Received: 09 Apr 2023 | Revised: 30 May 2023 | Accepted: 08 Jun 2023

Electronic Journal of Plant Breeding

Research Article

Study of heterosis, combining ability and gene action in brinjal (*Solanum melongena* L.) landraces of Odisha

Subha Laxmi Mishra[1*], Pradyumna Tripathy[1], Gouri Shankar Sahu[1], Devraj Lenka[2], Mihira Kumara Mishra[3], Swapan Kumar Tripathy[4], Gargi Gautami Padhiary[1], Anita Mohanty[5] and Swarnalata Das[5]

[1]Department of Vegetable Science, College of Agriculture, OUAT, Bhubaneswar- 751003, Odisha, India
[2]Department of Plant Breeding and Genetics, College of Agriculture, OUAT, Bhubaneswar- 751003, Odisha, India
[3]Department of Plant Pathology, College of Agriculture, OUAT, Bhubaneswar- 751003, Odisha, India
[4]Department of Molecular Biology and Biotechnology, College of Agriculture, OUAT, Bhubaneswar- 751003, Odisha, India
[5]AICRP on Vegetable Crops, College of Agriculture, OUAT, Bhubaneswar- 751003, Odisha, India
***E-Mail:**subhalaxmimishra02@gmail.com

Abstract
Twenty one F_1 crosses resulting from half diallel mating of seven diverse local landraces of brinjal were studied to know the magnitude of heterosis. The results revealed that, among the 21 crosses, BBSR-08-2 × Selection from BBSR-145-1, BBSR-08-2 × BBSR-10-25 and BBSR-08-2 × BBSR-10-26 exhibited significantly positive heterosis for vegetative growth, fruit yield and fruit yield attributing traits over mid parent, better parent and standard check. The combining ability analysis revealed that, the parents *viz*. BBSR-08-2, BBSR-10-26 and BBSR-195-3 were good general combiners for plant height, primary branches plant^{-1}, fruit length, fruit girth, average fruit weight, number of fruits plants^{-1}, incidence of bacterial wilt (%) at 90 DAT and fruit yield plant^{-1}. The estimate of *sca* effect indicated that F_1 crosses *viz.* BBSR-08-2 × BBSR-10-25, BBSR-08-2 × BBSR-10-26, BBSR-08-2 × Selection from BBSR-145-1 and BBSR-10-26 × BBSR-195-3 were most promising for vegetative traits, fruit yield attributes, reaction to incidence of bacterial wilt at 90 DAT and fruit yield plant^{-1}. Analysis of gene action revealed prevalence of both additive and non additive gene action for yield and its contributing traits. Thus, it may be concluded that, crosses involving parents *viz.* BBSR-08-2, BBSR-10-26 and BBSR-195-3 exhibited higher heterosis for fruit yield and tolerance to bacterial wilt.

Keywords: Heterosis, Combining ability, Gene action, Brinjal, Landraces

INTRODUCTION

Brinjal (*Solanum melongena* L.) belongs to the family Solanaceae, has chromosome number 2n= 24. It is one of the most common, popular and principal vegetable crop grown in India. India is regarded as the primary centre of origin (Vavilov, 1931). Brinjal has several ayurvedic medicinal properties and it's good for diabetic patients (Gangadhara *et al.*, 2021). It has also been recommended as an excellent remedy for people suffering from liver complaints (Shukla and Naik, 1993). In India, brinjal is grown in an area of 0.753 m ha with total production of 13.023 m t having an average productivity of 17.3 t/ha (3rd advance estimate 2021-2022,GOI). India is the second largest producer of brinjal next only to China. The major brinjal producing states in the country are West Bengal, Odisha, Gujarat, Bihar and Madhya Pradesh. Odisha stands second in brinjal production with share of 16.34% (3rd advance estimate 2021-2022, GOI). Odisha being a major source of diverse local landraces hastens the scope of brinjal improvement with the preference of local consumers.

Exploitation of hybrid vigour or heterosis is one of the most reliable crop improvement methods which utilize the heterozygous lines to develop hybrids with higher yield. Nagai and Kida (1926) were the first to observe hybrid vigour in brinjal. The commercial exploitation of this phenomenon has been possible in the brinjal because of the low cost of F_1 seed production and the low seed requirement per unit area (Chaudhari *et al*., 2020). Selection of parental lines is very crucial in developing hybrids for commercialization. Combining ability effects rank among the important parameters commonly used by plant breeders to evaluate genetic potential of the materials which aids heterosis breeding more feasible (Kumar and Arumugam, 2013). Besides this, combining ability of parents give useful information on making the choice of parents in terms of expected performance of their hybrids and progenies (Dhillion, 1975). Knowledge about the nature of gene effects as measured by of general combining ability and specific combining ability is always helpful in selection of effective and efficient breeding method. Therefore, the present study was undertaken to find out extent of heterosis, general combiners and specific combiners in seven diverse landraces of Odisha and their 21 F_1 crosses developed through half diallel mating.

MATERIALS AND METHODS

The present investigation was carried out at All India Coordinated Research Project on Vegetable Crops, OUAT, Bhubaneswar, Odisha, India during *Rabi* 2021-2022. Six divergent landraces of brinjal *viz*., BBSR-08-02, BBSR-10-25, BBSR-10-26, BBSR-9-6, BSR-195-3 and Selection from BBSR-145-1 and one bacterial wilt susceptible variety, Arka Neelanchal Shyama were used in the hybridization programme. The resultant 21 F_1 crosses evolved through half diallel mating (excluding the reciprocals) along with seven parents and one hybrid check Mahy Green of Mahyco Private Limited, India were studied by adopting RBD. One month old seedlings were transplanted in the main field during September, 2021. Recommended package of practices were adopted uniformly for raising of the crops. Observations were recorded for vegetative, flowering and fruit yield and yield attributes and percentage of incidence of bacterial wilt at 90 days after transplanting (DAT). Percentage disease incidence (PDI) of F_1 hybrids was calculated as per Bainsla *et al*. (2016).

Bacterial wilt PDI (%) =

$$\frac{\text{Number of wilted plant due to bacterial wilt disease}}{\text{Total number of plants}} \times 100$$

The magnitude of percent heterosis of F_1 over mid parent (MP), better parent (BP) and commercial checks was calculated as per procedure suggested by Fonseca and Paterson (1968).

Relative Heterosis (%) *i.e* heterosis over mid parent (MP) =

$$RH = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

Where,

MP = Mean performance of parent P_1 and P_2

F_1 = Mean performance of F_1 hybrid

Heterobeltiosis (%) *i.e* heterosis over better parent (BP) =

$$HB = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

Where,

BP = Mean performance of better parent

F_1 = Mean performance of F_1 hybrid

Standard Heterosis (%) *i.e* heterosis over standard hybrid =

$$SH = \frac{\overline{F_1} - \overline{SC}}{\overline{SC}} \times 100$$

Where,

BP = Mean performance of standard check

F_1 = Mean performance of F_1 hybrid

The combining ability analysis was carried out according to the procedure given by Griffing (1956).

RESULTS AND DISCUSSION

Mid parent or relative heterosis (RH): A perusal of **Table 2** regarding relative heterosis (RH) or average heterosis (AH) estimated for 21 F_1 crosses involving seven parents showed significant variations. The study indicated that the traits like fruit plant^{-1} and bacterial wilt incidence at 90 DAT showed maximum negative heterosis. The results on important vegetative growth parameters *viz.* plant height at final harvest, plant spread (East-West), plant spread (North- South) and primary branches plant^{-1} showed significant variations among the crosses for RH (%) ranging from (-)5.85 (C_{19}) to 33.45 (C_1), (-)9.90 (C_{10}) to 12.90 (C_{20}), (-)4.64 (C_2) to 24.96 (C_1) and (-)19.64 (C_6) to 40.26 (C_{10}), respectively. Considering all the growth parameters, the results showed relatively higher RH in the crosses *viz.* C_1, C_4, C_8, C_9 and C_{17}. Thus, the study indicated that BBSR-08-2, BBSR-10-25, BBSR-09-6 and BBSR-195-3 should be considered for exploitation of hybrid vigour in brinjal for vegetative traits. The results are in agreement with Deshmukh *et al.* (2015), Shahjahan *et al.* (2016), Pramila *et al.* (2017), Mistry *et al.* (2018), Reddy *et al.* (2020), Makasare *et al*. (2020), Bagade *et al*. (2020), and Rameshkumar and Vethamonai (2020).

Regarding the flowering parameters *viz.* days to 1st flowering and days to 50% flowering, the study showed significant variations ranging from (-)3.90 (C_{14}) to 21.75 (C_{20}) and (-)6.74 (C_{17}) to 20.66 (C_{13}), respectively. Considering the earliness, the F_1 crosses *viz.* C_{14} and C_{17} showed negative heterosis. The results also showed that the parents, BBSR-10-25 and Selection from BBSR-145-1induced earliness to their progeny which may be considered in brinjal improvement programme. Similar

Table 1. Details of parents and crosses

S. No.	Parents	Notations
1	BBSR-08-2	P_1
2	BBSR-10-25	P_2
3	BBSR-10-26	P_3
4	BBSR-09-6	P_4
5	BBSR-195-3	P_5
6	Selection from BBSR-145-1	P_6
7	Arka Neelanchal Shyama	P_7
F_1 Crosses		
1	BBSR-08-2 × BBSR-10-25	C_1
2	BBSR-08-2 × BBSR-10-26	C_2
3	BBSR-08-2 × BBSR-09-6	C_3
4	BBSR-08-2 × BBSR-195-3	C_4
5	BBSR-08-2 × Selection from BBSR-145-1	C_5
6	BBSR-08-2 × Arka Neelanchal Shyama	C_6
7	BBSR-10-25 × BBSR-10-26	C_7
8	BBSR-10-25 × BBSR-09-6	C_8
9	BBSR-10-25 × BBSR-195-3	C_9
10	BBSR-10-25 × Selection from BBSR-145-1	C_{10}
11	BBSR-10-25 × Arka Neelanchal Shyama	C_{11}
12	BBSR-10-26 × BBSR-09-6	C_{12}
13	BBSR-10-26 × BBSR-195-3	C_{13}
14	BBSR-10-26 × Selection from BBSR-145-1	C_{14}
15	BBSR-10-26 × Arka Neelanchal Shyama	C_{15}
16	BBSR-09-6 ×BBSR-195-3	C_{16}
17	BBSR-09-6 × Selection from BBSR-145-1	C_{17}
18	BBSR-09-6 × Arka Neelanchal Shyama	C_{18}
19	BBSR-195-3 × Selection from BBSR-145-1	C_{19}
20	BBSR-195-3 × Arka Neelanchal Shyama	C_{20}
21	Selection from BBSR-145-1 × Arka Neelanchal Shyama	C_{21}

findings were also confirmed by Ramireddy *et al*. (2011), Deshmukh *et al*. (2015), Shahjahan *et al*. (2016), Mistry *et al.* (2018), Ramesh kumar and Vethamonai (2020), Reddy *et al.* (2020) and Makasare *et al*. (2020).

In brinjal the fruit yield plant^{-1} primarily depends not only on vegetative traits but also on fruit yield attributing parameters *viz*. fruit length, fruit girth, average fruit weight and fruits plant^{-1}. The results showed significant variations among 21 F_1 crosses for fruit yield attributing parameters *viz*. fruit length, fruit girth, average fruit weight and fruit plant^{-1} which varied from (-)8.22 (C_{16}) to 18.62 (C_4), (-)15.98 (C_{18}) to 25.23 (C_9), (-)6.04 (C_{16}) to 56.52 (C_1) and (-)33.89 (C_8) to 23.59 (C_1), respectively. Considering all the fruit yield attributing traits the study also showed significantly higher RH for the crosses *viz*. C_1, C_5 and C_9 , which revealed that the parents *viz*. BBSR-08-2 and BBSSR-10-25 may be used in further hybridization programme for higher RH for fruit yield attributing traits in brinjal. The findings are in agreement with Deshmukh *et al*. (2015), Pramila *et al*. (2017), Mistry *et al.* (2018), Makasare *et al*. (2020) and Reddy *et al.* (2020).

Regarding the incidence of bacterial wilt at 90 DAT the data on RH showed significant variations ranging from (-)61.41 (C_3, C_8, and C_{19}) to 132.94 (C_{10}). The results also indicated that out of 21 F_1 crosses, 11 crosses showed negative or 0.00 RH which is considered as desirable trait for resistance or tolerance to bacterial wilt disease.

In the present study significant variations were observed for fruit yield plant^{-1} ranging from (-)12.37 (C_{10}) to 62.57 (C_1). The study also showed that out of 21 F_1 crosses, nine crosses showed significantly posistive RH. F_1 crosses *viz*. C_1, C_5, C_3, C_2 and C_9 showed more than 25% RH over their corresponding parents. Similar type of results were also reported by Pramila *et al*. (2017), Mistry *et al.* (2018), Reddy *et al.* (2020), Bagade *et al.* (2020) and Rameshkumar and Vethamonai (2020).

Table 2. Percentage of Relative Heterosis (RH)

S. No.	Crosses	PH	PS E-W	PS N-S	PB	DFF	D50F	FL	FG	AFW	FP	TSS	AA	BW	FYP
1	C_1	33.45**	10.71**	24.96**	9.89	10.44**	-2.13	18.44**	17.28**	56.52**	23.59**	23.25**	15.38*	0.00	62.57**
2	C_2	23.16**	-8.32**	-4.64	-1.15	15.06**	18.63**	18.62**	15.51*	52.10**	-11.76	37.61**	16.89**	0.00	39.36**
3	C_3	17.76**	-2.13	13.95*	7.32	2.86	5.26*	6.37	6.52	21.17*	-8.31	16.54**	17.58**	-61.41	41.51**
4	C_4	15.49**	6.05*	19.31**	12.36*	-1.97	7.44**	18.59**	21.26**	27.73**	-7.43	19.17**	29.39**	-44.31	24.98**
5	C_5	13.47**	0.61	-2.56	27.50**	7.98**	2.39	14.80*	16.58*	47.87**	5.97	11.71*	25.05**	44.31	56.54**
6	C_6	17.53**	-1.75	1.36	-19.64**	9.09**	11.05**	0.85	-0.98	3.36	-5.06	14.68**	23.04**	15.70	15.57*
7	C_7	12.58**	1.39	-3.47	11.90*	9.64**	-3.13	14.84*	-4.54	6.06	-15.38*	19.16**	19.12**	0.00	-11.63
8	C_8	23.82**	6.29*	15.94*	8.86	6.56*	-4.06	-2.33	-11.58	6.81	-33.89**	16.46**	14.87*	-61.41	8.89
9	C_9	17.73**	4.74	3.28	4.65	14.98**	-2.35	16.91**	25.23**	33.83**	7.93	17.25**	18.28**	44.31	25.35**
10	C_{10}	16.28**	-9.90**	22.47**	40.26**	-0.53	2.64	15.43**	20.68**	2.57	-8.67	14.10**	35.16**	132.94*	-12.37*
11	C_{11}	15.91**	-0.42	0.00	-17.43**	17.77**	8.63**	5.10	2.86	-1.22	-3.81	9.62*	12.89*	15.70	3.76
12	C_{12}	-1.71	-6.79*	-2.86	20.00**	2.63	9.69**	2.30	22.18*	19.29*	-26.65**	19.98**	20.39**	61.41	4.73
13	C_{13}	9.04*	-4.16	-2.83	9.76	7.68**	20.66**	15.30**	-6.28	29.68**	-6.86	23.54**	38.64**	-44.31	18.13**
14	C_{14}	21.50**	-9.63**	6.68	17.81**	-3.90	-2.57	4.81	-1.35	4.91	6.21	21.04**	19.27**	-44.31	22.52**
15	C_{15}	19.77**	-0.10	-0.86	-10.48**	17.20**	13.03**	-1.22	0.25	0.91	-11.90	6.96	9.50	-3.34	7.99
16	C_{16}	5.01	-0.24	6.60	3.90	2.06	5.89*	-8.22	-7.07	-6.04	-24.66**	18.23**	7.43	47.82	-1.40
17	C_{17}	0.85	6.89**	7.17	29.41**	-3.19	-6.74**	0.16	-9.79	2.18	-26.10**	17.80**	10.16	23.49	4.09
18	C_{18}	15.58**	9.30**	-1.44	-14.00**	13.52**	10.60**	0.22	-15.98*	7.19	-24.24**	9.62*	13.90*	-15.41	7.72
19	C_{19}	-5.85	4.28	9.10	20.00**	12.53**	16.70**	12.72*	22.56**	42.03**	-22.44**	-2.27	31.79**	-61.41	-3.64
20	C_{20}	10.75*	12.90**	-1.86	-10.28*	21.75**	14.84**	0.00	9.32	8.44	-16.94*	2.83	13.54*	26.32	-10.25*
21	C_{21}	10.74*	6.72*	-2.44	-0.00	9.97**	7.12*	5.84	-4.20	-4.19	4.03	10.48*	17.17*	13.81	2.39

(PH-Plant height at final harvest, PS E-W -Plant spread (East-West), PS N-S - Plant spread (North-South), PB- Primary branches plant $^{-1}$, DFF- Days to 1st flowering, D50F- Days to 50% flowering, FL- Fruit length, FG- Fruit girth, AFW- Average fruit weight, FP- Fruits plant^{-1}, TSS- Fruit TSS, AA- Ascorbic acid content, BW- Incidence of bacterial wilt at 90 DAT, FYP- Fruit yield plant $^{-1}$)

Better Parent Heterosis or Heterobeltiosis (HB): Data presented in **table 3** indicated significant variations for better parent heterosis.The results on vegetative parameters like plant height at final harvest, plant spread (E-W), plant spread (N–S) and primary branches plant^{-1} showed significant variations for HB ranging from (-)13.70 (C_{19}) to 20.46 (C_{14}), (-)12.24 (C_{14}) to 10.27 (C_{20}), (-)11.34 (C_7) to 22.12 (C_{10}) and (-)33.85 (C_{18}) to 25.71 (C_{17}), respectively. The result also indicated that the F_1 cross C_1, C_{14} and C_{10} exhibited relatively higher HB in most of the growth attributes than other crosses. So the crosses involving BBSR-08-2 and BBSR-10-25 as parent exhibited better vegetative growth in brinjal. The results are in conformity with the findings of Dudhat *et al*. (2013), Deshmukh *et al*. (2015), Shahjahan *et al*. (2016), Magar *et al*. (2016), Sharma *et al*. (2016) and Singh *et al*. (2021).

The results on flowering parameters showed significant variations for days to 1st flowering and days to 50% flowering ranging from (-)9.52(C_{14}) to 14.10 (C_9) and (-)14.73 (C_7) to 19.62 (C_{13}), respectively. The crosses *viz*. C_{14} and C_{17} exhibited significant negative heterosis so it indicated that these crosses can be used for improvement of earliness in brinjal.

The result on fruit yield attributes *viz.* fruit length, fruit girth, average fruit weight and fruits per plant^{-1} showed significant variations ranging from (-)20.79 (C_{16}) to 14.23 (C_1), (-)32.18 (C_{18}) to 22.39 (C_9), (-)23.51 (C_{16}) to 52.66 (C_1) and (-)40.70 (C_8) to 11.08 (C_1), respectively. The crosses *viz*. C_1, C_5 and C_9 showed relatively higher positive HB. So these crosses can be exploited for fruit yield attributing traits as they performed superior than their better parent. The results are in agreement with Reddy *et al.* (2020), Makasare *et al*. (2020), Bagade *et al.* (2020), Rameshkumar and Vethamonai (2020) and Singh *et al*. (2021).

For bacterial wilt incidence the range of HB varied from (-) 76.09 (C_3, C_8) to 61.41 (C_{10}). The result also revealed that except the crosses C_{10} and C_{16}, rest of the F_1 crosses showed negative or 0.00 HB. The result indicated that majority of the crosses showed heterosis in desired directions indicating greater tolerance or resistance of F_1 crosses over their parents. Similar findings were also reported earlier by Bhavidoddi (2013) and Kurhade (2017). Regarding the fruit quality parameters *viz.* TSS and ascorbic acid content, results showed significant variations ranging from (-)5.06 (C_{19}) to 35.59 (C_2) and

Table 3. Percentage of Heterobeltiosis (HB)

S. no.	Crosses	PH	PS E-W	PS N-S	PB	DFF	D50F	FL	FG	AFW	FP	TSS	AA	BW	FYP
1	C_1	20.02**	9.35**	18.43**	6.38	3.52	-7.74**	14.23*	11.14	52.66**	11.08	22.22**	11.11	0.00	56.77**
2	C_2	11.20**	-10.39**	-7.76	-8.51	7.63**	10.25**	13.13*	0.00	44.84**	-25.00**	35.59**	15.00*	0.00	29.21**
3	C_3	16.07**	-3.78	12.39	-6.38	-1.57	4.20	2.98	-13.67	6.47	-25.13**	13.45*	12.69	-76.09**	35.16**
4	C_4	14.56**	4.46	14.86*	6.38	-7.44**	0.67	5.28	12.45	16.84*	-19.41**	17.29**	24.72**	-61.41	8.45
5	C_5	3.25	-0.06	-7.40	8.51	7.24*	0.49	6.06	11.48	38.13**	0.00	10.23	12.31	0.00	48.70**
6	C_6	-3.84	-5.44	-0.58	-30.77**	-6.07*	-1.18	0.43	-1.51	-5.38	-6.87	9.07	21.76**	-34.59*	10.70
7	C_7	12.09*	0.31	-11.34	6.82	9.40**	-14.73**	13.51*	-13.27	3.48	-20.56**	16.44**	16.56*	0.00	-20.75**
8	C_8	12.81**	3.25	11.34	-2.27	4.28	-10.42**	-8.70	-25.12**	-4.05	-40.70**	12.44*	14.30	-76.09**	0.47
9	C_9	6.66	4.45	1.61	2.27	14.10**	-13.39**	7.26	22.39**	19.68**	4.12	14.44**	18.16*	0.00	5.48
10	C_{10}	14.79**	-11.58**	22.12**	22.73**	-6.15*	-1.49	10.39	19.52*	-6.39	-13.29	13.53*	25.70**	61.41	-19.57**
11	C_{11}	4.13	-3.01	-3.44	-30.77**	7.49*	-8.18**	0.95	-3.02	-11.59	-12.03	5.10	7.62	-34.59*	-3.99
12	C_{12}	-10.08*	-10.40**	-7.28	12.50	0.21	2.92	-5.41	12.96	9.58	-30.15**	18.51**	17.22*	0.00	1.52
13	C_{13}	-0.83	-4.91	-9.40	7.14	6.61*	19.62**	6.93	-13.03	13.48	-9.44	23.40**	35.79**	-61.41	9.91
14	C_{14}	20.46**	-12.24**	-1.76	7.50	-9.52**	-11.00**	1.37	-11.15	-6.35	-5.00	17.71**	8.71	-61.41	19.43**
15	C_{15}	7.19	-1.66	-5.88	-27.69**	7.19*	7.83*	-6.18	-13.61	-11.62	-23.89**	0.31	6.62	-45.35**	4.37
16	C_{16}	4.35	-3.37	4.00	-4.76	0.64	0.17	-20.79**	-19.78*	-23.51**	-30.15**	16.92**	6.79	19.70	-10.87*
17	C_{17}	-7.02	5.79	3.20	25.71**	-6.75*	-9.39**	-10.17	-24.21**	-15.32*	-36.68**	13.20*	2.93	0.00	3.49
18	C_{18}	-4.35	3.48	-2.00	-33.85**	1.61	-0.69	-2.58	-32.18**	-12.68	-37.19**	1.63	8.07	-34.59*	7.39
19	C_{19}	-13.70**	2.05	7.64	7.14	6.94*	7.44*	7.92	18.66*	38.85**	-28.82**	-5.06	22.46**	-61.41	-12.44**
20	C_{20}	-8.80*	10.27**	-3.71	-26.15**	10.35**	8.65*	-11.55*	0.86	8.34	-26.47**	-3.67	8.34	-15.46	-19.09**
21	C_{21}	-1.65	2.05	-5.53	-24.62**	-4.76	-6.23*	-2.60	-8.86	-6.24	0.00	6.42	4.26	-23.83	1.50

(PH-Plant height at final harvest, PS E-W -Plant spread (East-West), PS N-S - Plant spread (North-South), PB- Primary branches plant $^{-1}$, DFF- Days to 1st flowering, D50F- Days to 50% flowering, FL- Fruit length, FG- Fruit girth, AFW- Average fruit weight, FP- Fruits plant^{-1}, TSS- Fruit TSS, AA- Ascorbic acid content, BW- Incidence of bacterial wilt at 90 DAT, FYP- Fruit yield plant $^{-1}$)

2.93 (C_{17}) to 35.79 (C_{13}) respectively. The crosses *viz.* C_2, C_4, C_7, C_9, C_{10}, C_{12} and C_{13} showed significantly higher HB indicating superior fruit quality in F_1 crosses.

The present study on HB for fruit yield per plant showed significant variations ranging from (-)20.75 (C_7) to 56.77 (C_1). The result also revealed that the crosses *viz.* C_1 (56.77), C_2 (29.21), C_3 (35.16) and C_5 (48.70) exhibited more than 20% HB. Hence, these F_1 crosses should be considered for future improvement programme. The results are confined to the results of Makasare *et al*. (2020), Bagade *et al.* (2020), Rameshkumar and Vethamonai (2020) and Singh *et al*. (2021).

Standard Heterosis (SH): The SH of F_1 crosses were calculated against the standard hybrid check Mahy Green. A perusal of **Table 4** indicated significant variations among the F_1 crosses. The results revealed that maximum negative SH was recorded by number of fruits plant^{-1} and incidence of bacterial wilt at 90 DAT.

The results on vegetative growth parameters *viz*. plant height at final harvest, plant spread (E-W), plant spread (N-S) and primary branches plant^{-1} showed significant variations ranging from (-)6.82 (C_{21}) to 38.71 (C_1), (-)3.13 (C_{14}) to 19.24 (C_{17}), 3.09 (C_{21}) to 34.39 (C_1) and -21.57(C_{16}) to 5.88 (C_{10}), respectively. Except the trait number of primary branches plant^{-1}, the F_1 crosses *viz.* C_1, C_3, C_4, C_8 and C_{16} showed significantly higher SH for growth attributes. It clearly indicated that, the cross involving parents *viz*. BBSR-08-2, BBSR-10-25, BBSR-09-6 and BBSR-195-3 exhibited better performance for the above traits over the standard hybrid check. Similar findings in brinjal were also reported by Dudhat *et al*. (2013), Deshmukh *et al*. (2015), Pramila *et al*. (2017), Reddy *et al.* (2020) and Singh *et al*. (2021).

Regarding the flowering attributes *viz*. days to 1st flowering and days to 50% flowering, the range of SH varied from (-)3.59 (C_{14}) to 16.28 (C_2) and (-)5.98 (C_{14}) to 13.50 (C_{19}), respectively. The result also revealed that the crosses, C_{14}, C_{16} and C_{17} negative standard heterosis for days to 1st flower and days to 50% flower which indicated earliness in flowering. In brinjal, similar results were earlier reported by Ramireddy *et al*. (2011), Dudhat *et al*. (2013), Sharma *et al*. (2016), Rani *et al*. (2018) and Singh *et al*. (2021).

Table 4. Percentage of Standard Heterosis (SH)

S. No.	Crosses	PH	PS E-W	PS N-S	PB	DFF	D50F	FL	FG	AFW	FP	TSS	AA	BW	FYP
1	C_1	38.71**	19.11**	34.39**	-1.96	11.84**	5.98*	20.42**	62.10**	75.66**	3.24	22.09**	16.96*	-80.03**	26.95**
2	C_2	28.52**	-2.40	12.00	-15.69**	16.28**	12.14**	22.08**	45.86**	66.67**	-20.59**	33.19**	21.05**	-80.03**	22.46**
3	C_3	34.15**	8.46*	27.54**	-13.73*	6.34*	5.98*	0.83	25.92*	22.52*	-12.35	11.43*	18.62*	-80.03**	20.24**
4	C_4	32.40**	13.78**	30.34**	-1.96	-0.00	2.39	32.92**	64.01**	62.10**	-19.41**	15.21**	31.29**	-80.03**	19.41**
5	C_5	19.32**	10.32**	5.08	0.00	15.86**	6.15*	22.50**	62.61**	83.07**	-16.47*	11.21*	18.23*	-48.24*	33.81**
6	C_6	11.13*	3.00	12.81	-11.76*	1.48	0.51	-1.67	45.22**	31.03**	-28.24**	18.76**	30.90**	0.00	-2.12
7	C_7	4.38	6.59*	7.66	-7.84	3.38	-2.05	22.50**	13.25	13.21	-15.88*	16.32**	18.71*	-80.03**	-24.90**
8	C_8	26.64**	16.38**	22.90**	-15.69**	2.96	2.91	-3.75	-2.23	4.96	-30.59**	12.32*	11.40	-80.03**	-10.62
9	C_9	21.26**	10.99**	6.70	-11.76*	9.51**	-0.51	35.42**	59.81**	66.05**	4.12	14.32*	15.40*	-48.24*	16.14**
10	C_{10}	8.76	-2.40	24.82**	5.88	0.00	13.16**	27.50**	59.11**	24.07*	-19.41**	14.54**	22.51**	-16.46	-27.62**
11	C_{11}	-3.88	3.06	5.38	-11.76*	1.59	5.47	6.42	42.99**	22.43*	-18.24*	14.43**	15.69*	0.00	-15.11*
12	C_{12}	0.94	1.00	12.59	-11.76*	-1.06	2.56	2.08	20.51*	14.05	-18.24*	12.99*	19.40**	-16.46	-3.79
13	C_{13}	12.76**	0.47	10.01	-11.76*	2.33	6.32*	35.00**	8.41	57.45**	-4.12	17.65**	38.30**	-80.03**	21.01**
14	C_{14}	14.13**	-3.13	19.29*	-15.69**	-3.59	-5.98*	17.08*	18.28	24.11*	0.59	18.76**	10.72	-80.03**	13.19*
15	C_{15}	-0.19	2.26	14.29	-7.84	0.85	-5.81*	1.25	27.39**	22.38*	-19.41**	9.21	14.62	-16.46	-1.09
16	C_{16}	18.64**	8.92**	14.80*	-21.57**	-0.63	-0.17	0.00	-0.00	6.12	-18.24*	11.21*	4.29	0.00	-1.86
17	C_{17}	4.38	19.24**	13.92	-13.73*	-0.63	-4.27	3.75	0.89	12.23	-25.88**	14.21*	-0.68	-16.46	-6.87
18	C_{18}	7.38	16.64**	8.17	-15.69**	0.32	-1.03	-5.42	0.00	20.92*	-26.47**	10.65	16.18*	0.00	-4.46
19	C_{19}	-1.88	12.65**	13.03	-11.76*	13.95**	13.50**	36.25**	57.96**	92.64**	-28.82**	-4.22	19.59**	-80.03**	-3.59
20	C_{20}	3.69	16.51**	5.08	-5.88	5.92*	-3.42	11.67	48.73**	50.31**	-26.47**	4.88	16.47*	29.25	-10.91
21	C_{21}	-6.82	12.65**	3.09	-3.92	1.48	-0.94	12.50	34.39**	29.83**	-16.47*	15.87**	12.09	16.46	-8.66

(PH-Plant height at final harvest, PS E-W -Plant spread (East-West), PS N-S - Plant spread (North-South), PB- Primary branches plant $^{-1}$, DFF- Days to 1st flowering, D50F- Days to 50% flowering, FL- Fruit length, FG- Fruit girth, AFW- Average fruit weight, FP- Fruits plant^{-1}, TSS- Fruit TSS, AA- Ascorbic acid content, BW- Incidence of bacterial wilt at 90 DAT, FYP- Fruit yield plant $^{-1}$)

The results on fruit yield attributing traits revealed significant variations for fruit length, fruit girth, average fruit weight and number of fruits plant^{-1} ranging from (-)5.42 (C_{18}) to 36.25 (C_{19}), (-)2.23 (C_8) to 64.01 (C_4), 4.96 (C_8) to 92.64 (C_{19}) and (-)30.59 (C_8) to 4.12 (C_9), respectively. The F_1 crosses *viz*. C_1 and C_9 showed positive SH for all the fruit yield attributing traits. Excluding the trait number of fruits plant^{-1}, the crosses *viz*. C_1, C_2, C_4, C_5, C_9, C_{10} and C_{19} showed significant positive SH for other yield attributing traits. The results on present study are in agreement with the reports of Rani *et al*. (2018), Chaudhari *et al*. (2020), Bagade *et al*. (2020) and Singh *et al*. (2021).

Similarly regarding the fruit quality attributes like TSS and ascorbic acid content, significant variations were observed ranging from (-)4.22 (C_{19}) to 33.19 (C_2) and (-)0.68 (C_{17}) to 38.30 (C_{13}), respectively. Out of 21 crosses, 12 F_1 crosses showed significantly positive SH. Siimilar results were also reported by Suneetha *et al.* (2008), Patel *et al*. (2017a), Rani *et al*. (2018) and Chaudhari *et al*. (2020).

The results on SH for % of bacterial wilt incidence at 90 DAT revealed that except the crosses C_{20} and C_{21}, rest of the crosses exhibited negative or 0.00 SH indicating their resistance or tolerance nature comparing to standard check, Mahy Green. Similar findings in brinjal was earlier reported by Ajjappalavara *et al.* (2013).

Fruit yield plant^{-1} is one of the important attributes for selection of superior F_1 cross. In the present study, the result revealed significant variations ranging from (-) 27.62 (C_{10}) to 33.81 (C_5). The F_1 crosses *viz.* C_1, C_2, C_5 and C_{13} showed more than 20% positive SH. The result also indicated that the crosses involving parents BBSR-08-2 and BBSR-10-26 showed higher heterosis. So these parents can be used in the future brinjal improvement programme to increase the fruit yield plant^{-1}. Similar type of observations for SH in brinjal were also confirmed by Patel *et al*. (2017a), Rani *et al*. (2018), Chaudhari *et al*. (2020), Deshmukh *et al*. (2020), Bagade *et al*. (2020) and Singh *et al*. (2021).

Considering all the estimate of heterosis *viz.* RH, HB and SH five best crosses were identified *i.e* $C_5 > C_1 > C_2 > C_{13} > C_4$. On the basis of overall growth parameters, fruit yield attributes along with resistance to bacterial wilt, the F_1 cross C_5 recorded maximum estimate of heterosis in terms of RH, HB and SH with respect to fruit length (14.80, 6.06 and 22.50), fruit girth (16.58, 11.48 and 62.61), average fruit weight (47.87, 38.13 and 83.07), fruits plant^{-1} (5.97, 0.00 and (-)16.47) and reaction to incidence of bacterial wilt at 90 DAT (44.31, 0.00 and (-)48.24) along with highest fruit yield plant^{-1}(56.54, 48.70 and 33.81). Similarly the cross C_1 recorded relatively higher heterosis in terms of RH, HB and SH for plant height at final harvest (33.45, 20.02 and 38.71), plant spread E-W (10.71, 9.35 and 19.11), plant spread N-S (24.96, 18.43 and 34.39), primary branches plant $^{-1}$ (9.89, 6.38 and (-)1.96), fruit length (18.44, 14.23 and 20.42), fruit girth (17.28, 11.14 and 62.10), average fruit weight (56.52, 52.66 and 75.66), fruits plant^{-1} (23.59, 11.08 and 3.24), TSS (23.25, 22.22 and 22.09), reaction to bacterial wilt at 90 DAT (0.00, 0.00 and (-)80.03) and overall high fruit yield plant^{-1}(62.57, 56.77 and 26.95), respectively, closely followed by C_2 for traits *viz*. plant height at final harvest (29.07, 12.22 and 22.20), fruit length (18.62, 13.13 and 22.08), fruit girth (15.51,0.00 and 45.86), average fruit weight (52.10, 44.84 and 66.67), TSS (37.61, 35.59 and 33.19), reaction to bacterial wilt at 90 DAT (0.00,0.00 and (-)80.03) and fruit yield plant^{-1} (39.36, 29.21 and 22.46). The result of the present study also indicated better performance of F_1 cross C_{13} for fruit length, average fruit weight, ascorbic acid content, TSS, reaction to bacterial wilt and fruit yield plant^{-1} followed by C_4 for plant spread (E-W), plant spread (N-S), days to 1st flower, fruit length, fruit girth, average fruit weight, ascorbic acid content, TSS, reaction to bacterial wilt and fruit yield plant^{-1}. So these crosses can be utilized directly in further evaluations or isolation of transgressive segregants in later generations.

Combining ability: Results on *gca* (general combining ability) for various traits in brinjal has been presented in the **Table 5**. The result indicated that, among the seven diverse parents, BBSR-08-2 was identified as the good combiner having high *gca* effect for the traits *viz*. plant height at final harvest, primary branches plant^{-1}, plant spread, fruit girth, average fruit weight, TSS, ascorbic acid content, incidence of bacterial wilt at 90 DAT and fruit yield plant^{-1} closely followed by BBSR-195-3 for plant height at final harvest, primary branches plant^{-1}, fruit length, fruit girth, average fruit weight, number of fruits plants^{-1}, ascorbic acid content, incidence of bacterial wilt at 90 DAT and fruit yield plant^{-1}. The result also revealed that BBSR-10-26 exhibited average combining ability for the traits *viz*. days to 1st flowering, plant spread (N-S), fruit length, fruits plant^{-1}, TSS, ascorbic acid content, incidence of bacterial wilt at 90 DAT and fruit yield plant^{-1}. Thus, these local landraces as parental lines can be used in hybridization programme as a good source of favourable gene for increasing fruit yield and yield attributing traits. Similar results were reported in brinjal by Dishri and Mishra (2017), Kachouli *et al*. (2019), Gangadhara *et al*. (2021) and Timmareddygari *et al*. (2021).

The estimates of *sca* (specific combining ability) for the F_1 crosses *viz*. C_1 and C_5 exhibited the highest significant *sca* effect for fruit yield plant^{-1} (0.41) (**Table 6**). Out of 21 crosses, nine crosses *viz*. C_1, C_2, C_3, C_5, C_9, C_{13}, C_{14}, C_{15} and C_{18} showed significant *sca* effect for fruit yield. The F_1 cross, C_1 revealed significant *sca* effect for plant height at final harvest (12.43), plant spread E-W (7.62), plant spread N-S (11.10), primary branches plant^{-1} (0.21), fruit length (0.76), fruit girth (1.46), average fruit weight (39.66), fruit plant^{-1} (3.10), TSS (0.34) along with fruit yield (0.41). Regarding earliness in flowering, the F_1 crosses *viz*. C_{14} and C_{17} showed significant *sca* effect in desired directions. However, the crosses *viz*. C_2, C_5, and C_{13} showed significant *sca* effect for fruit yield attributes *viz*. fruit length, fruit girth and average fruit weight. In the present study, top three crosses *viz*. C_1 (BBSR-08-2 × BBSR-10-25), C_5 (BBSR-08-2 × Selection from BBSR-145-1) and C_9 (BBSR-10-25 × BBSR-195-3) had high

Table 5. Estimate of *gca* effect in parents

Parent	PH	PS E-W	PS N-S	PB	DFF	D50F	FL	FG	AFW	FP	TSS	AA	BW	FYP
P_1	10.51**	0.54	3.34**	0.15*	2.60**	1.81**	-0.06	2.58**	13.32**	-0.55*	0.13*	0.25**	-0.80**	0.15**
P_2	0.31	0.22	0.01	0.10	-0.00	2.99**	0.29	0.81*	-4.98*	0.48	0.06	-0.04	-0.55**	-0.14**
P_3	-2.69**	-4.24**	1.04	-0.15*	-0.63*	-1.74**	0.25	-1.79**	-7.38**	0.95**	0.08	0.13	-0.74**	0.04
P_4	3.52**	2.71**	1.19	-0.38**	-0.71*	-0.22	-1.55**	-3.90**	-26.30**	0.35	-0.12*	-0.23**	0.39*	-0.04*
P_5	3.31**	0.92	-1.13	-0.07	0.25	-0.83*	1.42**	0.67	18.45**	0.44	-0.16**	0.10	-0.12	0.11**
P_6	-4.41**	0.54	-1.60	-0.13*	1.15**	1.58**	0.71**	0.87*	8.28**	-0.44	-0.05	-0.30**	0.01	-0.02
P_7	-10.54**	-0.67	-2.85*	0.48**	-2.66**	-3.59**	-1.05**	0.77*	-1.39	-1.23**	0.05	0.10	1.82**	-0.10**
SE(gi)±	0.78	0.52	1.07	0.06	0.30	0.36	0.18	0.34	2.37	0.24	0.05	0.08	0.15	0.02
SE (gi-gj)±	1.19	0.80	1.63	0.09	0.45	0.56	0.27	0.52	3.63	0.36	0.08	0.12	0.24	0.03
CD(P=0.05)	2.43	1.64	3.35	0.18	0.93	1.14	0.55	1.06	7.44	0.75	0.16	0.24	0.48	0.06

(PH-Plant height at final harvest, PS E-W -Plant spread (East-West), PS N-S - Plant spread (North-South), PB- Primary branches plant $^{-1}$, DFF- Days to 1st flowering, D50F- Days to 50% flowering, FL- Fruit length, FG- Fruit girth, AFW- Average fruit weight, FP- Fruits plant^{-1}, TSS- Fruit TSS, AA- Ascorbic acid content, BW- Incidence of bacterial wilt at 90 DAT, FYP- Fruit yield plant $^{-1}$)

Table 6. Estimate of *sca* effect in crosses

Crosses	PH	PS E-W	PS N-S	PB	DFF	D50F	FL	FG	AFW	FP	TSS	AA	BW	FYP
C_1	12.43**	7.62**	11.10**	0.21**	1.91**	-1.94**	0.76**	1.46**	39.66**	3.10**	0.34**	-0.00	-0.04	0.41**
C_2	7.28**	-4.07**	-5.31**	-0.24**	4.64**	6.39**	1.00**	1.51**	31.91**	-1.43**	0.82**	0.03	0.15	0.17**
C_3	5.57**	-2.87**	5.27**	0.09	0.03	1.27*	0.25	0.49	1.03	0.57	0.04	0.28*	-0.99**	0.21**
C_4	4.38**	2.92**	9.49**	0.38**	-3.94**	-0.22	1.13**	1.90**	0.93	-0.72*	0.25**	0.59**	-0.48*	0.05
C_5	1.65	0.70	-7.19**	0.53**	2.66**	-0.42	0.59*	1.48**	34.74**	0.66*	-0.04	0.32**	0.52*	0.41**
C_6	1.23	-3.59**	-0.69	-0.68**	-0.32	1.44**	-0.55*	-1.14*	-14.28**	-0.55	0.20**	0.57**	0.43*	-0.07**
C_7	-1.82	3.00**	-4.76**	0.21**	1.15**	-3.08**	0.70**	-1.84**	-10.09**	-1.66**	0.13	0.21	-0.10	-0.28**
C_8	9.78**	3.40**	5.44**	0.04	1.03*	-1.71**	-0.65**	-2.16**	-0.47	-3.56**	0.15*	0.20	-1.24**	0.02
C_9	5.69**	1.14	-3.24*	-0.07	3.17**	-3.10**	1.08**	3.01**	23.68**	2.25**	0.29**	0.07	0.40	0.29**
C_{10}	3.41**	-8.53**	9.54**	0.89**	-2.23**	2.50**	0.84**	2.70**	-13.51**	-0.87*	0.18**	0.84**	1.40**	-0.26**
C_{11}	-0.57	-3.22**	-2.41	-0.62**	2.33**	3.17**	0.06	0.27	-5.68	0.12	0.08	0.09	0.18	0.02
C_{12}	-7.78**	-3.69**	-2.59	0.49**	-0.24	2.83**	0.10	4.01**	12.18**	-1.93**	0.15*	0.43**	1.21**	-0.05
C_{13}	1.88	-2.30**	-2.02	0.18*	0.40	5.64**	1.08**	-2.46**	16.38**	0.38	0.41**	1.07**	-0.54*	0.19**
C_{14}	10.70**	-4.62**	4.76**	0.03	-3.30**	-3.97**	-0.37	-1.11*	-11.06**	2.06**	0.35**	0.06	-0.67**	0.20**
C_{15}	5.38**	0.64	2.61	-0.18*	2.61**	1.30*	-0.51*	0.42	-3.33	-0.55	-0.18*	-0.15	-0.21	0.06*
C_{16}	0.38	-2.90**	1.08	-0.09	-0.92*	0.32	-1.32**	-1.67**	-22.61**	-1.42**	0.32**	-0.31**	1.17**	-0.09**
C_{17}	-3.31**	5.23**	0.96	0.37**	-1.82**	-4.49**	-0.17	-1.73**	-5.54	-1.84**	0.34**	-0.16	0.45*	-0.03
C_{18}	5.22**	4.49**	-1.69	-0.34**	2.44**	2.58**	0.49*	-1.77**	13.93**	-1.15**	0.09	0.30**	-0.76**	0.09**
C_{19}	-8.09**	2.07**	2.68	0.16*	4.12**	6.52**	0.76**	2.66**	40.41**	-2.43**	-0.44**	0.55**	-1.29**	-0.14**
C_{20}	2.48*	6.18**	-1.47	-0.16*	4.13**	1.79**	-0.43	1.31**	2.33	-1.24**	-0.13	-0.02	0.79**	-0.17**
C_{21}	1.80	3.66**	-2.35	0.00	1.13**	0.83	0.38	-1.31*	-10.60**	1.33**	0.25**	0.16	0.20	0.00
SE(sij)±	2.26	1.52	3.11	0.16	0.86	1.06	0.51	0.99	6.90	0.69	0.14	0.23	0.45	0.06
SE(sij-sik)±	3.35	2.26	4.62	0.24	1.28	1.57	0.76	1.46	10.26	1.03	0.21	0.33	0.67	0.08
CD(P=0.05)	6.88	4.63	9.48	0.50	2.62	3.23	1.56	3.00	21.04	2.11	0.44	0.69	1.37	0.17

(PH-Plant height at final harvest, PS E-W -Plant spread (East-West), PS N-S - Plant spread (North-South), PB- Primary branches plant $^{-1}$, DFF- Days to 1st flowering, D50F- Days to 50% flowering, FL- Fruit length, FG- Fruit girth, AFW- Average fruit weight, FP- Fruits plant^{-1}, TSS- Fruit TSS, AA- Ascorbic acid content, BW- Incidence of bacterial wilt at 90 DAT, FYP- Fruit yield plant $^{-1}$)

Fruit yield plant $^{-1}$ being the most important attribute exhibited non-additive gene action as the ratio between the *gca* and *sca* variance is less than one. Similar results for fruit yield plant^{-1} in brinjal also reported by Gangadhara *et al*. (2021), Timmareddygari *et al*. (2021) and Rajan *et al*. (2022).For the traits exhibiting additive gene action, simple selection would be desirable for improvement of these characters as it is fixable. In the traits where non-additive gene action is present, it is advocated for heterosis breeding or selection has to be postponed for later generations for improvement of these traits. Thus, the present study clearly established the better performance of local landraces as parent *viz*. BBSR-08-2, BBSR-10-25, BBSR-10-26 and BBSR-195-3 not only for better growth, flowering, fruit yield attributing but also for resistance or tolerance towards bacterial wilt, fruit quality along with higher fruit yield plant^{-1}. Thus, the performance of superior crosses *viz.* C_5 (BBSR-08-2 × Selection from BBSR-145-1), C_1 (BBSR-08-2 × BBSR-10-25), C_2 (BBSR-08-2 × BBSR-10-26), C_{13} (BBSR-10-26 × BBSR-195-3) and C_4 (BBSR-08-2 × BBSR-195-3) could *sca* effect for yield plant^{-1} in which good ×poor (C_1), good × average (C_5) and poor × good (C_9) (**Table 7**) general combiners were involved which clearly indicated that the parental contribution to the heterosis is primarily through non-additive gene effects. Hence, exploitation of heterosis appeared to be an appropriate strategy for improvement in brinjal. The results were in accordance with Dishri and Mishra (2017), Kachouli *et al*. (2019), Gangadhara *et al*. (2021) and Rajan *et al*. (2022).

Gene action: The data presented in **Table 8** elucidates the nature of gene action for various traits in brinjal. The result indicated that vegetative traits *viz*. plant height at final harvest, plant spread (E-W) and (N-S) and primary branches plant^{-1} showed higher *sca* variance than *gca* variance as evidenced by ratio less than one indicating involvement of non-additive gene action. Similar results were reported in brinjal by Patel *et al*. (2017b) and Gangadhara *et al*. (2021) for plant height, primary branches plant^{-1} and Aswani and Khandelwal (2005), Singh *et al*. (2013) and Ramani *et al*. (2017) for plant

Table 7. **Categorization of parents**

Parents	PH	PS E-W	PS N-S	PB	DFF	D50F	FL	FG	AFW	FP	TSS	AA	BW	FYP
P_1	G	A	G	G	P	P	A	G	G	P	G	G	G	G
P_2	A	A	A	A	A	P	A	G	P	A	A	A	G	P
P_3	P	P	A	P	G	G	A	P	P	G	A	A	G	A
P_4	G	G	A	P	G	A	P	P	P	A	P	P	P	P
P_5	G	A	A	A	A	G	G	A	G	A	P	A	A	G
P_6	P	A	A	P	P	P	G	G	G	A	A	P	A	A
P_7	P	A	P	G	G	G	P	G	A	P	A	A	P	P

G= Good parent having significant *gca* effect in desired direction
A= Average parent having positive or negative but non significant *gca* effect
P= Poor parent having significant *gca* effect in the undesired direction (Barot *et al*., 2014)
(PH-Plant height at final harvest, PS E-W -Plant spread (East-West), PS N-S - Plant spread (North-South), PB- Primary branches plant $^{-1}$, DFF- Days to 1st flowering, D50F- Days to 50% flowering, FL- Fruit length, FG- Fruit girth, AFW- Average fruit weight, FP- Fruits plant^{-1}, TSS- Fruit TSS, AA- Ascorbic acid content, BW- Incidence of bacterial wilt at 90 DAT, FYP- Fruit yield plant $^{-1}$)

Table 8. Nature of gene action

S. No.	Character	*gca* variance (σ^2g)	*sca* variance (σ^2s)	*gca/sca* (σ^2g/ σ^2s) variance	Nature of gene action
1	Plant height at final harvest	44.57	58.75	0.75	Non-additive
2	Plant spread (East-West)	4.23	17.55	0.24	Non-additive
3	Plant spread (North- South)	2.93	21.77	0.13	Non-additive
4	Primary branches plant^{-1}	0.07	0.21	0.34	Non-additive
5	Days to 1st flowering	2.59	9.13	0.28	Non-additive
6	Days to 50% flowering	5.08	13.57	0.37	Non-additive
7	Fruit length	0.99	0.59	1.69	Additive
8	Fruit girth	4.45	3.59	1.24	Additive
9	Average fruit weight	219.97	514.19	0.43	Non-additive
10	Fruits plant^{-1}	0.51	3.58	0.14	Non-additive
11	Fruit TSS	0.01	0.17	0.05	Non-additive
12	Ascorbic acid content	0.03	0.3	0.11	Non-additive
13	Bacterial wilt incidence at 90 DAT	0.80	0.34	2.33	Additive
14	Fruit yield plant^{-1}	0.01	0.05	0.21	Non-additive

spread, respectively. Regarding flowering attributes *viz.* days to 1st flowering and days to 50% flowering variance due to *sca* was higher than variance due to *gca* and the ratio being less than one revealing the non-additive nature of gene action. Similar results on flowering in brinjal were also reported by Kumar and Arumugam (2016) and Rajan *et al*. (2022).

Variance due to *gca* was higher than variance due to *sca* for fruit yield attributing traits *viz.*fruit length and fruit girth showing involvement of additive gene action. The findings are in agreement with Aswani and Khandelwal (2005), Uddin *et al*. (2015) and Patel *et al*. (2017b). Other yield attributing traits in brinjal *viz.* average fruit weight and fruits plant^{-1} showed higher *sca* variance than *gca* expressing presence of non-additive gene action. Similar results were also reported in brinjal by Gangadhara *et al*. (2021), and Rajan *et al*. (2022).Variance due to *sca* was higher than variance due to *gca* for fruit quality attributes *viz.* TSS and ascorbic acid content indicating non-additive gene action. The results are in agreement with Ambade *et al*. (2012) and Ramani *et al*. (2017) for TSS and by Rajan *et al*. (2022) for ascorbic acid in brinjal.

In the present study the incidence of bacterial wilt at 90 DAT showed additive gene action as the *gca* variance was higher than *sca*. Similar type of gene action for bacterial wilt incidence was also reported by Chattopadhyay *et al*. (2012), Lebeau *et al*. (2013) and Bainsla *et al*. (2016) in brinjal.

Fruit yield plant -1 being the most important attribute exhibited non-additive gene action as the ratio between the gca and sca variance is less than one. Similar results for fruit yield plant-1 in brinjal also reported by Gangadhara et al. (2021), Timmareddygari et al. (2021) and Rajan et al. (2022).For the traits exhibiting additive gene action, simple selection would be desirable for improvement of these characters as it is fixable. In the traits where non-additive gene action is present, it is advocated for heterosis breeding or selection has to be postponed for later generations for improvement of these traits.

Thus, the present study clearly established the better performance of local landraces as parent viz. BBSR-08-2, BBSR-10-25, BBSR-10-26 and BBSR-195-3 not only for better growth, flowering, fruit yield attributing but also for resistance or tolerance towards bacterial wilt, fruit quality along with higher fruit yield plant-1. Thus, the performance of superior crosses viz. C5 (BBSR-08-2 × Selection from BBSR-145-1), C1 (BBSR-08-2 × BBSR-10-25), C2 (BBSR-08-2 × BBSR-10-26), C13 (BBSR-10-26 × BBSR-195-3) and C4 (BBSR-08-2 × BBSR-195-3) could be tested in multi-location trials for further confirmation of their performance for yield and quality traits.

REFERENCES

Ajjappalavara, P.S., Dharmatti, P.R. and Salimath. 2013. Heterosis for yield and bacterial wilt resistant in brinjal (*Solanum melongena* L.). *Asian Journal of Horticulture*, **8**(1): 12-20.

Ambade, R.L., Verma, S.K., Tiwari, J.K. and Mehta, Nandan. 2012. Combining ability analysis for fruit traits in brinjal (*Solanum melongena* L.). *Research Journal of Agricultural Sciences*, **3**(6): 1183-1188.

Aswani, R.C. and Khandelwal, R.C. 2005. Combining ability studies in brinjal. *Indian Journal of Horticulture*, **62**(1):37-40.

Bagade, A.B., Deshmukh, J.D. and Kalyankar, S.V. 2020. Heterosis studies for yield and yield traits in brinjal. *The Pharma Innovation Journal*, **9**(11): 205- 208.

Bainsla, N.K., Singh, S., Singh, P.K., Kumar, K., Singh, A.K. and Gautam, R.K. 2016. Genetic behaviour of bacterial wilt resistance in brinjal (*Solanum melongena* L.) in tropics of Andaman and Nicobar Islands of India, *American Journal of Plant Sciences*, **7**:333-338. [Cross Ref]

Barot, H.G., Patel, M.S., Sheikh, W.A., Patel, L.P. and Allam, C.R. 2014. Heterosis and combining ability analysis for yield and its component traits in wheat (*Triticum aestivum* L.). *Electronic Journal of Plant Breeding*, **5**(3): 350-359.

Bhavidoddi, A. 2013. Inheritance of bacterial wilt disease in brinjal (*Solanum melongena* L.). PhD Thesis. University of agricultural Sciences, GKVK, Banglore.

Chattopadhyay, A., Seth, T., Dutta, S., Ghosh, P.P., Chattopadhyay, S.B., Majumdar, D. and Hazra, P. 2012. Breeding eggplant for higher productivity and bacterial wilt tolerance. *International Journal of Vegetable Science*, **18**(4): 376-392. [Cross Ref]

Chaudhari, B.N., Patel, A.I. and Vashi, J.M. 2020. Study on heterosis over environments in brinjal (*Solanum melongena* L.). *International Journal of Current Microbiology and Applied Sciences*, **9**(7): 3358-3367. [Cross Ref]

Deshmukh, J.D., Kalpande, H.V. and Kalyankar, S.V. 2020. Heterosis and combining ability analysis for productivity traits in brinjal (*Solanum melongena* L.). *The Pharma Innovation Journal*, **9**(11): 177-180.

Deshmukh, S.B., Narkhede, G.W., Gabale, L.K. and Dod, V.N. 2015. Hybrid vigour in brinjal (*Solanum melongena* L.). *The Bioscan*, **10**(2): 869-876.

Dhillion, B.S. 1975. The application of partial diallel crosses in plant breeding – A review. *Crop Improvement*, **2**:17.

Dishri, M. and Mishra, H.N. 2017. Estimation of combining ability and gene action studies in round brinjal (*Solanum melongena* L.). *International Journal of Current Microbiology and Applied Sciences*, **6**(10): 3584-91. [Cross Ref]

Dudhat, N.M., Savaliya, J.J., Sharma, L.K. and Kelaiya, D.S. 2013. Heterosis for earliness and plant stature in brinjal (*Solanum melongena* L.). *Progressive Researchs*, **8**:555-559.

Fonseca, S. and Patterson, F.L. 1968. Hybrid vigour in seven parent diallel cross in common winter wheat (*Triticum aestivum* L.). *Crop Science*, **8**: 85-88. [Cross Ref]

Gangadhara, K., Abraham, M. and Selvakumar, R. 2021. Combining ability and gene action for structural and economical traits in brinjal (*Solanum melongena* L.). *Indian Journal of Agricultural Sciences*, **91** (7): 32-36. [Cross Ref]

Griffing, B. 1956. Concept of general and specific combining ability in relation to diallel crossing system. *Australia Journal of Biological Sciences*, **9**: 463-493. [Cross Ref]

Kachouli, B., Singh, A.K., Jatav, S.K. and Kushwah, S.S. 2019. Combining ability analysis for yield and yield attributing characters in brinjal (*Solanum melongena* L.). *Journal of Pharmacognosy and Phytochemistry*, **8**(3): 4009-4012.

Kumar, S.R. and Arumugam, T. 2013. Gene action and combining ability analysis in brinjal (*Solanum melongena* L.). *Journal of Horticultural Sciences*, **8**(2): 249-254.

Kumar, S.R. and Arumugam, T. 2016. Gene action in eggplant landraces and hybrids for yield and quality traits. *International Journal of Farm Sciences*, **6**(1): 79-89.

Kurhade, GM. 2017. Heterosis and combining ability for yield and its traits with genetics of bacterial wilt resistance in brinjal (*Solanum melongena* L.). *Ph.D Thesis*. Dr. Bala sahib Sawant Konkon Krishi vidyapeeth, Dapoli.

Lebeau, A., Gouy, M., Daunay, M.C., Wicker, E., Chiroleu, F., Prior, P., Farry, A. and Dintinger, J. 2013. Genetic mapping of a major dominant gene for resistance to *Ralstonia solanacearum* in eggplant. *Theoretical and Applied Genetics*, **126**:143-158. [Cross Ref]

Magar, P.G., Magar, V.G. and Gaikwad, S.S. 2016. Heterosis studies for growth and flowering characters in brinjal (*Solanum melongena* L.). *International Journal of Tropical Agriculture*, **34**(7): 2279-2281.

Makasare, P.V., Bagade, A.B. and Kalyankar, S.V. 2020. Identification of heterotic hybrids for yield and yield traits in brinjal. *Journal of Pharmacognosy and Phytochemistry*, **9**(6): 333-336.

Mistry, C.R., Kathiria. K.B., Sabolu, S. and Kumar, S. 2018. Heterosis and inbreeding depression for fruit yield attributing traits in eggplant. *Current Plant Biology*, **16**: 27-31. [Cross Ref]

Nagai, K. and Kida, M. 1926. An experiment with some varietal crosses of eggplant. *Japanese Journal of Genetics*, **4**: 10-30.

Patel, A.A., Gohil, D.P., Dhruve, J.J. and Damor, H.I. 2017a. Heterosis for fruit yield and its quality characters in brinjal (*Solanum melongena* L.). *Journal of Pharmacognosy and Phytochemistry*, **6**(6): 975-978.

Patel, A.A., Gohil, D.P., Patel, N.B. and Patel, D.D. 2017b. Combining ability and gene action studies in brinjal (*Solanum melongena* L.). *Journal of Pharmacognosy and Phytochemistry*, **6**(5): 2137-2147.

Pramila, K., Kushwaha, M.L. and Singh, Y.P. 2017. Studies on heterosis in brinjal (*Solanum melongena* L.). *International Journal of Current Microbiology and Applied Sciences*., **6**(11): 641-651. [Cross Ref]

Rajan, N., Debnath, S., Dutta, A.K., Pandey, B., Singh, A.K., Singh, R.K., Singh, A.K. and Dugbakie, B.N. 2022. Elucidation of nature of gene action and estimation of combining ability effects for fruit yield improvement and yield attributing traits in brinjal landraces. *Hindawi Journal of Food Quality*, (https://doi.org/10.1155/2022/8471202). [Cross Ref]

Ramani, P.S., Vaddoria, M.A., Mehta, D.R. and Ukani, J.D. 2017. Combining ability and gene action for fruit yield and its attributes in brinjal (*Solanum melongena* L.). *Indian Journal of Agricultural Research*, **51**(6): 606-610. [Cross Ref]

Rameshkumar, D. and Vethamonai, I.P. 2020. Heterosis for quantitative and qualitative traits in brinjal (*Solanum melongena* L.). *Vegetable Science*, **47**(1): 55-61.

Ramireddy, S.R.K.M., Lingaiah, H.B., Naresh, P., Reddy, P.V.K. and Kuchi, V.S. 2011. Heterosis studies for yield and yield attributing characters in brinjal (*Solanum melongena* L.). *Plant Archives*, **11**(2): 649-653.

Rani, M., Kumar, S. and Kumar, M. 2018. Estimation of heterosis for yield and its contributing traits in brinjal. *Journal of Environmental Biology*, **39**: 710-718. [Cross Ref]

Reddy, C.V.K., Deshmukh, J.D. and Kalpande, H.V. 2020. Heterosis for fruit and its yield attributing traits in brinjal (*Solanum melongena* L.). *Journal of Pharmacognosy and Phytochemistry*, **9**(6): 480-486.

Shahjahan, M., Kabir, K., Zomo, S.A., Sarkar, M.D. and Fazlullah, M.U. 2016. Evaluation of heterosis in exotic eggplant. *International Research Journal of Agriculture and Food Sciences*, **1**(2): 23-32.

Sharma, T.K., Pant, S.C., Kumar, K., Kurrey, V.K., Pandey, P.K. and Bairwa, P.L. 2016. Studies on heterosis in brinjal (*Solanum melongena* L.). *International Journal Bio-rresource and Stress Management*, **7**(5): 964-969. [Cross Ref]

Shukla, V. and Naik, L.B. 1993. Agro-techniques of solanaceous vegetables. *Advances in Horticulture*, Vol 5, Veg Crops, part 1, pp 365 Chadha, K.L., Kalloo, G. (Eds). Malhotra publishing House, New Delhi.

Singh, O., Singh, B., Singh, K.V., Chand, P. and Vaishali. 2013. Combining ability studies for yield and its component in brinjal (*Solanum melongena* L.). *Annals of Horticulture*, **6**(2): 343-353.

Singh, S., Sharma, H.D., Dogra, R.K., Verma, V. and Aditika, Shilpa. 2021. Study of heterosis for vegetative and quantitative traits in brinjal (*Solanum melongena* L.). *The Pharma Innovation Journal*, **10**(12): 335-338. [Cross Ref]

Suneetha, Y., Kathiria, K.B. and Patel, J.S. and Srinivas T.

2008. Studies on heterosis and combining ability in late summer brinjal. *Indian Journal of Agricultural Research*, **42**(3): 171-176.

Timmareddygari, S., Pidigam, S., Natarajan, S., Amrapalli, G. and Komatireddy, R.R. 2021. Combining ability analysis for yield attributes and quality parameters in brinjal (*Solanum melongena* L.) hybrids. *Journal of Pharmacognosy and Phytochemistry*, **10**(1): 1649-1658. [Cross Ref]

Uddin, M.S., Rahman, M.M., Hossain, M.M. and Mian, M.A.K. 2015. Combining ability of yield and yield components in eggplant (*Solanum melongena* L.) during summer. *Universal Journal of Plant Science*, **3**(4): 59-66. [Cross Ref]

Vavilov, N.I. 1931. The role of Central Asia in the origin of cultivated plants. *Bulletin of Applied Botany-Genetics and Plant Breeding*, **26**(3): 3-44.