Vegetable Science (2021) 48 (1) : 86-94

# Combining ability studies for yield components, quality characters and relative susceptibility to fruit and shoot borer in brinjal

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Received: June 2021/ Accepted: July 2021

## Abstract

Six diverse brinjal lines were crossed in a diallel fashion, excluding reciprocals to obtain fifteen cross combinations to study combining ability for yield components, quality characters and relative susceptibility to brinjal fruit and shoot borer. Significant differences were observed among genotypes for most of the characters studied. Both additive and non-additive gene action conditioned most of the characters while non-additive gene action was preponderant for the control of total phenol content of fruit, seed protein content and shoot infestation by borer. Maximum significant gca effects in desired directions were registered by Garia for 7 characters followed by BCB-40, BCB-50 and Punjab Sadabahar for 6 characters. However, considering the second highest *per se* performance for marketable fruit yield/ plant (2.59 kg/plant) along with second lowest severity of fruit borer infestation (18.55%) together, the parental line BCB-40 emerged as the best followed by BCB-30, being the highest yielder (2.69 kg/plant) and low severity of fruit borer infestation (22.07%). The most promising cross combination Garia × Punjab Sadabahar registering the second highest marketable fruit yield per plant (3.74 kg / plant) exhibited the highest significantly positive sca effects for marketable fruit yield/ plant along with high and significantly positive sca effect for plant height, fruit pedicel length, fruit weight, fruits per plant and total phenol content of shoot and significantly negative sca effect for fruit infestation by brinjal fruit and shoot borer. Keeping in view of low narrow sense heritability for some important characters *viz*., fruit weight, marketable fruit yield per plant, total phenol content of fruit and fruit infestation by brinjal fruit and shoot borer selection should be based primarily on replicated family testing in $F_3$ and later generations. In the perspective of importance of non-additive genetic variance along with additive genetic variance for the conditioning of most of the characters, heterosis breeding to develop high yielding hybrids possessing better fruit size, colour, quality and less susceptibility to brinjal fruit and shoot borer may be the best breeding strategy.

**Key words:** Diallel analysis, Gene action, Yield components, Fruit quality, Brinjal

## Introduction

Brinjal or eggplant (*Solanum melongena* L.) is a warm-weather crop and widely cultivated in tropical and subtropical regions of the world. It is the fifth most economically important solanaceous crop in the world after potato, tomato, pepper and tobacco. In India, it ranks 4$^{th}$ in total vegetable production after potato, onion and tomato. Brinjal has a very low caloric value and is considered amongst the top ten vegetables for its high content of protein, various vitamins, minerals like, iron, calcium, potassium, magnesium, dietary fibre and different bio-active phyto-chemicals which are desirable for body growth. Brinjal breeding in India was relied heavily on single plant selection from the farmers' variety, land races for the development of improved varieties. Combining ability analysis help breeders in choosing suitable genotypes as parents for hybridization programme and selection of superior cross combinations through general combining ability (GCA) and specific combining ability (SCA) studies, respectively. Hence, present investigation was undertaken to study the combining ability for yield components, quality characters and relative susceptibility to brinjal fruit and shoot borer.

## Materials and Methods

The study was carried out during autumn-winter seasons (September–March) between 2016 and 2018 at "C" Block Farm of Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, West Bengal under the research field of All India Coordinated Research project on Vegetable

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Science. The farm is situated at 23.5 $^0$N latitude and 89 $^0$E longitude at an elevation of 9.75 m above the mean sea level in open field condition under the average day temperature range of 23.8–32.6 °C and night temperature range of 8.4–24.8 °C, the average day/ night being 28.3/16.2 °C. The experimental material consisted of six parents namely, BCB-40, BCB-11, BCB-30, Garia, BCB-50 and Punjab Sadabahar which were selected on the basis of fruit characters and yield potentiality. These 6 parental lines were crossed in 6 x 6 diallel mating design excluding reciprocals to develop 15 hybrids. Conventional hybridization method was followed in which the matured flower buds that would open in the next day morning was emasculated in the afternoon hours and covered with small paper packet. In the next day morning hours between 8-9 a.m. the emasculated flowers were pollinated by the pollens of the desired male parent in the crossing scheme. The 15 hybrids and 6 parents were evaluated in a randomized block design with three replications in autumn-winter season (September 2017 to March 2018) keeping 20 plants per genotype per replication at 75 x 75 cm spacing without any insecticidal cover to allow natural infestation by brinjal fruit and shoot borer. Five randomly selected plants, excluding the border ones, from each plot of all the three replications were tagged and used for recording the observations and average values were computed. The data recorded for 18 characters were plant height (cm), primary branches/ plant, days to first flower, fruit length (cm), fruit girth (cm), fruit pedicel length (cm), fruit weight (g), fruits/ plant, marketable fruit yield per plant (kg), total phenol content of shoot (mg/ 100 g), total phenol content of shoot (mg/ 100 g), anthocyanin content of peel (mg/100 g), seed protein content (%), total sugar content (%),reducing sugar content (%),non reducing sugar content (%),shoot infestation by borer (%) and fruit infestation by borer (%). Observations on plant height, primary branches per plant, were recorded at last picking and data on fruit length, fruit girth, fruit weight, fruits per plant and fruit yield per plant were recorded at periodical pickings and then averaged.

Five fruits of marketable maturity sampled periodically were used for estimation of different quality characters. After taking the fruit weight (g), length (cm) and girth (cm) the fruits were cut into pieces. The cut fruits were used to make composite sample to estimate different fruit quality characters on fresh weight basis *viz*., total, reducing and non-reducing sugar content (Dubois et al.1951), total phenol content spectrophotometrically (Singleton and Rossi 1965), anthocyanin content of fruit peel spectrophotometrically (Sadasivam and Manickam 1996) and protein content of seed (Lowry et al.1951). Fort nightly observations on infestation of fruit and shoot borer were taken beginning 30 days after transplanting till the last fruit harvest was done. After recording the number of borers infested dead shoots, they were clipped off just above the point of insect burrow without destroying the larvae inside it. Single borer damage in the fruit was also considered as infested fruit. The percentage of borer infestation of both shoots and fruits were determined on number basis. All the data expressed in percentage were subjected to angular transformation before further calculation. The estimates of combining ability, variances and effects were determined following Method 2 of Model - I (fixed effect), suggested by Griffing (1956).

## Results and Discussion

**Estimates of general and specific combining ability variances:** Mean of the 18 characters recorded in the 6 parental lines and its 15 hybrids (Table 1) clearly indicated significant variation among the genotypes for all the characters. Analysis of variance for parents, hybrids and parent *vs* hybrids (Table 2) revealed that the parents and hybrids were significantly different for all the characters excepting non-reducing sugar content in the fruits (%) and shoot infestation by borer (%). High divergence in the parental lines for most of the characters indicated their suitability for developing divergent hybrids. Significant difference among the hybrids suggested varying performance of the hybrids for most of the characters. As expected, variance due to parents *vs* hybrids was significant for most of the characters excepting total, reducing and non-reducing sugar contents of fruit and shoot infestation by borer which indicated that heterosis might not be manifested for these characters.

Estimates of various components of the total variance for 18 characters of the 6 parental lines and their 15 $F_1$ hybrid combinations (Table 3) revealed that both general and specific combining ability variances ($ó^2$gca and $ó^2$sca) were significant for all the characters which indicated that the inheritance of the characters under study was apparently controlled by both additive and non-additive gene actions. Highly significant gca and sca variances for fruit yield / plant and most of the yield component characters recorded earlier in earlier studies (Agarwal et al. 2014; Prasad et al. 2015; Kumar and Arumugam 2016; Patel et al. 2017; Dishri and Mishra 2017; Pramila et al. 2018) agreed well to the present findings.

The estimates of general combining ability variances were higher in magnitude than specific combining ability variances for plant height, primary branches per plant,

**Table 1a:** Mean of different characters in 6 × 6 half diallel populations including parents

| Character | Plant height (cm) | Primary branches/ plant | Days to first flowering | Fruit length (cm) | Fruit girth (cm) | Fruit pedicel length (cm) | Fruit weight (g) | Fruits/ plant | Marketable fruit yield per plant (kg) |
|---|---|---|---|---|---|---|---|---|---|
| BCB-40 | 89.38 | 4.17 | 40.12 | 13.52 | 8.05 | 7.41 | 198.30 | 12.96 | 2.59 |
| BCB-11 | 84.22 | 4.19 | 38.28 | 16.88 | 7.55 | 10.65 | 200.77 | 10.72 | 2.15 |
| BCB-30 | 93.81 | 5.16 | 40.23 | 8.95 | 9.12 | 5.97 | 195.98 | 13.63 | 2.69 |
| Garia | 109.89 | 4.80 | 33.77 | 13.22 | 5.35 | 7.56 | 159.57 | 11.52 | 1.84 |
| BCB-50 | 125.97 | 6.10 | 42.32 | 11.84 | 5.22 | 4.59 | 182.63 | 5.54 | 1.04 |
| Punjab Sadabahar | 73.00 | 3.79 | 34.38 | 19.12 | 3.44 | 2.99 | 81.40 | 17.53 | 1.44 |
| BCB-40 × BCB-11 | 95.35 | 6.12 | 40.46 | 14.90 | 4.99 | 3.21 | 142.65 | 7.94 | 1.15 |
| BCB-40 × BCB-30 | 96.41 | 5.74 | 40.10 | 11.81 | 6.42 | 2.94 | 202.91 | 9.84 | 2.02 |
| BCB-40 × Garia | 92.96 | 5.40 | 39.59 | 17.41 | 4.46 | 3.43 | 164.13 | 9.95 | 1.63 |
| BCB-40 × BCB-50 | 111.45 | 5.44 | 40.38 | 12.84 | 6.34 | 4.73 | 158.87 | 7.72 | 1.22 |
| BCB-40 × Punjab Sadabahar | 93.54 | 5.28 | 32.00 | 22.26 | 4.42 | 3.13 | 210.48 | 18.79 | 3.94 |
| BCB-11 × BCB-30 | 115.68 | 4.52 | 41.51 | 13.79 | 6.58 | 4.06 | 197.98 | 11.97 | 2.36 |
| BCB-11 × Garia | 100.30 | 4.86 | 41.43 | 19.15 | 5.34 | 4.28 | 127.95 | 5.51 | 0.70 |
| BCB-11× BCB-50 | 103.03 | 4.48 | 40.27 | 15.10 | 6.12 | 3.39 | 172.84 | 10.47 | 1.85 |
| BCB-11× Punjab Sadabahar | 102.05 | 4.60 | 40.93 | 16.85 | 3.36 | 3.88 | 160.58 | 12.22 | 1.96 |
| BCB-30 × Garia | 95.42 | 5.78 | 38.60 | 10.65 | 7.33 | 7.90 | 177.58 | 9.08 | 1.63 |
| BCB-30 × BCB-50 | 96.79 | 5.41 | 40.83 | 6.47 | 5.92 | 6.06 | 210.85 | 8.65 | 1.84 |
| BCB-30 × Punjab Sadabahar | 76.09 | 4.99 | 36.26 | 13.51 | 3.54 | 3.75 | 157.36 | 12.62 | 1.98 |
| Garia × BCB-50 | 123.59 | 4.99 | 40.13 | 23.75 | 3.29 | 6.42 | 148.67 | 12.60 | 1.88 |
| Garia × Punjab Sadabahar | 100.31 | 4.34 | 31.32 | 17.39 | 3.41 | 7.03 | 218.83 | 17.00 | 3.74 |
| BCB-50 × Punjab Sadabahar | 102.32 | 4.37 | 40.71 | 12.76 | 3.13 | 5.86 | 158.60 | 8.77 | 1.41 |
| C.V. (%) | 4.20 | 12.83 | 3.48 | 5.70 | 5.30 | 10.70 | 2.35 | 5.35 | 5.80 |
| S.E.m (±) | 2.40 | 0.37 | 0.78 | 0.49 | 0.17 | 0.32 | 2.34 | 0.35 | 0.07 |
| C.D. at 5% | 6.87 | 1.05 | 2.23 | 1.40 | 0.47 | 0.92 | 6.69 | 0.99 | 0.19 |

Contd.

**Table 1b:** Mean of different characters in 6 × 6 half diallel populations including parents

| Character | Total phenol content of shoot (mg/ 100 g) | Total phenol content of shoot (mg/ 100 g) | Anthocyanin content of peel (mg/100 g) | Seed protein content (%) | Total sugar content (%) | Reducing sugar content (%) | Non-reducing sugar content (%) | Shoot infestation by borer (%) | Fruit infestation by borer (%) |
|---|---|---|---|---|---|---|---|---|---|
| BCB-40 | 3.97 | 3.23 | 91.60 | 20.98 | 1.42 | 1.10 | 0.32 | 0.56 | 18.55 |
| BCB-11 | 3.41 | 2.80 | 12.80 | 15.39 | 1.47 | 1.16 | 0.31 | 0.61 | 13.80 |
| BCB-30 | 3.71 | 2.91 | 95.56 | 15.59 | 1.36 | 1.09 | 0.30 | 0.32 | 22.07 |
| Garia | 3.13 | 2.50 | 52.88 | 18.49 | 2.62 | 2.06 | 0.56 | 0.45 | 38.07 |
| BCB-50 | 4.61 | 3.99 | 1.00 | 27.48 | 1.32 | 1.04 | 0.28 | 0.10 | 19.92 |
| Punjab Sadabahar | 4.58 | 3.35 | 98.75 | 17.70 | 1.39 | 1.08 | 0.30 | 0.23 | 25.08 |
| BCB-40 × BCB-11 | 3.50 | 3.01 | 87.51 | 20.51 | 1.10 | 0.87 | 0.23 | 0.78 | 31.54 |
| BCB-40 × BCB-30 | 3.60 | 2.72 | 92.38 | 21.74 | 1.81 | 1.74 | 0.13 | 0.78 | 38.78 |
| BCB-40 × Garia | 3.69 | 2.96 | 75.50 | 15.75 | 1.96 | 1.58 | 0.38 | 0.74 | 22.44 |
| BCB-40 × BCB-50 | 4.13 | 3.64 | 64.63 | 21.68 | 1.37 | 1.10 | 0.32 | 0.22 | 20.18 |
| BCB-40 × Punjab Sadabahar | 4.48 | 3.05 | 99.32 | 16.61 | 1.33 | 1.00 | 0.31 | 0.39 | 27.36 |
| BCB-11 × BCB-30 | 4.06 | 3.53 | 63.26 | 11.10 | 1.75 | 1.44 | 0.31 | 0.36 | 33.91 |
| BCB-11 × Garia | 3.48 | 3.53 | 58.19 | 13.70 | 2.06 | 1.64 | 0.40 | 0.69 | 32.99 |
| BCB-11 × BCB-50 | 3.70 | 2.49 | 7.39 | 18.37 | 1.73 | 1.32 | 0.41 | 0.51 | 25.13 |
| BCB-11 × Punjab Sadabahar | 3.98 | 3.46 | 77.81 | 13.40 | 1.03 | 0.94 | 0.19 | 0.28 | 35.06 |
| BCB-30 × Garia | 4.01 | 3.09 | 64.47 | 16.25 | 1.75 | 1.06 | 0.69 | 0.51 | 43.45 |
| BCB-30 × BCB-50 | 4.16 | 3.18 | 8.61 | 14.08 | 1.54 | 1.28 | 0.26 | 0.49 | 40.40 |
| BCB-30 × Punjab Sadabahar | 4.40 | 3.49 | 98.30 | 16.58 | 1.31 | 1.03 | 0.28 | 0.25 | 27.06 |
| Garia × BCB-50 | 3.73 | 2.85 | 56.50 | 13.59 | 1.84 | 1.43 | 0.42 | 0.41 | 30.50 |
| Garia × Punjab Sadabahar | 4.33 | 2.97 | 77.33 | 15.38 | 1.65 | 1.31 | 0.35 | 0.28 | 24.04 |
| BCB-50 × Punjab Sadabahar | 3.77 | 3.93 | 13.73 | 12.54 | 1.77 | 1.43 | 0.34 | 0.45 | 47.27 |
| C.V. (%) | 4.88 | 6.44 | 2.09 | 7.42 | 5.83 | 4.95 | 12.52 | 12.45 | 11.06 |
| S.E.m (±) | 0.11 | 0.12 | 0.74 | 0.73 | 0.05 | 0.04 | 0.02 | 0.03 | 1.88 |
| C.D. at 5% | 0.32 | 0.34 | 2.13 | 2.08 | 0.15 | 0.10 | 0.07 | 0.09 | 5.37 |

days to first flowering, fruit length, fruit girth, fruits per plant, anthocyanin content of fruit, protein content of seed, total phenol content of shoot and fruit and total and reducing sugar content of fruit and shoot infestation by borer (Table 3). On the other hand, the specific combining ability variances were higher than the general combining ability variances only for fruit infestation by borer. Both general and specific combining ability

**Table 2a:** Analysis of variance for different characters in 6 × 6 half diallel population

| Source | d.f. | Plant height (cm) | Primary branches/ plant | Days to first flowering | Fruit length (cm) | Fruit girth (cm) | Fruit pedicel length (cm) | Fruit weight (g) | Fruits/ plant | Marketable fruit yield per plant (kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| Replication | 2 | 3.44 | 0.05 | 2.79 | 0.22 | 0.06 | 0.38 | 15.38 | 0.18 | 0.83 |
| Genotypes | 20 | 534.87** | 1.29** | 31.20** | 52.32** | 9.05** | 12.79** | 3225.90** | 38.14** | 1.90** |
| Parents | 5 | 1084.50** | 2.13** | 35.42** | 39.31** | 13.59** | 21.23** | 6324.17** | 46.67** | 1.26** |
| Hybrids | 14 | 359.75** | 0.95* | 31.35** | 59.10** | 6.07** | 7.52** | 2333.24** | 36.70** | 2.27** |
| Parent *vs* Hybrids | 1 | 238.38** | 1.91* | 7.94* | 22.38** | 28.18** | 44.35** | 231.84** | 15.77** | 0.68 ** |
| Error | 40 | 17.32 | 0.41 | 1.82 | 0.72 | 0.08 | 0.31 | 16.44 | 0.36 | 0.13 |

**Table 2b:** Analysis of variance for different characters in 6 × 6 half diallel population

| Source | d.f. | Total phenol content of shoot (mg/100g) | Total phenol content of shoot (mg/100g) | Anthocyanin content of peel (mg/100 g) | Seed protein content (%) | Total sugar content (%) | Reducing sugar content (%) | Non-reducing sugar content (%) | Shoot infestation by borer (%) | Fruit infestation by borer (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| Replication | 2 | 0.06 | 0.02 | 0.46 | 79.51 | 0.01 | 0.02 | 0.01 | 0.01 | 1.23 |
| Genotypes | 20 | 0.50** | 0.52** | 3412.22** | 44.29** | 0.39** | 0.27** | 0.04 | 0.11 | 237.81** |
| Parents | 5 | 1.11** | 0.81** | 5708.18** | 61.19** | 0.76** | 0.47** | 0.03 | 0.14 | 207.76** |
| Hybrids | 14 | 0.31** | 0.46** | 2819.51** | 32.09** | 0.29** | 0.22** | 0.05 | 0.12 | 189.65** |
| Parent *vs* Hybrids | 1 | 0.02 | 0.05 | 230.26** | 130.47** | 0.00 | 0.01 | 0.00 | 0.01 | 1062.28** |
| Error | 40 | 0.04 | 0.04 | 1.66 | 1.59 | 0.05 | 0.02 | 0.02 | 0.08 | 10.57 |

**Table 3a:** Estimates of various components of the total variance for the characters of the 6 parents and 15 $F_1$ hybrids

| Characters / Parameters | Plant height (cm) | Primary branches/ plant | Days to first flowering | Fruit length (cm) | Fruit girth (cm) | Fruit pedicel length (cm) | Fruit weight (g) | Fruits / plant | Marketable fruit yield per plant (kg) |
|---|---|---|---|---|---|---|---|---|---|
| $\sigma^2_{gca}$ | 433.98** | 0.68** | 25.04** | 37.07 ** | 8.25** | 3.44** | 1094.72** | 28.22** | 0.58** |
| $\sigma^2_{sca}$ | 93.06** | 0.35** | 5.52 ** | 10.90 ** | 1.27** | 4.54** | 1068.83** | 7.55** | 0.65** |
| $\sigma^2_e$ | 5.77 | 0.14 | 0.61 | 0.24 | 0.03 | 0.10 | 5.48 | 0.12 | 0.04 |

cont...

**Table 3b:** Estimates of various components of the total variance for the characters of the 6 parents and 15 $F_1$ hybrids

| Characters / Parameters | Total phenol content of shoot (mg/ 100 g) | Total phenol content of shoot (mg/ 100 g) | Anthocyanin content of peel (mg/100 g) | Seed protein content (%) | Total sugar content (%) | Reducing sugar content (%) | Non-reducing sugar content (%) | Shoot infestation by borer (%) | Fruit infestation by borer (%) |
|---|---|---|---|---|---|---|---|---|---|
| $\sigma^2_{gca}$ | 0.40** | 0.23** | 3611.40** | 23.98** | 0.35** | 0.16** | 0.03** | 0.08** | 56.72** |
| $\sigma^2_{sca}$ | 0.09** | 0.16** | 312.74** | 11.69** | 0.06** | 0.07** | 0.01** | 0.02** | 86.79** |
| $\sigma^2_e$ | 0.01 | 0.01 | 0.55 | 0.53 | 0.016 | 0.006 | 0.006 | 0.026 | 3.52 |

ó$^2_{gca}$ = General combining ability variance ó$^2_{sca}$ = Specific combining ability variance ó$^2_e$ = Environmental variance

variances corresponded very closely for fruit weight, marketable fruit yield per plant, fruit pedicel length and non-reducing sugar content of fruit.

**Genetic control of different characters:** A general trend of the genetic control of the character could be ascertained from the estimates of additive and non-additive variance components. The relative importance of additive and non-additive genetic effects for the character is reflected by the predictability ratio *i.e.* additive genetic variance expressed as proportion of total genetic variance as per Baker (1978). He emphasized that predictability ratio close to unity (more than 0.8) indicated predominance of additive gene effect, ratio varies between e" 0.5 and < 0.8 indicated importance of both additive and non-additive gene effect, and ratio < 0.5 indicated predominance of non-additive gene effect for the particular character.

The present study reflected the preponderance of non-additive gene effects for the control of total phenol content of fruit, seed protein content and shoot infestation by borer as their predictability ratios were less than 0.50 (Table 4). On the other hand, plant height, primary branches per plant, fruit length, fruit girth, fruit pedicel length, fruit weight, fruit number per plant, marketable fruit yield per plant, total phenol content of shoot, anthocyanin content of fruit peel, total sugar and non-reducing sugar content of fruit and fruit infestation by borer were controlled by both additive and non-additive gene action, additive gene action being predominant as predictability ratios for these characters

**Table 4:** Estimates of additive, non-additive variance and heritability

| Characters | Additive variance ($V_A$) | Non-additive variance ($V_D$) | Heritability in narrow sense ($h^2_{ns}$) (%) |
|---|---|---|---|
| Plants height (cm) | 91.77 | 79.79 | 53.00 |
| Primary branches / plant | 109.59 | 28.85 | 28.00 |
| Days to first flowering | 0.16 | 0.19 | 53.00 |
| Fruits length (cm) | 0.38 | 0.10 | 46.00 |
| Fruit girth (cm) | 6.82 | 4.59 | 62.00 |
| Fruit pedicel length (cm) | 6.67 | 1.76 | 16.00 |
| Average fruit weight (g) | 11.02 | 9.68 | 20.00 |
| Number of fruits/plants | 16.78 | 4.42 | 48.00 |
| Marketable fruit yield per plant (kg) | 2.02 | 0.97 | 18.00 |
| Shoot phenol content (mg/100 g fresh) | 0.46 | 0.12 | 53.00 |
| Fruit phenol content (mg/100 g fresh | 0.91 | 3.12 | 26.00 |
| Anthocyanin content in peel (mg/100 g) | 2.31 | 0.61 | 74.00 |
| Seed protein content (%) | 199.44 | 877.16 | 33.00 |
| Total sugar content (%) | 1497.68 | 394.23 | 59.00 |
| Reducing sugar content (%) | 7.10 | 7.04 | 38.00 |
| Non-reducing sugar content (%) | 5.74 | 1.51 | 47.00 |
| Borer infestation in shoot (%) | 0.19 | 0.58 | 46.00 |
| Borer infestation in fruit (%) | 0.93 | 0.24 | 13.00 |

were greater than 0.50 and less than 0.80. Both additive and non-additive genetic variance corresponded very closely for days to first flowering and reducing sugar content of fruit indicating almost equal importance of both the variances for the control of these characters.

Genetic control of different quantitative characters of brinjal was documented through several earlier studies. Conditioning of non-additive gene actions for days to 1st flowering (Dishri and Mishra 2017; Hussain et al. 2017), days to 50% flowering (Patel et al., 2017; Pramila et al. 2018), plant height (Dishri and Mishra 2017; Pramila et al. 2018), and fruit yield / plant (Prasad et al. 2010; Dishri and Mishra 2017; Hussain et al. 2017; Pramila et al. 2018) partially corroborated to the findings of the present investigation. In contrast to the present findings, Shende et al. (2016) reported non-additive genetic control for total sugar content of fruit and fruit borer infestation employing round fruited brinjal genotypes as parent materials. Predominance of both additive and non-additive gene action for the control of fruit length (Aswani and Khandelwal 2005; Kumar *et al*. 2017), fruit diameter (Hussain et al. 2017; Kumar et al. 2017), fruit weight (Rai and Asati 2011; Kumar et al. 2013), number of fruits / plant (Aswani and Khandelwal 2005; Kumar et al. 2013), and fruit yield / plant (Kumar et al. 2017) agreed well to the present findings. Non-additive genetic control of total phenol content of fruit agreed well to the earlier report of Shende et al. (2016).

Both additive and non-additive variance corresponded very closely for days to first flowering and reducing sugar content of fruit. There emerged the possibility of deriving high performing pure line for the characters namely, plant height, primary branches per plant, days to first flowering, fruit length, fruit girth, fruit pedicel length, fruit weight, fruit number per plant, marketable fruit yield per plant, total phenol content of shoot, anthocyanin content of fruit peel, total, reducing and non-reducing sugar content of fruit and fruit infestation by borer because larger proportion of non-additive gene effects in self pollinated crops seems to be due to additive ´ additive epistatic effect. So, deferred selection would be profitable for improving fruit yield per plant and other mentioned characters. The characters, total phenol content fruit, seed protein content and shoot infestation by brinjal fruit and shoot borer was governed overwhelmingly by non-additive gene action. Hence, for improvement of these characters heterosis breeding appeared to be the best possible approach.

**Combining ability effects:**Relative potentiality / merit of the parents and the hybrids could be judged in terms of general combining ability effects of parents ($g_i$) and specific combining ability effects of hybrids ($s_{ij}$) along with their *per se* performance so as to use them in an appropriate breeding programme.

**General combining ability (gca) effects:** The parents differed in their gca effects for all the characters (Table 5). No single parent was found to be a good combiner for all the characters under study. Among the parental lines, the maximum significant gca effects in desired directions were registered by Garia for 7 characters (plant height, fruit length, fruit pedicel length, anthocyanin content of fruit peel, total sugar, reducing sugar and non-reducing sugar contents of fruits) followed by BCB-40 for 6 characters (fruit girth, fruit weight, fruit number per plant, marketable fruit yield / plant, anthocyanin content of fruit peel and seed protein content), BCB-50 for 6 characters (plant height, primary branches per plant, days to first flowering, total phenol

**Table 5:** Estimates of general combining ability (GCA) effects on different characters of six parental lines

| Genotypes / Characters | BCB-40 | BCB-11 | BCB-30 | Garia | BCB-50 | Punjab Sadabahar | CD (Gi – Gj)* |
|---|---|---|---|---|---|---|---|
| Plants height (cm) | -3.17 ** | -1.13 | -3.23 ** | 4.81 ** | 11.91 ** | -9.19 ** | 3.09** |
| Primary branches / plant | 0.19 | -0.23 | 0.24 | 0.02 | 0.26 * | 0.46 ** | 0.47** |
| Days to first flowering | 0.20 | 1.24 ** | 0.82 ** | -1.57 ** | 1.97 ** | -2.65 ** | 1.00** |
| Fruits length (cm) | 0.28 | 1.19 ** | -3.74 ** | 1.34 ** | -1.18 ** | 2.12 ** | 0.63*** |
| Fruit girth (cm) | 0.62 ** | 0.46 ** | 1.28 ** | -0.41 ** | -0.32 ** | -1.63 ** | 0.21** |
| Fruit pedicel length (cm) | -0.52 ** | 0.46 ** | 0.03 | 0.97 ** | -0.10 | -0.85 ** | 0.41** |
| Average fruit weight (g) | 8.25 ** | -0.76 | 16.12 ** | -6.67 ** | 0.68 | -17.62 ** | 3.01** |
| Number of fruits/plants | 0.23 * | -1.10 ** | 0.13 | -0.14 | -2.38 ** | 3.27 ** | 0.44** |
| Marketable fruit yield per plant (kg) | 0.18 ** | -0.17 ** | 0.19 ** | -0.05 * | -0.43 ** | 0.28 ** | 0.08** |
| Shoot phenol content (mg /100 g fresh) | -0.02 | -0.24 ** | 0.02 | -0.25 ** | 0.15 ** | 0.33 ** | 0.14** |
| Fruit phenol content (mg/100 g fresh) | -0.05 | -0.08 | -0.05 | -0.23 ** | 0.23 ** | 0.17 ** | 0.15** |
| Anthocyanin content in Peel (mg/100 g) | 21.25 ** | -14.09 ** | 10.70 ** | 0.65 ** | -34.95 ** | 16.43 ** | 0.96** |
| Seed protein content (%) | 2.41 ** | -1.39 ** | -1.01 ** | -0.92 ** | 2.03 ** | -1.13 ** | 0.94** |
| Total sugar content (%) | -0.10 ** | -0.07 ** | -0.04 * | 0.41 ** | -0.04 * | -0.17 ** | 0.07** |
| Reducing sugar content (%) | -0.05 ** | -0.05 ** | -0.02 | 0.28 ** | -0.03 ** | -0.13 ** | 0.05** |
| Non-reducing sugar content (%) | -0.04 ** | -0.03 ** | -0.01 | 0.12 ** | -0.01 | -0.04 ** | 0.03** |
| Borer infestation in shoot (%) | 0.11 ** | 0.09 ** | -0.01 | 0.05 ** | -0.11 ** | -0.13 ** | 0.04** |
| Borer infestation in fruit (%) | -3.56 ** | -2.46 ** | 2.74 ** | 2.96 ** | -0.32 | 0.64 | 2.41** |

*(Gi-Gj) = Differences between two GCA estimates of parental lines

content of shoot, total phenol content of fruit and seed protein content), Punjab Sadabahar for 6 characters (primary branches per plant, fruit length, fruits per plant, marketable fruit yield per plant, total phenol content of shoot, total phenol content of fruit and anthocyanin content of fruit peel), BCB-30 for 5 characters (days to first flowering, fruit girth, fruit weight, marketable fruit yield per plant and anthocyanin content of fruit peel) and BCB-11 for 4 characters (days to first flowering, fruit length, fruit girth and fruit pedicel length). However, significant and positive gca effect for marketable fruit yield per plant was registered by three parents *viz.*, BCB-40, BCB-30 and Punjab Sadabahar and significantly negative gca effect for fruit infestation by brinjal fruit and shoot borer was registered by only BCB-40. Several earlier reports showing significant and positive gca effects for different characters *viz.*, fruit yield/plant and fruit number/plant (Dharwad et al. 2011, Kumar and Arumugam 2013, Hussain et al. 2017) ; fruit weight (Shafeeq et al. 2007, Dharwad et al. 2011, Kumar and Arumugam 2013, Sharma et al. 2016, Hussain et al. 2017) ; fruit diameter (Kumar and Arumugam 2013, Sharma et al. 2016, Hussain et al. 2017) ; fruit length (Shafeeq et al. 2007, Kumar and Arumugam 2013, Sharma et al. 2016), phenol content, number of primary branches/ plant and plant height (Kumar and Arumugam 2013, Sharma et al. 2016, Hussain et al. 2017) agreed well to the present findings. Considering the second highest *per se* performance for marketable fruit yield / plant (2.59 kg / plant) along second lowest severity of fruit borer infestation (18.55%) together, the parental line BCB-40 emerged as the best followed by BCB-30, being the highest yielder (2.69 kg / plant) and low severity of fruit borer infestation (22.07%).

**Specific combining ability (sca) effects:** The sca effects for hybrids pertaining to 18 characters are presented in Table 4.20. Significantly positive sca effects were recorded in six crosses for average fruit weight, five crosses each for fruit number per plant and marketable fruit yield/ plant and four crosses for total sugar content of fruit (Table 6). Significantly negative sca effect for fruit infestation by brinjal fruit and shoot borer was recorded in four cross combinations viz., BCB-40 × Garia, BCB-40 × BCB-50, BCB-30 × Punjab Sadabahar and Garia × Punjab Sadabahar. The most promising cross combination Garia × Punjab Sadabahar registering the second highest marketable fruit yield per plant (3.74kg / plant) exhibited the highest significantly positive sca effects for marketable fruit yield / plant along with high and significantly positive sca effect for plant height, fruit pedicel length, fruit weight, fruits per plant and total phenol content of shoot and significantly negative sca effect for fruit infestation by brinjal fruit and shoot borer. The other promising cross BCB-40 × Punjab Sadabahar having the highest marketable fruit yield per plant (3.94kg / plant) registered the second highest significantly positive sca effect for marketable fruit yield per plant along with significantly positive sca effect for plant height, fruit length, fruit weight, fruits per plant and total phenol content of shoot and positive but non-significant sca effect of low magnitude for fruit infestation by brinjal fruit and shoot borer. These two hybrids were expected to produce desirable segregates for high yield and better tolerance to fruit borer infestation

**Table 6:** Estimates of specific combining ability (SCA) effects on different characters of the fifteen hybrids

| Characters | Plants height (cm) | Primary branches/plant | Days to first flowering | Fruit length (cm) | Fruit girth (cm) | Fruit pedicel length (cm) |
|---|---|---|---|---|---|---|
| Hybrids | | | | | | |
| BCB-40 × BCB-11 | 0.53 | 1.19 ** | 0.28 | -1.43** | -1.49** | -1.93** |
| BCB-40 × BCB-30 | 3.69 | 0.34 | 0.34 | 0.41 | -0.87** | -1.77** |
| BCB-40 × Garia | -7.81 ** | 0.23 | 2.23 ** | 0.92 | -1.15** | -2.22** |
| BCB-40 × BCB-50 | 3.59 | 0.03 | -0.53 | -1.12* | 0.64** | 0.14 |
| BCB-40 × Punjab Sadabahar | 6.78 ** | 0.58 | -4.29** | 5.00** | 0.04 | -0.71 * |
| BCB-11 × BCB-30 | 20.91** | -0.46 | 0.70 | 1.48** | -0.56** | -1.64** |
| BCB-11 × Garia | -2.51 | 0.10 | 3.02** | 1.76 ** | -0.11 | -2.36** |
| BCB-11 × BCB-50 | -6.88 ** | -0.52 | -1.69 * | 0.23 | 0.58 ** | -2.18** |
| BCB-11 × Punjab Sadabahar | 13.25** | 0.32 | 3.60** | -1.32 ** | -0.87** | -0.94 ** |
| BCB-30 × Garia | -5.28 * | 0.55 | 0.61 | -1.81** | 1.06 *** | 1.70** |
| BCB-30 × BCB-50 | -11.01** | -0.06 | -0.70 | -3.47** | -0.44 ** | 0.93** |
| BCB-30 × Punjab Sadabahar | -10.61** | 0.23 | -0.65 | 0.26 | -1.51** | -0.64 * |
| Garia × BCB-50 | 7.74** | -0.26 | 0.99 | 8.73** | -1.38** | 0.35 |
| Garia × Punjab Sadabahar | 5.57 * | -0.19 | -3.19** | -0.94 * | 0.05 | 1.70** |
| BCB-50 × Punjab Sadabahar | 0.49 | -0.40 | 2.65 ** | -3.04 *** | -0.32 * | 1.60** |
| CD (Sij – Sik) | 6.82 | 1.05 | 2.21 | 1.39 | 0.47 | 0.91 |
| CD (Sij – Skl) | 6.31 | 0.97 | 2.05 | 1.29 | 0.43 | 0.84 |

(Sij – Sik) = Difference between two SCA of two hybrids, with a common parent

(Sij – Skl) = Difference between two SCA of two hybrids, with a non-common parent

of fixable nature in segregating generations through simple pedigree method breeding because both the parents of these two cross combinations were good general combiner for fruit yield per plant and showed less susceptibility to brinjal fruit and shoot borer.

Different cross combinations revealed that the crosses involved four types of combinations namely, H × H, H × L, L × H and L × L, where H stands for significant gca effect in desired direction and L for non-significant gca effect or negative gca effect of the parent (Table 5). In the H × H type cross combinations which involved parents having significantly positive gca effect for the concerned character (BCB 40 × Punjab Sadabahar for marketable fruit yield per plant, fruit number per plant and anthocyanin content of fruit peel), additive as well as additive × additive type epistatic effects were involved for the expression of characters in the hybrid. Desirable segregates from this type of cross could be fixed in early advanced generation.

On the other hand, H × L type cross combinations which involved at least one parent with significant gca effect for the concerned character (Garia × Punjab Sadabahar for marketable fruit yield per plant, fruit number / plant), predominantly additive gene effect in good combiner and possibly complementary epistatic effect in poor combiner acted in complementary fashion to maximize the expression of the character. This proposition has found support from the earlier report of Salimath and Bahl (1985). In the crosses involving L × L category parents (BCB 40 × Punjab Sadabahar for plant height), sca effects seemed to have played a very important role and high performance was due to non-additive gene action which was also recorded earlier (Bhutia et al. 2015).

Results of the diallel analysis suggested the importance of both additive and non-additive genetic effects in conditioning of different characters including fruit quality characters although, additive gene effects were more important for most of the characters. The methods, which exploit both additive and non-additive gene action would be effective to improve different characters including the fruit quality characters. The predominant breeding methods for self-pollinated crops such as pedigree, single seed descent and backcross method may be effective to improve some characters like, plant height, primary branches per plant, days to first flowering, fruit length, fruit girth, fruit pedicel length, fruit weight, fruit number per plant, marketable fruit yield per plant, total phenol content of shoot, anthocyanin content of fruit peel, total, reducing and non-reducing sugar content of fruit and fruit infestation by borer which were predominantly controlled by additive gene action. However, importance of non-additive gene action along with additive gene action for these important characters suggested that selection might not be effective in early generations. It implied that single plant selection in the $F_2$ for these characters will not be effective. The $F_3$ lines derived from $F_2$ segregates showing improvement in the traits may not high in these characters which are probably due in part to reduction in dominance effects associated with increased inbreeding (Hallauer and Miranda 1981).

Another major hindrance for realizing genetic gain is the revelation of low narrow sense heritability for some important characters *viz*., fruit weight, marketable fruit yield per plant, total phenol content of fruit and fruit infestation by brinjal fruit and shoot borer. It could be concluded that diallel selective mating could be employed for the exploitation of additive and non-additive gene action for these characters. Selection for these characters should be based primarily on replicated family testing in $F_3$ and later generations. In the perspective of importance of non-additive genetic variance along with additive genetic variance for the conditioning of most of the characters, heterosis breeding to develop high yielding hybrids possessing better fruit size, colour, quality and less susceptibility to brinjal fruit and shoot borer may be the best breeding strategy.

## lkjk'k

बैंगन के 6 विविध वंशक्रमों का डायलिल संकरण पद्धति (व्युतक्रम को छोड़कर) से कुल 15 संकर संयोज्य विकसित कर उपज घटकों, गुणवत्ता गुणों व बैंगन के फल व तना बेधक के प्रति आपेक्षिक सुग्राहयता हेतु संयोजन क्षमता का अध्ययन किया गया। अध्ययन के अन्तर्गत सभी प्रभेदों में सार्थक विविधता पायी गयी। अधिकतम गुणों के लियो योज्य एवं अयोज्य दोनों जीन प्रक्रिया में परिस्थिति थे जबकि अयोज्य जीन प्रक्रिया फल में कुल फिनाल की मात्रा बीज प्रोटीन की मात्रा तथा फल बेधक के प्रति संक्रमण को नियंत्रित करता है। अधिकतम सार्थक सामान्य संयोजन क्षमता वांछित दिशा में गैरिया के 7 गुणों में तथा उसके बाद बी सी बी–40, बी सी बी–50 तथा पंजाब सदाबर में 6 गुणों के लिये पाया गया। जबकि द्वितीय उत्तम लाक्षणिक बाजार योग्य फल उपज प्रति पौध (2.59 किग्रा. प्रति पौध) के साथ द्वितीय कमतर फल बेधक संक्रमण की गहनता (18.55 प्रतिशत) पितृ वंशक्रम बी सी बी–40 सबसे उत्तम पाया गया तथा इसके बाद बी सी बी–30 अधिक उपज (2.69 किग्रा. प्रति पौध 7 एवं कमतर फल बेधक संक्रमण (22.07 प्रतिशत) में रहा। सबसे उपयुक्त संकर संयोज्य गैरिया x पंजाब सदाबहार में दुसरे स्थान पर अधिक बाजार योज्य फल उपज प्रति पौध (3.74 किग्रा. प्रति पौध) में सबसे अधिक सार्थक विशिष्टि संयोजन क्षमता बाजार याज्य फल उपज प्रति पौध के साथ उच्च व सार्थक धनात्मक सामान्य संयोजन क्षमता पौध की ऊँचाई, फल डंठल की लम्बाई, फल भार, फल प्रति पौध व कुल फिनाल की मात्रा एवं नकारात्मक रूप से सार्थक फल संक्रमण के प्रति सामान्य संयोजन क्षमता पाया गया। कम व संकीर्ण वंशागतित्व को ध्यान में रखते हुए कुछ गुणों जैसे–फल भार, बाजार योज्य फल प्रति पौध फल में फिनाल की मात्रा तथा बैंगन में फल व तना बेधक का संक्रमण के प्रति चुनाव एफ–3 एवं बाद की पीढ़ियों में किया जाना चाहिए। अयोजय अनुवांशिक प्रसारण के साथ योजय अनुवांशिक प्रसरण जिससे अनेकों गुण संचालित हो रहे है, ओज प्रजनन का अधिक उपज देने वाले संकरों के विकास में कर सकते हैं जिनमें अच्छी फल का आकार, रंग, गुणवत्ता तथा फल व तना बेधक का संक्रमण सबसे कम हो। यही उत्तम प्रजनन की रणनीति होगी।

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