HETEROSIS AND COMBINING ABILITY STUDY IN BRINJAL [*Solanum melongena* L.]

BY

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B. Sc. (Hons.) Agriculture

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CHIMANBHAI PATEL COLLEGE OF AGRICULTURE
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IN

GENETICS AND PLANT BREEDING

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ABSTRACT

An experiment was conducted in randomized block design with three replications (*rabi*, 2021-22) to study the magnitude of heterosis, to assess the combining ability and nature of gene action of the parents and crosses in the expression of fruit yield and its components for twelve characters in brinjal (*Solanum melongena* L.). The material for the present study involves seven diverse parents and their twenty-one resultant hybrids derived from half diallel mating and one standard check (GJBH 4) which were grown and evaluated at Horticultural Instructional Farm, C. P. College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar. The objectives of this study were to investigate the *per se* performance, magnitude of heterosis, combining ability and gene action for different characters under study.

The observations were recorded for days to flower initiation, days to flowering, days to maturity, number of flowers per cluster, number of primary branches per plant, number of fruits per plant, fruit length (cm), fruit girth (cm), plant height (cm), fruit weight (g), fruit volume (cm^3) and fruit yield per plant (kg).

Analysis of variance for individuals indicated significant differences among genotypes (Parents + F_1) for all the characters for yield and yield contributing traits. Parents *vs.* hybrids differed significantly for all the characters except for days flowering, number of flowers per cluster and fruit girth indicated the presence of conspicuous heterosis. The magnitude of heterosis varied from the cross to cross for all the characters. Fruit yield per plant was the most desirable heterotic character whereas, the least heterosis was observed for days to flowering.

Based on the mean value of the parent, DOLI 5 exhibited the highest fruit yield per plant followed by JNB-110 whereas, in hybrids PLR 1 x JBCL-16-12, ISD-006 x DOLI 5 and PLR 1 x DOLI 5 recorded the highest fruit yield per plant (kg).

The best hybrid based on significant and desirable heterosis over mid-parent and better parent was PLR 1 x JBCL-16-12 (71.63 and 64.69%, respectively). The cross PLR 1 x JBCL-16-12 (12.5%) exhibited significant and positive heterosis over the standard check (GJBH 4) for fruit yield per plant.

Combining ability analysis ($\sigma^2_{gca}/\sigma^2_{sca}$) revealed that non-additive variances were significant for fruit yield per plant and its related traits except fruit girth indicated their involvement in the expression of various traits. The magnitude of non-additive variance was higher for fruit yield per plant and its contributing traits indicated the predominant role of non-additive gene action in the inheritance of the traits.

None of the parents was a good general combiner for all the traits under study. Among parents, were classified as good general combiners for fruit yield per plant and related traits. The parents with high *per se* performance had high gca effects for most of the traits indicating that selection for good combiners for different characters could also be made based on the *per se* performance of the parents.

Among the parents, ISD-006, DOLI 5 and GRB 7 were good general combiners for fruit yield per plant and its contributing traits. The hybrid based on sca effects for fruit yield per plant were PLR 1 x JBCL-16-12, GRB 7 x GJB 3 and ISD-006 x DOLI 5.

Finally, it can be concluded that a preponderance of non-additive gene action and high heterosis was observed for fruit yield per plant and its contributing character (except fruit girth), which suggested that heterosis breeding can be profitable and used for commercial exploitation of hybrid vigour in brinjal. In the present investigation, based on the *per se* performance, combining ability and heterosis the cross PLR 1 x JBCL-16-12 was found superior. Therefore, this cross was identified as potential for fruit yield per plant and suggested further evaluation for generation advancement in the future breeding programme to isolate good transgressive segregants for fruit yield per plant.

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CERTIFICATE – I

Date:07/10/2022

This is to certify that the thesis entitled, **"HETEROSIS AND COMBINING ABILITY STUDY IN BRINJAL (*Solanum melongena* L.)"** submitted for the degree of **MASTER OF SCIENCE** in the subject of **GENETICS AND PLANT BREEDING** is a record of bonafide research work carried by **PAMPANIYA HIREN KANUBHAI** under my guidance and supervision and that no part of this thesis has been submitted for any other degree, diploma, associateship, fellowship or other similar title. The assistance and help received during the course of investigation have been fully acknowledged.

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This is to certify that **PAMPANIYA HIREN KANUBHAI**, Department of Genetics and Plant Breeding, C. P. College of Agriculture, Sardarkrushinagar has made all corrections/modifications in the thesis entitled, **"HETEROSIS AND COMBINING ABILITY STUDY IN BRINJAL (*Solanum melongena* L.)"** as suggested by the External Examiner and the Advisory Committee in the oral examination held on **28th September, 2022.**

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Place : Sardarkrushinagar

Dated : 07/10/2022

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LIST OF SYMBOL AND ABBREVIATIONS USED

%	**:**	Per cent
x	**:**	Multiply
;	**:**	semi colon
/	**:**	Per
2n	**:**	Chromosome number
CD	**:**	Critical difference
CV	**:**	Coeficient of variance
cm	**:**	Centimeter
cm^3	**:**	Centimeter cube
et al.	**:**	And associates
etc.	**:**	Etcetera
Fig.	**:**	Figure
kg	**:**	Kilogram
g	**:**	Gram(s)
GM	**:**	General mean
i.e.	**:**	That is
Ha	**:**	Hectare
No.	**:**	Number
viz.,	**:**	Namely
GCA	**:**	General combining ability
SCA	**:**	Specific combining ability
S.Em.	**:**	Standared error of mean
S.E.	**:**	Standared error
Max.	**:**	Maximum
Min.	**:**	Minimum
^oC	**:**	Degree Celsius
mm	**:**	Milli meter
SDAU	**:**	Sardarkrushinagar Dantiwada Agricultural University
JAU	**:**	Junagadh Agricultural University
vs.	**:**	versus

INTRODUCTION

I. INTRODUCTION

Vegetables are a rich source of nutrients, vitamins and minerals which can play a significant role in food and nutritional security. Vegetables, which are low in fat and carbohydrates but abundant in vitamins, minerals and dietary fibre can be consumed as raw or cooked and serve a vital part in human nutrition. More than 70 vegetable crops are grown in our country but more emphasis has been given to important vegetables like tomato, brinjal, chilli, potato, cabbage, cauliflower, pea and some cucurbits. Though a balanced diet requires 285 g/day/person, we can only meet about 210 g/day/person (Rai and Yadav, 2010). As a result, planned development in the field of vegetable production can not only meet the nutritional needs of the masses but also meet the issue of providing adequate food to India's rising population. Among these, brinjal is one of the major solanaceous, tender fruit vegetable crops of our country which is cultivated during the rainy (*kharif*), winter (*rabi*) and spring-summer seasons.

Brinjal or eggplant (*Solanum melongena* L.) is an important commercial vegetable crop of India and has chromosome number 2n= 2x= 24. It is often cross-pollinated crop belonging to the family Solanaceae. The name brinjal is popular in Indian subcontinents and is derived from Arabic and Sanskrit words whereas, the name eggplant has been derived from the shape of the fruit of some varieties, which are white and resemble in shape to chicken eggs. It is also called aubergine (French word) in Europe. Eggplant is grown throughout the year and is a common and popular vegetable crop in the subtropics and tropics mainly for its immature fruits as vegetables. India is considered the primary centre of origin of brinjal (Vavilov, 1935).

Brinjal or eggplant is a perennial but grown commercially as an annual crop. The inflorescence is often solitary but sometimes it constitutes a cluster of 2-5 flowers. The solitary or clustering nature of inflorescence is a varietal character. The flower is complete and hermaphrodite. Heterostyly is a common feature, and fruit-setting flowers consist of long (70-85%) and medium-styled (12-55%) flowers. The non-fruit setting flowers consist of short-styled and pseudo-styled. Eggplant is usually self-pollinated but the extent of cross-pollination has been reported as high as 29% and hence it is classified as often cross-pollinated or facultative cross-pollinated.

The cultivars of brinjal display a wide range of fruit shapes and colours. Several cultivars are grown throughout the country depending on the yield and consumers' preferences in colour, size and shape. It is the fourth most important vegetable crop in India and contributes about 8.3 per cent of the total production of vegetables in the country. It is named as "Poor man's vegetable" because of its low cost of production, ease of culture and availability throughout the year. As fruits are widely used in various culinary preparations *viz*., sliced bhaji, stuffed curry, bertha, chutney, pickles *etc*. Contrary to common belief, it is quite high in nutritive value as well as rich in vitamins, minerals (calcium, magnesium, phosphorus) and fatty acids.

Brinjal (*Solanum melongena* L.) is one of the important staple vegetables in our diet since ancient times and is consumed as a vegetable by most people. Brinjal (*Solanum melongena* L.) has been categorized in three main botanical varieties or subspecies. The round or egg-shaped varieties are grouped under var. *esculentun*, the long and slender types are included in var. *serpentinum* and the dwarf brinjal plants under var. *depressum* (Choudhary, 1976).

India is a major producer of brinjal in the world. The area under brinjal cultivation in India was 7.60 lacs hectares with an estimated annual production of 12.69 million tonnes during the year 2020 (Anon,2021[a]). In Gujarat, brinjal is grown in an area of 77.55 thousand hectares, with an annual production of 1533.67 metric tonnes during the year 2021 (Anon,2021[b]). The major states producing brinjal in India are Odisha, Bihar, Karnataka, West Bengal, Andhra Pradesh, Maharashtra and Uttar Pradesh. West Bengal is the largest producer of brinjal followed by Maharashtra and Bihar.

Breeding objectives for eggplant are mostly oriented toward developing high-yielding, early maturing, High fruit-quality varieties, along with stress resistance and high antioxidants. Breeders have performed research with wild relatives of eggplant for yield increase, fruit quality, disease resistance, and more recently, improved nutritional content.

Heterosis breeding has proved to be a potential method of increasing yield in cross-pollinated crops. However, commercial exploitation of heterosis in self-pollinated crops like brinjal has been limited owing to technical difficulties involved in hybrid seed production. Therefore, early identification of superior/potential crosses is quite necessary to handle the material in advanced generations effectively and gainfully.

Breeding high-yielding varieties of crop plants, breeders usually face the problem of selection of desirable parents. In general, parents are selected on basis of their *per se* performance, but sometimes, a high-yielding genotype may not transmit its superiority to progeny. Hence, the critical choice of parents is of utmost importance, particularly for the improvement of complex quantitative characters such as yield and its components. Different mating designs have been used by different workers as an aid in the choice of parents, and to understand their genetic nature. The most commonly used mating designs diallel and line x tester provide estimates of additive and non-additive components of gene effect about the whole population studied. However, partitioning genetic variance into its all probable components *i.e.* additive, dominance and all types of epistasis about the individual cross is of immense value in formulating an effective and sound breeding programme.

Looking to the increasing population of our nation there is an urgent need to satisfy the demand. The incidence of hunger (malnutrition) and poverty in the country is persistently high and India is way off the Millennium developmental goal. Though male sterility has not been commercially utilized in brinjal, many hybrids have been developed by manual hybridization as it has great advantages of setting more successful crossed fruits and a high number of seeds per fruit. The nature and interaction of the genes involved in the inheritance of a particular character influence the efficiency of selection for both quantitative and qualitative traits. Knowledge of gene action aids in the selection of parents for use in hybridization programmes, as well as the selection of the most suited breeding procedure for improving various quantitative traits genetically. The appropriate partitioning of genetic variance into its components, such as additive, dominance, and epistasis, aids in the formulation of a sound breeding programme.

The present investigation was undertaken to assess the extent of heterosis and combining ability in brinjal (*Solanum melongena* L.) for yield and other important traits. While breeding high-yielding varieties of crop plants, the breeder often deals with the problem of selecting the desirable parents. Combining ability is one of the important tools for selecting desirable parents and cross combinations to be used in the formulation of the systematic breeding programme.

Hence, the present study was undertaken using half-diallel crosses among seven genotypes with the following objectives.

[1] To study the nature and magnitude of heterosis for fruit yield and yield attributing traits

[2] To estimate the nature and magnitude of gene action

[3] To evaluate general combining ability (GCA) and specific combining ability (SCA) of parents and hybrids, respectively

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

The present investigation was primarily concerned with **Heterosis and combining ability study in Brinjal (S*olanum melongena* L.)**. The available literature concerning to objectives of the present study and the methodology adopted for the same has been reviewed under the following separate titles.

2.1 MAGNITUDE OF HETEROSIS

2.2 COMBINING ABILITY AND GENE ACTION

2.1 MAGNITUDE OF HETEROSIS:

The phenomenon of heterosis has been proved to be the most prominent genetic tool in increasing the yield of self as well as cross-pollinated crops and is considered as one of the greatest breakthroughs in the field of crop improvement. The term "heterosis" refers to the phenomenon in which the F_1 population obtained by crossing two genetically dissimilar gametes or decreased vigour over individuals showing increased or mid or better parental value (Rai, 1979). Shull (1914) coined the term 'heterosis' and he derived it from the Greek words 'hetero' means different and 'osis' means a different condition, *i.e.,* different from their parents. He referred to this phenomenon as the stimulus of heterozygosis. In current usage heterosis and hybrid vigour are used as synonyms and interchangeable. Heterosis leads to superiority in adaptation, yield, quality, maturity and general vigour over its parent.

Later on, Fonseca and Patterson (1968) used a new term "heterobeltiosis" to describe the improvement of the heterozygote to the better parent of the cross. Generally, positive heterosis is considered to be desirable but in some cases, negative heterosis is also desirable. As per Mather and Jinks (1971), heterosis is the amount by which the mean of the F_1 family exceeds its better parent. Heterosis over standard check is referred to as standard heterosis. The term useful heterosis was used by Meredith and Bridge (1972). It refers to the superiority of F_1 over the standard commercial check variety. For the present study, the literature pertaining to heterosis is reviewed as under.

Chowdhury *et al.* (2011) estimated the magnitude of heterosis over better parent and standard check for some important characters in 15 crosses resulting from a half-diallel mating design of 6 inbred lines of brinjal. The hybrid variety 'Tarapuri' was used as a standard check. The parents and the hybrids were evaluated at the farm of Olericulture Division, HRC, BARI, during the winter season of 2008-2009. A randomized complete block design with three replications was used. Significant levels of heterosis were detected for all the traits studied. Promising hybrids exhibited significant positive heterosis for fruit yield, the magnitude of which ranged from 9.63% to 74.89% and 8.52% to 72.60% over better parent and standard checks, respectively. Some of the promising hybrids showed desirable heterosis for earliness and increased fruit number.

Singh *et al.* (2012) studied fruit yield attributes. The experiment was conducted with 14 parents and 40 F_1s to study heterosis in brinjal. Crosses showing significant heterosis over the better parent were HE-12 x Aruna for the first fruit set; BR-112 x Aruna for fruit length and diameter; Pant Samrat x Punjab Neelam for a number of fruits per plant; H-7 x Aruna for fruit weight; H-9 x S-16 for total yield per plant.

Makani *et al.* (2013) estimated the magnitude of heterosis for yield in brinjal and its eleven yield components 28 F_1 hybrids were generated by half diallel crosses of eight pure diverse parents and these F_1s along with 8 parents were evaluated in a randomized block design with three replications. In order of merit F_1 hybrids AB-07-08 x GP-180 (136.39%), AB-07-08 x KS-331 (102.20%) and NDB-18 x AB-07-08 (97.63%) were observed significant heterosis over mid parent while the maximum heterobeltiosis for fruit yield per plant was exhibited by the hybrid AB-07-08 x GP-180 (125.78%) followed by NDB-18 x AB-07-08 (86.25%) and Doli-5 x GP-180 (72.09%). In the case of standard heterosis, significant and positive heterosis over standard check GBL-1 for fruit yield per plant was observed in hybrid GBL-1 x KS-331 (50.41%) followed by AB-07-08 x KS-331 (43.53%) and Doli-5 x GBL-1 (42.59%).

Sao and Mehta (2010) studied heterosis for fruit yield and its component traits in brinjal through line (8) x tester (6) analysis. They recorded a considerable magnitude of relative heterosis, heterobeltiosis and standard heterosis for fruit yield and related traits. The degree of heterosis was estimated at 162.98%, 139.13% and 127.41% as relative heterosis, heterobeltiosis and standard heterosis, respectively for marketable fruit yield per plant. In order of merit the crosses IGBL70 x Pusa Purple Long, IGBO 40 x KS 327, IGBO 83 x KS 327, IGBO 40 x IGBL 9 and IGBO 43 x KS 331 exhibited highly significant heterosis for fruit and related traits.

Ramireddy *et al*. (2011) made twelve crosses resulting from a line x tester mating design comprising three lines and four testers to check the magnitude of heterosis over the mid parent, better parent and a commercial check, Arka Anand. Among the 12 hybrids, 7, 4 and 1 hybrids exhibited significant positive heterosis for fruit yield per plant over the mid parent, better parent and commercial check, respectively. Maximum positive and significant heterosis was observed in cross Arka Shirish x West Coast Green Round (84.93%) over mid parent, Arka Shirish x West Coast Green Round (60.71%) over better parent and Arka Shirish x IIHR 7 (31.02%) over the commercial check. The hybrids Mattugulla x West Coast Green Round exhibited highly significant heterosis for the number of fruits per cluster, number of flowers per cluster and average fruit weight.

Nalini *et al.* (2011) studied heterosis in 28 F_1 hybrids of brinjal obtained through a half-diallel mating scheme. They observed hybrid, IC-112 x IC-996 exhibited maximum heterosis (72.7%) for fruit yield over local check followed by six other hybrids in which heterosis ranged between 60.81% (IC-112 x IC-136) to 46.17% (IC-112 x IC-909).

Kumar *et al.* (2013) evaluated the 40 F_1 hybrids derived through line x tester mating design using 10 lines and 4 testers. They observed expression of superiority over the commercial check occurred in 7 crosses, which ranged from -56.36% (Kariapatty Local x EP 65) to 34.07% (Keerikai Local x KKM 1). The hybrid Keerikai Local x KKM 1 exhibited good heterosis for growth and yield and is noted as the most promising combination for developing high-yielding hybrid varieties of brinjal. Most crosses involving KKM 1 as tester parent had significant positive heterosis over the mid-parent and standard variety.

Biswas *et al.* (2013) studied 60 hybrids along with ten parents and revealed mid parent heterosis for total fruit yield per plant that ranged from -67.53% (GL xSR) to 24.95% (MK x PPL). The highest mid-parent heterosis was exhibited by MK x PPL, MK x PR, WBPF x PR and PPL x PPC. The better parent heterosis for fruit yield per plant ranged from -50.24% (PPC x IBWL) to 88.18% (WBPF x PR). The highest better parent heterosis for total fruit yield per plant was reported in WBPF x PR followed by MK x PPL, MK x PR, PPL x PR and PPL x WBPF. The heterosis over the check for total fruit yield per plant was observed from -51.37% (PS x PPL) to 46.86% (IBWL x PPC). The highest standard heterosis was reported in IBWL x PPC followed by GL x PPL, MK x IBWL, PPC x WBF and WBPF x PR.

Dubey *et al.* (2014) conducted a study in brinjal to identify superior parental combinations and to estimate the magnitude of heterosis for yield and its eleven yield components. Forty-eight F_1 hybrids generated following line x tester mating design comprising of 12 lines and 4 testers and were evaluated in a randomized block design with three replications. The analysis revealed that Sel-4 was the best general combiner among the lines and IC-90099 was the best general combiner among the testers. There was a high heterosis response in most of the hybrids which supports the role of non-additive gene effects. Among the crosses, DBL-24 x PPC showed high sca effects for yield although the parents were poor general combiners. The maximum heterosis for total yield per plant over better parent was exhibited by the cross KS-314 x IC-90099 (94.72%) followed by KS-314 x PPC (85.10%). Indirect selection for traits such as plant height, long and medium styled flowers per cluster, fruits per plant, fruit length, fruit diameter and primary branches per plant could be done to achieve higher yield through heterosis breeding. The present study reveals good scope for isolation of pure lines from the progenies of heterotic F_1s as well as commercial exploitation of heterosis in brinjal.

Reddy and Patel (2014) evaluated 20 hybrids developed through line x tester design using 5 lines and 4 testers and found that there was maximum heterosis for fruit yield per plant in the cross AB-8-5 x GJB-2 (103.59%) followed by AB-8-5 x GBL-1 (41.52%) and JBR-6-7 x GJB-2 (35.17%). The hybrid AB-8-5 x GJB-2 also exhibited highly significant heterosis (245.26%) for a number of fruits per cluster while the hybrid JBR-6-7 x GJB-2 showed significant heterosis (17.53%) for average fruit weight.

Boddepalli *et al.* (2015) conducted an experiment having fifteen parents (12 lines and 3 testers) were selected based on divergence and mated them in line x tester design. Hybrids and parents rose to measured heterosis for different quantitative traits. Some of the hybrids exhibited positive standard heterosis. In the case of days to 50% flowering, plant height and days to maturity, where negative heterosis is desirable, seven hybrids showed negative standard heterosis for days to 50% flowering, twenty-four hybrids for plant height and three hybrids showed significant negative heterosis for days to maturity. For a number of branches per plant, three hybrids showed significant and twenty hybrids showed positive standard heterosis. In the case of fruit length and fruit diameter both positive and negative heterosis was observed. Twenty-six hybrids showed positive standard heterosis for a number of fruits per plant. Yield, the ultimate product of different yield components, nine hybrids showed positive standard heterosis for yield.

Desai *et al.* (2016) studied in brinjal to estimate the magnitude of heterosis for yield and its ten yield-related components. Twenty-eight brinjal hybrids generated from 8 x 8 diallel cross (excluding reciprocals) along with their parents and standard checks (Surati Ravaiya) were evaluated in a Randomized Block Design with three replications at Regional Horticultural Research Station (RHRS) at Navsari Agricultural University, Navsari, Gujarat. Appreciable heterosis was found over better parent and standard parent for all the traits studied in the desirable direction. In order of merit F_1 hybrids *viz*. AB-09-1 x AB-12-10 (48.95%), GJB-3 x JBL-08-8 (48.60%) and JBGR-1 x NSR-1 (35.10%) observed significant heterosis over better parents while maximum standard heterosis was exhibited by the hybrids *viz*. AB-09-1 x AB-12-10 (46.29%), AB-09-1 x AB-08-5 (42.02%) and AB-08-5 x JBL-08-8 (32.69%) for fruit yield per plant. The parent study reveals good scope for isolation of pure lines from the progenies of heterotic F_1s as well as commercial exploitation of heterosis in brinjal.

Vaishnav (2016) studied heterosis in brinjal obtained through generation mean analysis using four crosses of brinjal in twelve characters. The degree of heterosis over better parent recorded highest in fruit weight in NSR-1 x GBL-1; plant spread in JB-12-06 x Pant Rituraj; plant height in JB-12-06 x Pant Rituraj; total fruit yield per plant in JB-12-06 x Pant Rituraj; fruit borer infestation in JB-12-06 x Pant Rituraj; fruit girth in NSR-1 x GBL-1; number of branches per plant in NSR-1 x GBL-1; fruit yield per plant in NSR-1 x GBL-1; days to first picking in JBG-10-208 x GOB-1 and days to opening of first flower in JB-12-06 x GJB-2.

Ansari and Singh (2016) experimented with brinjal to estimate the magnitude of heterosis for eight fruit characters. Significant heterosis exhibited by different crosses for different characters over the years *viz.* fruit length (PR x WB-1, PB66 x PB-67 and PB-66 x WB-1), fruit diameter (PB-66 x PS and BARI x PS), average fruit weight (BARI x PR, BARI x PS and WB-1 x PS), number of healthy fruits per plant (S. aethiopicum x BARI and BARI x PB-66), number of infested fruits per plant (S. aethiopicum x BARI, BARI x PS and BARI x PR), weight of healthy fruits per plant (BARI x PB-66, BARI x PR and PB71 x PS) and weight of infested fruits per plant (PB-67 x PS, PB-66 x PR and BARI x PB-67) for almost all types of heterosis. The crosses BARI x PB-66, BARI x PR and PB-71 x PS exhibited the highest and significant positive heterosis over better parent, mid parent and standard checks for fruit yield over the years. The present study reveals good scope for isolation of purelines from the progenies of heterotic F_1s as well as commercial exploitation of heterosis in brinjal.

Biswas *et al.* (2016) generated the seeds of sixty hybrids along with ten parents and evaluated them along with national check PH-6. Heterosis analysis was carried out for days to 50% flowering, days to first picking, plant height, number of primary branches per plant, average fruit length (cm), average fruit girth (cm), average fruit weight (g), the total number of fruits per plant, number of fruits per plant per picking, marketable fruit yield per plant, total fruit yield per plant and total soluble solids (%). The highest standard heterosis was shown by IBWL x PPC (46.86%) followed by GL x PPL (46.13%), MK x IBWL (42.44%), PPC x WBPF (41.62%) and WBPF x PR (40.96%) for total fruit yield per plant.

Gharge *et al.* (2016) conducted a study to assess the magnitude of heterosis and combining ability in a diallel mating involving 28 hybrids generated by crossing eight diverse genotypes and two commercial hybrid standard checks (Krishna and Phule Arjun) in brinjal. Significant heterosis in the desirable direction was recorded by 23, 19, 19 and 6 hybrids over better, top parent, standard check 1 and standard check 2 in *kharif* season for fruit yield. The maximum heterosis for fruit yield per plant was observed in the cross RHRB-74 x DBSR-195 (55.06%) followed by JBR-2 x RHRB-74 (48.94%), RHRB-77 x Kudachi (37.88%) and RHRB-74 x Kudachi (36.94%). The hybrid RHRB-74 x DBSR-195 exhibited highly significant heterosis for all the characters except number of branches per plant.

Kumar *et al.* (2016) identified the high-yielding parents and F_1 hybrids through Line x Tester mating design to estimate the heterosis of 32 F_1 hybrids from eight lines and four testers. The heterosis was recorded for yield and its component characters. As a result, seven F_1 hybrids, AB-7-2 x NSR1, AB-8-14 x GJB-3, JBL-8-8 x NSR-1, JBL-8-8 x NSRP-1, JBR-12-6 x NSR-1, JBR-12-6 x Punjab Barsati and JBGR-6-8 x NSR-1 showed significant and desirable heterosis for fruit yield per plant over the standard check. The results suggest a high degree of variability and heterosis in the positive direction among the crosses.

Nagar *et al.* (2016) carried out an experiment by developing nine brinjal F_1 hybrids that were evaluated under this investigation to know the *per se* performance and to estimate the magnitude of economic heterosis (over two standard checks Pant Rituraj and Pant Samrat) for yield and yield attributing characters. For fruit yield per hectare, the F_1 hybrid Pusa Abhinav x DBL02 showed the highest economic heterosis (120.16% over Pant Rituraj and 29.22% over Pant Samrat) followed by PB-71 x BB-85 (110.71% over Pant Rituraj and 23.67% over Pant Samrat). The results indicated that Pusa Abhinav x DBL-02, PB-71 x BB-85 and BARI x Pant Rituraj could be exploited as commercial F_1 hybrids as they exhibited high economic heterosis over standard parents.

Shahjahan *et al.* (2016) studied the heterosis in selected crosses involving the eggplant genotypes, Ral 1, Ral 2, Ral 3, Ral 4, Ral 5, Ral 6, Ral 7, Ral 8, Ral 9, BARI Begun 7 and BARI Begun 8 were used. Data on days to first flowering, days to 50% flower, east-west plant canopy, north-south plant canopy, number of primary branches per plant, number of secondary branches per plant, fruit weight, fruit length, fruit breadth, days to fruit maturity, plant height, number of fruits per plant and yield per plant were recorded from five randomly selected plants from each plot. Heterosis was estimated following the additive dominance model. The mean values of the eight F1 were compared with better parents (BP) for heterobeltiosis (Hb%) and with mid parents (MP) for relative heterosis (Ht%). In the case of fruit length, fruit breadth and fruit weight, Ral 7 x Ral 8 and Ral 3 x Ral 8 crosses gave positive heterosis and heterobeltiosis. Some cross combinations such as Ral 5 x Ral 9, Ral 3 x BARI Begun 7, Ral 3 x Ral 7, Ral 6 x Ral 9 and Ral 6 x Ral 7 are exhibited significant positive relative heterosis and heterobeltiosis for the number of fruits per plant and besides these, all the cross combinations exhibited better for yield per plant.

Sharma *et al*. (2016[b]) studied 22 entries consisting of 6 diversified genotypes of brinjal along with their 15 F_1 Hybrids and one standard check that were evaluated during *kharif* season under randomized block design with three replications. Significant levels of heterosis were detected for all the traits studied. Pronounced heterosis over better parent was observed for plant height in Arka Nidhi x Arka Kusmakar (57.64%), Plant Stem girth in Pusa Purple Cluster x Arka Shirish (10.00%), fruit yield per plant and number of fruits per plant in Pusa Purple Cluster x Pant Samrat (56.16%, 40.56% respectively), fruit length in Arka Neelkanth x Arka Kusmakar (37.92%) and average fruit weight in Arka Neelkanth x Pant Samrat

(28.43%). The cross Pusa Purple Cluster x Pant Samrat showed significant negative heterosis over better parent and standard check for earliness (days to first flowering, days to 50% flowering and days to first harvesting).

Akpan *et al.* (2017) studied and estimated mid-parent heterosis (MPH) and better parent heterosis (BPH) in six eggplant hybrids generated from four superior and optimally divergent genotypes of eggplant namely 'Yalo', 'Uyo', 'K3' and 'Iyoyo' selected from the germplasm and were crossed in 4 x 4 half diallel mating design. The six hybrids were found to show a significant ($p < 0.05$) positive MPH in yield traits and the highest was obtained in the hybrid 'Yalo' x 'K3' for a number of fruits per plant (158.90%) and 'K3' x 'Iyoyo' for fruit yield per plant (63.14%) and fruit yield per hectare (62.20 %). The hybrid combinations 'Yalo' x 'K3' and 'K3' x 'Iyoyo' had significant positive BPH for the number of fruits per plant, 104.08% and 42.43%, respectively. For fruit yield per plant, the hybrid combination 'Yalo' x 'K3' (7.93%), 'Uyo' x 'K3' (8.48%) and 'K3' x 'Iyoyo' (12.26%) had significant positive BPH. However, the hybrid 'K3' x 'Iyoyo' (11.51%) showed significant positive BPH in fruit yield per hectare.

Ansari (2017) conducted a study in brinjal (*Solanum melongena* L. and *Solanum aethiopicum* L.) to estimate the magnitude of heterosis for growth, yield and its component characters. 28 F_1 hybrids were derived from eight parents of brinjal genotypes. Biometrical design diallel (method-II) fashion was used for making crosses and all F_1s along with 8 parents. Highly significant differences were observed among the genotypes for all the traits studied. For fruit yield per hectare the crosses BARI x PB-66, BARI x Pant Rituraj and PB-71 x Pant Samrat were found most heterotic hybrids over the years. These crosses could be exploited as commercial hybrids as they exhibited highly significant heterosis, over the standard parent. The cross BARI x PB-66 showed the highest economic heterosis for most of the traits studied including yield and attributing characters and may be utilized for commercial exploitation of heterosis for getting maximum yield.

Balwani *et al.* (2017) experimented to estimate the magnitude of heterosis for fruit yield and its components in brinjal. Forty-five F_1 hybrids (generated by line x tester mating design using diverse five lines and nine testers) along with 14 parents and one standard check were evaluated in a randomized block design. Appreciable heterosis was found over better and standard parent for all the traits studied in a desirable direction. In order of merit, the highest heterobeltiosis was recorded by cross ABSR 2 x GP BRJ-31 (52.52 %) followed by GOB 1 x AB 08-14 (45.31 %) and GOB 1 x GP BRJ-204 (37.78 %), while cross GOB 1 x AB 08-14 ranked first by recording the highest standard heterosis (88.88 %) for fruit yield per plant followed by followed by GOB 1 x GP BRJ-204 (71.42 %) and ABSR 2 x AB 08-14 (70.23 %). The cross GOB 1 x AB 08-14 also recorded significant standard heterosis for fruit girth, fruit weight and total soluble solids.

Khapte *et al.* (2017) studied 21 crosses resulting from line x tester mating design of 7 inbreds as lines and 3 inbreds as testers in manjari gota type of brinjal. Among the 21 crosses, IIHR-575 x IIHR-500 A was highly heterotic for fruit length (32.70%), number of fruits per plant (39.33%), plant height (23.50%) and yield per plant (69.56%) over a commercial check and could be exploited for commercial cultivation. The cross IIHR-574 x IIHR-571 exhibited significant heterosis over a commercial check for days for fifty percent flowering (-3.71%) and days to first fruit harvest (-14.27 %). The cross IIHR-575 x IIHR-438-2 showed the highest magnitude of heterosis (10.10%) over the commercial check for per cent fruit set. The cross IIHR-575 x IIHR-571 recorded the highest magnitude of heterosis (14.22%) over the commercial check for average fruit weight. The number of primary branches was significantly more in cross IIHR-592 x IIHR-438-2 (52.07%) over the commercial check.

Kumar *et al.* (2017[a]) selected six parents based on divergence and crossed in diallel design. Significant heterosis over better parents and the standard check was observed for fruit yield attributes and fruit borer incidence. The manifestations of hybrid vigour in thirty hybrids were studied. The hybrid KS-224 x Swarna Mani and SBRB-6/12 x SBRB-3/12 expressed significant and desirable heterobeltiosis and standard heterosis for yield and fruit borer incidence. Heterosis for fruit yield per plant ranged from -31.78% (SBRB-2/12 x KS224) to 60.40 % (KS224 x Swarna Mani) over better parent and -5.01% (SBRB-2/12 x KS224) to 88.79% (SBRB-3/12 x SBRB-2/12) over standard parent.

Patel *et al.* (2017[a]) recorded significant and moderate estimates of heterobeltiosis and standard heterosis for fruit yield. Ten genetically diverse parental lines, their 45 hybrids of brinjal obtained through half diallel and one standard check GABH 3 were studied to investigate the extent of heterosis over better parent and standard check for fruit yield and its quality characters. In order of merit, significantly the highest heterobeltiosis and standard heterosis for fruit yield per plant were recorded with hybrid Doli 5 x Kashi Taru (63.54%) and GBL 1 x Doli 5 (48.28%), respectively. For the quality traits, the estimates of heterotic effects were low to moderate for anthocyanin (higher *per se* performance and standard heterosis) were also registered in the hybrid GBL 1 x Doli 5. The top-ranking hybrids JBL 10-08-07 x AB 13-03, JBL 10-08-07 x GP-BRJ-216, JBL 10-08-07 x Kashi taru and GAOB 2 x JBL 10-08-01 depicted higher and significant estimates of heterobeltiosis as well as standard heterosis for fruit yield per plant and desirable heterosis for different two to three quality traits.

Santhosha *et al.* (2017) carried out a complete diallel cross study with six parents (Surya, L-3270, L-3263, R-2586, Arka Shirish and R-2583) and their F_1 progeny, to determine heterotic patterns and combining ability for fruit yield, its attributes and bacterial wilt resistance. The considerable magnitude of heterosis was expressed in F_1s for yield per plant character. The four hybrids *viz.* L-3270 x R-2586 (42.67%), L-3263 x L-3270 (30.91%), Arka Shirish x Surya (27.91%) and R-2583 x Surya (26.41%) qualify to be of commercial value as they manifested significant heterosis over the resistant check (Arka Anand) for yield per plant with higher *per se* resistance to bacterial wilt.

Shitap *et al.* (2017) conducted an experiment using the seeds of forty-five hybrids along with ten parents and were evaluated for earliness, fruit yields and yield contributing characters along with local check ABH-1 in three replications for the middle Gujarat location. Heterosis analysis was carried out for days to 50% flowering, days to first picking, plant height (cm), primary branches per plant, plant spread (cm), number of fruits per plant, fruit length (cm), fruit girth (cm), average fruit weight (g), fruit volume (cc), fruit yield per plant(kg), total soluble sugar (mg per 100 mg), total phenols (mg per100 mg) and dry matter content (mg per 100 mg). The highest economic heterosis was shown by AB-07-2 x AB-11-7 (20.75%) followed by GBL-1 x Doli-5 (12.77%) and AB-07-2 x Pusa Uttam (8.75%) for total fruit yield per plant.

Dishri *et al.* (2018) made twenty-eight crosses for ten quantitative traits in 8 x 8 half diallel mating design in brinjal and were evaluated in randomized block design with three replications to study heterosis over mid and better parents. Appreciable heterosis was observed over better parent and mid-parent for all the characters studied. The lines BBSR 202, BBSR 195-1, BB 26 and BB45C were found superior based on mean performance for earliness and yield-related characters. In order of merit, BB 68 x BB 13, BB 13 x BB 44, BB 45C x BB 13, BBSR 202 x BB 13 and BB 26 x BBSR 195-1 showing 69.45%, 66.38%, 40.33%, 35.65% and 31.52%, respectively were found to be the five best performing crosses with high heterobeltiosis and mean performance for yield per plant. These cross combinations can be advanced for further testing for commercial exploitation of hybrid vigour.

Hussain *et al.* (2018) conducted an experiment entitled "Studies in relation to commercial hybrid development in brinjal (*Solanum melongena* L.)" was carried out to generate information on the nature and magnitude of heterosis. There was a high heterosis response in most of the hybrids which supports the role of non-additive gene action. Significant positive better parent heterosis was observed in thirty-one cross combinations. Heterosis (%) over better parent ranged from -84.99 (SBPL-27 x A. Kusumakar) to 226.38 (GBL-1 x PPL). Most superior cross combinations for better parent heterosis were GBL-1 x PPL, PPC x SBW-11, PPC x GBL1, PPC x GOB-1 and A. Nidhi x P. Kranti exhibiting the heterosis (%) of 226.38, 82.03, 69.03, 67.36 and 64.54, respectively.

Kalaiyarasi *et al.* (2018) conducted an experiment through the line x tester mating design and undertaken with seven lines and three testers were evaluated along with twenty-one hybrids in randomized block design to estimate the magnitude of heterosis for yield and its yield contributing characters. The best way to utilize heterosis in the crop is to generate F_1 hybrids having maximum heterozygosity, thereby facilitating the identification and selection of hybrid vigor. The positive significant standard heterosis for fruit yield per plant was maximum with L3 x T1 (28.94%) followed by L7 x T3 (15.73%) and L7 x T1 (15.10%), respectively. Some of the promising hybrids have showed desirable heterosis for plant height, number of fruits per plant,1000 seed weight, seedling shoot length, seedling root length and seedling dry weight.

Mistry *et al.* (2018) performed an experiment to study heterobeltiosis and relative heterosis in F_1 and inbreeding depression in F_2 generation in eggplants. A set of four F_1 hybrids were generated by crossing six parents. In all crosses (Doli 5 x GBL1, Doli 5 x KS 331, Pusa Uttam x KS 331, AB-07-02 x GOB 1), fruit length, fruit volume and fruit yield per plant exhibited significantly positive heterobeltiosis which indicates that the hybrid vigor can be utilized on a commercial scale for these traits. The higher magnitude of heterobeltiosis for all the morphological traits suggested the presence of over-dominance.

Rani *et al.* (2018) developed twenty-one cross-combinations (excluding reciprocals) involving seven parents made in a diallel fashion for estimation of heterosis for yield and its contributing traits in brinjal. For fruit yield per plant and total fruit yield (kg per ha.) twenty-one and fourteen F_1 hybrids exhibited significant positive better parent and standard heterosis, respectively. The cross-combinations IC 354611 x IC 310886 and IC 261797 x IC 310886 exhibited the highest heterosis over better parent for fruit yield per plant and total fruit yield, respectively, whereas over standard check, the hybrid IC 261797 x IC 104101 had shown the highest heterosis for both the traits. The F_1 hybrid IC 104101 x IC 310886 exhibited the highest significant positive standard heterosis for a number of fruits per plant and hybrid IC 261797 x IC 104101 for fruit weight. Some of the promising hybrids showed desirable heterosis for days to flowering, ascorbic acid and phenol content.

Savaliya *et al*. (2018) studied heterosis for fruit yield and its components in brinjal through a set of 8 x 8 diallel cross (excluding reciprocal). Among the F_1s GBL 1 x BB 85, JBR 02-11 x K 331 and JBR 02- 11 x PB 69 and GBL 1 x DBL 02 had recorded significant standard heterosis for fruit yield and its important components.

Sujin *et al.* (2018) carried out an experiment to estimate heterosis in brinjal and six genotypes were selected as parents who showed greater divergence. They were then subjected to full-diallel design of mating. The heterosis was studied for the following fifteen economic characters *viz*. plant height, primary branches per plant, secondary branches per plant, long-styled flowers per plant, medium styled flowers per plant, short-styled flowers per plant, flowers per plant, days to first flower, number of flowers per plant, fruit set percentage, shoot and fruit borer incidence, fruit length, fruit girth, fruit weight and fruit yield per plant. It was observed that the maximum heterosis for fruit yield per plant was exhibited by P_1 x P_3 (214.53 %) followed by P_1 x P_6 (190.10 %), P_4 x P_5 (129.38 %) and P_2 x P_4 (104.51 %). The cross P_1 x P_3 showed maximum positive and significant heterosis of 11.80 per cent over the standard check while for fruit length desirable, negative heterosis was recorded for the crosses P_1 x P_2 (-27.81 %) and P_1 x P_4 (-17.74 %). Significant and desirable negative heterosis was recorded in two hybrids for the shoot and fruit borer infestation, the highest desirable heterosis was recorded for the characters *viz*. primary branches per plant, secondary branches per plant, long-styled flowers per plant, medium styled flowers per plant, short-styled flowers per plant, flowers per plant, days to first flower, fruits per plant, fruit set per centage, shoot and fruit borer incidence, fruit girth, fruit weight and fruit yield per plant in the cross P_1 x P_3 (-14.36 %) followed by the cross P_1 x P_6 (-10.64) for the characters *viz.* fruits per plant, fruit girth, fruit weight and fruit yield per plant.

Bhatt (2019) studied heterosis for fruit yield and its component in brinjal through diallel analysis involving nine elite genotypes. The magnitude for heterobeltiosis was high for days to 50 % flowering, plant height and total soluble solids; moderate for fruit length, number of fruits per plant, total fruit yield per plant, fruit borer infestation and shoot borer infestation and low for days to first picking, average fruit weight, number of primary branches per plant, total number of picking, days to last picking and total phenol. The high, significant and positive standard heterosis for fruit yield per plant and some of its component traits were recorded in the crosses, JBL-10-08-07 x Pant Rituraj, GJB-2 x JBR-15-01, GJB-2 x JBR-15-08, GJLB-4 x JBR-15-08 and JBR-15-08 x JBL-10-08-07.

Chaurasia *et al.* (2019) generated eighteen F_1's from line x tester mating design using six parents as lines and three parents as testers. The heterosis was worked out for the quantitative traits *viz*. days to 50 per cent flowering, plant height (cm), number of branches per plant, fruit length (cm), fruit girth (cm), fruit weight (g), number of fruits per plant, number of seeds per fruit, fruit yield per plant (kg), crude fiber content (%) and shelf life (days) of fruits. The magnitudes of mid-parent heterosis, better-parent heterosis and standard heterosis were obtained in all the eighteen F_1s for eleven characters. The study revealed that the SX x SM-6-7 gave the highest estimate of standard heterosis (40.17 %) and it was followed by the other promising F_1's *viz*., BM x SM-6-7 (39.19%), SX x Longai (36.61%), DH x Longai (36.12%), SX x JC-1(35.38%), MLC-1 x JC-1 (33.66%), MLC-1 x Longai (30.59%) and BM x Longai (25.80%) for fruit yield per plant.

Dutta *et al.* (2019) take five diverse parents and crossed in a diallel fashion without reciprocals to produce 10 F1 hybrids. The maximum extent of significant heterobeltiosis in desired directions was recorded for marketable fruit yield per plant (50.22%) and total fruit yield per plant (44.98%). We could able to isolate one promising hybrid BCB-40 x KS-224 having all the desirable attributes for export promotion and could commercially be exploited after critical evaluation. Partial to over-dominance reactions for different economic traits reflect the genetic basis of heterosis.

Modh *et al.* (2019) conducted a study to estimate the magnitudes of heterosis for fruit yield and its components in brinjal. Thirty-two F_1 hybrids (generated by line x tester mating design using diverse eight lines and four testers) along with 12 parents and one check. Appreciable heterosis was found over better and standard parents for all the traits studied in a desirable direction. In order of merit, the highest heterobeltiosis was recorded by cross NSR 1 x Swarna Mani Black (46.00%) followed by NBR-14-01 x Swarna Mani Black (40.03% and NSR-1 x Pant Rituraj (39.35%), while cross NSR 1 x Swarna Mani Black ranked first by recording the highest standard heterosis (62.00%) for fruit yield per plant followed by NBR-14-01 x Swarna Mani Black (55.39%) and AB-15-07 x Swarna Mani Black (50.09%). The above crosses also exhibited desirable heterosis for important yield attributing characters like fruit length, fruit girth, fruit weight and number of fruits per plant. The present study revealed good scope for isolation of pure lines from the progenies of heterotic F_1s as commercial exploitation of heterosis breeding in brinjal.

Valadares *et al.* (2019) carried out an experiment to estimate the heterosis of eggplant hybrids under high temperature conditions. Seven genitors, twelve hybrid combinations, originated from a partial diallel, and the Ciça F_1 hybrid, as control, were evaluated. The 1 x 4, 1 x 5 and 1 x 6 hybrids expressed positive heterosis for most analyzed traits. The 1x4 hybrid stood out for the highest averages for PV, FFI, NFP and PP. For FWe, FL, FWi and FLWR, both positive and negative heterosis were observed, as a consequence of the phenotypic variability of the genitors for these traits and suggests the possibility of selection for different sizes and formats.

Bagade *et al.* (2020) carried out an analysis through the diallel method by involving eight parents IBH-2, Utkal Keshari, IBH-3, SBJH631, Sep-034, Sep-034, A. Nerkanth and BH-2 to study of heterosis for yield characters. Significant and positive heterosis was observed for most of the characters. The percentage of heterotic crosses showing heterosis over better parent were total number of fruits per plant (52.73), total yield of fruits per plant (71.06), fruit length (8.29), fruit weight (85.60), fruit diameter (43.27), fruit cluster per plant (3.77), plant height (27.45), days to 50% flowering (-19.72), High heterosis was observed in the cross 4 x 5 (SBJH-631 x Sep-034) for total yield of fruits per plant.

Chaudhari *et al.* (2020) conducted an experiment in which total of 36 F_1 hybrids were generated following line x tester mating design comparing 12 lines and 3 testers. A study was conducted on brinjal to estimate the magnitude of heterosis for yield and its component traits. Higher heterosis for fruit yield per plant over commercial check was exhibited by the cross JBL-08-08 x NSR-1(33.47 %) followed by AB-09-1 x NBB-1 (28.21 %), GBL – 1 x NSR -1 (23.52 %) and GBL – 1 x NBB – 1 (17.25%).

Deshmukh *et al.* (2020) generated 24 hybrids through lines x tester design for the study of heterosis for vegetative and quantitative traits in brinjal (*Solanum melongena* L.). Appreciable heterosis was found for all the traits studied in a desirable direction. For the trait fruit yield per plant, the maximum positive and significant heterosis over Kashi Taru (50.68%) and Phule Arjun (66.49%) were observed in the cross JB-9 x JKGEH-6012. The extent of heterosis showed by hybrids over Phule Arjun (CC-1) and Kashi Taru (CC-2). The positive and significant heterosis was observed in two crosses for standard heterosis over CC-1 and CC-2, respectively for the number of primary branches per plant. The cross DBR-8 x B. *deoria* exhibited positive and significant standard heterosis over Kashi Taru (4.75%) and Phule Arjun (4.58%). In the case of days to 50% flowering and days to first picking negative heterosis for this trait indicate earliness which is desirable. Out of 24 hybrids generated through lines x tester design, none of them were showing significant negative heterosis for these traits. significantly positive heterosis was observed in 13 crosses over Kashi Taru (CC-1) and 6 crosses over Phule Arjun (CC-2) for the trait number of fruits per plant. the cross JB-9 x JKGEH-6012 exhibited maximum standard heterosis over CC-1(20.92%) and CC-2(16.11%) respectively. For the character number of fruits per cluster the cross JB-9 x DMU-1 recorded maximum significant heterosis over Kashi Taru (12.52%) and Phule Arjun (7.72%) followed by the cross JB-9 x DBR-31 for heterosis over commercial check-1(11.66%) and commercial check-2 (6.90%). Significantly negative and positive heterosis has been observed for fruit weight heterotic per centage ranging from (-14.24 to 8.47) and (-19.29 to 2.08) for CC-1 and CC-2 respectively. Among 24 crosses studied, seven crosses over Kashi Taru (check-1) and 12 crosses over Phule Arjun (check-2) showed positive and significant heterosis for a number of fruit yield per plant. The cross JB-9 x JKGEH-6012 exhibited maximum positive and significant heterosis over Kashi Taru (66.49%) and Phule Arjun (50.68%).

Kumar and Vethamonai (2020) conducted an experiment, consisting of 6 diversified genotypes of brinjal along with their hybrids and one standard check. Data on quantitative characters were recorded and better-parent and standard heterosis were determined. Significant levels of heterosis were detected for all the traits studied. Pronounced heterosis over standard check was observed for Plant height 22.49% in Seetipulam Local x Sevathampatti Local, number of branches per plant in Spiny Local x Sevathampatti Local (46.97%), fruit yield per plant in Sevatham patti Local x Spiny Local (34.57%) and number of fruits per plant fruit in Spiny Local x Manaparai Local (36.68%). The crosses with the highest negative and significant heterosis was exhibited by the hybrids Sevatham patti Local x Seetipulam Local and Seetipulam Local x Sevatham patti Local (−10.06%) over the standard check for earliness (days to first flowering and days to first harvesting). In this study Seetipulam Local x Sevatham patti Local found superior for most of the characters (earliness and yield per plant) and it can be commercially exploited after assessing their stability.

Makasare *et al.* (2020) carried out an experiment through the diallel method of analysis was followed involving eight parents IBH-2, Utkal Keshari, IBH-3, SBJH631, Sep-034, Sep-034, A. Nerkanth and BH-2. Significant and positive heterosis was observed for most of the characters. The percentage of heterotic crosses showing heterosis over better parent was total yield of fruits per plant (71.06), fruit length (8.29), fruit weight (85.60), fruit diameter (43.27), plant height (27.45), days to 50% flowering (- 19.72) and shoot borer infestation (-81.70%). High heterosis was observed in the cross SBJH-631 x Sep-034 for fruits per plant.

Reddy *et al.* (2020) conducted an experiment in 24 F_1 hybrids by line x tester fashion along with 10 Parents (6 Females and 4 Males) and 2 checks (Kashi Taru and Phule Arjun) were evaluated in randomized block design. Appreciable heterosis was found over mid, better and standard parent for all the traits studied in a desirable direction. For the traits like Days to 50% flowering and Days to first picking negative heterosis is desirable for this the cross combination DBR-8 x JKGEH-6012 exhibited the highest significant heterosis over mid parent (-12.10%) and better parent (-17.79%). For the yield attributing characters *viz*. Fruit length (DBR-8 x DMU-1), Fruit girth (NBJ-19 x DMU-1), Fruit weight (DBR-8 x JB- 18). For the trait fruit yield per plant, the maximum positive and significant heterosis over mid parent (75.50) over the better parent (67.76%), over Check-1 (50.68%) and Check-2

(66.49%) observed in the cross JB-9 x JKGEH-6012. The heterosis for fruit yield ranged from (- 19.51 to 75.50) mid- parent, (-28.94 to 67.76) over better parents, (-32.19 to 50.68), (-25.08 to 66.49) and standard checks, respectively.

Varma *et al.* (2020) conducted an experiment to generate genetic information on heterosis and inbreeding depression for 12 quantitative traits in brinjal through generation mean analysis. The experimental materials comprise of six basic generations *viz.* P_1, P_2, F_1, F_2, BC_1 and BC_2 of four crosses of brinjal namely; AB-8-14 x S.Mani Black (cross 1), AB-15-07 x Pant Rituraj (cross 2), JB-12-06 x GJB-3 (cross 3) and NBR14-1 x GJLB-4 (cross 4). The results indicated that the heterosis and inbreeding depression differed for the same trait in different cross combinations. The magnitude of heterotic effect was high for plant height, fruit weight and plant spread. The highest positive heterobeltiosis for fruit weight was observed in cross 1 (AB-8-14 x S. Mani Black) followed by high positive heterobeltiosis for plant height in cross 3 (JB-12-06 x GJB-3). Negative estimates of heterotic effects which were observed in some traits may be attributed to inter-allelic interactions.

Singh *et al.* (2021) carried out an experiment in eight parents (six lines and two testers) and were selected based on divergence and mated in line x tester design to measure heterosis for different yield attributes. All the resultant twelve hybrids exhibited wide variation among them for different characters under study. Most of the hybrids exhibited positive heterobeltiosis and standard heterosis in a desirable direction. Based on heterosis per cent, most promising cross combinations were DBR-8 x PPC, IVBL-116-131 x PPC, IVBL-116-131 x PPL and Jawahar Brinjal x PPC which performed well for the majority of traits.

2.2 COMBINING ABILITY AND GENE ACTION:

In a hybridization programme, the selection of the right type of parents is a crucial step for a breeder. Combining ability analysis is a powerful tool to discriminate between good as well as poor combiners and the selection of appropriate parental material. The importance of combining ability has been well emphasized because often phenotypically promising parents don't always give desired cross combinations and produce superior offspring in segregating generations, whereas some combinations may give rise to promising segregants. Combining ability may be defined as the capacity of an individual to transmit its superior performance to its offspring. It is the phenomenon with which inbred lines when crossed give rise to hybrid vigour. In this way, the ability of a strain to produce superior progeny upon hybridization with other strains is called the combining ability.

The concept of general and specific combining ability was given by Sprague and Tatum (1942). General combining ability refers average performance of a line in a series of cross combinations, while specific combining ability is a deviation in performance of a cross combination from that predicted based on the general combining abilities of parents involved in the cross. It was also explained that genes with additive effects are more important for GCA, while SCA is dependent on genes with dominance (intra-allelic interactions) and epistatic (inter-allelic interactions) effects. General combining ability is relatively more important than specific combining ability in previously unselected material. Specific combining ability, on the other hand, assumes greater importance in the material which has been previously selected for general combining ability.

Fisher (1918) was the first to attempt the partition of total genetic variance into (i) additive components, resulting from average effects of genes, (ii) dominance components, from allelic interactions, and (iii) epistatic components, associated with non-allelic interactions.

In half diallel design, all possible crosses among the selected parents are made into one direction only *i.e.*, direct crosses. Main features of half diallel involved: (i) In half diallel, a parent is used either as a male or as a female in the mating. (ii) The number of single crosses required is equal to P(P-1) per 2, where P is the number of parents used. (iii) Half diallel is used when reciprocal differences are not significant. (iv) It can be used when parents have male sterility or self-incompatibility and it can be evaluated in two ways *i.e.*, with parents and without parents.

Griffing (1956[b]) gave the statistical concept of estimation of general combining ability (GCA) and specific combining ability (SCA) variances and effects using two models and four different methods of diallel analysis depending on the materials includes: (i) parents, F_1s and reciprocals (Method-I), (ii) parents and F_1s (Method-II), (iii) F_1s and reciprocals (Method-III) and (iv) F_1s only (Method-IV) for each of fixed and random models. A brief review of literature on brinjal with reference to combining ability has been given below.

Rai and Asati (2011) investigated combining ability and gene action through diallel mating design using seven homozygous lines namely, RCMB-10, RCMB-7, RCMB-4, RCMB-3, RCMB-1, BB-40 and BB-64. General combining ability studies revealed that RCMB-10 and BB-64 were the best combiners for major yield contributing characters *viz.* plant height, number of primary branches per plant, fruit weight and fruit yield. However, the estimates of specific combining ability showed the highest desirable sca effects in crosses RCMB-3 x BB-64 for plant height, number of branches and number of fruits, RCMB-10 x RCMB-4 for fruit breadth, fruit weight and yield, RCMB-10 x RCMB-3 for per cent fruit set and RCMB-1 x BB-64 for fruit length. Gene action analysis revealed a preponderance of both additive and non-additive genes for yield and its contributing characters.

Ambade *et al.* (2012) carried out an experiment through line x tester analysis using twelve parents with days to first flowering, days to first fruiting, number of flowers per inflorescence, number of long style flowers per inflorescence, number of medium style flowers per inflorescence, fruit length (cm), fruit girth (cm), plant height (cm), number of primary branches per plant, number of fruits per cluster, total number of fruits per plant, total soluble solids (%), average fruit weight (g), rind thickness (cm), stalk length (cm) and total fruit yield per plant (g). This suggests the possibility of exploiting heterosis in the present material. Line IGB-65 was found good general combiner for fruit length, number of primary branches per plant and total fruit yield per plant and line IGB-55 for days to first flowering and days to first fruiting. Among the testers, JBR-03-16 was found best general combiner for number of fruits per cluster, fruit girth and total fruit yield per plant. On the basis of sca effects, the hybrid, IGB-55 x KS-224 was found superior for number of flowers per inflorescence, number of long style flowers per inflorescence, fruit girth, number of fruits per cluster, average fruit weight and total fruit yield per plant.

Bhushan *et al.* (2012) evaluated 60 F_1 crosses derived from mating 15 lines with 4 testers and two standard checks (BH-1 and BH-2). This was grown in Randomized Block Design, with three replications. Lines *vs*. testers showed significance for all characters except plant height, plant spread, number of primary branches, dry matter, total sugars and total phenol. Analysis for parents *vs*. hybrids showed significance for all the characters except average fruit weight, number of fruits per plant, plant spread and number of primary branches. Analysis of Variance for combining ability revealed mean squares due to lines and testers were significant for all the characters except plant height, plant spread, number of primary branches, total sugars, total phenol and content of anthocyanins. The ratio of variance due to specific combining ability and general combining ability ($\sigma 2$ SCA: $\sigma 2$ GCA) was greater than unity, indicating non-additive genetic control for all traits except plant spread and total phenols. Among the females, Punjab Barsati, PBR-91-1, RCMBL-1-1, BSR-11; and among the males, BB-93-C and U-8-61-3 were best general combiners for yield and yield components. Punjab Barsati was the best combiner for days to 50% flowering, days to first fruit harvest, number of fruits per plant and number of primary branches. The cross JBR-3-16 x PB-64 manifested best SCA effects for days to 50% flowering; PBR-91-1JBSR-98-2 for average fruit weight; BSR-11 x PB-64 for fruit length; BSR-11x U-8-61-3 for fruit girth, and the cross HABL-1 x JBSR-98-2 for yield per plant and per hectare.

Khapte *et al.* (2013) evaluated twenty-one F_1 crosses of manjarigota type of brinjal in a line x tester (mating design) involving seven lines and three testers were evaluated for general combining ability (GCA) of the parents and specific combining ability (SCA) of the crosses for various quantitative characters. Combining ability analysis revealed that two lines *viz*, IIHR-574 (L3) and IIHR-575 (L4), and two testers, IIHR-438-2 (T1) and IIHR-500A (T2) were good general combiner for most of the characters studied and, hence, can be used for further improvement of quantitative traits in manjarigota type of brinjal. Among the 21 F_1 crosses evaluated, two crosses, L4 x T2 and L3 x T3, were found to be good specific combiners for most of the yield contributing traits.

Patel *et al.* (2013) studied combining ability for yield and its components in diallel crosses, involving seven genotypes of eggplant. The GCA and SCA were significant for all characters, indicating the importance of both additive and non-additive genetic components. The genotypes, R-1 proved as the best general combiner for days to 50 % flowering and earliness, P-3 for plant height (tall stature), C-2 proved as the best general combiner for average fruit weight, fruit diameter, fruits size and yield per plant, whereas I-9 for proved good general combiners fruit length. Among the crosses, C-2 x P-3, P-1 x P-2, P-2 x I-9and P-3 x R-1 were good specific combiners for yield per plant.

Singh *et al.* (2013[a]) experimented on eight parent diallel cross without reciprocal of brinjal and their twenty-eight F_1 hybrids were subjected to combining ability analysis for yield and its contributing characters. None of the parents was found to be a good general combiner for all the characters. However, among the parents, DBR-31, Pusa Bindu, Punjab Sadabhar and Pusa Kranti were good general combiner for fruit yield and its components. However, based on overall performance parents

DBR-31 was found to be good combiner for ten characters, Pusa Bindu was found good general combiner for nine characters, Punjab Sadabhar was found good general combiner for eight characters and Pusa Kranti was found good general combiner for eight characters. The crosses Pusa Bindu x KS-331, Pusa Kranti x KS-331, Pusa Kranti x Swarna Mani, DBR-31 x Swarna Mani, Pusa Kranti x Aruna, Pusa Bindu x Swarna Mani, KS-224 x Pusa Kranti and DBR-31 x Arun which displayed significant and desirable SCA effects for fruit yield per plant, involved at least one parent exhibiting significant GCA effects and could be placed in high x low category. SCA effects of cross combinations (KS-224 x Swarna Mani, KS224 x Aruna, Swarna Mani x KS-331 and Swarna Mani x Aruna) for fruit yield per plant were associated with low x low gene effects, indicating the preponderance role of non-additive type of gene action in them.

Ansari and Singh (2014) studied combining ability effects for seven characters of brinjal. Highly significant differences were observed among the genotypes for all the traits. Results revealed that Pant Rituraj found the best gca effect for days to first flowering, number of primary branches per plant and early yield per plant. Pant Samrat showed the good gca effect for days to first flowering, number of fruits per plant, early yield per plant and yield per hectare. S. *aethiopicum* was recorded the best general combiners for the trait number of flowers per inflorescence, plant height and number of fruits per plant. BARI was the best general combiner for yield per hectare and PB-71 was found the best gca effect for early yield. The cross BARI x PB-66, BARI x PR and BARI x PS were found highest specific combining ability effect for most of the characters. Other good specific combiners were PB-71 x PR, BARI x PB-71 and S. *aethiopicum* x BARI.

Singh (2014) envisaged that brinjal var. Pant Rituraj showed the best general combining ability (gca) effects for fruit diameter, average fruit weight and number of infested fruits per plant whereas, Pant Samrat for number of healthy fruits per plant, total number of fruits per plant and yield per plant and S. aethiopicum L. (2n=24) for the traits number of healthy fruits per plant, total number of fruits per plant and weight of infested fruits per plant whereas. BARI was found best general combiner for fruit length, average fruit weight, weight of healthy fruits per plant and yield per plant. PB-71 gave significant gca effect for fruit diameter, average fruit weight and yield per plant. The cross BARI x PB-66, BARI x Pant Rituraj and BARI x Pant Samrat was found highest specific combining ability (sca) effect for most of the characters studied. Other good specific combiners were PB-66 x PR, PB-66 x PS, BARI x PB-71 and S. aethiopicum x BARI.

Dubey *et al.* (2014) studied 48 F_1 hybrids generated following line x tester mating design comprising 12 lines and 4 testers. The analysis revealed that Sel-4 was the best general combiner among the lines and IC-90099 was the best general combiner among the testers. There was a high heterosis response in most of the hybrids which supports the role of non-additive gene effects. Among the crosses, DBL-24 x PPC showed high sca effects for yield although the parents were poor general combiners. The maximum heterosis for total yield per plant over a better parent was exhibited by the cross KS-314 x IC-90099 (94.72%) followed by KS-314 x PPC (85.10%).

Prasad *et al.* (2015) evaluated an 8 x 8 half-diallel set of crosses made to identify promising genotypes and crosses. The estimates of gca effects indicated that the parents, namely Black beauty, Pusa Purple Long, Pusa Purple Round and Surati Ravaiya excelled for eleven, nine, nine and eight economic traits, respectively. Desirable sca effects for a yield of marketable fruits per plant were observed in eleven crosses (Pusa Purple Long x Black Beauty, Manjari gota x Surati Ravaiya, BB-44 x Surati Ravaiya, Green Long x Black Beauty, Black Beauty x Surati Ravaiya, Pusa Purple Long x Green Long, Gulabi Long x Pusa Purple Round, Gulabi Long x Black Beauty, Pusa Purple Long x Gulabi Long, Pusa Purple Long x Pusa Purple Round, Gulabi Long x Surati Ravaiya). However, six cross combinations (Black Beauty x Surati Ravaiya, Pusa Purple Long x Black Beauty, Gulabi Long x Surati Ravaiya, Pusa Purple Long x Green Long, BB-44 x Black Beauty and Pusa Purple Long x Gulabi Long) were found to be the best for fruit yield.

Uddin *et al*. (2015) studied combining ability in eighteen eggplant genotypes and were evaluated for different quantitative characters. Highly significant variances due to general combining ability (GCA) and specific combining ability (SCA) for all the studied characters indicated the importance of both additive and non-additive gene actions. The predominance of additive gene action was found for most of the studied characters. Considering GCA effects, the parents P_1, P_2 and P_6 were the good general combiner for number of fruits per plant and yield per plant; P_3, P_5 and P_8 for fruit weight; P_4 for fruit length and P_3 and P_8 for fruit breadth and P_1, P_6, P_2 and P_7 for yield per plant. Considering SCA effects, the crosses P_5 x P_7 was important for fruit length, fruit weight, yield per plant; P_5 x P_8 for fruit breadth, fruit weight, and yield per plant; P_1 x P_6 and P_2 x P_7 for fruit breadth, number of fruit and yield per plant; P_1

x P_6, P_2 x P_7, P_4 x P_7 and P_5 x P_7 for number of fruits and yield breadth, number of fruit and yield per plant; P_1 x P_6, P_2 x P_7, P_4 x P_7 and P_5 x P_7 for number of fruits and yield per plant.

Makani *et al.* (2016) carried out an experiment in half-diallel fashion with eight parents in brinjal. The GCA and SCA ratio indicated that non-additive gene action was predominant for the inheritance of all the traits except fruit girth for which additive gene action was more important. The estimated general combining ability effects suggested that parents GBL-1 and KS-331 were good general combiners for fruit yield per plant and its related attributes. The estimated general combining ability effects suggested that parent GBL-1 was good general combiner for dry matter and total soluble sugars. The estimated specific combining ability effects indicated that cross combinations *viz*. Doli-5 x GBL-1, AB-07-08 x GP-180 and AB-07-08 x KS-331 were observed to be most promising for fruit yield and some of its related traits.

Sharma *et al.* (2016[a]) studied six diverse brinjal lines which were crossed in a diallel fashion (excluding reciprocals) to obtain fifteen cross combinations to study the combining ability for important horticultural traits. The parent Pusa Purple Cluster emerged as a good general combiner for day to first flowering, days to 50% flowering, days to first harvesting, per cent fruit set and number of fruits per plant. Whereas, the Arka Shirish was identified as good for plant height, plant stem girth, number of primary branches per plant, fruit length, fruit diameter and average fruit weight. The highest specific combining ability effects in desirable direction were observed in cross Pusa Purple Cluster x Pant Samrat for days to first flowering, days to 50% flowering, days to first harvesting, plant height and per cent fruit set, Pusa Purple Cluster x Arka Shirish for plant stem girth, Pusa Purple Cluster x Arka Kusmakar for number of primary branches per plant, Arka Neelkanth x Arka Kusmakar for fruit length (cm), Arka Shirish x Arka Kusmakar for fruit diameter, Arka Neelkanth x Arka Kusmakar for average fruit weight, Arka Nidhi x Arka Shirish for number of flowers per cluster and cross Pusa Purple Cluster x Pant Samrat for number of fruits plant and yield per plant.

Desai *et al.* (2017) carried out a field experiment with a view to estimate, combining ability and gene effects in brinjal (*Solanum melongena* L.). The experimental material comprised of 37 genotypes including 8 parents, 28 hybrids and one standard check (Surati Ravaiya). Combining ability analysis revealed that both additive as well as non-additive gene effects were important in the inheritance of all the traits studied. However, the magnitude of variances due to sca was comparatively larger than those of gca for most of the economic traits indicating a preponderance of non-additive gene action. Among the parents, JBGR-1, NSR-1 and JBL-08-8 were good general combiners for the majority of the traits. The crosses *viz*. AB-09-1 x AB-12-10, AB-09-1 x AB-08-5, AB-08-5 x JBL-08-8 and GJB-3 x AB-12-10 showed higher order sca effects in addition to performance for fruit yield and its component characters.

Kannan *et al.* (2017) carried out with seven lines and three testers to estimate the combining ability for thirteen characters *viz*, days to first flowering, plant height, total number of branches per plant, number of fruits per plant, fruit length, fruit girth, fruit weight, yield per plant, 1000 seed weight, seed germination per centage, seedling shoot length, seedling root length and seedling dry weight. Among the parents, based on as *per se* performance and gca effect SM-16 and KKM-1 were adjudged as the best for most of the traits studied. The *per se* performance and gca effects are related to each other which reflects the breeding behaviour of individual genotype. The present study revealed that these two parameters are in high order in the parents. When considering all the traits, four parents involving the lines *viz.* Palur-1 exhibits best for total number of branches, number of fruits per plant and yield per plant, CO-2 for total number of branches per plant and fruit weight and Annamalai for total number of branches per plant, fruit length, yield per plant. Among the Testers, SM-24 for number of fruits per plant, fruit girth, fruit weight and seed germination percentage were adjudged as the best parents.

Kumar *et al.* (2017[a]) studied general and specific combining in brinjal through a diallel analysis involving six parents. The combining ability analysis revealed highly significant differences among the treatments for all the parameters studied except days to 50% flowering and number of primary branches per plant. The genotype SBRB-6 per 12 was found best general combiner for number of fruit per plant and yield per plant. The top three crosses (SBRB-3 per 12 x SBRB-2 per 12, SBRB-6 per 12 x SBRB-3 per 12 and KS-224 x Swarna Mani) with high *per se* performance have exhibited high sca effects for yield. Both additive and non-additive gene actions were operating for all the traits except days to 50% flowering, fruit diameter and number of primary branches per plant. Therefore, the general combiner can be exploited for the creation of varieties lines, and the presence of specific combining in the hybrids.

Patel *et al.* (2017[b]) studied the combining ability analysis of a 10 x 10 half diallel set of crosses in brinjal was undertaken for fruit yield and its attributing characters. Ten parents, 45 F_1's and one standard check were evaluated. The magnitude of variance due to SCA was higher in comparison to variance due to the general combining ability for plant height, number of fruits per plant, fruit yield per plant, dry matter, ascorbic acid, total soluble sugars and acidity suggesting a greater role of non-additive genetic variance. Whereas, for the rest of the characters predominance of additive gene action is involved. Among the parental genotypes, GAOB 2 was a good general combiner and GBL1, Doli 5, GP-BRJ-215 and GP-BRJ-216 were average general combiners for fruit yield per plant and were also good or average general combiners for most of the yield contributing component characters and quality characters. With respect to estimates of SCA effects, for fruit yield per plant, the hybrids GBL 1 x Doli 5, JBL 10-08-07 x GP-BRJ-216, and GAOB 2 x JBL 10-08-01 registered high *per se* performance and significant high values of sca effects in the desired direction for the important yield contributing characters and nutritional quality parameters.

Chaurasia *et al.* (2018) assessed combining ability and magnitude of gene action for quantitative traits in brinjal using six lines and three testers in L x T mating design. The estimate of gca for lines and sca for hybrids represented that the lines Sagoli Xingiya, Baromohiya, MLC-1 and the testers SM-6-7 and Longai were the best general combiners for most of the traits whereas the hybrids Utsav x Longai, Dari Hariharka x Longai, MLC-3 x SM-6-7, MLC-1 x JC-1, Baromohiya x SM6-7 and Sagoli Xingiya x JC-1 were the best specific combiners for yield and yield contributing traits. The crosses BM x JC-1, Utsav x Longai, MLC-1 x JC-1, BM x SM-6-7, MLC-3 x SM-6-7 and MLC-3 x JC-1 had significant (good x poor/poor x good) sca effect for the traits fruit weight, number of fruits per plants and yield per plant which resulted from one good and one poor general combiner.

Kachouli *et al.* (2019) carried out an experiment on combining ability analysis was done in diallel analysis by using eight parents and 28 F_1's in a randomized block design with two replications. Analysis of variance for combining ability revealed that variances due to GCA and SCA were significant for all the traits. GCA and SCA interacted significantly. The estimates of dominance variance were higher in magnitude than corresponding estimates of additive variance indicating the preponderance of non-additive gene action. None of the parents exhibited desirable gca effects for all the traits simultaneously. Parents DRNKVO-2-26 identified as good general combiners for fruit yield per plant and most of the attributes including seed weight per fruit, average fruit weight and fruit length. The cross, DRNKVO-2-26 x JB-15, Arbha Kranti x Rajendra brinjal, and Aruna x DRNKVO-2-26 were good specific combiner for grain yield and various yield components.

Siva *et al.* (2020) studied 21 eggplant hybrids generated by 7 x 7 half diallel and evaluated along with their 7 parents and 2 checks. The ratio of σ^2gca per σ^2sca revealed that non-additive gene action was predominant in the inheritance of characters *viz*. plant height, days to final harvest, fruit weight, fruit yield per plant, fruit yield per plot, fruit yield per hectare, phenols content in fruit and ascorbic acid content in fruit, whereas, additive gene action was predominant in days to first flowering, days to 50% flowering, days to first harvest, fruits per cluster, fruit length and fruit girth. Among the parents, EC-169084, Pennada, Bhagyamati and EC-169089 were promising general combiners for fruit yield and other yield contributing traits *viz*. number of primary branches per plant, fruits per cluster, fruits per plant, ascorbic acid content. Based on the sca effects, four hybrids *viz*. Bhagyamati x EC-169084, Pennada x EC-169084, Bhagyamati x EC-169089 and EC-169084 x EC-169089 were identified as promising specific combiners for fruit yield per plant, number of fruits per plant, fruits per cluster and fruit weight.

MATERIAL AND METHODS

III. MATERIAL AND METHODS

3.1 Geographical and edaphic details

The present study entitled **"Heterosis and combining ability study in Brinjal (*Solanum melongena* L.)"** was undertaken to investigate the extent of heterosis and combining ability for yield and its component characters. The field experiment was conducted at Horticultural Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar which is situated at an altitude of 152.52 meters above mean sea level at 24^0 – 19' N latitude and 72^0 – 19' E longitude. The soil of the experimental site is sandy loam, porous and poor in organic matter content with a 7.5 pH. Details of weather parameters of the crop season during which the experiment was conducted are presented in Appendix-A.

3.2 Experimental materials

The experimental material consisted of 29 genotypes includes seven parents and their resulted twenty-one crosses produce by half diallel mating and one standard check (GJBH 4). The seeds of hybrids were produced during summer 2021 at the college farm, College of Horticulture, S. D. Agricultural University, Jagudan by manual emasculation and crossing. The seeds of parental lines were maintained through selfing. The source of the parents used in the experiment is mentioned below (Table 3.1).

3.3 Crossing programme

In brinjal, anthesis occurs between 8 to 12 a.m. Hence, well-developed flower buds likely to open the next morning were emasculated during evening hours and bagged. Petals were opened gently with a fine forceps and all the intact anthers were removed without injuring gynoecium. The emasculated flower buds were kept covered overnight with red butter paper bags. On the next day morning between 8 to 10 a.m. pollens of the desired male flowers were applied to the stigmas of the emasculated flowers. The pollinated flowers were enclosed with white paper bags and were labelled properly. The mature crossed fruits were harvested and the seed were collected separately for each cross. For obtaining selfed seeds, few well-developed buds of parents were selfed. In this way, all the required crosses were ready by the end of the summer 2021 (Plate I).

Table 3.1. List of parental lines selected for present investigation

Sr. no.	Genotype	Source	Features
1.	**JBCL-16-12**	Seed Spices Research Station, SDAU, Jagudan	Fruits are medium in size, round in shape and cluster bearing. Fruit is green in colour and glossy in appearance.
2.	**JNB-110**	Seed Spices Research Station, SDAU, Jagudan	Fruits are purple in colour and medium to long in size. Fruit pulp is creamy white and fruit surface is smooth.
3.	**ISD-006**	Seed Spices Research Station, SDAU, Jagudan	Dark purple colour fruit bearing. Fruit size is medium to long and oval in shape.
4.	**DOLI 5**	Seed Spices Research Station, SDAU, Jagudan	Dark pink fruit skin colour with strong glossiness. Club-shaped fruit with medium size and cluster fruiting pattern.
5.	**GRB 7**	Vegetable Research Station, JAU, Junagadh	Fruits are medium in size and round in shape along with cluster bearing.
6.	**PLR 1**	Vegetable Research Station, JAU, Junagadh	Fruits are small, medium-sized, purple in colour, egg shaped, dark purple and glossy in appearance.
7.	**GJB 3**	Vegetable Research Station, JAU, Junagadh	Fruit is medium to big in size with oval shape and green in colour. Fruit pulp is creamy white with less seeds and fruit surface is smooth.
8.	**GJBH 4 (check)**	Vegetable Research Station, JAU, Junagadh	Fruit is medium in size with an oblong shape and pink purple in colour with good shining. The fruit pulp is white with less seeds and the fruit surface is smooth.

3.4 Experimental design

A set of twenty-nine genotypes comprising seven parents, their twenty-one F_1 hybrids and one standard check (GJBH 4) were sown in Randomized Block Design (RBD) with three replications, during *rabi* 2021-22 (Plate II). Each hybrid and parent represented single rows of 6-meter length spaced at 60 cm between rows and 60 cm between plants. Recommended agronomic practices and plant protection operations were followed to raise a good crop. Fertilizers were applied at the rate of 100 kg N/ha, 50 kg P_2O_5/ha and 50 kg K_2O/ha. P_2O_5 and K_2O were applied as basal dose with 50 kg of nitrogen before one week of transplanting, while, the remaining 50 kg nitrogen was top dressed at the time of flowering.

3.5 Observations recorded:

The following observations were measured/recorded on five randomly selected plants per entry per replication. The average value per plant was computed for further statistical analysis except for days to flower initiation, days to flowering and days to maturity. The method used for data collection of individual character is described below.

3.5.1 Days to flower initiation

The number of days required for the opening of the first flower from day of transplanting was recorded on randomly selected plants.

3.5.2 Days to flowering

It is considered as the days from the date of transplanting to the first flower opening in 50 per cent of plants of a line in each replication were recorded.

3.5.3 Days to maturity

It is considered as the days required for the first fruit to attain physiological maturity at the first picking stage from the date of transplanting in each treatment.

3.5.4 Number of flowers per cluster

The number of flowers in a cluster was counted and recorded.

3.5.5 Number of primary branches per plant

The total number of primary branches that emerged on the main stem of the plant was recorded at the time of the last picking.

3.5.6 Number of fruits per plant

The total number of fruits obtained from the randomly selected plant during each picking was recorded and the mean value was reported as a number of fruits per plant.

3.5.7 Fruit length (cm)

Five fruits from each randomly selected plant were selected randomly during the 5^{th} picking period of harvesting for recording the fruit length. The length in centimeters was recorded from the pedicel end to the blossom end of a fruit and the average length of fruit was worked out.

3.5.8 Fruit girth (cm)

The fruits used for measuring fruit length were used to measure fruit girth. It was measured at the middle region of the fruit in centimeters and was recorded as fruit girth.

3.5.9 Plant height (cm)

It was measured from the first node of the stem at ground level to the end of the apical tip in centimeters at the time of the last picking.

3.5.10 Fruit weight (g)

The number of fruits harvested from randomly selected plants was recorded by weighing in grams during each picking and the mean fruit weight was computed.

3.5.11 Fruit volume (cm^3)

The volume of fruits was measured by the water displacement method at 5^{th} picking among five marketable fruits taken for the determination of volume. The fruits were immersed one by one into the beaker fully filled with water. The water displaced by the individual fruit was collected into the graduated measuring cylinder and the volume of the fruit was obtained by averaging and recorded in terms of a cubic centimetre (cm^3).

3.5.12 Fruit yield per plant (kg)

Yield of fruits of randomly selected plants at each picking was summed for the total number of picking and the average of randomly selected plants was calculated in kilograms and was taken as fruit yield per plant.

3.6 Statistical analysis

The analysis was carried out at the Department of Agricultural Statistics, C. P. College of Agriculture, S. D. Agricultural University, Sardarkrushinagar.

The following statistical parameters were employed.

3.6.1 Analysis of variance;

3.6.2 Estimation of heterosis;

3.6.3 Combining ability analysis.

Plate I. Overview of crossing block conducted at college farm, College of Horticulture, SDAU, Jagudan during summer 2021

Plate II. Overview of evaluation of parents and its hybrids conducted at Horticultural Instructional farm, SDAU, Sardarkrushinagar during *rabi* 2021-22

3.6.1 Analysis of variance

Analysis of variance technique suggested by Snedecor and Cochran (1967) and reviewed by Panse and Sukhatme (1978) followed to test the differences between the genotypes for the characters under study. The analysis was based on a statistical linear model for randomized block design (RBD) is as follows.

$$Y_{ij} = \mu + r_i + g_j + e_{ij}$$

Where,

Y_{ij} = Mean performance of j^{th} genotype in i^{th} replication,

μ = General means,

r_i = Effect of i^{th} replication,

g_j = Effect of j^{th} genotype,

e_{ij} = Uncontrolled variation associated with j^{th} genotype in i^{th} replication,

i = 1, 2,...,r and

j = 1, 2,...,g.

The assumptions of the above model are:

(a) All the observations should be independent
(b) The error involved in the population should be normally and independently distributed with zero mean and variance σ^2_e
(c) Different effects in the model should be additive

The analysis of variance and expectation of mean squares are presented below as per the fixed effect model.

Table 3.2: Analysis of variance (ANOVA) for experiment design (fixed effect model)

Sources of variation	d.f.	M.S.S.	Expectation of mean square	Cal.'F'
Replications	(r-1)	M_r	$\sigma^2_e + g\sigma^2_r$	M_r/M_e
Genotypes	(g-1)	M_g	$\sigma^2_e + r\sigma^2_g$	M_g/M_e
Parents	(p-1)	M_p	$\sigma^2_e + r\sigma^2_p$	M_p/M_e
Hybrids	(h-1)	M_h	$\sigma^2_e + r\sigma^2_h$	M_h/M_e
Parents vs. Hybrids	1	M_{ph}	$\sigma^2_e + r\sigma^2_{ph}$	M_{ph}/M_e
Check vs. Hybrids	1	MF_1 vs. M_{ch}	-	MF_1 vs. M_{ch}/M_e
Error	(r-1) (g-1)	M_e	σ^2_e	-

Where,

R = Number of replications,

G = Number of genotypes (Parents + Hybrids),

P = Number of parents,

H = Number of hybrids,

F_1 = Number of single crosses (F_1's)

σ^2_e = Error variance,

σ^2_r = Variance due to replications,

σ^2_g = Variance due to genotypes (Parents + Hybrids),

σ^2_p = Variance due to parents and

σ^2_{ph} = variance due to hybrids

The significance of each source was tested against the error mean square by applying the 'F' test.

The estimates of Standard Error of Mean (S.Em.), Critical Difference (C.D.) and Co-efficient of Variation (C.V.) were obtained by its usual formulae as under:

Standard error of mean (S.Em.)

$$\text{S.Em} = \sqrt{\frac{M_e}{r}}$$

$$\text{S.Ed.} = \sqrt{\frac{2M_e}{r}}$$

Critical Difference (C.D.)

$$\text{C.D.} = \text{S.Em.} \times \sqrt{2} \times t_{0.05} \text{ at error d.f.}$$

Where,

t = Table 't' value for error degree of freedom at 0.01 and 0.05 levels of probability

M_e = Error mean square

r = Number of replications

Coefficient of Variation (C.V.)

$$\text{C.V.} = \frac{\sqrt{\text{Me}}}{\bar{x}}$$

Where,

Me = Error mean square

$\overline{X}$ = General mean for the character

3.6.2 Estimation of heterosis

Heterosis was estimated as per cent increase or decrease in the mean value of F_1 hybrid over mid-parent *i.e.,* relative heterosis (Turner, 1953), over better parent *i.e.,* heterobeltiosis (Koelreuter,1766 and Fonseca and Patterson,1968) and over standard check *i.e.,* standard heterosis (Meredith and Bridge,1972) for each character by using the following formulae.

3.6.2.1 Relative heterosis (H_1)

Relative heterosis was measured as the proportion of deviation of F_1 value from the mid parent, expressed in percentage.

$$H_1\,(\%) = \frac{\overline{F1} - \overline{MP}}{\overline{MP}} \times 100$$

Where,

$\overline{MP}$ = Mean performance of the mid parent

$\overline{F_1}$ = Mean value of F_1.

3.6.2.2 Heterobeltiosis (H_2)

Heterobeltiosis was calculated using the method given by Fonesca and Patterson (1968). It was measured as the proportion of deviation of F_1 value from the better parent, expressed in percentage.

$$H_2\,(\%) = \frac{\overline{F1} - \overline{BP}}{\overline{BP}} \times 100$$

Where,

$\overline{BP}$ = Mean performance of better parent, and

$\overline{F_1}$ = Mean value of F_1.

3.6.2.3 Standard heterosis (H_3)

It was measured as the proportion of deviation of the F_1 value from the standard check, expressed in the percentage suggested by Meredith and Bridge (1972).

$$H_3\,(\%) = \frac{\overline{F1} - \overline{SC}}{\overline{SC}} \times 100$$

Where,

$\overline{SC}$ = Mean performance of standard check.

$\overline{F_1}$ = Mean value of F_1.

Test of significance

The test of significance was carried out by 't' test for the numerators of the expression of heterobeltiosis and standard heterosis *i.e.,*

$$H_1 = \overline{F_1} - \overline{BP}$$

$$H_2 = \overline{F_1} - \overline{SC}$$

The standard errors (S.E.) and critical differences were estimated using the following relations.

Standard heterosis for heterobeltiosis (H_1) S.Ed ($\overline{F_1} - \overline{BP}$) $= \sqrt{\frac{2Me}{r}}$

C.D. of H_1 = S.Ed of H_1 × 't'$_{0.05}$ n_e

Standard heterosis for standard check (H_2) S.Ed ($\overline{F_1} - \overline{SC}$) $= \sqrt{\frac{2Me}{r}}$

C.D. of H_2 = S.Ed of H_2 × 't'$_{0.05}$ ne

Where,

Me = Error mean squares, and

r = Number of replications.

The test of significance of heterobeltiosis and standard heterosis was carried out by comparing the calculated value of 't' with the tabulated value of 't' at 5 per cent (1.96) and 1 per cent (2.58) levels of significance.

3.6.3 Combining ability analysis

3.6.3.1 Analysis of variance for combining ability (Diallel)

The mean value of 28 genotypes (seven parent and their twenty- one F_1 hybrids) were subjected to combining ability analysis which was carried out according to the procedure given by Griffing (1956[a]) as per Method- II (in which parents and a set of F_1's without reciprocals are included) and Model- I [which assumes that the genotypes and block effects are constant (fixed) but environmental effect is variable].

The analysis of variance for combining ability is based on the following linear statistical model: (Model-I)

$$Y_{ijk} = \mu + g_i + g_j + s_{ij} + \frac{1}{Bc} + \sum_{k} \sum_{1} e_{ijk}$$

c = 1, 2 ….1 (number of plant)

Where,

Y_{ijk}	=	Performance of y_{ij}^{th} genotypes in k^{th} replication
i, j	=	1,2,3,......p (Number of parent)
K	=	1,2,3,......b (Number of replication)
μ	=	Population mean
g_i	=	GCA effect of i^{th} parent
g_j	=	GCA effect of j^{th} parent
s_{ij}	=	SCA effect of the hybrid between i^{th} and j^{th} parent
e_{ijk}	=	Experimental error or Environmental effect pertaining to ijk^{th} observations
P	=	Number of parent
B	=	Number of block (replication)
C	=	Number of observation per plot

The restriction imposed on the utility of the model is as under:

$\sum_{i} g_i = 0$ and $\sum_{j} s_{ij} + s_{ii} = 0$ (for each i)

Based on this model, the analysis of variance for combining ability is done as shown in Table 3.3.

Table 3.3: Analysis of variance for combining ability (Method-II)

Source	d.f.	S.S.	M.S.	Expection of mean square
GCA	P-1	S_g	M_g	$\sigma^2 e + \frac{(p+2)}{(p-1)} \sum_i g^2{}_i$
SCA	$\frac{P(P-1)}{2}$	S_s	M_s	$\sigma^2 e + \frac{(p+2)}{p(p-1)} \sum_i \sum_j s^2{}_{ij}$
Error	(r-1)(g-1)	S_e	MS_e’	$\sigma^2 e$

The Sum of squares (Sg) for general combining ability effects was calculated as:

$$S_g = \frac{1}{P+2}\left[\sum_{i=1}^{P}(X_{i.} + X_{ii})^2 - \frac{4}{P}X^2..\right]$$

The Sum of squares due to SCA effects (Ss) was estimated as:

$$S_{Sg} = \sum_{i \leq j} \sum X_{ij}^2 \frac{1}{P+2}\left[\sum_i (X_{i.} + X_{ii})^2 - \frac{2}{(P+1)(P+2)}X^2..\right]$$

Where,

P = Number of parents

$X_{i.}$ = Array total involving ‘i’ as recurrent parent

X_{ii} = Mean value of i^{th} parents

$X_{..}$ = Grand total of ‘p’ parents and P(P-1)/2, F_1’s

X_{ij} = Mean value of ij^{th} cross, such that ‘i’ is equal to or greater than ‘j’

MS_e’ = Error mean square (M_e/r)

For “F” test, each of the mean squares were tested against MS_e’.

3.6.3.2 Estimation of genetic components of variance:

Griffing (1956[b]) suggested techniques for the estimation of second degree heredity parameters. Variance due to gca effects and sca effects were made free from environmental variation. This was done by using following equations.

Estimation of genetic components of variance:

$$g^2{}_i = \frac{(M_g - M_e)}{(P+2)}$$

$$S^2{}_{ij}{}^2 = (M_g - M_e)$$

Where,

P = Number of parents

M_g = Mean squares due to GCA

M_s = Mean squares due to SCA

The relative importance of general and specific combining ability variance was assessed by the ratio given below:

$$= \left(\sum_{i} g_i{}^2\right) / \left(\sum_{ii \le j}\sum s_{ij}{}^2\right)$$

Estimates of general and specific combining ability were calculated for only those traits where variance due to general combining ability or specific combining ability were significant.

3.6.3.3 Estimation of gca and sca effect:

GCA effect g_i of i^{th} parent was estimated as.

$$\hat{g}_i = \frac{1}{(P+2)}\left[\left(X_{i.} + X_{ii}\right) - \frac{2}{P}X_{..}\right]$$

SCA effect of ij^{th} cross was calculated as under:

$$\hat{S}_{ij} = X_{ij} - \frac{1}{(P+2)}\left(X_{i.} + X_{ii} + X_{.j} + X_{jj}\right) + \frac{2}{(P+1)(P+2)}X_{..}$$

Where,

$X_{i+}X_{ii}$	=	Total of i^{th} array + mean value of parent i
$X_{j+}X_{jj}$	=	Total of j^{th} array + mean value of parent j
P	=	Number of parents
g_i	=	GCA effect of the i^{th} parent
S_{ij}	=	SCA effect of the cross-involving i^{th} and j^{th} parents
$X_{i.}$	=	Notal of array involving i^{th} parent
$X_{.j}$	=	Total of array involving j^{th} parent
X_{ii}	=	Mean value of the i^{th}parent
X_{jj}	=	Mean value of the j^{th} parent
$X_{..}$	=	Grand total of parents and F_1's

Estimation of standard errors:

Various standard errors required to test the significance of gca and sca effects and the difference between them are calculated as:

To test individual gca effects:

$$\text{S.E.}(g_i) = \sqrt{\frac{(P\text{-}1)\ \sigma^2 e}{P(P+2)}}$$

To test individual sca effects:

$$\text{S.E.}(s_{ij}) = \sqrt{\frac{(P^2 + P + 2))\ \sigma^2 e}{(P+1)(P+2)}}$$

To test difference between two gca effects:

$$\text{S.E.}(g_i - g_j) = \sqrt{\frac{2\ \sigma^2 e}{(P+2)}}$$

To test the difference between sca's of two crosses having 'i' as a common parent:

$$\text{S.E.}(s_{ij} - s_{ik}) = \sqrt{\frac{2(P+1)\ \sigma^2 e}{(P+2)}}$$

To test the sca effect of any two crosses having no parent in common:

$$\text{S.E.}(s_{ij} - s_k) = \sqrt{\frac{2P\ \sigma^2 e}{(P+2)}}$$

Where,

P	=	Number of parent
$\sigma^2 e$	=	Error m.s. (Me')

Each of the gca and sca effects were subjected to "t" test for significance.

For 't' test of gca : $t = \frac{(g_i - 0)}{S.E.(g_i)}$

For 't' test of sca : $t = \frac{(s_{ij} - 0)}{S.E.(s_{ij})}$

Since the value of calculated 't' is regarded as significant, if it exceeds 2.02 and 2.70 at 5 per cent and 1 per cent levels, respectively.

Alternatively, gca and sca effects were compared with critical difference calculated by following formulae.

C. D. (g_i) = S.E. (g_i) × table $t_{0.05}$ and $t_{0.01}$

C. D. (s_{ij}) = S.E. (s_{ij}) × table $t_{0.05}$ and $t_{0.01}$

RESULTS AND DISCUSSION

IV. RESULTS AND DISCUSSION

The present investigation entitled **“Heterosis and combining ability study in Brinjal (*Solanum melongena* L.)”** was undertaken using diallel analysis in order to get information on the magnitude of heterosis, nature of gene action and combining ability in brinjal. The results obtained in the present investigation have been presented under the following headings:

4.1 Analysis of variance for experimental design

4.2 Mean performance of parents and their hybrids

4.3 Estimation of heterosis

4.4 Combining ability analysis and gene action

4.5 Estimation of combining ability effects

4.1 ANALYSIS OF VARIANCE FOR EXPERIMENTAL DESIGN

The mean squares for twelve different characters are presented in Table 4.1. The mean squares due to genotypes, parents and hybrids (F_1) were highly significant for most of the characters revealing the existence of potential variability in the parental material used in the present study. The mean squares due to parents *vs.* hybrids were highly significant for the number of primary branches per plant, number of fruits per plant, plant height, fruit weight, fruit volume and fruit yield per plant at 1%. Whereas, mean squares due to parents *vs.* hybrids are significant at only 5% for days to flower initiation and fruit length. The analysis of variance revealed significant differences among the genotypes, parents and hybrids for all the characters. This indicated that a considerable amount of genetic variability was present in the material studied and the material was suitable for the study of the manifestation of heterosis, combining ability and genetic parameters involved in the inheritance of different traits. Mean squares due to parents *vs.* hybrids were also significant for all the characters except days to flowering, number of flowers per cluster and fruit girth which indicated F_1’s had heterotic effects for these characters.

4.2 MEAN PERFORMANCE OF PARENTS AND THEIR HYBRIDS

The mean values of all the characters studied are presented in Appendix II. Character-wise results of mean performance of parents and their hybrids are as under:

4.2.1 Days to flower initiation

The parent PLR 1 was the earliest (43.47 days) to flower initiation, while parent

Table 4.1 Analysis of variance (mean sum of square) for twelve characters under study in brinjal

Source of variation	d.f.	Days to flower initiation	Days to flowering	Days to maturity	Number of flowers per cluster	Number of primary branches per plant	Number of fruits per plant	Fruit length	Fruit girth	Plant height	Fruit weight	Fruit volume	Fruit yield per plant
Replications	2	0.25	13.26	7.45	0.04	0.15	0.04	0.04	0.91	12.24	5.21	30.00	0.001
Genotypes	28	14.28**	31.33**	31.80**	0.57**	2.89**	3.72**	14.43**	36.40**	315.90**	4360.35**	3275.82**	1.55**
Parents	6	20.54**	17.01**	21.12	1.38**	3.86**	3.66**	23.92**	76.36**	304.64**	1033.52**	817.51**	2.11**
Hybrids	20	12.90**	38.11**	35.88**	0.38**	2.82**	3.53**	12.73**	27.94**	319.67**	5133.22**	4089.26**	1.08**
Parents *vs.* Hybrids	1	18.63*	4.94	40.96	0.02	0.75**	11.48**	2.80*	0.29	147.87**	13204.45**	4976.62**	6.48**
Check *vs.* Hybrids	1	0.04	8.08	4.93	0.12*	0.77**	0.03	3.00*	1.94	475.94**	19.89	56.11	2.57**
Error	56	3.13	5.15	10.29	0.02	0.10	0.12	0.46	1.98	3.98	77.73	40.77	0.04

*, ** indicate the level of significance at 5% and 1%, respectively.

JNB-110 was late (51.61 days) in flower initiation. The cross PLR 1 x GRB 7 was earlier (44 days) in flower initiation whereas, PLR 1 x GJB 3 (52.19 days) was late in flower initiation. The overall mean for parents was 48.32 days and for crosses, it was 49.41 days.

4.2.2 Days to flowering

The parent PLR 1 was the earliest (50.83 days) to flower, while parent JNB-110 was late (57.89 days) in flowering. The cross GRB 7 x JBCL-16-12 was earlier (50.65 days) in flowering whereas, GJB 3 x JNB-110 (63.71 days) was late in flowering. The overall mean for parents was 55.23 days and for crosses, it was 55.79 days.

4.2.3 Days to maturity

The parent GRB 7 was the earliest (72.40 days) to mature, while the parent JBCL-16-12 was late (80.93 days) to mature. The cross PLR 1 x JBCL-16-12 was earlier (72.73 days) to mature, whereas, the cross GJB 3 x JNB-110 (86.67 days) was late to mature. The overall mean for parents was 76.29 days and for crosses, it was 77.90 days.

4.2.4 Number of flowers per cluster

The mean values of the number of flowers per cluster for parents ranged from 1.99 (ISD-006) to 3.88 (GRB 7). The range for hybrids was 2.02 (JBCL-16-12 x ISD-006) to 3.43 (GRB 7 x GJB 3). The overall mean for parents and hybrids were 2.59 and 2.55, respectively for flowers per cluster.

4.2.5 Number of primary branches per plant

The mean values of the number of primary branches per plant for parents ranged from 3.71 (ISD-006) to 7.45 (PLR 1). The range for hybrids was 3.77 (GJB 3 x ISD-006) to 7.15 (PLR 1 x GRB 7). The overall mean for parents and hybrids was 5.65 and 5.87, respectively for the number of primary branches per plant.

4.2.6 Number of fruits per plant

Among the parents, GJB 3 exhibited the lowest (13.8) number of fruits per plant, while JBCL-16-12 had the highest (16.55) number of fruits per plant. The mean performance of hybrids varied from 12.76 (PLR 1 x ISD-006) to 16.32 (PLR 1 x JBCL-16-12). An overall mean for parents was higher (15.19) than hybrids (14.33).

4.2.7 Fruit length (cm)

For fruit length, parents ranged from 6.83 cm (JBCL-16-12) to 14.89 cm (DOLI 5). Among the hybrids, the shortest fruit length (5.98 cm) was recorded by

JBCL-16-12 x DOLI 5 and the longest (13.2 cm) by GRB 7 x ISD-006. On average, fruit length of the parent was longer (9.56 cm) than the cross (9.14 cm).

4.2.8 Fruit girth (cm)

Fruit girth varied from 14.04 cm (JNB-110) to 29.41 cm (GJB 3) in parents, whereas in crosses it ranged from 13.57 cm (JBCL-16-12 x JNB-110) to 24.29 cm (GJB 3 x JNB-110). An overall mean was 18.80 cm and 18.66 cm for parents and hybrids, respectively.

4.2.9 Plant height (cm)

The parent PLR 1 was tallest (64.54 cm) and parent GRB 7 was dwarfest (44.42 cm). Mean performance for hybrids varied from 37.99 cm (GJB 3 x DOLI 5) to 82.24 cm (JBCL-16-12 x JNB-110). The overall mean for plant height of hybrids (56.37 cm) was higher than the parents' (53.31 cm).

4.2.10 Fruit weight (g)

The parent GRB 7 manifested the lowest (66.3 g) and DOLI 5 registered the highest (117.16 g) fruit weight. Among the crosses, the cross combinations JBCL-16-12 x JNB-110 recorded the lowest (65.42 g) fruit weight whereas, the PLR 1 x DOLI 5 expressed the highest (182.09 g) fruit weight. The overall mean of hybrids was higher (116.57 g) than the parents (87.61 g).

4.2.11 Fruit volume (cm^3)

For fruit volume, parents ranged from 79 cm^3 (ISD-006) to 122.67 cm^3 (GJB 3). Among the hybrids, the lowest fruit volume (76.37 cm^3) was recorded by JBCL-16-12 x DOLI 5 and the highest (193.51 cm^3) by PLR 1 x DOLI 5. On average, fruit volume in the parent and cross was 98.62 cm^3 and 116.40 cm^3 respectively.

4.2.12 Fruit yield per plant (kg)

The parent GJB 3 manifested the lowest (1.09 kg) and DOLI 5 registered the highest (3.21 kg) fruit yield per plant. Among the crosses, the cross combinations GJB 3 x JNB-110 recorded the lowest (1.04 kg) yield per plant whereas, the hybrids PLR 1 x JBCL-16-12 expressed the highest (3.33 kg) yield per plant. An overall mean of parents (2.49 kg) was higher than the hybrids (1.85 kg) (Fig. 4.1).

A perusal of data on mean values (Appendix II) revealed that none of the parental and hybrid genotypes was superior to all the traits under study. The mean performance of parents revealed that the parent DOLI 5, JNB-110 and GRB 7 was top ranking for fruit yield per plant. Mean values of cross combinations for various traits revealed that hybrid PLR 1 x JBCL-16-12 recorded highest fruit yield per plant.

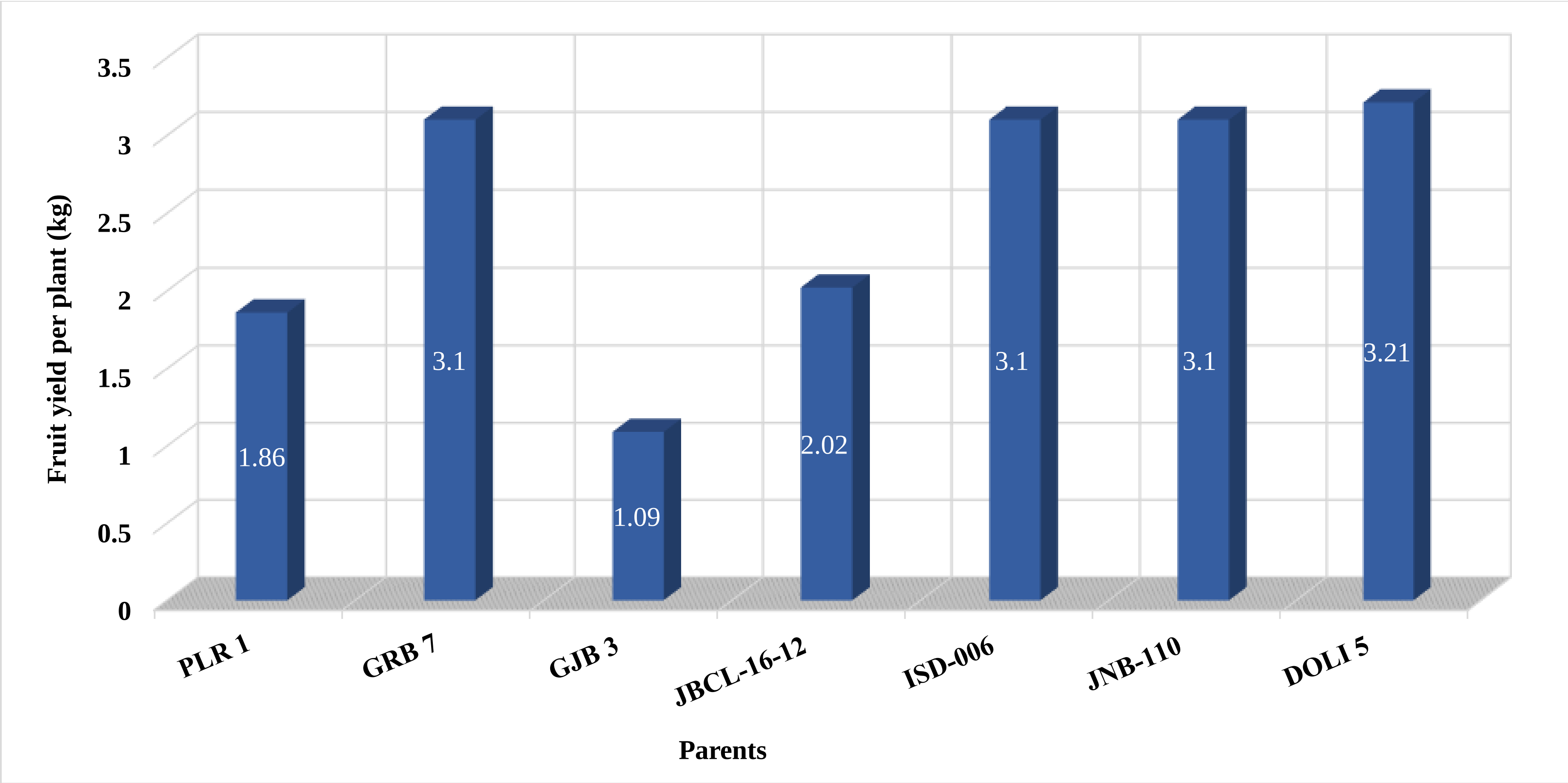

Fig. 4.1 Graphical representation of *per se* performance of parents for fruit yield per plant (kg)

Table 4.3 shows a comparison of the top two ranking hybrids. The cross combinations, PLR 1 x JBCL-16-12, ISD-006 x DOLI 5 and PLR 1 x DOLI 5 had high *per se* performance for fruit yield per plant.

4.3 ESTIMATION OF HETEROSIS

The concept of heterosis is proved the most important genetic tool for improving the yield of crop plants. The prime objective of heterosis breeding is to identify the specific parental combination capable of producing the maximum heterotic effect in F_1.

The extent of heterosis *i.e.*, relative heterosis (RH), heterobeltiosis (BH) and standard heterosis (SH) were estimated for all the characters under study. The relative heterosis (RH) was estimated over mid-parent value, heterobeltiosis over better parent and standard (economic) heterosis over the check (GJBH 4). Salient features of the results for each character studied are presented in Table 4.2.1 to Table 4.2.12.

4.3.1 Days to flower initiation

The heterosis over mid-parent ranged from -5.24 (GRB 7 x JNB-110) to 15.06 per cent (PLR 1 x GJB 3). Out of 21 hybrids, it was found significant and negative (desirable) in one hybrid while significant and positive in six hybrids.

The estimates of heterosis over better parent for days to flower initiation ranged from -1.83 (JBCL-16-12 x JNB-110) to 20.06 (PLR 1 x GJB 3) per cent. The estimate of better parent heterosis was significant and negative (desirable) in none of the crosses while nine crosses observed to be significant heterosis and positive for days to flower initiation.

Standard heterosis for days to flower initiation ranged from -10.25 (PLR 1 x GRB 7) to 6.49 (PLR 1 x GJB 3) per cent. Two crosses showed significant and positive heterosis and one cross showed significant and negative heterosis for days to flower initiation. Heterosis for earliness in brinjal was reported by Aswani and Khandelwal (2005), Chowdhury *et al.* (2011) and Varma *et al.* (2020).

4.3.2 Days to flowering

The heterosis over mid-parent ranged from -10.5 (GRB 7 x ISD-006) to 16.27 (GJB 3 x DOLI 5) per cent. Out of 21 hybrids, it was found significant and negative (desirable) in four hybrids while significant and positive in five hybrids.

The estimates of heterosis over better parent for days to flowering ranged from -8.39 (GRB 7 x ISD-006) to 18.75 (GJB 3 x DOLI 5) per cent. The estimate of better parent heterosis was significant and negative (desirable) in two crosses while

Table 4.2.1 Magnitude of heterosis for days to flower initiation expressed as percentage over mid parent value (H_1), over better parent (H_2) and over standard check GJBH 4 (H_3)

Sr. No.	Hybrids	Days to flower initiation		
		H_1	H_2	H_3
1	PLR 1 x GRB 7	-3.70	1.20	-10.25 **
2	PLR 1 x GJB 3	15.06 **	20.06 **	6.49 *
3	PLR 1 x JBCL-16-12	-0.80	6.44	-5.60
4	PLR 1 x ISD-006	10.34 **	16.29 **	3.15
5	PLR 1 x JNB-110	3.95	13.69 **	0.84
6	PLR 1 x DOLI 5	8.01 **	16.26 **	3.13
7	GRB 7 x GJB 3	0.40	1.10	-2.56
8	GRB 7 x JBCL-16-12	-0.27	1.73	-0.60
9	GRB 7 x ISD-006	-0.30	-0.02	-2.31
10	GRB 7 x JNB-110	-5.24 *	-1.57	-3.82
11	GRB 7 x DOLI 5	-2.62	-0.35	-2.64
12	GJB 3 x JBCL-16-12	1.95	4.72	0.94
13	GJB 3 x ISD-006	7.11 **	8.15 *	4.25
14	GJB 3 x JNB-110	2.74	7.49 *	3.62
15	GJB 3 x DOLI 5	6.07 *	9.29 **	5.35
16	JBCL-16-12 x ISD-006	3.56	5.34	3.49
17	JBCL-16-12 x JNB-110	-2.57	-0.82	0.80
18	JBCL-16-12 x DOLI 5	-2.11	-1.83	-0.23
19	ISD-006 x JNB-110	2.71	6.40 **	4.53
20	ISD-006 x DOLI 5	6.17 *	8.33 **	6.43 *
21	JNB-110 x DOLI 5	-1.44	0.04	2.27
S.Em. (±)		1.27	1.46	1.46
Range		-5.24 to 15.06	-1.83 to 20.06	-10.25 to 6.49
No. of positive significant		06	09	02
No. of negative significant		01	00	01
Total significant		07	09	03

*, ** indicate the level of significance at 5% and 1%, respectively.

Table 4.2.2 Magnitude of heterosis for days to flowering expressed as percentage over mid parent value (H_1), over better parent (H_2) and over standard check GJBH 4 (H_3)

Sr. No.	Hybrids	Days to flowering		
		H_1	H_2	H_3
1	PLR 1 x GRB 7	-6.76 *	-0.30	-6.12
2	PLR 1 x GJB 3	11.67 **	14.76 **	8.06 *
3	PLR 1 x JBCL-16-12	-2.41	2.24	-3.73
4	PLR 1 x ISD-006	4.33	8.91 *	2.56
5	PLR 1 x JNB-110	1.66	8.14 *	1.84
6	PLR 1 x DOLI 5	1.77	6.89	0.65
7	GRB 7 x GJB 3	-4.37	-0.60	-1.21
8	GRB 7 x JBCL-16-12	-7.83 **	-6.00	-3.04
9	GRB 7 x ISD-006	-10.50 **	-8.39 *	-6.17
10	GRB 7 x JNB-110	-8.66 **	-8.2 0 *	-2.54
11	GRB 7 x DOLI 5	-2.86	-1.16	2.41
12	GJB 3 x JBCL-16-12	-1.23	0.63	0.02
13	GJB 3 x ISD-006	2.16	3.73	3.10
14	GJB 3 x JNB-110	8.73 **	12.45 **	11.77 **
15	GJB 3 x DOLI 5	16.27 **	18.75 **	18.03 **
16	JBCL-16-12 x ISD-006	4.01	4.38	6.91 *
17	JBCL-16-12 x JNB-110	8.06 **	9.64 **	13.10 **
18	JBCL-16-12 x DOLI 5	2.06	2.30	5.53
19	ISD-006 x JNB-110	2.40	4.27	6.80
20	ISD-006 x DOLI 5	9.00 **	9.64 **	12.31 **
21	JNB-110 x DOLI 5	-4.62	-3.43	0.06
S.Em. (±)		1.60	1.85	1.85
Range		-10.50 to 16.27	-8.39 to 18.75	-6.17 to 18.03
No. of positive significant		05	07	06
No. of negative significant		04	02	00
Total significant		09	09	06

*, ** indicate the level of significance at 5% and 1%, respectively.

seven crosses observed to be significant heterosis and positive for days to flowering.

Standard heterosis for days to flowering ranged from -6.17 (GRB 7 x ISD-006) to 18.03 (GJB 3 x DOLI 5) per cent. Six crosses showed significant and positive heterosis and no crosses showed significant and negative heterosis (earlier) for days to flowering. Heterosis for earliness in brinjal was reported by Boddepalli *et al.* (2015), Chowdhury *et al*. (2011) and Singh *et al*. (2021).

4.3.3 Days to maturity

The heterosis over mid-parent ranged from -7.35 (PLR 1 x JBCL-16-12) to 13.74 per cent (GJB 3 x JNB-110). Out of 21 hybrids, it was found significant and negative (desirable) in one hybrid while significant and positive in four hybrids.

The estimates of heterosis over better parent for days to maturity ranged from -4.38 (PLR 1 x JBCL-16-12) to 15.56 (GJB 3 x JNB-110) per cent. The estimate of better parent heterosis was the significant and positive direction in four crosses while, no crosses observed to be significant and negative heterosis for days to maturity.

Standard heterosis for days to maturity ranged from -4.55% (PLR 1 x JBCL-16-12) to 13.74% (GJB 3 x JNB-110). The estimate of standard heterosis was the significant and positive direction in three crosses. While none of the crosses exhibits significant and negative direction for days to maturity. Heterosis for early maturity was supported by Boddepalli *et al.* (2015) and Shahjahan *et al.* (2016).

4.3.4 Number of flowers per cluster

The heterosis over mid-parent ranged from -29.16 (GRB 7 x JNB-110) to 37.88 per cent (JBCL-16-12 x DOLI 5). Out of 21 hybrids, it was found significant and negative in five hybrids while significant and positive (desirable) in five hybrids.

The range of heterobeltiosis was from -38.28% (GRB 7 x JNB-110) to 33.63% (JBCL-16-12 x DOLI 5) for number of flowers per cluster. The estimate of better parent heterosis was significant and positive direction in four crosses while 14 crosses observed to be significant and negative heterosis for number of flowers per cluster.

Standard heterosis for number of branches per plant ranged from -14.41% (JBCL-16-12 x ISD-006) to 45.44% (GRB 7 x GJB 3). One cross exhibit significant and negative direction heterosis over the standard check. While six crosses exhibit significant and positive direction for number of branches per plant. This result is supported by Ramireddy *et al*. (2011) and Santhosha *et al*. (2017).

Table 4.2.3 Magnitude of heterosis for days to maturity expressed as percentage over mid parent value (H_1), over better parent (H_2) and over standard check GJBH 4 (H_3)

Sr. no.	Hybrids	Days to maturity		
		H_1	H_2	H_3
1	PLR 1 x GRB 7	-0.40	2.12	-2.98
2	PLR 1 x GJB 3	-3.18	-2.49	-4.03
3	PLR 1 x JBCL-16-12	-7.35 *	-4.38	-4.55
4	PLR 1 x ISD-006	-1.04	-0.26	-0.44
5	PLR 1 x JNB-110	2.17	3.07	2.89
6	PLR 1 x DOLI 5	-0.00	0.71	-0.88
7	GRB 7 x GJB 3	5.38	7.27 *	1.93
8	GRB 7 x JBCL-16-12	-0.43	5.43	0.18
9	GRB 7 x ISD-006	-0.40	2.95	-2.19
10	GRB 7 x JNB-110	-0.31	3.13	-2.02
11	GRB 7 x DOLI 5	5.29	7.18	1.84
12	GJB 3 x JBCL-16-12	-0.38	3.56	1.93
13	GJB 3 x ISD-006	5.34	6.93	5.25
14	GJB 3 x JNB-110	13.74 **	15.56 **	13.74 **
15	GJB 3 x DOLI 5	9.33 **	9.33 **	7.62 *
16	JBCL-16-12 x ISD-006	1.56	3.97	5.43
17	JBCL-16-12 x JNB-110	0.04	2.33	3.94
18	JBCL-16-12 x DOLI 5	-1.75	2.13	0.53
19	ISD-006 x JNB-110	6.29 *	6.38	7.88 *
20	ISD-006 x DOLI 5	4.99	6.58	4.9
21	JNB-110 x DOLI 5	6.12 *	7.82 *	6.13
S.Em. (±)		2.26	2.61	2.61
Range		-7.35 to 13.74	-4.38 to 15.56	-4.55 to 13.74
No. of positive significant		04	04	03
No. of negative significant		01	00	00
Total significant		05	04	03

*, ** indicate the level of significance at 5% and 1%, respectively.

Table 4.2.4 Magnitude of heterosis for number of flowers per cluster expressed as percentage over mid parent value (H_1), over better parent (H_2) and over standard check GJBH 4 (H_3)

Sr. no.	Hybrids	Number of flowers per cluster		
		H_1	H_2	H_3
1	PLR 1 x GRB 7	-26.98 **	-36.22 **	4.67
2	PLR 1 x GJB 3	-5.95	-17.36 **	1.28
3	PLR 1 x JBCL-16-12	-11.17 *	-23.68 **	-6.36
4	PLR 1 x ISD-006	-4.02	-19.08 **	-0.85
5	PLR 1 x JNB-110	-23.23 **	-23.45 **	-5.94
6	PLR 1 x DOLI 5	-5.60	-16.67 **	2.12
7	GRB 7 x GJB 3	12.94 **	-11.59 **	45.34 **
8	GRB 7 x JBCL-16-12	4.80	-19.48 **	32.21 **
9	GRB 7 x ISD-006	-3.41	-26.95 **	19.92 **
10	GRB 7 x JNB-110	-29.16 **	-38.28 **	1.28
11	GRB 7 x DOLI 5	-20.48 **	-37.51 **	2.55
12	GJB 3 x JBCL-16-12	16.51 **	13.51 *	5.51
13	GJB 3 x ISD-006	5.73	0.76	-6.36
14	GJB 3 x JNB-110	1.05	-10.98 *	8.48
15	GJB 3 x DOLI 5	8.23	7.66	1.28
16	JBCL-16-12 x ISD-006	-0.49	-2.72	-14.41 *
17	JBCL-16-12 x JNB-110	27.92 **	10.17 *	34.33 **
18	JBCL-16-12 x DOLI 5	37.88 **	33.63 **	25.43 **
19	ISD-006 x JNB-110	1.92	-13.87 **	5.09
20	ISD-006 x DOLI 5	25.10 **	18.62 **	11.45 *
21	JNB-110 x DOLI 5	-2.55	-13.76 **	5.09
S.Em. (±)		0.11	0.13	0.13
Range		-29.16 to 37.88	-38.28 to 33.63	-14.41 to 45.34
No. of positive significant		05	04	06
No. of negative significant		05	14	01
Total significant		10	18	07

*, ** indicate the level of significance at 5% and 1%, respectively.

4.3.5 Number of primary branches per plant

The heterosis over mid-parent ranged from -36.33 (PLR 1 x JNB-110) to 52.08 per cent (JBCL-16-12 x ISD-006). Out of 21 hybrids, it was found significant and positive (desirable) in 12 hybrids while significant and negative in six hybrids.

The heterobeltiosis was ranged from -42.24% (PLR 1 x JNB-110) to 31.33% (JBCL-16-12 x ISD-006) for number of primary branches per plant. The estimate of better parent heterosis was the significant and positive direction in five crosses while eight crosses observed to be significant and negative heterosis for number of primary branches per plant.

Standard heterosis for a number of primary branches per plant ranged from -40.45% (GJB 3 x ISD-006) to 12.96% (PLR 1 x GRB 7). Eight cross exhibit significant and negative direction heterosis over the standard check. While five crosses exhibit significant and positive direction for number of primary branches per plant. The increase in number of branches per plant ultimately increased number of fruits per plant. The same type of findings for number of branches per plant in brinjal have been reported earlier by researchers *i.e.,* Singh *et al*. (2021) and Khapte *et al*. (2017).

4.3.6 Number of fruits per plant

The heterosis over mid-parent ranged from -19.87 (PLR 1 x JBCL-16-12) to 14.30 per cent (ISD-006 x DOLI 5). Out of 21 hybrids, it was found significant and positive (desirable) in three hybrids while significant and negative in 13 hybrids.

Out of 21 crosses, 17 crosses showed significant and negative heterobeltiosis with a range from -21.82% (JBCL-16-12 x DOLI 5) to 13.22% (ISD-006 x DOLI 5) for number of fruits per plant.

Standard heterosis ranged from -12.97% (PLR 1 x ISD-006) to 11.33% (PLR 1 x JBCL-16-12). Eleven crosses showed significant and negative heterosis, while three crosses showed significant and positive heterosis over check variety for number of fruits per plant. Numerous workers including Aswani and Khandelwal (2005), Chowdhury *et al*. (2011), Nalini *et al*. (2011), Makani *et al.* (2013) and Singh *et al*. (2021) observed positive heterosis for number of fruits per plant in brinjal.

4.3.7 Fruit length

The heterosis over mid-parent ranged from -45.99 (GRB 7 x DOLI 5) to 69.5 per cent (GRB 7 x ISD-006). Out of 11 hybrids, it was found significant and positive (desirable) in six hybrids while significant and negative in five hybrids.

Table 4.2.5 Magnitude of heterosis for number of primary branches per plant expressed as percentage over mid parent value (H_1), over better parent (H_2) and over standard check GJBH 4 (H_3)

Sr. No.	Hybrids	Number of primary branches per plant		
		H_1	H_2	H_3
1	PLR 1 x GRB 7	9.60 **	-3.94	12.96 **
2	PLR 1 x GJB 3	0.52	-8.37 *	7.75
3	PLR 1 x JBCL-16-12	-19.30 **	-31.99 **	-20.07 **
4	PLR 1 x ISD-006	19.68 **	-10.34 **	5.53
5	PLR 1 x JNB-110	-36.33 **	-42.24	-32.07 **
6	PLR 1 x DOLI 5	-10.72 **	-22.51	-8.85 *
7	GRB 7 x GJB 3	-8.49 *	-12.39 **	-15.17 **
8	GRB 7 x JBCL-16-12	24.29 **	18.72 **	5.22
9	GRB 7 x ISD-006	-5.97	-21.87 **	-30.81 **
10	GRB 7 x JNB-110	-12.99 **	-16.26 **	-19.75 **
11	GRB 7 x DOLI 5	22.12 **	20.74 **	6.96
12	GJB 3 x JBCL-16-12	14.83 **	5.22	1.90
13	GJB 3 x ISD-006	-23.43 **	-38.53 **	-40.45 **
14	GJB 3 x JNB-110	12.90 **	12.28 **	8.69 *
15	GJB 3 x DOLI 5	4.62	-0.92	-4.11
16	JBCL-16-12 x ISD-006	52.08 **	31.33 **	5.85
17	JBCL-16-12 x JNB-110	-10.62 *	-17.69 **	-21.17 **
18	JBCL-16-12 x DOLI 5	23.07 **	18.84 **	2.85
19	ISD-006 x JNB-110	21.00 **	-2.47	-6.64
20	ISD-006 x DOLI 5	22.51 **	2.74	-11.06 **
21	JNB-110 x DOLI 5	8.34 *	3.13	-1.27
S.Em. (±)		0.22	0.26	0.26
Range		-36.33 to 52.08	-42.24 to 31.33	-40.45 to 12.96
No. of positive significant		12	05	02
No. of negative significant		06	08	09
Total significant		18	13	11

*, ** indicate the level of significance at 5% and 1%, respectively.

Table 4.2.6 Magnitude of heterosis for number of fruits per plant expressed as percentage over mid parent value (H_1), over better parent (H_2) and over standard check GJBH 4 (H_3)

Sr. No.	Hybrids	Number of fruits per plant		
		H_1	H_2	H_3
1	PLR 1 x GRB 7	-12.82 **	-13.51 **	-6.14 **
2	PLR 1 x GJB 3	-6.82 **	-13.01 **	-5.60 **
3	PLR 1 x JBCL-16-12	0.51	-1.43	11.33 **
4	PLR 1 x ISD-006	-15.55 **	-19.79 **	-12.97 **
5	PLR 1 x JNB-110	-11.33 **	-11.66 **	-3.42
6	PLR 1 x DOLI 5	7.64 **	-1.32	9.96 **
7	GRB 7 x GJB 3	-9.90 **	-15.26 **	-9.49 **
8	GRB 7 x JBCL-16-12	-12.28 **	-14.64 **	-3.62
9	GRB 7 x ISD-006	-11.22 **	-15.04 **	-9.21 **
10	GRB 7 x JNB-110	-12.35 **	-13.37 **	-5.26 *
11	GRB 7 x DOLI 5	2.04	-3.23	3.42
12	GJB 3 x JBCL-16-12	-6.06 **	-13.87 **	-2.73
13	GJB 3 x ISD-006	1.40	-0.42	-2.80
14	GJB 3 x JNB-110	-7.93 **	-14.34 **	-6.35 **
15	GJB 3 x DOLI 5	-3.51	-4.34 *	-8.40 **
16	JBCL-16-12 x ISD-006	4.38 **	-2.68	9.90 **
17	JBCL-16-12 x JNB-110	-12.97 **	-14.33 **	-3.28
18	JBCL-16-12 x DOLI 5	-15.41 **	-21.82 **	-11.74 **
19	ISD-006 x JNB-110	-6.50 **	-11.52 **	-3.21
20	ISD-006 x DOLI 5	14.30 **	13.22 **	10.58 **
21	JNB-110 x DOLI 5	-0.28	-6.46 **	2.32
S.Em. (±)		0.24	0.28	0.28
Range		-15.55 to 14.30	-21.82 to 13.22	-12.97 to 11.33
No. of positive significant		03	01	03
No. of negative significant		13	15	10
Total significant		16	16	13

*, ** indicate the level of significance at 5% and 1%, respectively.

Heterobeltiosis for fruit length ranged from -59.8% (JBCL-16-12 x DOLI 5) to 62.65% (GRB 7 x ISD-006). Three crosses had significant and positive heterosis over better parent for fruit length. While 13 crosses had significant and negative over better parent heterosis.

The standard heterosis range for this character was recorded from -41.78% (JBCL-16-12 x DOLI 5) to 28.53% (GRB 7 x ISD-006). Only three crosses had significant and positive heterosis over standard heterosis. While, 12 crosses had significant and negative heterosis over standard heterosis. Above pronounced results regarding fruit length have been noticed by researchers like, Shitap *et al*. (2017), Bhatt *et al.* (2019), Reddy *et al.* (2020) and Singh *et al.* (2021).

4.3.8 Fruit girth

The heterosis over mid-parent ranged from -21.97 (JBCL-16-12 x DOLI 5) to 30.07 per cent (PLR 1 x DOLI 5). Out of 21 hybrids, it was found significant and positive (desirable) in four hybrids while significant and negative in four hybrids.

As regards heterobeltiosis, nine crosses depicted significant and negative heterobeltiosis over their better plant, whereas, one cross showed significant and positive heterobeltiosis. The crosses GJB 3 x ISD-006 showed minimum significant and minimum negative heterobeltiosis (-35.74%) followed by PLR 1 x DOLI 5 (29.65%) for fruit girth.

The standard heterosis ranged from -24.11% (JBCL-16-12 x JNB-110) to 35.86% (GJB 3 x JNB-110). Four crosses showed significant and negative heterosis, while seven crosses showed significant and positive heterosis over check variety for fruit girth. The present finding is in agreement with the findings of Chowdhury *et al.* (2011), Shitap *et al.* (2017) and Reddy *et al.* (2020).

4.3.9 Plant height

The heterosis over mid-parent ranged from -16.92 (GJB 3 x DOLI 5) to 50.41 per cent (JBCL-16-12 x JNB-110). Out of 21 hybrids, it was found significant and positive (desirable) in ten hybrids while significant and negative in five hybrids.

The heterobeltiosis was range from -29.20% (GRB 7 x JNB-110) to 32.98% (JBCL-16-12 x DOLI 5). The estimate of better parent heterosis was the significant and positive direction in three crosses while nine crosses observed to be significant and negative heterosis for plant height.

Table 4.2.7 Magnitude of heterosis for fruit length expressed as percentage over mid parent value (H_1), over better parent (H_2) and over standard check GJBH 4 (H_3)

Sr. No.	Hybrids	Fruit length		
		H_1	H_2	H_3
1	PLR 1 x GRB 7	-11.05	-11.09	-29.80 **
2	PLR 1 x GJB 3	35.36 **	16.87 **	26.88 **
3	PLR 1 x JBCL-16-12	11.30	2.53	-19.09 **
4	PLR 1 x ISD-006	-22.50 **	-25.60 **	-41.29 **
5	PLR 1 x JNB-110	-4.80	-15.35 **	-14.22 *
6	PLR 1 x DOLI 5	-26.97 **	-43.61 **	-18.21 **
7	GRB 7 x GJB 3	-0.35	-13.93 **	-6.53
8	GRB 7 x JBCL-16-12	24.51 **	14.65 *	-9.45
9	GRB 7 x ISD-006	69.50 **	62.65 **	28.53 **
10	GRB 7 x JNB-110	16.97 **	4.04	5.46
11	GRB 7 x DOLI 5	-45.99 **	-58.28 **	-39.54 **
12	GJB 3 x JBCL-16-12	23.39 **	-0.53	7.99
13	GJB 3 x ISD-006	0.74	-15.95 **	-8.77
14	GJB 3 x JNB-110	-21.19 **	-23.80 **	-17.24 **
15	GJB 3 x DOLI 5	-33.94 **	-42.24 **	-16.27 **
16	JBCL-16-12 x ISD-006	9.01	4.41	-24.25 **
17	JBCL-16-12 x JNB-110	-4.17	-20.67 **	-19.58 **
18	JBCL-16-12 x DOLI 5	-44.87 **	-59.80 **	-41.78 **
19	ISD-006 x JNB-110	1.29	-13.09 *	-11.88 *
20	ISD-006 x DOLI 5	-6.07	-29.52 **	2.15
21	JNB-110 x DOLI 5	-5.64	-19.83 **	16.27 **
S.Em. (±)		0.48	0.55	0.55
Range		-45.99 to 69.5	-59.8 to 62.65	-41.78 to 28.53
No. of positive significant		05	03	03
No. of negative significant		06	13	12
Total significant		11	16	15

*, ** indicate the level of significance at 5% and 1%, respectively.

Table 4.2.8 Magnitude of heterosis for fruit girth expressed as percentage over mid parent value (H_1), over better parent (H_2) and over standard check GJBH 4 (H_3)

Sr. No.	Hybrids	Fruit girth		
		H_1	H_2	H_3
1	PLR 1 x GRB 7	12.76 *	9.65	2.97
2	PLR 1 x GJB 3	-6.64	-26.67 **	20.59 **
3	PLR 1 x JBCL-16-12	9.56	1.01	12.37
4	PLR 1 x ISD-006	-6.39	-11.21	-7.05
5	PLR 1 x JNB-110	21.66 **	11.70	4.87
6	PLR 1 x DOLI 5	30.07 **	29.65 **	22.49 **
7	GRB 7 x GJB 3	-1.68	-24.32 **	24.45 **
8	GRB 7 x JBCL-16-12	-0.75	-10.81	-0.79
9	GRB 7 x ISD-006	4.74	-3.25	1.29
10	GRB 7 x JNB-110	-2.20	-7.82	-18.24 **
11	GRB 7 x DOLI 5	9.72	6.36	0.51
12	GJB 3 x JBCL-16-12	-8.13 *	-23.00 **	26.63 **
13	GJB 3 x ISD-006	-21.46 **	-35.74 **	5.71
14	GJB 3 x JNB-110	11.82 *	-17.40 **	35.86 **
15	GJB 3 x DOLI 5	-8.39	-27.87 **	18.63 **
16	JBCL-16-12 x ISD-006	5.05	1.95	13.43 *
17	JBCL-16-12 x JNB-110	-20.01 **	-31.78 **	-24.11 **
18	JBCL-16-12 x DOLI 5	-21.97 **	-27.85 **	-19.75 **
19	ISD-006 x JNB-110	12.00	-2.00	2.58
20	ISD-006 x DOLI 5	-6.57	-11.12	-7.00
21	JNB-110 x DOLI 5	-11.47	-18.96 *	-23.44 *
S.Em. (±)		0.99	1.14	1.14
Range		-21.97 to 30.07	-35.74 to 29.65	-24.11 to 35.86
No. of positive significant		04	01	07
No. of negative significant		04	09	04
Total significant		08	10	11

*, ** indicate the level of significance at 5% and 1%, respectively.

Table 4.2.9 Magnitude of heterosis for plant height expressed as percentage over mid parent value (H_1), over better parent (H_2) and over standard check GJBH 4 (H_3)

Sr. No.	Hybrids	Plant height		
		H_1	H_2	H_3
1	PLR 1 x GRB 7	16.60 **	-3.15	-7.61 **
2	PLR 1 x GJB 3	10.91 **	-5.00	-9.85 **
3	PLR 1 x JBCL-16-12	10.39 **	-5.10 *	-10.01 **
4	PLR 1 x ISD-006	-4.85 *	-4.97	-9.81 **
5	PLR 1 x JNB-110	-1.95	-3.68	-8.67 **
6	PLR 1 x DOLI 5	-9.88 **	-23.24 **	-26.85 **
7	GRB 7 x GJB 3	4.10	0.30	-29.47 **
8	GRB 7 x JBCL-16-12	1.42	-2.68	-31.87 **
9	GRB 7 x ISD-006	9.42 **	-9.03 **	-13.09 **
10	GRB 7 x JNB-110	-15.98 **	-29.20 **	-32.50 **
11	GRB 7 x DOLI 5	-1.33	-4.31	-35.41 **
12	GJB 3 x JBCL-16-12	24.34 **	23.81 **	-14.31 **
13	GJB 3 x ISD-006	5.30 *	-9.71 **	-12.19 **
14	GJB 3 x JNB-110	-16.82 **	-27.66 **	-33.12 **
15	GJB 3 x DOLI 5	-16.92 **	-17.48 **	-44.10 **
16	JBCL-16-12 x ISD-006	2.23	-12.02 **	-15.59 **
17	JBCL-16-12 x JNB-110	50.41 **	31.28 **	21.04 **
18	JBCL-16-12 x DOLI 5	34.45 **	32.98 **	-8.50 **
19	ISD-006 x JNB-110	5.85 *	4.12	-1.71
20	ISD-006 x DOLI 5	20.45 **	2.70	-3.01
21	JNB-110 x DOLI 5	-3.81	-16.83 **	-25.17 **
S.Em. (±)		1.43	1.65	1.65
Range		-16.92 to 50.41	-29.20 to 32.98	-44.1 to 21.04
No. of positive significant		10	03	01
No. of negative significant		05	09	18
Total significant		15	12	19

*, ** indicate the level of significance at 5% and 1%, respectively.

Standard heterosis for plant height ranged from -44.1% (GJB 3 x DOLI 5) to 21.04% (JBCL-16-12 x JNB-110) The estimate of standard heterosis was significant and positive direction in one cross. While 18 of the crosses exhibits significant and negative direction for plant height. Heterosis for these traits was supported by Biswas *et al*. (2016), Sharma *et al.* (2016[b]), Khapte *et al*. (2017) and Varma *et al*. (2020).

4.3.10 Fruit weight

The heterosis over mid-parent ranged from -32.65 (JBCL-16-12 x DOLI 5) to 122.23 per cent (PLR 1 x JBCL-16-12). Out of 21 hybrids, it was found significant and positive (desirable) in 12 hybrids while significant and negative in four hybrids.

Out of 21 crosses, four crosses showed significant and negative heterobeltiosis with a range from -43.34% (JBCL-16-12 x DOLI 5) to 117.06% (PLR 1 x JBCL-16-12). Ten crosses showed significant and positive heterobeltiosis for fruit weight.

Standard heterosis ranged from -41.57% (JBCL-16-12 x JNB-110) to 75.25% (PLR 1 x DOLI 5). Nine crosses showed significant and negative heterosis, while six crosses showed significant and positive heterosis over check variety fruit weight. Heterosis for these traits was supported by Ramireddy *et al*. (2011), Singh (2016), Varma *et al.* (2020) and Singh *et al*. (2021).

4.3.11 Fruit volume

The heterosis over mid-parent ranged from -28.45 (JBCL-16-12 x DOLI 5) to 78.85 per cent (PLR 1 x DOLI 5). Out of 21 hybrids, it was found significant and positive (desirable) in ten hybrids while significant and negative in five hybrids.

The heterobeltiosis was range from -36.27% (GJB 3 x ISD-006) to 68.68% (GRB 7 x ISD-006). The estimate of better parent heterosis was the significant and positive direction in seven crosses while eight crosses observed to be significant and negative heterosis for fruit volume.

Standard heterosis for fruit volume ranged from -29% (JBCL-16-12 x DOLI 5) to 79.93% (PLR 1 x DOLI 5). The estimate of standard heterosis was the significant and positive direction in nine crosses. While nine crosses exhibit significant and negative direction for fruit volume. Heterosis for fruit volume was supported by Shitap *et al.* (2017).

Table 4.2.10 Magnitude of heterosis for fruit weight expressed as percentage over mid parent value (H_1), over better parent (H_2) and over standard check GJBH 4 (H_3)

Sr. No.	Hybrids	Fruit weight		
		H_1	H_2	H_3
1	PLR 1 x GRB 7	11.65	-0.05	-25.11 **
2	PLR 1 x GJB 3	84.71 **	63.15 **	59.49 **
3	PLR 1 x JBCL-16-12	122.23 **	117.06 **	62.66 **
4	PLR 1 x ISD-006	-2.38	-7.34	-30.57 **
5	PLR 1 x JNB-110	71.53 **	68.76 **	26.46 **
6	PLR 1 x DOLI 5	71.54 **	47.19 **	54.04 **
7	GRB 7 x GJB 3	18.85 *	-4.57	-6.72
8	GRB 7 x JBCL-16-12	43.22 **	30.97 **	-6.43
9	GRB 7 x ISD-006	75.59 **	65.04 **	11.10
10	GRB 7 x JNB-110	8.32	-1.61	-28.66 **
11	GRB 7 x DOLI 5	-16.84 *	-34.89 **	-31.87 **
12	GJB 3 x JBCL-16-12	67.55 **	45.01 **	41.76 **
13	GJB 3 x ISD-006	-18.61 **	-31.28 **	-32.83 **
14	GJB 3 x JNB-110	74.31 **	51.81 **	48.40 **
15	GJB 3 x DOLI 5	3.52	0.11	4.77
16	JBCL-16-12 x ISD-006	8.20	5.07	-24.94 **
17	JBCL-16-12 x JNB-110	-18.81 *	-19.41 *	-41.57 **
18	JBCL-16-12 x DOLI 5	-32.65 **	-43.34 **	-40.71 **
19	ISD-006 x JNB-110	23.73 **	19.30 *	-13.5 *
20	ISD-006 x DOLI 5	86.03 **	52.85 **	59.96 **
21	JNB-110 x DOLI 5	13.88 *	-3.60	0.88
S.Em. (±)		6.32	7.30	7.30
Range		-32.65 122.23	-43.34 to 117.06	-41.57 to 62.66
No. of positive significant		12	10	07
No. of negative significant		04	04	09
Total significant		16	14	16

*, ** indicate the level of significance at 5% and 1%, respectively.

Table 4.2.11 Magnitude of heterosis for fruit volume expressed as percentage over mid parent value (H_1), over better parent (H_2) and over standard check GJBH 4 (H_3)

Sr. No	Hybrids	Fruit volume		
		H_1	H_2	H_3
1	PLR 1 x GRB 7	-4.04	-13.19 *	-19.61 **
2	PLR 1 x GJB 3	63.85 **	48.45 **	69.33 **
3	PLR 1 x JBCL-16-12	63.38 **	61.00 **	49.12 **
4	PLR 1 x ISD-006	-12.39 *	-21.45 **	-27.26 **
5	PLR 1 x JNB-110	34.06 **	30.94 **	21.28 **
6	PLR 1 x DOLI 5	78.85 **	65.70 **	79.93 **
7	GRB 7 x GJB 3	7.97	-10.53 *	2.05
8	GRB 7 x JBCL-16-12	8.64	-0.39	-10.44 *
9	GRB 7 x ISD-006	70.39 **	68.68 **	26.46 **
10	GRB 7 x JNB-110	-6.00	-13.10 *	-23.27 **
11	GRB 7 x DOLI 5	-12.28 **	-25.86 **	-19.50 **
12	GJB 3 x JBCL-16-12	39.27 **	24.53 **	42.04 **
13	GJB 3 x ISD-006	-22.47 **	-36.27 **	-27.31 **
14	GJB 3 x JNB-110	53.57 **	36.23 **	55.39 **
15	GJB 3 x DOLI 5	2.26	-0.20	13.84 **
16	JBCL-16-12 x ISD-006	-0.83	-9.91	-19.00 **
17	JBCL-16-12 x JNB-110	-19.22 **	-19.94 **	-28.02 **
18	JBCL-16-12 x DOLI 5	-28.45 **	-34.60 **	-29.00 **
19	ISD-006 x JNB-110	16.02 **	6.27	-6.16
20	ISD-006 x DOLI 5	25.22 **	4.96	13.98 **
21	JNB-110 x DOLI 5	10.65 *	0.31	8.93
S.Em. (±)		4.55	5.25	5.25
Range		-28.45 to 78.85	-36.27 to 68.68	-29.00 to 79.93
No. of positive significant		10	07	09
No. of negative significant		05	08	09
Total significant		15	15	18

*, ** indicate the level of significance at 5% and 1%, respectively.

Table 4.2.12 Magnitude of heterosis for fruit yield per plant expressed as percentage over mid parent value (H_1), over better parent (H_2) and over standard check GJBH 4 (H_3)

Sr. No.	Hybrids	Fruit yield per plant		
		H_1	H_2	H_3
1	PLR 1 x GRB 7	-37.37 **	-49.95 **	-47.64 **
2	PLR 1 x GJB 3	-16.42	-33.75 **	-58.45 **
3	PLR 1 x JBCL-16-12	71.63 **	64.69 **	12.50 *
4	PLR 1 x ISD-006	-10.48	-28.46 **	-25.00 **
5	PLR 1 x JNB-110	-47.72 **	-58.22 **	-56.09 **
6	PLR 1 x DOLI 5	-10.26	-29.18 **	-23.32 **
7	GRB 7 x GJB 3	8.35	-26.85 **	-23.65 **
8	GRB 7 x JBCL-16-12	-25.18 **	-38.24 **	-35.14 **
9	GRB 7 x ISD-006	-43.39 **	-43.39 **	-40.55 **
10	GRB 7 x JNB-110	-28.36 **	-28.36 **	-25.34 **
11	GRB 7 x DOLI 5	-42.98 **	-43.93 **	-39.19 **
12	GJB 3 x JBCL-16-12	2.79	-20.96 *	-45.95 **
13	GJB 3 x ISD-006	-32.22 **	-54.24 **	-52.03 **
14	GJB 3 x JNB-110	-50.20 **	-66.38 **	-64.87 **
15	GJB 3 x DOLI 5	-50.81 **	-67.08 **	-64.19 **
16	JBCL-16-12 x ISD-006	-34.55 **	-45.97 **	-43.25 **
17	JBCL-16-12 x JNB-110	-18.93 **	-33.08 **	-29.73 **
18	JBCL-16-12 x DOLI 5	-57.04 **	-65.01 **	-62.17 **
19	ISD-006 x JNB-110	-37.49 **	-37.49 **	-34.46 **
20	ISD-006 x DOLI 5	-3.80	-5.40	2.71
21	JNB-110 x DOLI 5	-32.10 **	-33.23 **	-27.71 **
S.Em. (±)		0.15	0.17	0.17
Range		-57.04 to 71.63	-67.08 to 64.69	-64.87 to 12.50
No. of positive significant		01	01	01
No. of negative significant		14	19	19
Total significant		15	20	20

*, ** indicate the level of significance at 5% and 1%, respectively.

3.12 Fruit yield per plant

The heterosis over mid-parent ranged from -57.04 (JBCL-16-12 x DOLI 5) to 71.63 per cent (PLR 1 x JBCL-16-12). Out of 21 hybrids, it was found significant and positive (desirable) in one hybrid while, significant and negative in 14 hybrids.

Fruit yield is an attribute of economic importance. Hence, attempts of breeders are in the direction of breeding varieties with high fruit yield. The heterobeltiosis for fruit yield per plant ranged from -67.08% (GJB 3 x DOLI 5) to 64.69% (PLR 1 x JBCL-16-12). Out of 21 hybrids, one hybrid showed significant and positive heterobeltiosis for fruit yield per plant.

As a regarded to standard heterosis, 19 hybrids showed significant and negative heterosis, with a ranged from -64.87% (GJB 3 x JNB-110) to 12.50% (PLR 1 x JBCL-16-12) and one cross showed significant and positive (desirable) standard heterosis for fruit yield per plant (Fig. 4.2). Positive heterosis in desirable direction for fruit yield per plant was observed by Ansari and Singh (2016), Bhatt *et al.* (2019), Shitap *et al*. (2017), Varma *et al.* (2020) and Singh *et al*. (2021).

For a successful heterosis breeding programme in any crop, there are two important pre-requisites, first, there must be ample evidence of the presence of significant heterotic effect in the hybrids that can be of practical utility and second, the production of economically feasible hybrid seed at the commercial scale. Brinjal is quite diverse in its character and it continues to be a choice of breeders for exploitation of heterosis due to the hardy nature of the crop, comparatively large size of flowers and more number of seeds in a single fruit enabling the production of a large number of F_1 seeds with a single act of pollination. Highly varied consumer acceptance from region to region also demands for development of a large number of high-yielding F_1 hybrids. Hand emasculation and pollination are still followed in the hybrid seed production of brinjal.

Hybrids offer opportunities for improvement in earliness, uniformity, productivity, quality, wider adaptability and rapid deployment of dominant genes for resistance to disease and pests. Information on the magnitude of heterosis in different cross combinations is a basic requisite to assess for identifying crosses that exhibit a high amount of exploitable heterosis. India being the centre of origin, brinjal has a huge genetic divergence and this offers much scope for improvement through heterosis breeding.

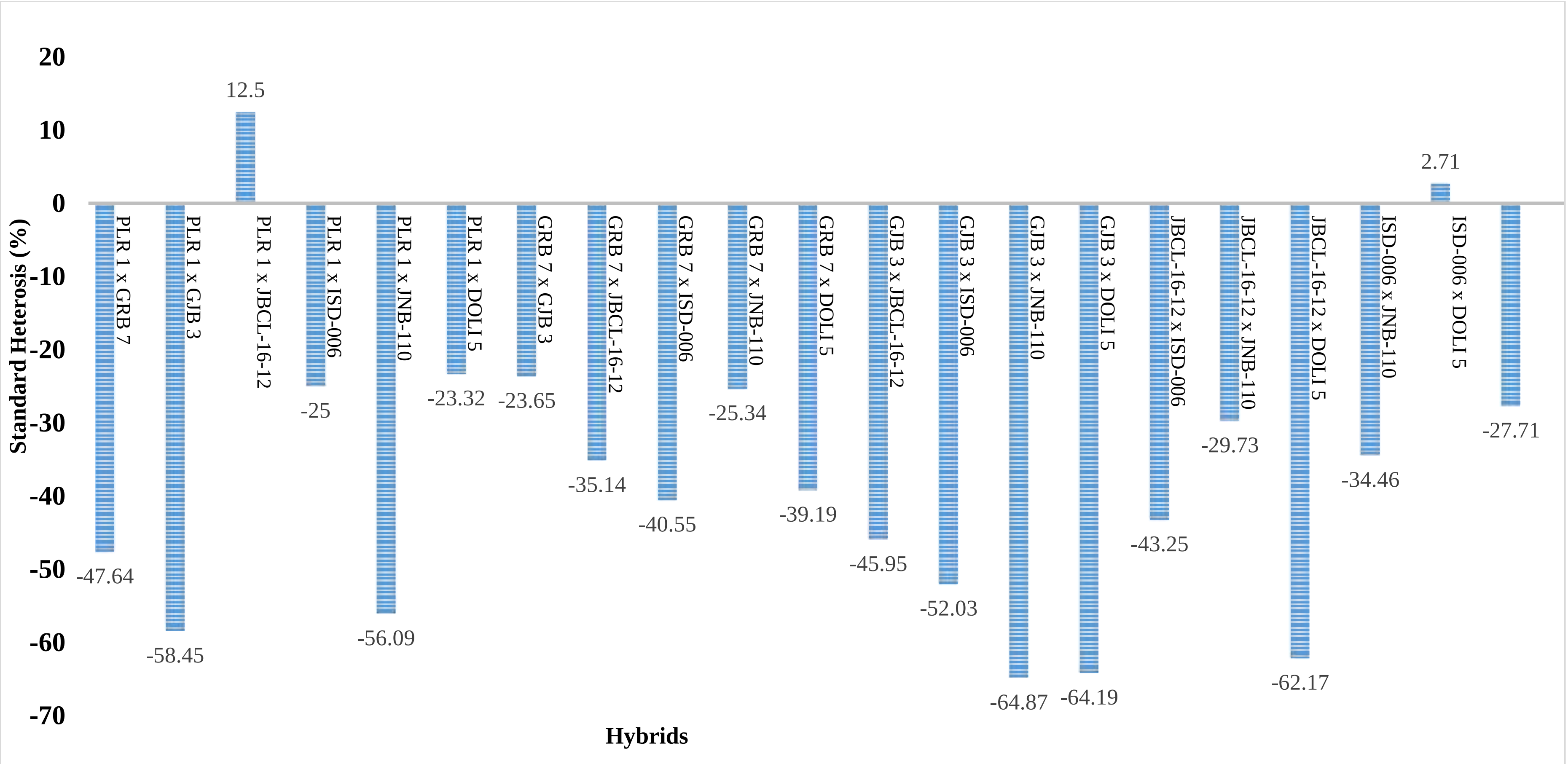

Fig.4.2 Graphical representation of Standard Heterosis (%) of hybrids for fruit yield per plant

In the present investigation, several crosses exhibited conspicuous heterotic responses over better parent for different traits. However, apart from indicating genetic interaction, a measure of heterosis over better parent is relatively less importance than standard heterosis.

Hence, it is better to measure heterosis in terms of superiority over standard check variety, rather than over better parent. In the material studied, the degree of heterosis varied from cross to cross for all the characters. Considerable high heterosis in certain crosses and low in the other crosses suggested that the nature of gene action varied with the genetic architecture of the parents.

It will be considered interesting to know the cause of heterosis for fruit yield. Whitehouse *et al.* (1958) and Grafius (1959) have suggested that there cannot be any gene system for yield *per se* and yield is an end product of the multiplicative interaction between the yield components. This would indicate that the heterosis for fruit yield should be through heterosis for the individual yield components or alternatively due to the multiplicative effects of partial dominance of component characters. Williams and Gilbert (1960) have reported that even simple dominance in respect of yield components may lead to the expression of heterosis in respect of yield. In order to see whether a similar situation exists in brinjal or not, a comparison of standard heterosis crosses for fruit yield was made for other yield-related characters along with average fruit yield per plant (Table 4.3). It was observed high positive and significant standard heterosis for fruit yield in the cross PLR 1 x JBCL-16-12 and ISD-006 x DOLI 5.

When cross PLR 1 x JBCL-16-12 was significant and positive in fruit yield per plant accompanied by high significant and positive standard heterosis for number of fruits per plant, fruit weight and fruit volume.

When cross ISD-006 x DOLI 5 was significant and positive in fruit yield per plant accompanied by high significant and positive standard heterosis for number of flowers per cluster, number of fruits per plant, fruit weight and fruit volume.

A comparison of best performing three crosses, each in a case for fruit weight, fruit volume and fruit yield per plant was common in comparison. This indicates that the selection of crosses based on either *per se* performance or heterotic response would be equally important, but the forming is more desirable.

Table 4.3 Comparative study of heterotic crosses in brinjal for fruit yield per plant with other characters

Hybrid	Fruit yield per plant (kg)	Standard heterosis (%)	sca effect	Useful and significant standard heterosis for other characters
PLR 1 x JBCL-16-12	3.22	12.50	1.41**	FPP,FW,FV
ISD-006 x DOLI 5	3.04	2.71	0.59**	FPC,FPP,FW, FV

*P ≤ 0.05, **P ≤ 0.01 **FW** : Fruit weight **FPC** : Number of flowers per cluster
FV : Fruit volume **FPP** : Number of fruits per plant

4.4 COMBINING ABILITY ANALYSIS AND GENE ACTION

Analysis of combining ability provides information on specific combinations to exploit heterosis and helps in the identification and early assessment of a breeding programme. Nature and magnitude of combining ability effects help in identifying superior parents and the parents classified as good, average and poor combiners based on estimates of general combining ability (GCA) effects. Combining ability effects are favourable in the positive direction for number of flowers per cluster, plant height, number of primary branches per plant, fruit weight, fruit length, fruit girth, number of fruits per plant, fruit volume and fruit yield per plant while, days to flower initiation, days to flowering and days to maturity shows negative combining ability effects are favourable.

Analysis of variance for combining ability revealed that GCA and SCA mean sum of squares were highly significant for all the traits *viz.* days to flower initiation, days to flowering, days to maturity, number of flowers per cluster, number of primary branches per plant, number of fruits per plant, fruit length, fruit girth, plant height, fruit weight, fruit volume and fruit yield per plant indicating both additive and non-additive gene actions were important for the inheritance of these traits (Table 4.4).

4.5. ESTIMATION OF COMBINING ABILITY EFFECTS

The estimates of general combining ability (gca) effects of seven parents are presented in Table 4.5, while the classification of parents based on gca effects is depicted in Table 4.7. The estimates of specific combining ability (sca) effects of 21 hybrids are furnished in Table 4.6. The salient features of the results and discussion on gca and sca effects of twelve traits are given in the following paragraphs.

4.5.1 Days to flower initiation

This trait is most important for earliness or lateness in brinjal. Early initiation of flowering generally produced early fruits. The data revealed that gca effects of parent varied from -1.57 (GRB 7) to 0.91 (JNB-110 and DOLI 5). Estimation of gca effects indicated that parents PLR 1 and GRB 7 had significant and negative gca effects and were found to be good general combiners for earliness. On the other hand, ISD-006, JNB-110 and DOLI 5 exhibited significant and positive effects. Hence, they were good general combiners towards lateness.

Estimates of sca effects revealed that four crosses expressed significant sca effects. Out of these significant crosses, one and three crosses had negative and positive sca effects, respectively. The range of sca effects was from -2.11 (PLR 1 x GRB 7) to 4.04 (PLR 1 x GJB 3).

4.5.2 Days to flowering

This character is considered to be important for earliness or lateness in brinjal. A plant having lesser days to flowering mostly produced early fruits. The data revealed that gca effects of parent varied from -1.99 (PLR 1) to 1.29 (DOLI 5). Estimation of gca effects indicated that parents PLR 1 and GRB 7 had significant and negative gca effects and were found to be good general combiners for earliness. While JNB-110 and DOLI 5 exhibited significant and positive effects. So, they were good general combiners towards late flowering.

Estimates of sca effects revealed that nine crosses expressed significant sca effects. Out of these, significant crosses, four and five crosses had negative and positive sca effects, respectively. The range of sca effects was from -4.04 (JNB-110 x DOLI 5) to 5.94 (GJB 3 x DOLI 5).

4.5.3 Days to maturity

Three out of seven parents showed a significant gca effect for days to maturity. The range of gca effect was observed from -2.28 (GRB 7) to 1.86 (JNB-110). The parents PLR 1 and GRB 7 had significant and negative gca effects for days to maturity indicating that they were good combiners for early maturity.

The estimates of sca effects, four cross combinations showed significant effects for days to maturity. Out of these significant crosses, two crosses each showed negative and positive sca effect. The range of estimate sca effect for days to maturity was -3.26 (PLR 1 x JBCL-16-12) to 6.49 (GJB 3 x JNB-110).

Table 4.4 Analysis of variance for combining ability for twelve characters in brinjal

Source of variation	d.f.	Days to flower initiation	Days to flowering	Days to maturity	Number of flowers per cluster	Number of primary branches per plant	Number of fruits per plant	Fruit length	Fruit girth	Plant height	Fruit weight	Fruit volume	Fruit yield per plant
GCA	6	10.60**	15.38**	21.77**	0.39**	1.07**	1.25**	5.28**	39.46**	246.23**	1590.25**	1629.86**	0.73**
SCA	21	3.31**	9.40**	7.83**	0.13**	0.96**	1.29**	4.85**	4.87**	62.49**	1483.26**	989.35**	0.44**
Error	54	1.07	1.72	3.41	0.008	0.03	0.04	0.15	0.66	1.36	26.67	13.82	0.01
σ^2gca		1.05	1.51	2.03	0.04	0.11	0.13	0.57	4.31	27.20	173.73	179.56	0.07
σ^2sca		2.24	7.68	4.42	0.13	0.93	1.25	4.69	4.20	61.12	1456.59	975.53	0.42
σ^2gca/σ^2sca		0.47	0.19	0.46	0.32	0.12	0.10	0.12	1.02	0.44	0.11	0.18	0.18

*,** Significant at P=0.05 and P=0.01, respectively against error mean square.

4.5.4 Number of flowers per cluster

The estimates of gca effects revealed that six parents expressed significant gca effects. The range of gca effect of parents was observed -0.22 (ISD-006) to 0.44 (GRB 7). GRB 7 and JNB-110 observed a significant and positive gca effect of parents which indicates good general combiner for number of flowers per cluster.

Out of 21 crosses, eleven crosses exhibited significant sca effects. Out of these, five crosses were significant with positive values. The range of sca effects was observed from -0.67 (GRB 7 x JNB-110) to 0.59 (JBCL-16-12 x JNB-110) for number of flowers per cluster.

4.5.5 Number of primary branches per plant

The estimates of gca effects revealed that four parents expressed significant gca effects. The range of gca effect of parents was observed -0.67 (ISD-006) to 0.46 (PLR 1). PLR 1, GJB 3 and DOLI 5 recorded significant and positive gca effect which suggested that a good general combiner for number of primary branches per plant.

Out of 21 crosses, 20 crosses exhibited significant sca effects. Out of these, twelve crosses were significant with positive values. The range of sca effects was observed from -1.87 (PLR 1 x JNB-110) to 1.55 (JBCL-16-12 x ISD-006) for number of primary branches per plant.

4.5.6 Number of fruits per plant

The estimates of gca effects indicated that of seven parents studied, four parents showed significant gca effects. The gca effects ranged from -0.67 (GJB 3) to 0.52 (JBCL-16-12). Two parents, JBCL-16-12 (0.39) and JNB-110 (0.33) identified as good general combiners as they exhibited significant and positive gca effect for this character.

Estimates of sca effects showed that 15 crosses noticed significant sca effects of which, four crosses had significant and positive sca effects. The corresponding range was observed from -1.59 (PLR 1 x JBCL-16-12) to 1.57 (JBCL-16-12 x ISD-006) for number of fruits per plant.

4.5.7 Fruit length

Out of seven parents, six parents showed significant gca effects. The gca effects ranged from -1.07 (JBCL-16-12) to 0.95 (GJB 3). Three parents *viz.*, GJB 3, JNB-110 and DOLI 5 exhibited significant and positive gca effect, thereby indicating good general combiners for fruit length.

Out of 21 crosses, seven crosses showed significant and positive sca effects. The corresponding range was observed -3.71 (GRB 7 x DOLI 5) to 4.45 (GRB 7 x ISD-006) for fruit length.

4.5.8 Fruit girth

Only three parents showed significant gca effects. However, parent GJB 3 exhibited a significant and positive gca effect. So, GJB 3 is considered a good general combiner. The range of gca effects was observed from -2.03 (JNB-110) to 4.45 (GJB 3) for fruit girth.

Seven crosses found significant and positive sca effect for fruit girth. The corresponding range was -3.89 (GJB 3 x ISD-006) to 4.17 (PLR 1 x DOLI 5).

4.5.9 Plant height

All seven parents showed significant gca effects. The range of gca effect was observed from -6.45 (GRB 7) to 5.96 (ISD-006). The parents PLR 1, JBCL-16-12, ISD-006 and JNB-110 showed significant and positive gca effects for plant height indicating that they were good combiners for the tall plant. For this trait, tallness in the positive direction is desirable.

The results on sca effects indicated that 19 crosses showed significant sca effects. The corresponding range was -9.09 (GJB 3 x JNB-110) to 21.21 (JBCL-16- 12 x JNB-110) for this trait. The 10 crosses showed a significant and positive sca effect for plant height.

4.5.10 Fruit weight

Six parents showed significant gca effects. The range of gca effect was observed from -18.72 (GRB 7) to 16.06 (GJB 3). The parents PLR 1, GJB 3 and DOLI 5 expressed significant and positive gca effects, thereby indicating that they were good combiners for fruit weight.

The results on sca effects indicated that 17 crosses showed significant sca effects. The corresponding range was -46.37 (JBCL-16-12 x DOLI 5) to 70.03 (ISD-006 x DOLI 5) for this trait. The ten crosses showed a significant and positive sca effect for fruit weight.

Table 4.5 Estimation of general combining ability effect associated with each parent for various brinjal characters

Parents	Days to flower initiation	Days to flowering	Days to maturity	Number of flowers per cluster	Number of primary branches per plant	Number of fruits per plant
PLR 1	-1.47 **	-1.99 **	-2.03 **	-0.07 *	0.46 **	0.27 **
GRB 7	-1.57 **	-1.61 **	-2.28 **	0.44 **	0.01	-0.17 **
GJB 3	0.48	0.83 *	0.81	-0.07 *	0.12 *	-0.67 **
JBCL-16-12	-0.00	0.02	0.52	-0.04	0.01	0.52 **
ISD-006	0.75 *	0.34	0.84	-0.22 **	-0.67 **	-0.10
JNB-110	0.91 **	1.12 **	1.86 **	0.06 *	-0.11	0.09
DOLI 5	0.91 **	1.29 **	0.28	-0.09 **	0.16 **	0.06
S.E. (g_i)	0.32	0.40	0.57	0.02	0.05	0.06
Range	-1.57 to 0.91	-1.99 to 1.29	-2.28 to 1.86	-0.22 to 0.44	-0.67 to 0.46	-0.67 to 0.52

*, ** indicate the level of significance at 5% and 1%, respectively.

Table 4.5 *Contd...*

Parents	Fruit length	Fruit girth	Plant height	Fruit weight	Fruit volume	Fruit yield per plant
PLR 1	-0.67 **	0.15	4.91 **	14.37 **	14.97 **	-0.06
GRB 7	-0.16	-0.97 **	-6.45 **	-18.72 **	-15.19 **	0.18 **
GJB 3	0.95 **	4.45 **	-5.01 **	16.06 **	18.01 **	-0.59 **
JBCL-16-12	-1.07 **	-0.12	1.53 **	-5.92 **	-5.76 **	-0.04
ISD-006	-0.35 **	-0.36	5.96 **	-9.63 **	-14.95 **	0.24 **
JNB-110	0.47 **	-2.03	3.71 **	-5.50 **	-3.35 **	0.09 *
DOLI 5	0.82 **	-1.11 **	-4.65 **	9.34 **	6.28 **	0.19 **
S.E. (gi)	0.12	0.25	0.36	1.59	1.14	0.03
Range	-1.07 to 0.95	-2.03 to 4.45	-6.45 to 5.96	-18.72 to 16.06	-15.19 to 18.01	-0.59 to 0.24

*, ** indicate the level of significance at 5% and 1%, respectively.

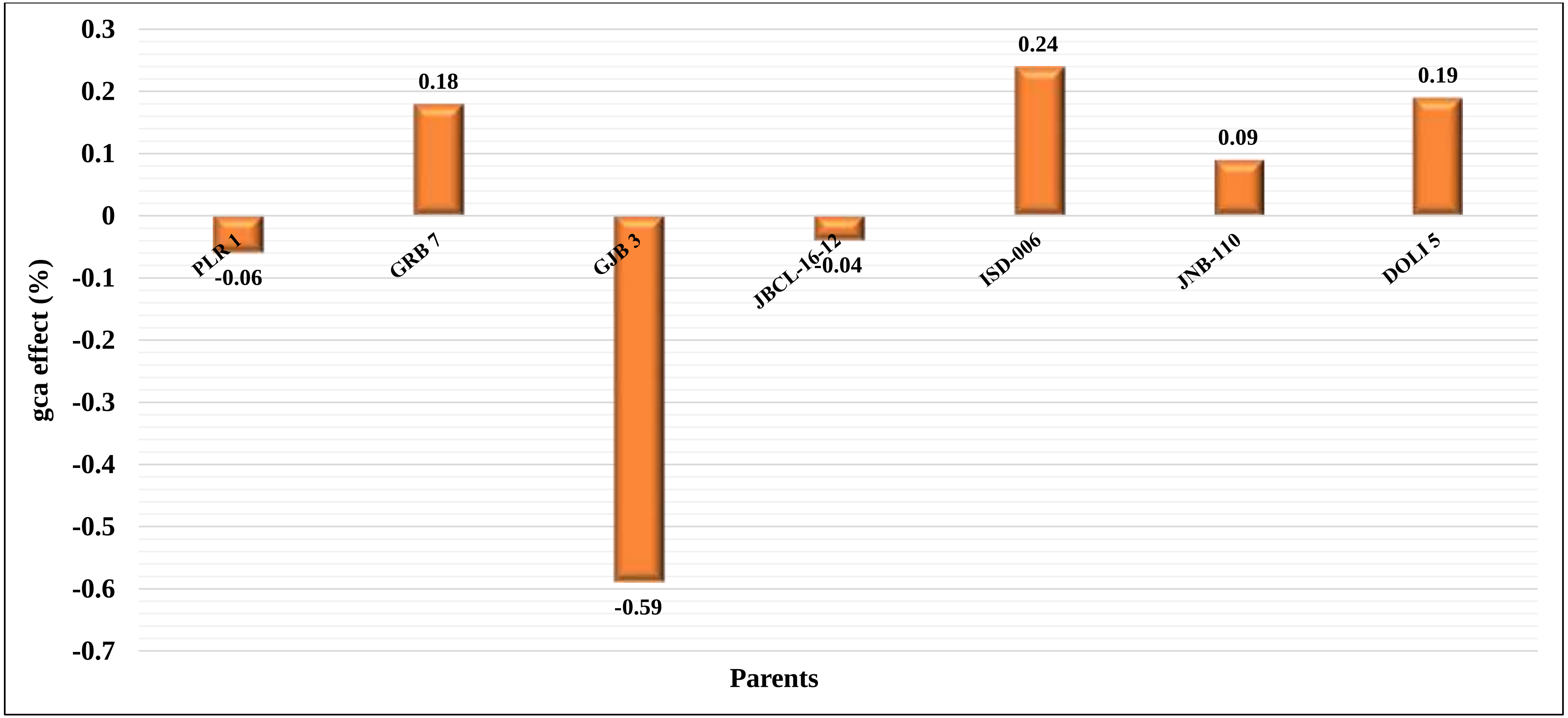

Fig. 4.3. Graphical representation of gca effet for fruit yield per plant

4.5.11 Fruit volume

All seven parents showed significant gca effects. The range of gca effects was observed from -15.19 (GRB 7) to 18.01 (GJB 3) for fruit volume. However, parent PLR 1, GJB 3 and DOLI 5 exhibited significant and positive gca effects, thereby indicating that they were good combiners for fruit volume.

The results on sca effects indicated that 16 crosses showed significant sca effects. The corresponding range was -36.83 (GJB 3 x ISD-006) to 60.31 (PLR 1 x DOLI 5) for this trait. The nine crosses showed significant and positive sca effect fruit volume.

4.5.12 Fruit yield per plant

The range of gca effects was observed from -0.59 (GJB 3) to 0.24 (ISD-006) for fruit yield per plant. The gca effects of the parents indicated that parents ISD-006 (0.24) and DOLI 5 (0.19) were found good general combiners for fruit yield per plant. Whereas, GJB 3 (-0.59) and PLR 1 (-0.06) were found poor general combiners for fruit yield per plant (Fig. 4.3).

With regard to sca effects, 15 hybrids showed significant effects. Out of them four crosses showed significant and positive sca effects. The sca effects ranged from -1.04 (JBCL-16-12 x DOLI 5) to 1.41 (PLR 1 x JBCL-16-12) (Fig. 4.4).

The success of any breeding programme largely depends upon choice of parents and the breeding procedure adopted. Sprague and Tatum (1942) provided the concept of general and specific combining ability. Combining ability is an efficient tool to discriminate good as well as poor general combiners for choosing suitable parental lines in a hybridization programme. It also provides information of specific promising combination to exploit heterosis. General combining ability is the result of additive effect and specific combining ability of non-allelic interaction effects which was explained by Jinks (1958). Whereas the statistical concept of general and specific combining ability was presented by Griffing (1956[b]). Fisher (1918) outlined the partition of total genotypic variance into additive and non-additive components. The breeder will primarily be interested in a higher magnitude of additive genetic variance for the establishment of superior genotypes.

Table 4.6 Estimates of specific combining ability effects associated with each hybrid for various brinjal characters

Hybrids	Days to flower initiation	Days to flowering	Days to maturity	Number of flowers per cluster
PLR 1 x GRB 7	-2.11 **	-1.37	0.74	-0.45 **
PLR 1 x GJB 3	4.04 **	3.84 **	-3.15 *	-0.02
PLR 1 x JBCL-16-12	-1.40	-1.71	-3.26 *	-0.24 **
PLR 1 x ISD-006	2.12 **	1.36	-0.44	0.08
PLR 1 x JNB-110	0.84	0.19	1.07	-0.34 **
PLR 1 x DOLI 5	1.96 *	-0.62	-0.21	0.01
GRB 7 x GJB 3	-0.29	-1.53	1.63	0.50 **
GRB 7 x JBCL-16-12	1.15	-1.72	0.59	0.16 *
GRB 7 x ISD-006	-0.45	-3.73 **	-1.53	0.06
GRB 7 x JNB-110	-1.34	-2.54 *	-2.42	-0.67 **
GRB 7 x DOLI 5	-0.76	-0.04	2.10	-0.49 **
GJB 3 x JBCL-16-12	-0.14	-2.51 *	-1.17	0.04
GJB 3 x ISD-006	0.72	-1.17	1.04	-0.06
GJB 3 x JNB-110	0.25	2.73 **	6.49 **	0.01
GJB 3 x DOLI 5	1.11	5.94 **	3.41 *	-0.02
JBCL-16-12 x ISD-006	0.83	1.70	1.47	-0.28 **
JBCL-16-12 x JNB-110	-0.64	4.26 **	-0.69	0.59 **
JBCL-16-12 x DOLI 5	-1.14	0.00	-1.70	0.53 **
ISD-006 x JNB-110	0.42	0.55	1.99	0.08
ISD-006 x DOLI 5	1.36	3.34 **	1.31	0.38 *
JNB-110 x DOLI 5	-0.83	-4.04 **	1.22	-0.06
S.E.(Sij) ±	0.79	1.00	1.40	0.07
Range	-2.11 to 4.04	-4.04 to 5.94	-3.26 to 6.49	-0.67 to 0.59
No. of positive significant	03	05	02	05
No. of negative significant	01	04	02	06
Total significant	04	09	04	11

*, ** indicate the level of significance at 5% and 1%, respectively.

Table 4.6 *Contd...*

Hybrids	Number of primary branches per plant	Number of fruits per plant	Fruit length	Fruit girth
PLR 1 x GRB 7	0.86 **	-0.88 **	-1.21 **	0.54
PLR 1 x GJB 3	0.42 **	-0.31 *	3.51 **	-1.74 **
PLR 1 x JBCL-16-12	-1.22 **	0.98 **	0.79 **	1.37 *
PLR 1 x ISD-006	1.07 **	-1.95 **	-2.20 **	-1.86 **
PLR 1 x JNB-110	-1.87 **	-0.75 **	-0.24	1.93 **
PLR 1 x DOLI 5	-0.67 **	1.24 **	-1.01 **	4.17 **
GRB 7 x GJB 3	-0.58 **	-0.44 **	-0.44	0.08
GRB 7 x JBCL-16-12	0.82 **	-0.76 **	1.28 **	0.14
GRB 7 x ISD-006	-0.78 **	-0.97 **	4.45 **	0.75
GRB 7 x JNB-110	-0.64 **	-0.58 **	1.27 **	-1.08
GRB 7 x DOLI 5	0.78 **	0.72 **	-3.71 **	1.36 *
GJB 3 x JBCL-16-12	0.50 **	-0.14	1.97 **	-0.38
GJB 3 x ISD-006	-1.50 **	0.47 **	-0.47	-3.89 **
GJB 3 x JNB-110	1.05 **	-0.24	-2.17 **	3.16 **
GJB 3 x DOLI 5	-0.03	-0.51 **	-2.42 **	-0.83
JBCL-16-12 x ISD-006	1.55 **	1.15 **	-0.05	2.07 **
JBCL-16-12 x JNB-110	-0.73 **	-0.98 **	-0.39	-2.98 **
JBCL-16-12 x DOLI 5	0.53 **	-2.19 **	-3.02 **	-3.11 **
ISD-006 x JNB-110	0.88 **	-0.35 *	-0.32	2.04 **
ISD-006 x DOLI 5	0.32 *	1.70 **	0.77 *	-0.59
JNB-110 x DOLI 5	0.38 **	0.29	1.40 **	-1.86 **
S.E.(Sij) ±	0.14	0.15	0.30	0.62
Range	-1.87 to 1.55	-2.19 to 1.70	-3.71 to 4.45	-3.89 to 4.17
No. of positive significant	12	06	07	07
No. of negative significant	08	12	08	06
Total significant	20	18	15	13

*, ** indicate the level of significance at 5% and 1%, respectively.

Table 4.6 *Contd...*

Hybrids	Plant height	Fruit weight	Fruit volume	Fruit yield per plant
PLR 1 x GRB 7	8.68 **	-21.14 **	-25.26 **	-0.58 **
PLR 1 x GJB 3	6.05 **	38.78 **	37.18 **	-0.14
PLR 1 x JBCL-16-12	-0.57	64.31 **	39.21 **	1.41 **
PLR 1 x ISD-006	-4.91 **	-36.34 **	-33.72 **	0.03
PLR 1 x JNB-110	-1.82 *	23.37 **	6.85 *	-0.75 **
PLR 1 x DOLI 5	-6.14 **	39.40 **	60.31 **	0.12
GRB 7 x GJB 3	2.21 *	-2.24	-5.02	0.67 **
GRB 7 x JBCL-16-12	-5.33 **	20.07 **	5.33	-0.24 *
GRB 7 x ISD-006	3.68 **	43.39 **	54.19 **	-0.67 **
GRB 7 x JNB-110	-8.61 **	-5.23	-10.89 **	-0.06
GRB 7 x DOLI 5	-0.88	-23.67 **	-16.46 **	-0.58 **
GJB 3 x JBCL-16-12	5.58 **	39.23 **	28.56 **	0.22 *
GJB 3 x ISD-006	1.80 *	-40.56 **	-36.83 **	-0.24 **
GJB 3 x JNB-110	-9.09 **	46.25 **	40.50 **	-0.47 **
GJB 3 x DOLI 5	-7.81 **	-17.44 **	-13.81 **	-0.56 **
JBCL-16-12 x ISD-006	-6.24 **	-9.74 *	-4.12	-0.53 **
JBCL-16-12 x JNB-110	21.21 **	-32.49 **	-25.42 **	0.01
JBCL-16-12 x DOLI 5	9.49 **	-46.37 **	-36.10 **	-1.04 **
ISD-006 x JNB-110	2.01 *	2.65	7.27 *	-0.40 **
ISD-006 x DOLI 5	9.46 **	70.03 **	19.29 **	0.59 **
JNB-110 x DOLI 5	-2.68 **	-0.24	2.26	-0.15
S.E.(Sij) ±	0.89	3.96	2.83	0.09
Range	-9.09 to 21.21	-46.37 to 70.03	-36.83 to 60.31	-1.04 to 1.41
No. of positive significant	10	10	09	04
No. of negative significant	09	07	07	11
Total significant	19	17	16	15

*, ** indicate the level of significance at 5% and 1%, respectively.

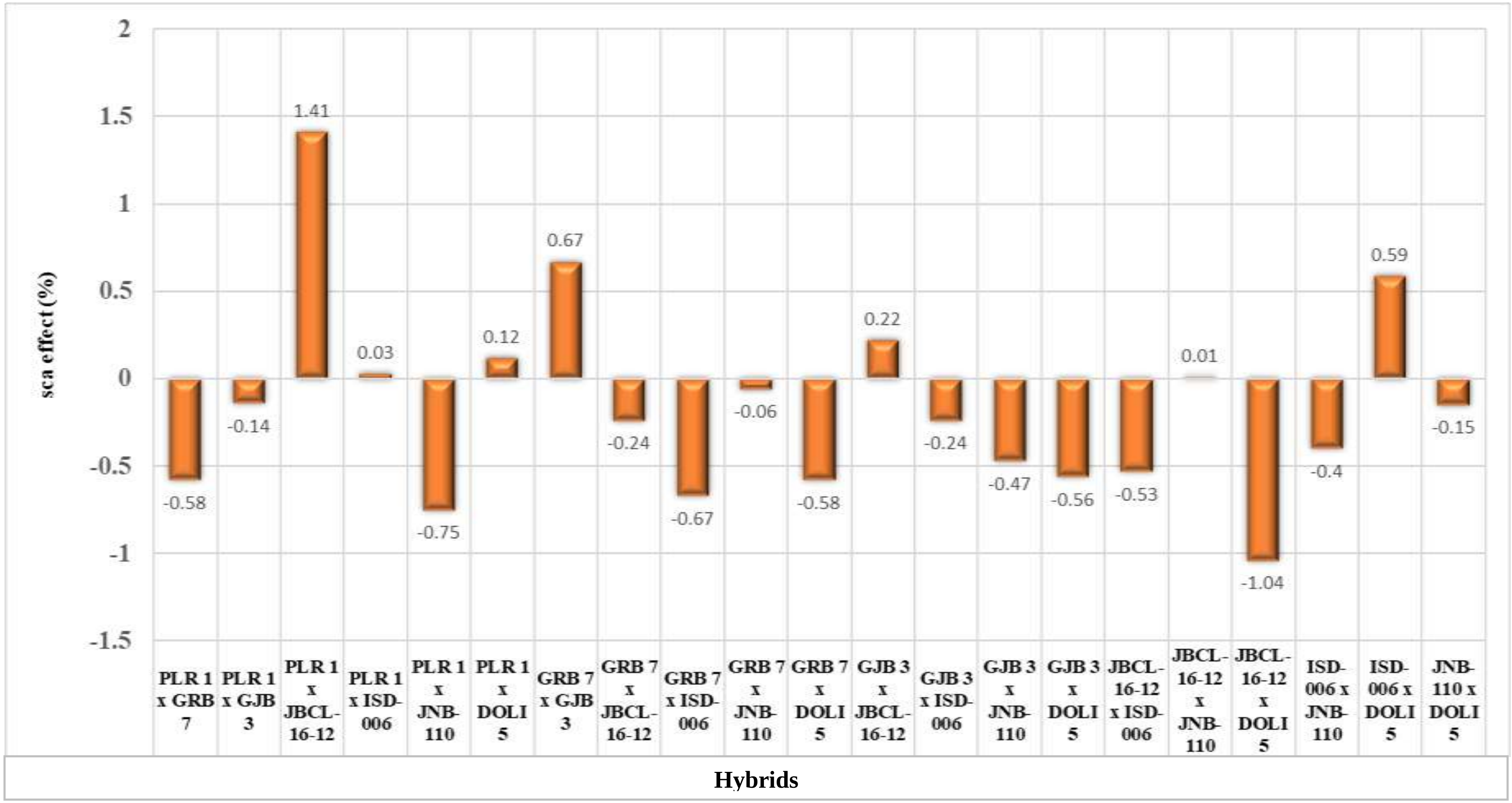

Fig.4.4. Graphical representation of sca effect of hybrids for fruit yield per plant

On the other side, specific, combining ability is mainly a function of dominance variance, if epistasis is present, it would, generally, include additive x dominance and dominance x dominance type of gene interaction. The selection of suitable parents with desirable characters is essential for the exploitation of heterosis. Accordingly, the present investigation was undertaken to have an idea of the combining ability for yield and its components in brinjal with a view to identify good combiners which may be used to build up a population with favourable genes for effective yield improvement in brinjal. The parents are classified as good, average and poor general combiner for different traits based on estimates of gca effect (Table 4.7).

PLR 1 and GJB 3 were good general combiners for days to flower initiation; days to flowering and days to maturity; GRB 7 and JNB-110 for number of flowers per cluster; PLR 1 , GJB 3 and DOLI 5 for number of primary branches per plant; PLR 1 and JBCL-16-12 for number of fruits per plant; GJB 3, JNB-110 and DOLI 5 for fruit length; GJB 3 for fruit girth; PLR 1 , JBCL-16-12, ISD-006 and JNB-110 for plant height; PLR 1, GJB 3 and DOLI 5 for fruit weight; PLR 1, GJB 3 and DOLI 5 for fruit volume and DOLI 5, JNB-110 and GRB 7 for fruit yield per plant.

As regards to specific combining ability effects, the best cross combination were PLR 1 x GRB 7 for days to flower initiation; JNB-110 x DOLI 5, GRB 7 x ISD-006 and GJB 3 x JNB-110 for days to flowering; PLR 1 x JBCL-16-12 and PLR 1 x GJB 3 for days to maturity; JBCL-16-12 x JNB-110, JBCL-16-12 x DOLI 5 and GRB 7 x GJB 3 for number of flowers per cluster; JBCL-16-12 x ISD-006, PLR 1 x ISD-006 and GJB 3 x JNB-110 for number of primary branches per plant; JBCL-16-12 x ISD-006, GRB 7 x DOLI 5 and JNB-110 x DOLI 5 for number of fruits per plant; GRB 7 x ISD-006, PLR 1 x GJB 3 and GJB 3 x JBCL-16-12 for fruit length; PLR 1 x DOLI 5, GJB 3 x JNB-110 and JBCL-16-12 x ISD-006 for fruit girth; JBCL-16-12 x JNB-110, JBCL-16-12 x DOLI 5 and ISD-006 x DOLI 5 for plant height; PLR 1 x DOLI 5, GRB 7 x ISD-006 and GJB 3 x JNB-110 for fruit weight; PLR 1 x DOLI 5, GRB 7 x ISD-006 and GJB 3 x JNB-110 for fruit volume and PLR 1 x JBCL-16-12, GRB 7 x GJB 3 and ISD-006 x DOLI 5 for fruit yield per plant.

Table 4.7 Classification of parents with respect to general combining ability (gca) effects for twelve characters in brinjal

Parents	Days to flower initiation	Days to flowering	Days to maturity	Number of flowers per cluster	Number of primary branches per plant	Number of fruits per plant
PLR 1	G	G	G	P	G	G
GRB 7	G	G	G	G	A	P
GJB 3	P	P	A	P	G	P
JBCL-16-12	A	A	A	A	A	G
ISD-006	P	A	A	P	P	A
JNB-110	P	P	P	G	A	A
DOLI 5	P	P	A	P	G	A

Table 4.7 ***Contd…***

Parents	Fruit length	Fruit girth	Plant height	Fruit weight	Fruit volume	Fruit yield per plant
PLR 1	P	A	G	G	G	A
GRB 7	A	P	P	P	P	G
GJB 3	G	G	P	G	G	P
JBCL-16-12	P	A	G	P	P	A
ISD-006	P	A	G	P	P	G
JNB-110	G	A	G	P	P	A
DOLI 5	G	P	P	G	G	G

Estimates of σ^2_{gca} and σ^2_{sca} revealed that the magnitude of SCA variance was higher than the GCA variance for all the characters except fruit girth suggesting the involvement of non-additive gene action in the inheritance of these characters.

However, the perusal of $\sigma^2_{gca}/\sigma^2_{sca}$ ratio revealed a preponderance of non-additive gene action for fruit yield and the majority of yield contributing traits. As the preponderance of non-additive gene action and high heterosis is apparent for fruit yield and the majority of yield contributing traits, it is recommended that heterosis breeding could be used for the exploitation of hybrid vigour on a commercial scale.

The importance of non-additive genetic variances for fruit yield per plant has been reported by several workers such as Makani *et al*. (2016), Dubey *et al*. (2014), Ansari and Singh (2014), Desai *et al*. (2017), Kachouli *et al*. (2019) and Siva *et al.* (2020). For days to initiation and days to flowering by Singh and Mital (1988) and Deshmukh *et al*. (2014), Sharma *et al.* (2016), Desai *et al*. (2017) and Siva *et al.* (2020). For days to maturity by Aswani and Khandelwal (2005) and Singh *et al.* (2013[b]); For number of flowers per cluster by Nalini *et al*. (2011). For number of primary branches per plant by Peter and Singh (1974), Shinde and Patil (1984). For number of fruits per plant by Chadha and Hedge (1989) and Chaudhary (2001). For fruit length Bhutani *et al.* (1980), Patel (1990). For fruit weight by Ingale Patil (1997) and Deshmukh *et al*. (2014). For fruit volume Bhakta *et al.* (2009) and Makani *et al.* (2016). For fruit weight by Siva *et al*. (2020) and Deshmukh *et al*. (2014), Kachouli *et al.* (2019). For plant height by Siva *et al.* (2020), Singh and Mital (1988) and Kachouli *et al.* (2019). A preponderance of additive gene action was reported for fruit girth by Makani *et al.* (2016) and Patel *et al.* (2017[b]).

For the improvement of the material under investigation, it was suggested that (i) characters having a predominance of additive genetic variance could be improved by simple selection following the pedigree method of selection. (ii) characters having a predominance of non-additive genetic variance could be improved by the exploitation of hybrids vigour for commercial utilization.

A list of three best parents selected based on *per se* performance and gca effects and three best F_1 crosses based on *per se* performance, heterosis over mid parent, better parent and standard check and sca effects of various characters studied is given in Table 4.8. A perusal of this table revealed that in most cases, linearity was found between standard heterosis and sca effects. This means that a cross showing the highest standard heterosis may the show highest sca effects. With respect to specific combining ability effects, the following conclusion could be drawn from the present study;

1. No cross combination exhibited consistently high specific combining ability effects for all the characters studied.
2. The crosses exhibiting high sca effects did not always involve parents with high gca effects suggesting that interallelic interactions were important for the characters.
3. Crosses having high sca effects for fruit yield may or may not have high sca effects for yield contributing characters.

The cross exhibiting high specific combining ability effects for various characters suggested the possibilities of improvement of such characters by selection and hybridization. The cross exhibiting high positive or negative specific combining ability effects involved either average x good, average x poor, poor x good and poor x poor parents. Therefore, information on combining ability alone may not be sufficient to predict the extent of heterosis. Hence, information on combining ability effects needs to be supplemented by that of *per se* performance.

High sca denotes undoubtedly a high heterotic response, but this may be due to the very poor performance of the parents in comparison with their hybrids. With the same amount of heterotic effects, the sca may be less, where the mean performance of the parents was higher but this estimate may also be biased (Ziauddin *et al.*,1979). This suggested that the selection of cross combination based on a heterotic response would be more realistic rather than based on sca effects.

The marked undesirable effect in crosses between good x good and good x average combiners could be attributed to the lack of co-adaption between favourable alleles of the parents involved, whereas marked desirable specific combining ability effects in crosses between poor x poor, poor x average, or average x average could be due to better complementation between favourable alleles of parents involved. The present investigation suggested that non-additive genetic variances were important for most of the characters. So, suggested attempting heterosis breeding for enhancing the fruit yield potential of brinjal.

The overall summarized accounts of results and discussion revealed that the cross PLR 1 x JBCL-16-12 recorded high fruit yield per plant and reported a higher heterotic effect along with a positive sca effect for fruit yield per plant and its contributing characters (Plate III). Hence, this cross was identified as potential for getting good transgressive segregants for fruit yield per plant and its contributing characters and suggested further evaluation for generation advancement in the future breeding programme to isolate good transgressive segregants for fruit yield per plant.

P1
(PLR 1)

P2
(JBCL-16-12)

F_1
(PLR 1 x JBCL-16-12)

Plate III. Best cross based on *per se* performance and heterosis

Table 4.8 Three best parents selected on the basis of *per se* performance and gca effects and three best crosses selected on the basis of *per se* performance, heterosis over mid parent, better parent and standard check and sca effects for twelve characters in brinjal

Characters	*Per se* performance		Combining ability effects		Magnitude of heterosis over		
	Parents	F_1	GCA	SCA	Mid parent	Better Parent	Standard Check
Days to flower initiation	PLR 1 GJB 3 GRB 7	PLR 1 x GRB 7 PLR 1 x JBCL-16-12 GRB 7 x JNB-110	GRB 7 PLR 1	PLR 1 x GRB 7	GRB 7 x JNB-110	-	PLR 1 x GRB 7
Days to flowering	PLR 1 GJB 3 ISD-006	GRB 7 x JBCL-16-12 PLR 1 x GJB 3 GRB 7 x GJB 3	PLR 1 GRB 7	JNB-110 x DOLI 5 GRB 7 x ISD-006 GJB 3 x JNB-110	GRB 7 x ISD-006 GRB 7 x JNB-110 GRB 7 x JBCL-16-12	GRB 7 x ISD-006 GRB 7 x JNB-110	-
Days to maturity	GRB 7 GJB 3 DOLI 5	PLR 1 x JBCL-16-12 PLR 1 x GJB 3 PLR 1 x GRB 7	GRB 7 PLR 1	PLR 1 x JBCL-16-12 PLR 1 x GJB 3	PLR 1 x JBCL-16-12	-	-
Number of flowers per cluster	GRB 7 PLR 1 JNB-110	GRB 7 x GJB 3 JBCL-16-12 x JNB-110 GRB 7 x JBCL-16-12	GRB 7 JNB-110	JBCL-16-12 x JNB-110 JBCL-16-12 x DOLI 5 GRB 7 x GJB 3	JBCL-16-12 x DOLI 5 JBCL-16-12 x JNB-110 ISD-006 x DOLI 5	JBCL-16-12 x DOLI 5 JBCL-16-12 x JNB-110 ISD-006 x DOLI 5	GRB 7 x GJB 3 JBCL-16-12 x JNB-110 GRB 7 x JBCL-16-12
Number of primary branches per plant	PLR 1 GJB 3 JNB-110	PLR 1 x GRB 7 GJB 3 x JNB-110 PLR 1 x GJB 3	PLR 1 DOLI 5 GJB 3	JBCL-16-12 x ISD-006 PLR 1 x ISD-006 GJB 3 x JNB-110	JBCL-16-12 x ISD-006 GRB 7 x JBCL-16-12 JBCL-16-12 x DOLI 5	JBCL-16-12 x ISD-006 GRB 7 x DOLI 5 GRB 7 x JBCL-16-12	PLR 1 x GRB 7 GJB 3 x JNB-110
Number of fruits per plant	JBCL-16-12 JNB-110 PLR 1	PLR 1 x JBCL-16-12 ISD-006 x DOLI 5 PLR 1 x DOLI 5	JBCL-16-12 PLR 1	JBCL-16-12 x ISD-006 GRB 7 x DOLI 5 JNB-110 x DOLI 5	ISD-006 x DOLI 5 JBCL-16-12 x ISD-006 PLR 1 x DOLI 5	JBCL-16-12 x ISD-006 GRB 7 x DOLI 5 JNB-110 x DOLI 5	PLR 1 x JBCL-16-12 ISD-006 x DOLI 5 PLR 1 x DOLI 5

Table 4.8s *Contd…*

Characters	*Per se* performance		Combining ability effects		Magnitude of heterosis over		
	Parents	F_1	GCA	SCA	Mid parent	Better Parent	Standard Check
Fruit length	DOLI 5 GJB 3 JNB-110	GRB 7 x ISD-006 PLR 1 x GJB 3 JNB-110 x DOLI 5	GJB 3 DOLI 5 JNB-110	GRB 7 x ISD-006 PLR 1 x GJB 3 GJB 3 x JBCL-16-12	GRB 7 x ISD-006 PLR 1 x GJB 3 GRB 7 x JBCL-16-12	GRB 7 x ISD-006 PLR 1 x GJB 3 GRB 7 x JBCL-16-12	GRB 7 x ISD-006 PLR 1 x GJB 3 JNB-110 x DOLI 5
Fruit girth	GJB 3 JBCL-16-12 ISD-006	GJB 3 x JNB-110 GJB 3 x JBCL-16-12 GRB 7 x GJB 3	GJB 3	PLR 1 x DOLI 5 GJB 3 x JNB-110 JBCL-16-12 x ISD-006	PLR 1 x DOLI 5 PLR 1 x JNB-110 PLR 1 x GRB 7	PLR 1 x DOLI 5	GJB 3 x JNB-110 GJB 3 x JBCL-16-12 GRB 7 x GJB 3
Plant height	PLR 1 ISD-006 JNB-110	JBCL-16-12 x JNB-110 ISD-006 x JNB-110 ISD-006 x DOLI 5	ISD-006 PLR 1 JNB-110	JBCL-16-12 x JNB-110 JBCL-16-12 x DOLI 5 ISD-006 x DOLI 5	JBCL-16-12 x JNB-110 JBCL-16-12 x DOLI 5 GJB 3 x JBCL-16-12	JBCL-16-12 x DOLI 5 JBCL-16-12 x JNB-110 GJB 3 x JBCL-16-12	JBCL-16-12 x JNB-110
Fruit weight	DOLI 5 GJB 3 PLR 1	PLR 1 x JBCL-16-12 ISD-006 x DOLI 5 PLR 1 x DOLI 5	GJB 3 PLR 1 DOLI 5	ISD-006 x DOLI 5 PLR 1 x DOLI 5 GJB 3 x JNB-110	PLR 1 x JBCL-16-12 ISD-006 x DOLI 5 PLR 1 x GJB 3	PLR 1 x JBCL-16-12 PLR 1 x JNB-110 GRB 7 x ISD-006	PLR 1 x JBCL-16-12 ISD-006 x DOLI 5 PLR 1 x GJB 3
Fruit volume	GJB 3 DOLI 5 PLR 1	PLR 1 x DOLI 5 PLR 1 x GJB 3 GJB 3 x JNB-110	GJB 3 PLR 1 DOLI 5	PLR 1 x DOLI 5 GRB 7 x ISD-006 GJB 3 x JNB-110	PLR 1 x DOLI 5 GRB 7 x ISD-006 PLR 1 x GJB 3	GRB 7 x ISD-006 PLR 1 x DOLI 5 PLR 1 x JBCL-16-12	PLR 1 x DOLI 5 PLR 1 x GJB 3 GJB 3 x JNB-110
Fruit yield per plant	DOLI 5 JNB-110 GRB 7	PLR 1 x JBCL-16-12 ISD-006 x DOLI 5 PLR 1 x DOLI 5	ISD-006 DOLI 5 GRB 7	PLR 1 x JBCL-16-12 GRB 7 x GJB 3 ISD-006 x DOLI 5	PLR 1 x JBCL-16-12	PLR 1 x JBCL-16-12	PLR 1 x JBCL-16-12

SUMMARY AND CONCLUSIONS

V. SUMMARY AND CONCLUSIONS

The present investigation on **“Heterosis and combining ability study in Brinjal (*Solanum melongena* L.)”** was undertaken with a view to study the heterosis, combining ability and nature of gene action for fruit yield and other traits in order to suggest a sound breeding methodology for the developing of high yielding genotypes in brinjal. The experimental material comprised of seven parents and their twenty-one resultant hybrids derived from half-diallel mating and one standard check (GJBH 4). These 29 genotypes were evaluated in a Randomized Block Design with three replications at the Horticulture Instructional Farm, C. P. College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar during *rabi* 2021. The observations on five randomly selected plants were recorded for twelve characters (except days to flower initiation, days to flowering, days to maturity and number flowers per cluster) *viz*., number of primary branches per plant, number of fruits per plant, fruit length, fruit girth, plant height, fruit weight, fruit volume and fruit yield per plant. The salient findings of the present study are summarized below:

1. The analysis of variance for the experimental design revealed highly significant mean squares among the genotype, parents and hybrids indicating enormous genetic variation among the genotypes. The mean squares due to parents *vs*. hybrids were also found significant for days to flower initiation, number of primary branches per plant, number of fruits per plant, fruit length, plant height, fruit weight, fruit volume and fruit yield per plant which indicated that the performance of parents as a group was different than that of crosses as a group, thereby supporting the presence of mean heterosis for characters studied. Significant mean square for various characters indicating the presence of considerable genetic diversity in the material studied.
2. The study of mean values indicated that the parent DOLI 5 exhibited the highest fruit yield per plant followed by JNB-110 and were also superior for yield contributing traits. Considering *per se* performance of hybrids, the superior cross combinations for fruit yield per plant were PLR 1 x JBCL-16-12, ISD-006 x DOLI 5 and PLR 1 x DOLI 5. These cross combinations also had high *per se* performance for one or more yield contributing traits.

3. The crosses expressed desirable relative heterosis and heterobeltiosis, respectively for different characters *viz*., GRB 7 x JNB-110 for days to flower initiation; GRB 7 x ISD-006 and GRB 7 x JNB-110 for days to flowering; PLR 1x JBCL-16-12 for days to maturity; JBCL-16-12 x DOLI 5, JBCL-16-12 x JNB-110 and ISD-006 x DOLI 5 for number of flowers per cluster; JBCL-16-12 x ISD-006 for number of primary branches per plant; JBCL-16-12 x ISD-006 for number of fruits per plant; GRB 7 x ISD-006, PLR 1 x GJB 3 and GJB 3 x JBCL-16-12 for fruit length; PLR 1 x DOLI 5 for fruit girth; JBCL-16-12 x JNB-110, JBCL-16-12 x DOLI 5 and GJB 3 x JBCL-16-12 for plant height; PLR 1 x DOLI 5 and GRB 7 x ISD-006 for fruit weight; PLR 1 x DOLI 5 and GRB 7 x ISD-006 for fruit volume; PLR 1 x JBCL-16-12 for fruit yield per plant. Such crosses could be exploited further for yield advancement in brinjal.
4. Significant standard heterosis in the desirable direction was reported for all characters except for days to flowering and days to maturity. Standard heterosis for fruit yield per plant was ranged from -64.87 per cent (GJB 3 x JNB-110) to 12.5 per cent (PLR 1 x JBCL-16-12). Out of 21 hybrids, only one hybrid *viz*., PLR 1 x JBCL-16-12 (12.5 per cent) recorded higher positive standard heterosis for fruit yield per plant.
5. The analysis of variance for combining ability revealed that mean squares were found highly significant for all the characters under study. These findings indicated more importance of non-additive gene action as compared to additive gene action in the expression of fruit yield and its component traits. The non-additive gene action was observed in the inheritance of fruit yield and other yield-associated traits.
6. The magnitude of σ^2_{sca} was higher than σ^2_{gca} for all the characters except fruit girth, indicating a preponderance of non-additive gene action in the expression of yield and yield attributing traits and these traits can be improved by heterosis breeding. These hybrids would be advantageous for production and quality improvement. The character like fruit girth showed additive gene action which can be improved by reciprocal recurrent selection.

7. The results on gca effects of the parents indicated that none of the parents was found to be a good general combiner simultaneously for all the characters. The estimates of gca effects of parents include PLR 1 and GJB 3 for days to flower initiation, days to flowering and days to maturity respectively, GRB 7 and JNB-110 for number of flowers per cluster; PLR 1, GJB 3 and DOLI 5 for number of primary branches per plant; PLR 1 and JBCL-16-12 for number of fruits per plant; GJB 3, JNB-110 and DOLI 5 for fruit length; GJB 3 for fruit girth; PLR 1, JBCL-16-12, ISD-006 and JNB-110 for plant height; PLR 1, GJB 3 and DOLI 5 for fruit weight; PLR 1, GJB 3 and DOLI 5 for fruit volume and DOLI 5, JNB-110 and GRB 7 for fruit yield per plant.
8. As regards to specific combining ability effects, the best cross combination was PLR 1 x GRB 7 for days to flower initiation; JNB-110 x DOLI 5 for days to flowering; PLR 1 x JBCL-16-12 for days to maturity; BCL-16-12 x JNB-110 for flowers per cluster; JBCL-16-12 x ISD-006 for number of primary branches; JBCL-16-12 x ISD-006 for number of fruits per plant; GRB 7 x ISD-006 for fruit length; PLR 1 x DOLI 5 for fruit girth; JBCL-16-12 x JNB-110 for plant height; PLR 1 x DOLI 5 for fruit weight; PLR 1 x DOLI 5 for fruit volume and PLR 1 x JBCL-16-12, GRB 7 x GJB 3, ISD-006 x DOLI 5 for fruit yield per plant.
9. Parents exhibiting high mean performance also evinced good general combining ability effects for most of the characters. This showed consonance between *per se* performance and gca effects of parents that could be used as a reliable and efficient selection criterion for good combiners for different characters based on *per se* performance of parents.
10. In a summarized account of the present findings, it can be concluded that the cross PLR 1 x JBCL-16-12 recorded high fruit yield per plant and reported a higher heterotic effect along with a positive sca effect for fruit yield per plant and its contributing characters. Hence, this cross was identified as potential for getting good transgressive segregants for fruit yield per plant and its contributing characters and suggested to further evaluation for generation advancement in the future breeding programme to isolate good transgressive segregants for fruit yield per plant.

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APPENDICES

APPENDICES

APPENDIX I: Weekly meteorological data recorded during the crop seasons (November 2021 to May 2022)

Months	Std. Weeks	Temperature (ºc)		Relative humidity (%)		Rainfall (mm)	Rainy Days
		Max.	Min.	Morning	Evening		
November 2021	47	28.9	17.5	77	55	31.0	2
December 2021	48	31.6	15.4	74	47	0.0	0
	49	28.1	13.6	70	35	0.0	0
	50	26.5	10.6	70	32	0.0	0
	51	25.2	7.6	70	30	0.0	0
	52	27.1	11.7	76	41	3.0	1
January 2022	01	25.9	12.7	76	53	0.0	0
	02	21.9	7.0	67	45	0.0	0
	03	24.9	8.5	68	39	0.0	0
	04	25.0	6.0	57	35	0.0	0
	05	27.6	8.8	65	33	0.0	0
February 2022	06	27.9	9.5	64	31	0.0	0
	07	30.3	10.0	65	29	0.0	0
	08	32.4	12.6	69	26	0.0	0
	09	32.9	15.4	69	23	0.0	0
March 2022	10	35.0	16.1	69	22	0.0	0
	11	39.2	17.7	71	20	0.0	0
	12	38.8	18.1	71	25	0.0	0
	13	40.5	19.5	76	22	0.0	0
April 2022	14	42.2	22.5	77	23	0.0	0
	15	41.1	22.5	73	30	0.0	0
	16	40.7	21.8	75	37	0.0	0
	17	41.4	22.3	71	38	0.0	0
	18	42.0	23.8	70	42	0.0	0
May 2022	19	43.1	24.0	68	38	0.0	0
	20	41.6	25.0	68	43	0.0	0
	21	39.0	25.2	80	54	0.0	0

Source:- Agricultural Meteorology Department, C.P.C.A., S.D.A.U. Sardarkrushinagar.

Appendix-B: Mean performance of the parents and their F_1 hybrids for twelve characters in brinjal

Sr. No.	Genotypes	Days to flower initiation	Days to flowering	Days to maturity	Number of flowers per cluster	Number of primary branches	Number of fruits per plant
1	PLR 1	43.47	50.83	76.07	2.90	7.45	15.91
2	GRB 7	47.90	57.89	72.40	3.88	5.61	15.66
3	GJB 3	47.25	53.65	75.00	2.19	6.13	13.80
4	JBCL-16-12	49.82	55.68	80.93	2.08	5.10	16.55
5	ISD-006	48.15	55.29	77.27	1.99	3.71	14.31
6	JNB-110	51.61	57.31	77.40	2.88	6.06	16.03
7	DOLI 5	50.11	55.93	75.00	2.22	5.48	14.04
	Hybrids						
8	PLR 1 x GRB 7	44.00	58.33	73.93	2.47	7.15	13.76
9	PLR 1 x GJB 3	52.19	51.97	73.13	2.39	6.82	13.84
10	PLR 1 x JBCL-16-12	46.27	55.36	72.73	2.21	5.06	16.31
11	PLR 1 x ISD-006	50.55	54.97	75.87	2.34	6.68	12.76
12	PLR 1 x JNB-110	49.42	54.33	78.40	2.22	4.30	14.16
13	PLR 1 x DOLI 5	50.54	53.33	75.53	2.41	5.77	16.12
14	GRB 7 x GJB 3	47.76	52.34	77.67	3.43	5.37	13.27
15	GRB 7 x JBCL-16-12	48.73	50.65	76.33	3.12	6.66	14.13
16	GRB 7 x ISD-006	47.88	52.61	74.53	2.83	4.38	13.31
17	GRB 7 x JNB-110	47.14	55.28	74.67	2.39	5.08	13.89
18	GRB 7 x DOLI 5	47.72	53.99	77.60	2.42	6.77	15.16

Sr. No.	Genotypes		Days to flower initiation	Days to flowering	Days to maturity	Number of flowers per cluster	Number of primary branches	Number of fruits per plant
19	GJB 3 x JBCL-16-12		49.48	55.65	77.67	2.49	6.45	14.26
20	GJB 3 x ISD-006		51.09	60.33	80.20	2.21	3.77	14.25
21	GJB 3 x JNB-110		50.78	63.71	86.67	2.56	6.88	13.73
22	GJB 3 x DOLI 5		51.63	57.71	82.00	2.39	6.07	13.43
23	JBCL-16-12 x ISD-006		50.73	61.05	80.33	2.02	6.70	16.11
24	JBCL-16-12 x JNB-110		49.41	56.96	79.20	3.17	4.99	14.18
25	JBCL-16-12 x DOLI 5		48.91	57.65	76.60	2.96	6.51	12.94
26	ISD-006 x JNB-110		51.23	60.62	82.20	2.48	5.91	14.19
27	ISD-006 x DOLI 5		52.16	54.01	79.93	2.63	5.63	16.21
28	JNB-110 x DOLI 5		50.13	55.28	80.87	2.48	6.25	15.00
29	GJBH 4 (Check)		49.01	53.98	76.20	2.36	6.33	14.66
	Parental Mean		48.32	55.23	76.29	2.59	5.65	15.19
	Hybrid mean		49.41	55.79	77.90	2.55	5.87	14.33
	General Mean		49.14	55.65	77.50	2.56	5.81	14.55
	Range	**Parent**	43.47 to 51.61	50.83 to 57.89	72.40 to 80.93	1.99 to 3.88	3.71 to 7.45	13.80 to 16.55
		Hybrid	44.00 to 52.19	50.65 to 63.71	72.73 to 86.67	2.02 to 3.43	3.77 to 7.15	12.76 to 16.32
	S. Em. ±		1.03	1.31	1.84	0.09	0.18	0.20
	C.D. (5%)		2.90	3.67	5.17	0.25	0.52	0.57
	C.V. %		3.60	4.08	4.12	6.15	5.51	2.40

Appendix-B: ***Contd…***

Sr. No.	Genotypes	Fruit length (cm)	Fruit girth (cm)	Plant height (cm)	Fruit weight (g)	Fruit volume (cm^3)	Fruit yield per plant (kg)
1	PLR 1	8.10	16.79	64.54	83.89	99.61	1.86
2	GRB 7	8.11	15.86	44.42	66.30	80.62	3.10
3	GJB 3	11.15	29.41	46.51	109.43	122.67	1.09
4	JBCL-16-12	6.83	19.89	46.85	79.99	96.70	2.02
5	ISD-006	7.45	18.72	63.60	75.36	79.00	3.10
6	JNB-110	10.41	14.04	62.00	81.18	94.97	3.10
7	DOLI 5	14.89	16.89	46.10	117.16	116.78	3.21
	Hybrids						
8	PLR 1 x GRB 7	7.21	18.41	62.78	83.84	86.47	1.55
9	PLR 1 x GJB 3	13.03	21.56	61.26	178.54	182.11	1.23
10	PLR 1 x JBCL-16-12	8.31	20.09	61.15	182.09	160.37	3.33
11	PLR 1 x ISD-006	6.03	16.62	61.29	77.73	78.24	2.22
12	PLR 1 x JNB-110	8.81	18.75	62.06	141.57	130.43	1.30
13	PLR 1 x DOLI 5	8.40	21.90	49.71	172.44	193.51	2.27
14	GRB 7 x GJB 3	9.60	22.25	47.93	104.43	109.75	2.26
15	GRB 7 x JBCL-16-12	9.30	17.74	46.30	104.76	96.33	1.92
16	GRB 7 x ISD-006	13.20	18.11	59.06	124.37	136.00	1.76
17	GRB 7 x JNB-110	10.83	14.62	45.87	79.87	82.53	2.21
18	GRB 7 x DOLI 5	6.21	17.97	43.89	76.28	86.58	1.80
19	GJB 3 x JBCL-16-12	11.09	22.64	58.23	158.69	152.76	1.60
20	GJB 3 x ISD-006	9.37	18.90	59.67	75.20	78.18	1.42
21	GJB 3 x JNB-110	8.50	24.29	45.45	166.13	167.12	1.04

Sr. No.	Genotypes		Fruit length (cm)	Fruit girth (cm)	Plant height (cm)	Fruit weight (g)	Fruit volume (cm^3)	Fruit yield per plant (kg)
22	GJB 3 x DOLI 5		8.60	21.21	37.99	117.29	122.43	1.06
23	JBCL-16-12 x ISD-006		7.78	20.28	57.36	84.04	87.12	1.68
24	JBCL-16-12 x JNB-110		8.26	13.57	82.24	65.42	77.42	2.08
25	JBCL-16-12 x DOLI 5		5.98	14.35	62.18	66.38	76.37	1.12
26	ISD-006 x JNB-110		9.05	18.34	66.79	96.84	100.93	1.94
27	ISD-006 x DOLI 5		10.49	16.63	65.91	179.07	122.58	3.04
28	JNB-110 x DOLI 5		11.94	13.69	50.85	112.93	117.15	2.14
	Check							
29	GJBH 4		10.27	17.88	67.95	111.95	107.55	2.96
	Parental mean		9.56	18.80	53.31	87.61	98.62	2.49
	Hybrid mean		9.14	18.66	56.37	116.57	116.40	1.85
	General Mean		9.25	18.70	55.61	109.33	111.95	2.01
	Range	**Parent**	6.83 to 14.89	14.04 to 29.41	44.42 to 64.54	66.30 to 117.16	79.00 to 122.67	1.09 to 3.21
		Hybrid	5.98 to 13.20	13.57 to 24.29	37.99 to 82.24	65.42 to 182.09	76.37 to 193.51	1.04 to 3.33
	S. Em. ±		0.39	0.81	1.16	5.16	3.71	0.12
	C.D. (5%)		1.10	2.27	3.27	14.46	10.40	0.35
	C.V. %		7.29	7.53	3.56	8.18	5.71	10.43

CERTIFICATE

This is to certify that I have no objection for supplying to any scientist only one copy or any part of this thesis at a time through reprographic process, if necessary for rendering reference service in a library or documentation centre.

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