient of variation (14.12) and phenotypic co-efficient of variation (14.45) were close to each other (Figure 4). Heritability (95.51) estimates for this trait was very high, genotypic advance (2.41) was low and genotypic advance in percent of mean (28.43) was found high (Table 5b & Figure 5)

4.3.6 Number of fruits per plant

The maximum number of fruit per plant was found 36.11 in BARI Bt Begun 1 and the minimum was recorded 9.67 in BARI begun 6 with mean value 24.31 (Table 5a). Phenotypic variance (98.09) for this trait was higher than the genotypic variance (97.23) and there is little influence of environment on the expression of the genes controlling this character. The genotypic co-efficient of variation and phenotypic co-efficient of variation were 40.57 and 49.75 respectively which were close to each other (Figure 4). Heritability (99.12%) estimates for this trait was high, genetic advance (20.22) and genetic advance in percent of mean (83.21) were found high (Table 5b & Figure 5). The high heritability estimate coupled with high expected genetic advance for number of fruits per plant indicated the importance of both additive and non-additive genetic effects for the control of this character. Genetic improvement of this character would therefore be highly effective.

4.3.7 Weight of individual fruit (g)

Mean sum of square for single fruit weight was significant indicating existence of considerable difference for this trait. The maximum weight per fruit was found 218.62 g in BARI Bt Begun 4 and the minimum was recorded 50.79 g in BARI Begun 1 with mean value 109.65 (Table 5a). The differences between genotypic (4862.38) and phenotypic (4865.63) variances was relatively low for this trait. The genotypic co-efficient of variation and phenotypic co-efficient of variation were 63.60 and 63.62 respectively for single fruit weight (Figure 4). Heritability (99.93%) estimates for this trait was high together with considerable high genetic advance (143.60) and genetic advance in percent of mean (130.96) indicated that selection for this character would be effective (Table 5b & Figure 5).

Table 5b. Estimation of genetic parameters in twelve characters of eight varieties in Brinjal

Parameters	σ^2 p	σ^2g	σ^2 e	PCV	GCV	ECV	Heritability	Genetic advance (5%)	Genetic advance (% mean)
DFF	3.47	3.13	0.35	3.66	3.47	1.15	90.02	3.46	6.78
PH	13.67	12.69	0.98	6.07	5.85	1.63	92.84	7.07	11.61
BPP	2.68	1.90	0.78	8.31	6.99	4.48	70.85	2.39	12.12
LL	2.78	2.47	0.31	10.98	10.35	3.68	88.76	3.05	20.08
LB	1.50	1.44	0.07	14.45	14.12	3.06	95.51	2.41	28.43
FPP	98.09	97.23	0.86	40.75	40.57	3.81	99.12	20.22	83.21
FW	4865.63	4862.38	3.26	63.62	63.60	1.65	99.93	143.60	130.96
FL	8.91	8.54	0.36	23.88	23.39	4.82	95.92	5.90	47.18
FD	3.58	3.51	0.07	32.44	32.14	4.41	98.15	3.82	65.59
IFP	1049.30	1044.58	4.72	77.93	77.75	5.23	99.55	66.43	159.81
DFH	2.38	2.26	0.13	2.47	2.41	0.57	94.64	3.01	4.82
FYP	0.19	0.18	0.01	20.68	19.92	5.53	92.85	0.83	39.55

**, * indicates significant at the 0.01 and 0.05 level, respectively.

DFF = Days of first flowering, PH = Plant height (cm), BPP = Branches per plant, LL = Leaf length (cm), LB = Leaf breadth (cm), FPP = Fruits per plant, FW = fruit weight g), FL = Fruit length (cm), FD = Fruit diameter (cm), IFP = Infested fruit per plant, DFH = Days of 1st harvest and FYP = Fruit yield per plant (Kg), MS = Mean sum of square, SE= Standard error, σ^2 p = Phenotypic variance, σ^2g = Genotypic variance, σ^2 e = Environmental variance, PCV = Phenotypic Coefficient of Variation, GCV= Genotypic Coefficient of Variation and ECV= Environmental Coefficient of Variation.

4.3.8 Fruit length (cm)

Different types of genotypes showed wide differences in terms of fruit length. The range of length was from the highest 16.48 cm in BARI Bt Begun 2 to lowest 8.84 cm in BARI Begun 5 (Table 5a). The phenotypic variance (8.91) was little higher than the genotypic variance (8.54). There found low difference between phenotypic coefficient of variation (23.88) and the genotypic coefficient of variation (23.39) (Figure 4). The low difference for this parameter was also suggested a minimum influence of environment. High heritability (95.92%) in Fruit length attached with low genetic advance (5.90) and high genetic advance in percent of mean (47.18) (Table 5b & Figure 5). The high heritability along with high genetic advance in percent of mean of Fruit length indicated the possible scope for improvement through selection of the character.

4.3.9 Fruit diameter (cm)

Mean sum of square fruit diameter was significant due to genotypes in brinjal indicating existence of considerable variation for this trait. The maximum fruit diameter was found 8.63 cm in BARI Bt Begun 4 and the minimum was recorded 3.91 cm in BARI Begun 1 with mean value 5.83 (Table 5a). The genotypic variance and phenotypic variance were 3.51 and 3.58 respectively (Figure 4). The genotypic co-efficient of variation and phenotypic co-efficient of variation were 32.14 and 32.44, respectively. Heritability (98.15%) estimates for this trait was high along with low genetic advance (3.82) and high genetic advance in percent of mean (65.59) (Table 5b & Figure 5).

4.3.10 Number of infested fruit per plant

Genotype mean sum of square for number of infested fruit per plant was found significant. The maximum number of infested fruit per plant was found 79.44 in BARI Begun 4 and the minimum was recorded 7.72 in BARI Bt Begun 2 with mean value 41.57 (Table 5a). Phenotypic variance (1049.30) for this trait was higher than the genotypic variance (1044.58) and there is little influence of environment on the expression of the genes controlling this character. The genotypic co-efficient of variation and phenotypic co-efficient of variation were 77.75 and 77.93, respectively (Figure 4). Heritability (99.55%) estimates for this trait was high, genetic advance (66.43) and genetic advance in percent of mean (159.81) were found high (Table 5b & Figure 5).

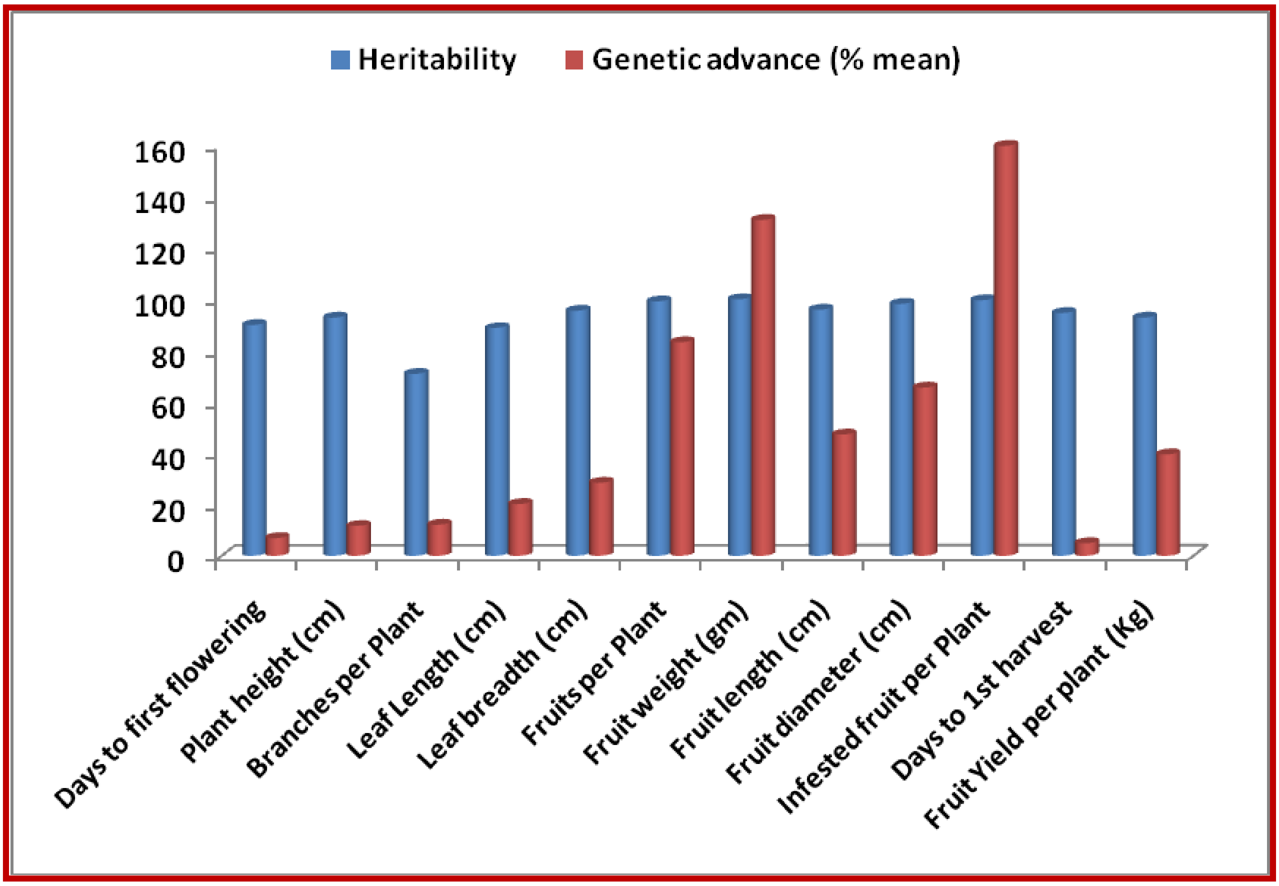


Fig. 5. Heritability and genetic advance over mean in Brinjal

4.3.11 Days to first harvest

Highly significant variations were observed for days to first harvesting. The early genotype in terms of fruit harvesting was BARI Begun 6 (60.33 days) and the late genotype was BARI Begun 1 (64.67 days) (Table 5a). Phenotypic variance (2.38) was higher than the genotypic variance (2.26) that indicating that low environmental influence of this characters which was supported by narrow difference between phenotypic (2.47) and genotypic (2.41) co- efficient of variation (Figure 4). High heritability (94.64%) in days required for 1st harvest attached with low genetic advance (3.01) and genetic advance in percentage of mean (4.82) (Table 5b & Figure 5).

4.3.12 Yield per plant (kg)

Significant mean sum of square for yield indicated considerable difference among the genotypes studied. The maximum yield was found 2.81 kg in BARI Bt Begun 4 and the minimum was recorded 1.51 kg in BARI Begun 1 with mean value 2.11 kg (Table 5a). The differences between genotypic (0.18) and phenotypic (0.19) variances for this trait indicating little environmental influence on this character. The genotypic coefficient of variation and phenotypic co-efficient of variation were 19.92 and 20.68 respectively (Figure 4). High heritability (92.85%) required for yield per plant attached with low genetic advance (0.83) and high genetic advance in percentage of mean (39.55) (Table 5b & Figure 5). The high heritability along with high genetic advance in percent of mean of yield per plant indicated the possible scope for improvement through selection of the character.

4.4 CORRELATION COEFFICIENT

Yield is a complex product being influenced by several interdependent quantitative characters. Selection for yield may not be effective unless the other yield components influencing it directly or indirectly are taken into consideration. When selection pressure is exercised for improvement of any character highly associated with yield, it simultaneously affects a number of other correlated traits. Hence knowledge regarding association of character with yield and among themselves provides guideline to the plant breeder for making improvement through selection provide a clear understanding about the contribution in respect of establishing the association by genetic and non-genetic factors. The results of genotypic correlation coefficients (Table 6) and phenotypic correlation coefficients (Table 7) are discussed under the following heads:

4.4.1 Days to first flowering

Days to first flowering found to display highly significant positive relationships with fruit length, fruit per plant and infested fruit per plant at both genotypic and phenotypic level. Days to first flowering showed insignificant positive correlation with branch per plant genotypically. Insignificant positive association indicated that the association between these traits is largely influenced by environmental factors. Non-significant relations was found with days of first harvesting genotypically. The character reflected highly significant negative association with fruit weight, fruit diameter and fruit yield per plant genotypically (Table 6) and with fruit diameter and fruit yield per plant phenotypically (Table 7).

4.4.2 Plant height (cm)

The character reflected highly significant positive relationships with branch per plant, leaf length, leaf breadth, fruit weight, fruit diameter and fruit yield per plant at both levels. This character also showing highly significant negative association with number of fruit per plant and days of first harvesting at both genotypic and phenotypic level (Table 6 and 7). It also showed significant positive correlation with fruit yield per plant and insignificant negative association with fruit length at both genotypically and phenotypically.

Table 6. Genotypic correlation coefficients among different pairs of yield and yield contributing characters for different varieties of Brinjal

	PH	BPP	LL	LB	FPP	FW	FL	FD	IFP	DFH	FYP
DFF	-0.223	0.353	-0.418*	-0.348	0.437*	-0.524**	0.816**	-0.683**	0.445*	0.367NS	-0.581**
PH		0.672**	1.000**	0.978**	-0.797**	0.921**	-0.272	0.741**	0.046	-0.713**	0.474*
BPP			0.542**	0.613**	-0.189	0.403NS	0.549**	0.191NS	-0.217	-0.418*	0.315
LL				0.999**	-0.895**	1.002**	-0.457*	0.897**	-0.053	-0.826**	0.622**
LB					-0.867**	0.972**	-0.383	0.870**	-0.069	-0.865**	0.652**
FPP						-0.933**	0.722**	-0.918**	-0.252	0.772**	0.311
FW							-0.601**	0.947**	-0.033	-0.804**	0.658**
FL								-0.768**	-0.115	0.429*	-0.407*
FD									-0.132	-0.802**	0.784**
IFP										0.111	-0.601**
DFH											-0.702**

** = Significant at 1%, * = Significant at 5%.
DFF = Days of first flowering, PH = Plant height (cm), BPP = Branches per plant, LL = Leaf length (cm), LB = Leaf breadth (cm), FPP = Fruits per plant, FW = fruit weight g), FL = Fruit length (cm), FD = Fruit diameter (cm), IFP = Infested fruit per plant, DFH = Days of 1st harvest and FYP = Fruit yield per plant (Kg)

Table 7. Phenotypic correlation coefficients among different pairs of yield and yield contributing characters for different varieties of Brinjal

	PH	BPP	LL	LB	FPP	FW	FL	FD	IFP	DFH	FYP
DFF	-0.226	0.295	-0.401	-0.342	0.415*	-0.497*	0.762**	-0.642**	0.414*	0.372	-0.527**
PH		0.566**	0.907**	0.917**	-0.764**	0.890**	-0.256	0.705**	0.049	-0.663**	0.434*
BPP			0.479*	0.538**	-0.137	0.334	0.429*	0.136	-0.184	-0.316	0.267
LL				0.973**	-0.832**	0.946**	-0.430*	0.827**	-0.061	-0.728**	0.587**
LB					-0.840**	0.949**	-0.382	0.833**	-0.070	-0.815**	0.622**
FPP						-0.929**	0.703**	-0.905**	-0.252	0.747**	0.287
FW							-0.589**	0.938**	-0.033	-0.781**	0.636**
FL								-0.721**	-0.111	0.428*	-0.379
FD									-0.130	-0.765**	0.757**
IFP										0.102	-0.583**
DFH											-0.664**

** = Significant at 1%. * = Significant at 5%.

DFF = Days of first flowering, PH = Plant height (cm), BPP = Branches per plant, LL = Leaf length (cm), LB = Leaf breadth (cm), FPP = Fruits per plant, FW = fruit weight g), FL = Fruit length (cm), FD = Fruit diameter (cm), IFP = Infested fruit per plant, DFH = Days of 1st harvest and FYP = Fruit yield per plant (Kg)

4.4.3 Number of branches per plant

Number of branches per plant showed highly significant positive relationships with leaf length, leaf breadth and fruit length at both genotypic and phenotypic level. Significant negative association was observed with days of first harvesting and non-significant relations was found with fruit weight and fruit diameter genotypically (Table 6). Number of branches per plant reflected insignificant negative associations with number of fruit per plant, infested fruit per plant and days of first harvesting phenotypically (Table 7).

4.4.4 Length of leaf (cm)

The character reflected highly significant positive relationships with leaf breadth, fruit weight, fruit diameter and fruit yield per plant at both genotypic and phenotypic level. Highly significant negative association was observed with number of fruit per plant and days of first harvesting and significant negative correlation observed with fruit length genotypically and phenotypically (Table 6 and 7).

4.4.5 Breadth of leaf (cm)

Leaf breadth (cm) reflected highly significant positive relationships with fruit weight, fruit diameter and fruit yield per plant at both genotypic and phenotypic level. It showed highly significant negative association with number of fruit per plant and days to first harvesting and also showed insignificant negative correlation with fruit length and number of infested fruit per plant genotypically and phenotypically (Table 6 and 7).

4.4.6 Number of fruits per plant

The character reflected highly significant positive relationship with fruit length and days to first harvest and insignificant positive relationship with fruit yield per plant both genotypically and phenotypically. Highly significant negative associations was observed with fruit weight, fruit diameter and also showed insignificant negative associations with infested fruit per plant at both genotypic and phenotypic level (Table 6 and 7).

4.4.7 Weight of individual fruit (g)

Weight of individual fruit (g) showed highly significant positive relationship with fruit diameter and fruit yield per plant genotypically and phenotypically (Table 6 and 7). Highly significant negative association observed with fruit length and days to first harvest and also showed insignificant negative association with number of infested fruit per plant at both genotypic and phenotypic level.

4.4.8 Fruit length (cm)

This character showed significant positive relationship with days to first harvest genotypically and phenotypically. Highly significant negative association observed with fruit diameter and insignificant negative associations with days to first harvest and fruit yield per plant at both genotypic and phenotypic level (Table 6 and 7). Insignificant association indicated that the association between these traits is largely influenced by environmental factors.

4.4.9 Fruit diameter (cm)

Fruit diameter (cm) reflected highly significant positive relationship with fruit yield per plant at both genotypically and phenotypically. This character reflected highly significant negative association with days to first harvest and also showed insignificant negative association with number of infested fruit per plant at both genotypic and phenotypic level (Table 6 and 7). Insignificant association indicated that the association between these traits is largely influenced by environmental factors.

4.4.10 Number of infested fruit per plant

Number of infested fruit per plant reflected insignificant positive relation with days to first harvest and highly significant negative association with fruit yield per plant at both genotypically and phenotypically (Table 6 and 7).

4.4.11 Days to first harvest

This character showed highly significant negative association with fruit yield per plant at both genotypically and phenotypically (Table 6 and 7).

4.5 PATH COEFFICIENT ANALYSIS

Partitioning of genotypic correlation of yield and its contributing traits in brinjal genotypes are shown in (Table 8) and discussed character wise as follows:

4.5.1 Days to first flowering (DFF)

Days to first flowering showed the positive direct effect on yield per plant (1.778). DFF showed maximum positive indirect effect through number of fruit per plant (2.141) followed by fruit weight (1.045) and number of infested fruit per plant (0.131). The negative indirect effect of this character on yield via fruit diameter (-3.584) was the highest followed by fruit length (-1.292), leaf breadth (-0.386), plant height (-0.237), leaf length (-0.088), number of branch per plant (-0.068) and days to first harvest (-0.026) which finally made highly significant negative correlation between Days to first flowering and yield per plant.

4.5.2 Plant height (cm)

Plant height showed the positive direct effect on yield per plant (1.063). Plant height showed maximum positive indirect effect through fruit diameter (3.888) followed by leaf breadth (1.085), fruit length (0.431), leaf length (0.211), days to first harvest (0.050) and number of infested fruit per plant (0.014). The negative indirect effect of this character on yield via number of fruit per plant (-3.905) was the highest followed by single fruit weight (-1.836), days to first flowering (-0.396) and number of branch per plant (-0.129) which finally made significant positive correlation between plant height and yield per plant.

4.5.3 Number of branches per plant

Number of primary branch per plant showed negative direct effect on yield per plant (-0.192). This character, however, showed positive indirect effect through days to first flowering (0.628), plant height (0.714), leaf length (0.114), leaf breadth (0.680), fruit diameter (1.002) and days to first harvest (0.029). This character also showed negative indirect effect via number of fruit per plant (-0.926), single fruit weight (-0.804), fruit length (-0.869) and number of infested fruit per plant (-0.064) contributed to result total insignificant positive genotypic correlation with yield per plant. This discrepancy with present finding might be due to environmental variation.

Table 8. Path coefficient analysis showing direct and indirect effects of different characters on yield of Brinjal

	Direct effect	Indirect Effect via											Genotypic correlation with yield
		DFF	PH	BPP	LL	LB	FPP	FW	FL	FD	IFP	DFH	
DFF	1.778	-	-0.237	-0.068	-0.088	-0.386	2.141	1.045	-1.292	-3.584	0.131	-0.026	-0.581**
PH	1.063	-0.396	-	-0.129	0.211	1.085	-3.905	-1.836	0.431	3.888	0.014	0.050	0.474*
BPP	-0.192	0.628	0.714	-	0.114	0.680	-0.926	-0.804	-0.869	1.002	-0.064	0.029	0.315
LL	0.211	-0.743	1.063	-0.104	-	1.108	-4.385	-1.998	0.723	4.707	-0.016	0.058	0.622**
LB	1.109	-0.619	1.040	-0.118	0.211	-	-4.247	-1.938	0.606	4.565	-0.020	0.061	0.652**
FPP	4.899	0.777	-0.847	0.036	-0.189	-0.962	-	1.860	-1.143	-4.817	-0.074	-0.054	0.311
FW	-1.994	-0.932	0.979	-0.077	0.211	1.078	-4.571	-	0.951	4.969	-0.010	0.056	0.658**
FL	-1.583	1.451	-0.289	-0.105	-0.096	-0.425	3.537	1.198	-	-4.030	-0.034	-0.030	-0.407*
FD	5.247	-1.214	0.788	-0.037	0.189	0.965	-4.497	-1.888	1.216	-	-0.039	0.056	0.784**
IFP	0.295	0.791	0.049	0.042	-0.011	-0.077	-1.235	0.066	0.182	-0.693	-	-0.008	-0.601**
DFH	-0.070	0.653	-0.758	0.080	-0.174	-0.959	3.782	1.603	-0.679	-4.208	0.033	-	-0.702**

Residual effect: 0.118
* = Significant at 5%.
** = Significant at 1%.
DFF = Days of first flowering, PH = Plant height (cm), BPP = Branches per plant, LL = Leaf length (cm), LB = Leaf breadth (cm), FPP = Fruits per plant, FW = fruit weight g), FL = Fruit length (cm), FD = Fruit diameter (cm), IFP = Infested fruit per plant, DFH = Days to 1st harvest and FYP = Fruit yield per plant (Kg).

4.5.4 Length of leaf (cm)

Length of leaf showed positive direct effect on yield per plant (0.211). This character, however, showed positive indirect effect through plant height (1.063), leaf breadth (1.108), fruit length (0.723), fruit diameter (4.707) and days to first harvest (0.058). This character also showed negative indirect effect via days to first flowering (-0.743), number of branch per plant (-0.104), number of fruit per plant (-4.385), single fruit weight (-1.998) and number of infested fruit per plant (-0.016) contributed to result total highly significant positive genotypic correlation with yield per plant. Yield per plant would be significantly increased by direct selection of genotypes based on these traits.

4.5.5 Breadth of leaf (cm)

Breadth of leaf showed positive direct effect on yield per plant (1.109). This character, however, showed positive indirect effect through plant height (1.040), leaf length (0.211), fruit length (0.606), fruit diameter (4.565) and days to first harvest (0.061). This character also showed negative indirect effect via days to first flowering (-0.619), number of branch per plant (-0.118), number of fruit per plant (-4.247), single fruit weight (-1.938) and number of infested fruit per plant (-0.020) contributed to result total highly significant positive genotypic correlation with yield per plant. Yield per plant would be significantly increased by direct selection of genotypes based on these traits.

4.5.6 Number of fruits per plant

A high positive direct effect was registered by number of fruit per plant on yield per plant (4.899). The indirect effect via days to first flowering (0.777), number of branch per plant (0.036) and single fruit weight (1.860) was observed to be positive. The negative indirect effect via plant height (-0.847), leaf length (-0.189), leaf breadth (-0.962), fruit length (-1.143), fruit diameter (-4.817), number of infested fruit per plant (-0.074) and days to first harvest (-0.054) which finally made significant positive correlation between number of fruit per plant and yield per plant.

4.5.7 Weight of individual fruit (g)

Single fruit weight had the negative direct effect on yield per plant (-1.994). This character, however, showed positive indirect effect through plant height (0.979), leaf length (0.211), leaf breadth (1.078), fruit length (0.951), fruit diameter (4.969) and days to first harvest

(0.056). This character also showed negative indirect effect via days to first flowering (-0.932), number of branch per plant (-0.077)**,** number of fruit per plant (-4.571) and number of infested fruit per plant (-0.010) contributed to result total highly significant positive genotypic correlation with yield per plant. Yield per plant would be significantly increased by direct selection of genotypes based on these traits.

4.5.8 Fruit length (cm)

Fruit length had the negative direct effect on yield per plant (-1.583). The indirect effect via days to first flowering (1.451), number of fruit per plant (3.537) and single fruit weight (1.198) was observed to be positive. The negative indirect effect via plant height (-0.289), number of branch per plant (-0.105), leaf length (-0.096), leaf breadth (-0.425), fruit diameter (-4.030), number of infested fruit per plant (-0.034) and days to first harvest (-0.030) which finally made significant negative correlation between Fruit length and yield per plant.

4.5.9 Fruit diameter (cm)

Fruit diameter showed maximum positive direct effect on yield per plant (5.247). This character, however, showed positive indirect effect through plant height (0.788), leaf length (0.189), leaf breadth (0.965), fruit length (1.216) and days to first harvest (0.056). This character also showed negative indirect effect via days to first flowering (-1.214), number of branch per plant (-0.037)**,** number of fruit per plant (-4.497), single fruit weight (-1.888) and number of infested fruit per plant (-0.039) contributed to result total highly significant positive genotypic correlation with yield per plant. Yield per plant would be significantly increased by direct selection of genotypes based on these traits.

4.5.10 Number of infested fruit per plant

A positive direct effect was registered by number of infested fruit per plant on yield per plant (0.295). The indirect effect via days to first flowering (0.791), plant height (0.049), number of branch per plant (0.042), single fruit weight (0.066) and fruit length (0.182) was observed to be positive. The negative indirect effect via leaf length (-0.011), leaf breadth (-0.077), number of fruit per plant (-1.235), fruit diameter (-0.693) and days to first harvest (-0.008) which finally made highly significant negative correlation between number of infested fruit per plant and yield per plant.

4.5.11 Days to first harvest

Days to first harvest showed negative direct effect on yield per plant (-0.070). The indirect effect via days to first flowering (0.653), number of branch per plant (0.080), number of fruit per plant (3.782), single fruit weight (1.603) and number of infested fruit per plant (0.033) was observed to be positive. The negative indirect effect via plant height (-0.758), leaf length (-0.174), leaf breadth (-0.959), fruit length (-0.679) and fruit diameter (-4.208) which finally made highly significant negative correlation between days to first harvest and yield per plant.

CHAPTER IV

SUMMARY AND CONCLUSION

In order to evaluate the variability and interrelationship of yield and yield contributing traits in Bt Brinjal *(Solanum melongena L.)* along with parents, an experiment was conducted with 8 brinjal genotypes in RCBD with three replication during the period from November 2015 to April 2016 in the experimental area of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka.

Mean sum of square for all the characters were highly significant due to genotypes in brinjal indicating wide range of variability among the genotypes for this traits. The σ^2g and σ^2 p and the GCV and PCV were close to each other for all the traits, indicating less environmental influence and additive gene action for this traits.

Amongst the characters the highest genotypic coefficient of variation was recorded for no. of infested fruit per plant (77.75) followed by individual fruit weight (63.60), no. of fruit per plant (40.57) and fruit diameter (32.14 cm). The highest estimated heritability amongst eight characters of brinjal was 99.93% for fruit weight and the lowest for (70.85) no. of branch per plant. The highest GA amongst all the characters was found in individual fruit weight (58.92) g and the lowest genetic advance was carried out in fruit yield per plant (0.83). The maximum genetic advance in percent of mean was observed for no. of infested fruit per plant (98.91) followed by fruit weight (130.96) and no. of fruit per plant (83.21), whereas the lowest was for days to first harvesting (4.82) and followed by plant height (11.61) and no. of branch per plant (12.12). The high heritability (94.64%) with low genetic advance in percent of mean (4.82) indicated non-additive gene action for expression of the characters.

Days to first flowering found to display highly significant positive relationships with fruit length and significant positive correlation with fruit per plant and infested fruit per plant at both genotypic and phenotypic level. The character reflected highly significant negative association with fruit weight, fruit diameter and fruit yield per plant genotypically and with fruit diameter and fruit yield per plant phenotypically. Plant height reflected highly significant positive relationships with branch per plant, leaf length, leaf breadth, fruit weight and fruit diameter and highly significant negative association with number of fruit per plant and days of first harvesting at both genotypic and phenotypic level. Number of branches per plant showed highly significant positive relationships with leaf length, leaf breadth and fruit length and significant negative association was observed with days of first harvesting genotypically. Number of branches per plant reflected highly significant positive relationship with leaf breadth phenotypically. Leaf length reflected highly significant positive relationships with leaf breadth, fruit weight, fruit diameter and fruit yield per plant at both genotypic and phenotypic level. Highly significant negative association was observed with number of fruit per plant and days of first harvesting. Leaf breadth (cm) reflected highly significant positive relationships with fruit weight, fruit diameter and fruit yield per plant at both genotypic and phenotypic level. It showed highly significant negative association with number of fruit per plant and days of first harvesting genotypically and phenotypically. Number of fruits per plant reflected highly significant positive relationship with fruit length and days to first harvest and highly significant negative associations was observed with fruit weight, fruit diameter at both genotypic and phenotypic level. Weight of individual fruit (g) showed highly significant positive relationship with fruit diameter and fruit yield per plant and highly significant negative association observed with fruit length and days to first harvest at both genotypic and phenotypic level. Fruit length showed significant positive relationship with days to first harvest and highly significant negative association observed with fruit diameter genotypically and phenotypically. Fruit diameter (cm) reflected highly significant positive relationship with fruit yield per plant and highly significant negative association with days to first harvest at both genotypically and phenotypically. Number of infested fruit per plant reflected insignificant positive relation with days to first harvest and highly significant negative association with fruit yield per plant at both genotypically and phenotypically. Days to first harvest showed highly significant negative association with fruit yield per plant at both genotypically and phenotypically.

Fruit diameter (5.247 cm) and number of fruit per plant (4.899) showed high positive direct effect on yield per plant followed by days to first flowering and leaf breadth. Fruit weight showed the highest negative direct effect on yield per plant. Number of branch per plant, fruit length and days of first harvesting also showed negative direct effect on yield per plant.

Considerable σ^2_g and σ^2_p; considerable difference of GCV and PCV; high heritability with high GAPM; significant r_g and high direct effects were observed for fruit diameter. These trait must be considered for the improvement of yield per plant of brinjal genotypes.

From the experiment it was observed maximum days required for 1st flowering (54.33) was recorded from BARI Begun 4, whereas the minimum days required for 1st flowering (49.33) was attained from BARI Bt Begun 3. The plant height was maximum (66.78 cm) in BARI Begun 6 and the shortest plant (58.00 cm) was found from BARI Bt Begun 1. It was observed that the maximum numbers of branches per plant (21.78) were produced by BARI Bt Begun 4 and least number of branches (17.78) recorded from BARI Begun 5. The longest leaf (17.73 cm) was found from BARI Bt Begun 4, whereas the shortest leaf (13.83 cm) was recorded from BARI Begun 1. The highest breadth of leaf (10.38 cm) was attained from BARI Bt Begun 4, whereas the lowest breadth of leaf (7.25) was attained from BARI Begun 1. It was revealed that the maximum numbers of fruits per plant (36.11) were produced by BARI Bt Begun 1 and the least number of fruits (9.67) produced by BARI Begun 6. The highest fruit weight (218.6 g) was obtained from BARI Bt Begun 4 and the least individual fruit weight (50.79 g) was produced by BARI Begun 1. The highest Fruit length (16.48 cm) was attained from BARI Bt Begun 2, whereas the lowest length (8.85 cm) was found from BARI Begun 5. The highest diameter of brinjal (8.33 cm) was recorded from BARI Bt Begun 4 and the lowest diameter (6.55cm) was found from BARI Begun 5. It was revealed that the maximum number of infested fruits per plant (79.44) was found from BARI Begun 4, whereas the minimum number (7.72) was recorded from BARI Bt Begun 2. The maximum days required for 1st harvesting (64.67) was recorded from BARI Begun 1, whereas the minimum days required for 1st harvesting (60.33) was attained from BARI Begun 6. The highest yield per plant of brinjal (2.81 kg) was observed from BARI Bt Begun 4, while The lowest yield per plant (1.51 kg) was recorded from BARI Begun 1.

Findings of the present investigation indicated minimum differences between genotypic and phenotypic variance and coefficient of variation which were observed for all the traits studied. High heritability, moderate to low genetic advance and genetic advance in percent of mean were observed for all the traits studied. Fruit diameter showed high degree of significant positive correlation with yield per plant. Based on above conclusion selection should made on fruit diameter to improve the yield of brinjal genotypes. Considering fruit diameter and yield per plant the genotype BARI Bt Begun 4 performed best. BARI Bt Begun 3 and BARI Bt Begun 2 produce higher yield next to the genotype BARI Bt Begun 4.

Based on the comparison of eight brinjal variety, BARI Bt Begun 4 was found to be highest yielder followed by BARI Bt Begun 3 and BARI Bt Begun 2. The other variety showed much less yields compared to the former. As no insecticide was used to study the resistance capacity of the brinjal genotypes against Lepidopteran insects like fruit and shoot borer, all Bt Brinjal varieties showed much higher yields compared to their non Bt Brinjal parents.

RECOMMENDATIONS:

- Minimum differences between genotypic and phenotypic variance and coefficient of variation which were observed for all the traits studied.
- High heritability and moderate to high genetic advance in percent of mean were observed for all the traits studied.
- Fruit diameter showed high degree of significant positive correlation with yield per plant.
- Considering fruit diameter and yield per plant the genotype BARI Bt Begun 4 performed best.
- Based on the comparison of eight brinjal variety, BARI Bt Begun 4 was found to be highest yielder followed by BARI Bt Begun 3 and BARI Bt Begun 2.

CHAPTER VI

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APPENDICES

Appendix I. Monthly average of air temperature, Relative Humidity and Total rainfall of the experimental site during the period from November 2015 to April 2016

Month	Air Temperature (°C)		Relative humidity (%)	Total rainfall (mm)
	Maximum	Minimum		
November, 2015	30.3	18	70	1
December, 2015	26.7	13	73	0
January, 2016	26.0	13.2	72	1
February, 2016	32.9	19.2	61	1
March, 2016	35.8	22.5	65	60
April, 2016	37.9	23.1	62	67

Source: Bangladesh Metrological Department (Climate division), Agargaon. Dhaka-1212.

Appendix II. Characteristics of soil of the experimental field

A. Morphological characteristics of of the experimental field

Morphological features	Characteristics
Location	Experimental field, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Sallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical and chemical characteristics of initial soil

characteristics	Value
% Sand	27
% Silt	43
% Clay	30
Textural class	Silty-clay
pH	5.6
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Sourse: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka.

Appendix III. ANOVA Table

Source	d.f.	MS											
		DFF	PH	BPP	LL	LB	FPP	FW	FL	FD	IFP	DFH	FYP
Rep	2	0.91	0.70	0.35	0.49	0.15	2.50	4.94	0.34	0.06	2.33	0.14	0.04
Genotype	7	9.73**	39.06**	6.48**	7.72**	4.37**	292.55**	14590.39**	26.00**	10.60**	3138.46**	6.89**	0.54**
Error	14	0.35	0.98	0.78	0.31	0.07	0.86	3.26	0.36	0.07	4.72	0.13	0.01

** = Significant at 1%.
DFF = Days to first flowering, PH = Plant height (cm), BPP = Branches per plant, LL = Leaf length (cm), LB = Leaf breadth (cm), FPP = Fruits per plant, FW = fruit weight (g), FL = Fruit length (cm), FD = Fruit diameter (cm), IFP = Infested fruit per plant , DFH = Days to 1st harvest, FYP = Fruit yield per plant (Kg), df = degrees of freedom, MS = mean sum of square.