Doi:

International Journal of Economic Plants

https://ojs.pphouse.org/index.php/IJEP

Crossref

IJEP January 2025, 12(1): 01-08

Article IJEP5725

Full Research

Natural Resource Management

Doi: HTTPS://DOI.ORG/10.23910/2/2025.5725

Estimation of Heterosis and Inbreeding Depression for Fruit Yield Attributing Characters in Brinjal (*Solanum melongena* L.)

Jagruti S. Mahla[1*], R. R. Acharya[2], M. M. Pandya[2], Sushil Kumar[3], D. A. Patel[3] and D. J. Parmar[4]

[1]Dept. of Genetics and Plant Breeding, [2]Main Vegetable Research Station, [3]Dept. of Agricultural Biotechnology, [4]Dept. of Agricultural Statistics, Anand Agricultural University, Anand, Gujarat (388 110), India

Corresponding Author

Jagruti S. Mahla

e-mail: mahlajagruti@gmail.com

Article History

Received on 20th August, 2024

Received in revised form on 25th November, 2024

Accepted in final form on 21st December, 2024

Published on 07th January 2025

Abstract

The present investigation on generation mean analysis of brinjal was conducted in Anand (388 110), Gujarat, India, from September to March 2023–2024 to study heterosis and inbreeding depression for yield traits. The observations were recorded on thirteen traits such as days to first flowering, branches per plant, plant height, leaf blade length, leaf blade width, fruit length, fruit girth, fruit length/girth ratio, fruits plant^{-1}, fruit yield plant^{-1}, total soluble solids and shoot and fruit borer incidences. The experimental material consisted of twelve basic generations *viz*., P_1, P_2, F_1, F_2, B_1, B_2, B_{11}, B_{12}, B_{21}, B_{22}, B_{1S} and B_{2S} of four families of brinjal namely, AB 20-19×GAOB 2, AB 20-13×CO 2, Anand Harit×GJB 3 and GPBRJ 204×Arka Harshitha. The results revealed that all four families exhibited positive and significant heterobeltiosis for plant height, leaf blade length, leaf blade width, fruit length, fruit girth, fruit weight and fruit yield plant^{-1}. The families AB 20-19×GAOB 2 and GPBRJ 204×Arka Harshitha showed promising results for fruit yield plant^{-1} and its component traits, along with early flowering. The positive significant heterosis over the mid-parent and better parent, coupled with negative inbreeding depression, can be attributed to the major contribution from dominance (h) and additive×additive (i) gene effects. The family exhibiting the least inbreeding depression and high heterosis should be further explored for commercial production.

Keywords: Brinjal, heterosis, inbreeding depression and fruit yield

1. Introduction

Brinjal or eggplant (*Solanum melongena* L.) originated in India, also considered a center of diversity. Brinjal is an important year round widely consumed vegetable in tropical and subtropical regions of the globe (Sharma et al., 2016). Within the Solanaceae family, brinjal ranks as the third most important crop after potato and tomato, with an annual global production of 56.62 mt from 1.8 mha of cultivated land (Anonymous, 2020). During 2019–20, India had 0.728 mha under brinjal cultivation, producing an estimated 12.66 million tonnes with a productivity of 17.39 t ha^{-1}. Currently, India cultivates brinjal over an area of 6.781 lakh hectares, yielding 129.589 lakh tonnes with a productivity of 19.10 mt ha^{-1}. In Gujarat, brinjal is grown on about 0.81 lakh hectares, producing 16.24 thousand tonnes with a productivity of 19.89 mt ha^{-1} (Anonymous, 2024). The plant habit is erect and multi-stemmed. The branching stem is simple, long and flat. Coarsely lobed leaves are green in colour and are arranged alternately on the branches. The leaves can measure 10 to 20 cm in length and 5 to 10 cm in width. Seeds propagate it and germination occurs in about 8–12 days. The fruits can be harvested in 105–133 days (Anonymous, 2024). The flowers are violet and white colours and formed in solitary or in clusters of two or more. The flower consists of five sepals and petals, usually cup-shaped with five stamens, alternate with a corolla, carpels are united with a superior ovary. It has heterostyly features four types of flowers that have been observed depending on the length of styles *viz*., long-styled with large ovary, medium-styled with medium size ovary, Pseudo short-styled with rudimentary ovary and true short-styled with very rudimentary ovary (Krishnamurthy and Subramanian, 1954). The fruit setting percentage is higher in long-styled and medium long-styled flowers, while true short-styled and pseudo short-styled flowers do not occur in fruit sets (Banik et al., 2018). It contains a higher content of free reducing sugars, anthocyanin, phenols and glycoalkaloids (solasodine). Bitterness in eggplant is due to the presence of saponins and glycoalkaloids. Eggplant is well known for its medicinal properties. (Sabolu et al., 2014).

The primary goal of the brinjal breeding program is to develop high yielding varieties, predominantly F_1 hybrids, that possess strong stress tolerance. Heterosis, or hybrid vigour, occurs when the offspring of genetically diverse parents exhibit superior (or sometimes inferior) performance compared to the average of the parents (average heterosis) or the better-performing parent (heterobeltiosis). Heterosis breeding involves evaluating elite parents and their first-generation offspring to identify heterotic hybrids and suitable parents. This method, which exploits hybrid vigour, is a proven approach to enhancing crop yield and other quantitative traits. Estimating heterosis for yield and its components is essential for selecting the best hybrid combinations. The commercial application of heterosis in brinjal is feasible due to the low cost of F_1 seed production and the low seed requirement per unit area (Mistry et al., 2018).

Inbreeding depression, characterized by reduced vigour in inbred individuals due to inbreeding, is the inverse of heterosis. The extent of inbreeding depression varies across species, but both phenomena result from non-additive gene action. Despite its negative impact, inbreeding is a valuable tool in crop breeding, essential for developing superior genotypes. Hence, this investigation was conducted to evaluate the magnitude of heterosis in various families to create superior F_1 hybrids, to study the extent of inbreeding depression in the F_2 generation and to explore its possible useful in future crop enhancement programmes (Mistry et al., 2018).

2. Materials and Methods

2.1. Field trial

The experimental materials comprised twelve generations *viz*., P_1, P_2, F_1, F_2, B_1, B_2, B_{11}, B_{12}, B_{21}, B_{22}, B_{1S} and B_{2S} of four families of brinjal namely AB 20-19×GAOB 2, AB 20-13×CO 2, Anand Harit×GJB 3 and GPBRJ 204×Arka Harshitha in brinjal which were raised at Main Vegetable Research Station, Anand Agricultural University, Anand, Gujarat during *kharif-rabi* 2023–24 to study heterosis and inbreeding depression for fruit yield and its component traits. The experiment was laid out in Compact Family Block Design (CFBD) with three replications. The observations were recorded on thirteen characters *viz*., days first flowering, branches per plant, plant height (cm), leaf blade length (cm), leaf blade width (cm), fruit length (cm), fruit girth (cm), fruit length girth^{-1} ratio, fruits per plant, fruit yield plant^{-1} (kg), total soluble solids (°Brix) and shoot and fruit borer (%) incidences. Each hybrid and parent represented single rows of 6 meter length spaced at 90 cm between rows and 60 cm between plants. Recommended agronomic practices and plant protection operations were followed to raise good crops.

2.2. Statistical analysis

Heterosis for each trait was worked out by using the overall mean of each hybrid over replications for each trait.

Relative heterosis (RH) was as calculated as per cent the deviation of F_1 value from its over mid-parental value (Turner, 1953). The formula used for estimating relative heterosis was as follows

$$\text{Relative heterosis (\%)}=\frac{\bar{F}_1-\overline{MP}}{\overline{MP}}\times 100$$

Where,

F_1=Mean performance of F_1

$\overline{MP}$=Mean value of mid parent value

Heterobeltiosis was calculated at the superiority of hybrid from the better parent as follows.

$$\text{Heterobeltiosis (\%)}=\frac{F_1-\overline{BP}}{\overline{BP}}\times 100$$

Where,

F_1=Mean performance of F_1

$\overline{BP}$ =Mean value of better parent of respective cross combination

Inbreeding depression: It was computed by using the following formula:

$$\text{Inbreeding depression (\%)}=\frac{\bar{F}_1-\bar{F}_2}{\bar{F}_1}\times 100$$

Where,

F_1=Mean performance of F_1

F_2=Mean performance of F_2

The significance of heterosis, heterobeltiosis and inbreeding depression was tested by comparing the calculated 't' value with the table 't' value at 5% (1.960) and 1% (2.576) levels of significance.

3. Results and Discussion

The degree of heterosis is measured as the superiority of F_1 hybrids over the best parent (heterobeltiosis). The possibility of exploitation of hybrid vigour depends on the feasibility of hybrid seed production at a commercial scale. Heterobeltiosis is an indicator of the level of transgressive segregants as the superiority of hybrids helps identify promising cross combinations with the potential to produce the highest level of transgressive segregants in conventional crop improvement programme. In the present study, heterosis is reported over mid-parent (relative heterosis) and better-parent (heterobeltiosis). The inbreeding depression is an important criterion for crop breeding programme. Due to minimal genetic load self-pollinated crop species like brinjal, show little inbreeding depression (Voillemot and Pannell, 2017). Natural selection and/or plant breeding would be expected to eliminate deleterious gene mutations with large effects. Therefore, the inbreeding depression observed in the present study is assumed not to be due to the expression of homozygous deleterious alleles as a case in cross-pollinated crops (Burton and Brownie, 2006). The magnitude of inbreeding depression varied from cross to cross indicating the influence of genetic constitution of families. In the present study, either a low or moderate amount of inbreeding as well as outbreeding depression was detected. It is desirable to have highly significant and positive heterosis with low inbreeding depression (Mistry et al., 2018). The results of heterosis and inbreeding depression were depicted in Table 1 and Figure 1 to 2.

3.1. Days to first flowering

For this trait, heterosis in the negative direction is desirable as it suggests earliness in flowering. The relative heterosis ranged from -13.60 to 13.16%. Significant and negative relative heterosis was obtained for Anand Harit×GJB 3 (-13.60%), while significant and positive relative heterosis was obtained for AB 20-19×GAOB 2 (13.16%). Non-significant relative heterosis was depicted for AB 20-13×CO 2 (-3.87%) and GPBRJ 204×Arka Harshitha (2.50%). Similar results for days first to flowering were also observed by Sao and Mehta (2011) and Rameshkumar and Vethamonai (2020) who reported -13.29 to 9.04%. Heterobeltiosis ranged from -5.87 to 24.19%. AB 20-19×GAOB 2 (18.18%) and GPBRJ 204×Arka Harshitha (24.19%) exhibited significant and positive heterobeltiosis. Non-significant heterobeltiosis was found by the remaining two families, AB 20-13×CO 2 (-1.07%) and Anand Harit×GJB 3 (-5.87%). Similar results are from Kamani and Monpara (2009) who found -3.49 to 23.53%.

Inbreeding depression fluctuated from -30.38 to -6.71%. Significant inbreeding depression was obtained for all four families *viz*., AB 20-19×GAOB 2 (-30.38%), AB 20-13×CO 2 (-6.71%), Anand Harit×GJB 3 (-8.70%) and GPBRJ 204×Arka Harshitha (-11.00%). To improve the traits, self-pollination should be avoided. Similar results for days first to flowering were reported by Kamani and Monpara (2009) who recorded -25.76 to -6.31%.

3.2. Branches plant^{-1}

The relative heterosis ranged from -5.38 to 10.34%. Non-significant relative heterosis was obtained for all four families *viz*., AB 20-19×GAOB 2 (8.51%), AB 20-13×CO 2 (-4.17%) Anand Harit×GJB 3 (10.34%) and GPBRJ 204×Arka Harshitha (-5.38%). The results do not agree with the findings of Shafeeq et al. (2007), Das et al. (2009), Kamani and Monpara (2009), Sao and Mehta (2011), Al-Hubaity and Teli (2013), Patidar et al. (2017), Savaliya et al. (2017), Mistry et al. (2018), Rameshkumar and Vethamonai (2020) and Mishra et al. (2023). Heterobeltiosis ranged from 2.33 to 33.33%. The positive significant heterobeltiosis for branches per plant manifested by AB 20–19×GAOB 2 (27.50%) and Anand Harit×GJB 3 (33.33%). Non-significant results were for AB 20-13×CO 2 (15.00%) and GPBRJ 204×Arka Harshitha (2.33%). For this trait, heterosis in the positive direction is desirable as it suggests an increase in the number of effective branches per plant. Positive relative heterosis was also reported by Barik et al. (2022) who recorded 2.82% and Abdelkader et al. (2022) who obtained 5.31 to 34.90%.

Inbreeding depression varied from -1.09 to 16.18%. Significant inbreeding depression was observed for AB 20-19×GAOB 2 (16.18%), while the other three families were found non-significant for branches plant^{-1}. A positive magnitude of inbreeding depression was obtained in family I for this trait, suggesting the least chances of useful segregants in the F_2 population. These results are in contradict those of Rai et al. (2007), Kamani and Monpara (2009), Sao and Mehta (2011), Mistry et al. (2018), Varma et al. (2020) who reported -0.48 to 0.10% and Barik et al. (2022).

Table 1: Estimates of relative heterosis (RH %), heterobeltiosis (HB %) and inbreeding depression (ID %) for different traits

Family/ Traits	Days to first flowering	Branches plant^{-1}	Plant height	Leaf blade length	Leaf blade width	Fruit length	Fruit girth
Family I (AB 20-19×GAOB 2)							
RH (%)	13.16*	8.51	28.00**	16.98**	15.35**	9.82	3.34
HB (%)	18.18**	27.50**	47.60**	39.02**	24.33**	18.62**	7.69**
ID (%)	-30.38**	16.18**	16.11**	8.07**	10.38**	8.38	2.86
Family II (AB 20-13×CO 2)							
RH (%)	-3.87	-4.17	9.92**	12.98**	18.00**	17.70**	7.18
HB (%)	-1.07	15.00	10.46**	30.84**	25.82**	31.81**	17.91**
ID (%)	-6.71*	-1.09	1.48	8.75**	3.58	16.47**	0.90
Family III (Anand Harit×GJB 3)							
RH (%)	-13.60**	10.34	19.96**	14.26**	5.25	11.19**	5.25
HB (%)	-5.87	33.33**	48.30**	30.15**	10.05*	26.78**	10.05*
ID (%)	-8.70**	7.29	9.03**	7.37***	0.39	9.01*	0.39
Family IV (GPBRJ 204×Arka Harshitha)							
RH (%)	2.50	-5.38	10.78**	7.91**	10.90*	12.45**	10.90*
HB (%)	24.19**	2.33	39.96**	23.08**	22.29**	21.02**	22.29**
ID (%)	-11.00*	3.98	5.11*	11.71**	0.96	1.30	0.96

Table 1: Continue...

Family/Traits	Fruit length/girth ratio	Fruit weight	Fruits plant^{-1}	Fruit yield plant^{-1}	Total soluble solids	Shoot and fruit borer incidence
Family I (AB 20-19×GAOB 2)						
RH (%)	5.72	39.64**	39.64**	17.74**	2.74	-6.44
HB (%)	9.72*	48.84**	48.84**	34.59**	4.67	-2.19
ID (%)	5.93	11.31*	11.31*	8.75	0.26	-30.96**
Family II (AB 20-13×CO 2)						
RH (%)	8.24	-8.17	4.31	8.26	3.69	-17.15**
HB (%)	35.95**	19.61*	117.83**	60.02**	9.44	-2.98
ID (%)	15.19**	-25.82**	13.64**	-4.92	-3.83	-11.87
Family III (Anand Harit×GJB 3)						
RH (%)	2.20	54.38**	6.26	36.14**	-3.85	2.15
HB (%)	7.31	63.85**	10.67**	82.43**	-2.29	7.24
ID (%)	9.42**	2.95	9.45**	9.09	-4.47	5.15
Family IV (GPBRJ 204×Arka Harshitha)						
RH (%)	0.89	22.45**	6.95	25.42*	1.38	0.75
HB (%)	3.11	55.55**	28.97**	41.84**	5.64	12.61
ID (%)	-0.85	14.66*	5.36	16.98	-4.38	14.35**

* and ** indicates significant at (*p*=0.05) and (*p*=0.01) levels of probability, respectively

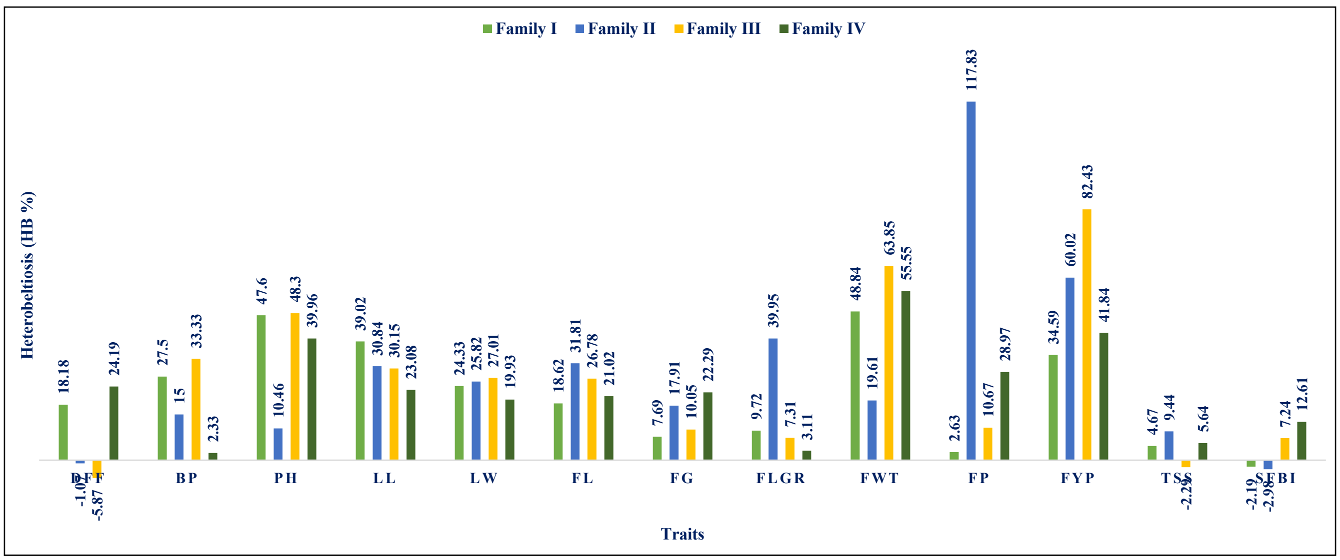

Figure 1: Graphical representation of per cent heterobeltiosis for different traits in four families of brinjal; DFF: Days first to flowering; BP: Branches plant^{-1}; PH: Plant height; LL: Length blade length; LW: Length blade width; FL: Fruit length; FG: Fruit girth; FFGR: Fruit length/girth ratio; FWT: Fruit weight; FP: Fruits plant^{-1}; FYP: Fruit yield plant^{-1}; TSS: Total soluble solids and SFBI: Shoot and fruit borer incidence

3.3. Plant height

The relative heterosis and heterobeltiosis ranged from 9.92 to 28.00% and 10.46% to 48.30%. Significant positive relative heterosis and heterobeltiosis were found for all families: AB 20-19×GAOB 2 (28.00% and 47.60%), AB 20-13×CO 2 (9.92% and 10.46%), Anand Harit×GJB 3 (19.96% and 48.30%) and GPBRJ 204×Arka Harshitha (10.78% and 39.96%). For these traits, heterosis in the positive direction is needed. These results do not conform with those obtained by Shafeeq et al. (2007), Ansari et al. (2009), Das et al. (2009), Sao and Mehta (2011), Patidar et al. (2017), Rameshkumar and Vethamonai (2020), Abdelkader et al. (2022) and Mishra et al. (2023) who found relative heterosis (-5.85 to 33.45%) and heterobeltiosis (-13.70 to 20.46%).

Inbreeding depression fluctuated from 1.48 to 16.11%. Significant inbreeding depression was shown for three families *viz*., AB 20-19×GAOB 2 (16.11%), Anand Harit×GJB 3 (9.03%) and GPBRJ 204×Arka Harshitha (5.11%). Non-significant

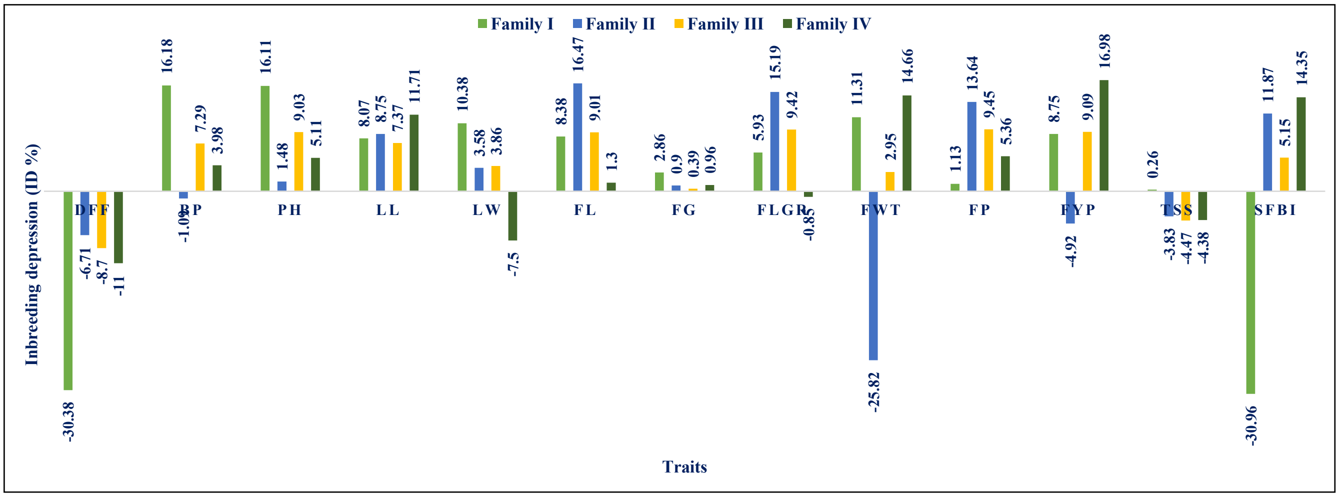

Figure 2: Graphical representation of per cent inbreeding depression for different traits in four families of brinjal; DFF: Days first to flowering; BP: Branches plant^{-1}; PH: Plant height; LL: Length blade length; LW: Length blade width; FL: Fruit length; FG: Fruit girth; FFGR: Fruit length/girth ratio; FWT: Fruit weight; FP: Fruits plant^{-1}; FYP: Fruit yield plant^{-1}; TSS: Total soluble solids and SFBI: Shoot and fruit borer incidence

inbreeding depression was found for AB 20-13×CO 2 (1.48%). Similar findings were reported by Savaliya et al. (2017) who depicted 1.52 to 10.65% and Barik et al. (2022) who found 6.38%.

3.4. Leaf blade length

The relative heterosis and heterobeltiosis ranged from 7.91 to 16.98% and 23.08% to 39.60%, respectively. The experimental data presented in Table 1 for leaf blade length indicated significant positive relative heterosis and heterobeltiosis for AB 20-19×GAOB 2 (16.98% and 39.02%), AB 20-13×CO 2 (12.98% and 30.84%), Anand Harit×GJB 3 (14.26% and 30.15%) and GPBRJ 204×Arka Harshitha (7.91% and 23.08%). These above results contradict Kaushik (2019), who obtained relative heterosis (-20.43%).

Inbreeding depression fluctuated from 7.37 to 11.71%. Significant inbreeding depression was found for AB 20-19×GAOB 2 (8.07%), AB 20-13×CO 2 (8.75%), Anand Harit×GJB 3 (7.37%) and GPBRJ 204×Arka Harshitha (11.71%).

3.5. Leaf blade width

For leaf blade width, the relative heterosis ranged from 0.53 to 18.00%. Three families *viz*., AB 20-19×GAOB 2 (15.35%), AB 20-13×CO 2 (18.00%) and Anand Harit×GJB 3 (16.83%) showed significant positive relative heterosis, making them desirable. However, GPBRJ 204×Arka Harshitha (0.53%) exhibited non-significant relative heterosis. Heterobeltiosis ranged from 19.93 to 27.01% with all families displaying positive significant heterobeltiosis *i.e*., AB 20-19×GAOB 2 (24.33%), AB 20-13×CO 2 (25.82%), Anand Harit×GJB 3 (27.01%) and GPBRJ 204 × Arka Harshitha (19.93%). These above results are not in accordance with Kaushik (2019) who reported relative heterosis (-25.24%).

Significant inbreeding depression was observed in AB 20-19×GAOB 2 (10.38%), Anand Harit×GJB 3 (3.86%) and GPBRJ 204×Arka Harshitha (-7.50%), while AB 20-13×CO 2 (3.58%) recorded non-significant inbreeding depression.

3.6. Fruit length

Relative heterosis for fruit length ranged from 9.82 to 17.70%. Significant positive relative heterosis was found in AB 20-13×CO 2 (17.71%), Anand Harit×GJB 3 (11.19%) and GPBRJ 204×Arka Harshitha (12.45%), while AB 20-19×GAOB 2 (9.82%) was non-significant. These findings align with Kamani & Monpara (2009), Mistry et al. (2018) and Mohamed et al. (2022), who observed a range between 13.20 to 48.03%. Heterobeltiosis ranged from 18.62 to 31.81%, with all families showing significant values *viz*., AB 20-19×GAOB 2 (18.62%), AB 20-13×CO 2 (31.81%), Anand Harit×GJB 3 (26.78%) and GPBRJ 204×Arka Harshitha (21.02%). These results are consistent with findings by Mistry et al. (2018), Rani et al. (2018) and Abdelkader et al. (2022). Positive heterosis in this trait indicates a higher potential for hybrids to produce larger fruits plant^{-1}.

Inbreeding depression varied from 1.30 to 16.47% with significant value in AB 20-13×CO 2 (16.47%) and Anand Harit×GJB 3 (9.01%). The other two families showed non-significant. The results are similar to Kamani and Monpara (2009) who found 15.52 to 22.70% and Mistry et al. (2018) who observed 1.19 to 8.80. The positive magnitude of inbreeding depression suggests fewer chances of valuable segregants in the F_2 population for this trait.

3.7. Fruit girth

Relative heterosis for fruit girth ranged from 3.34 to 10.90%. Significant positive heterosis was observed in GPBRJ 204×Arka Harshitha (10.90%), whereas non-significant heterosis was found in AB 20-19×GAOB 2 (3.34%), AB 20-13×CO 2 (7.18%), Anand Harit×GJB 3 (5.25%). These results are consistent with

Das et al. (2009), Kamani and Monpara (2009), who recorded 8.67 to 14.61% and Mistry et al. (2018). Heterobeltiosis for fruit girth fluctuated from 7.69 to 22.29%. Significant negative heterobeltiosis was found in all families *viz*., AB 20-19×GAOB 2 (7.69%), AB 20-13×CO 2 (17.91%), Anand Harit×GJB 3 (10.05%) and GPBRJ 204×Arka Harshitha (22.29%). These findings align with Kamani and Monpara (2009), Mistry et al. (2018) and Mohamed et al. (2022). Positive heterosis in this trait is desirable, suggesting a higher potential for hybrids to produce large fruits plant^{-1}.

Inbreeding depression for fruit girth ranged from 0.39 to 2.86%. Non-significant inbreeding depression was recorded in AB 20-19×GAOB 2 (2.86%), AB 20-13×CO 2 (0.90%), Anand Harit×GJB 3 (0.39%) and GPBRJ 204×Arka Harshitha (0.96%). The findings are similar to Kamani and Monpara (2009), Mistry et al. (2018) and Barik et al. (2022) who exhibited 3.89%. The positive magnitude of inbreeding depression indicates the least chances of beneficial segregants in the F_2 population for this trait.

3.8. Fruit length/girth ratio

Relative heterosis ranged from 0.89 to 8.24%. Non-significant relative heterosis was shown for AB 20-19×GAOB 2 (5.72%), AB 20-13×CO 2 (8.24%), Anand Harit×GJB 3 (2.20%) and GPBRJ 204×Arka Harshitha (0.89%). Heterobeltiosis ranged from 3.11 to 35.95%. Significant positive heterobeltiosis was found in AB 20-19×GAOB 2 (9.72%) and AB 20-13×CO 2 (35.95%). Non-significant values were observed in Anand Harit×GJB 3 (7.31%) and GPBRJ 204×Arka Harshitha (3.11%).

Inbreeding depression for this trait ranged from -0.85 to 15.19%. Inbreeding depression was significant for AB 20-13×CO 2 (15.19%) and Anand Harit×GJB 3 (9.42%), while the remaining three families were found non-significant.

3.9. Fruit weight

Relative heterosis ranged from -8.17 to 54.38%. Significant positive relative heterosis was found in AB 20-19×GAOB 2 (39.64%), Anand Harit×GJB 3 (54.38%) and GPBRJ 204× Arka Harshitha (22.45%). Non-significant relative heterosis was observed in AB 20-13×CO 2 (-8.17%). The results are consistent with Rameshkumar and Vethamonai (2020) who recorded -8.66 to 22.08% and Mishra et al. (2023) who found -6.04 to 56.52%. Heterobeltiosis ranged from 19.61 to 63.85%. Significant heterobeltiosis was found in all families *viz*., AB 20-19×GAOB 2 (48.84%), AB 20-13×CO 2 (19.61%), Anand Harit × GJB 3 (63.85%) and GPBRJ 204×Arka Harshitha (55.55%). Similar results were reported by Naresh et al. (2014) who obtained 15.39 to 67.00%, Mistry et al. (2018) and Rani et al. (2018). Positive heterosis in this trait suggests a higher potential for hybrids to increase fruit weight.

Inbreeding depression for fruit weight fluctuated from -25.82 to 14.66. Significant inbreeding depression was found in AB 20-19×GAOB 2 (11.31%), AB 20-13×CO 2 (-25.31%) and GPBRJ 204×Arka Harshitha (14.66%), while non-significant values were found in Anand Harit×GJB 3. These findings are similar to those of Mistry et al. (2018) who found -26.08 to -8.85 and Verma et al. (2020). Positive inbreeding depression suggests fewer chances of beneficial segregants in the F_2 population for this trait.

3.10. Fruits plant^{-1}

Relative heterosis for fruits per plant ranged from -3.95 to 6.95. Non-significant values were observed in all families *viz*., AB 20-19×GAOB 2 (-3.95%), AB 20-13×CO 2 (4.31%), Anand Harit×GJB 3 (6.26%) and GPBRJ 204×Arka Harshitha (6.26%). Contradictory findings were reported by Shafeeq et al. (2007), Kamani and Monpara (2009), Sao and Mehta (2011), Al-Hubaity and Teli (2013), Patidar et al. (2017), Reddy et al. (2020) and Mishra et al. (2023). Heterobeltiosis ranged from 2.63 to 117.83%. Significant heterobeltiosis was found in AB 20-13×CO 2 (117.83%), Anand Harit×GJB 3 (10.67%) and GPBRJ 204×Arka Harshitha (28.97%), while non-significant value was observed in AB 20-19×GAOB 2 (2.63%). Similar results were noted by Suneetha et al. (2008), Mistry et al. (2018) and Rani et al. (2018). Positive heterosis in this trait suggests a higher potential for hybrids to produce more fruits plant^{-1}.

The inbreeding depression fluctuated from 1.13 to 13.64%. Significant inbreeding depression was found in AB 20-13×CO 2 (13.64%) and Anand Harit×GJB 3 (9.45%), while the other two families showed non-significant values. Kamani and Monpara (2009) who found 11.06 to 13.63% reported similar findings for fruits plant^{-1}. Positive inbreeding depression suggests fewer chances of beneficial segregants in the F_2 population for this trait.

3.11. Fruit yield plant^{-1}

Relative heterosis for fruit yield plant^{-1} ranged from 8.26 to 36.14%. Significant positive relative heterosis was observed in AB 20-19×GAOB 2 (17.74%), Anand Harit×GJB 3 (36.14%) and GPBRJ 204×Arka Harshitha (25.42%). Non-significant relative heterosis was found in AB 20-13×CO 2 (8.26%). Similar findings were reported by Kamani and Monpara (2009) who found 15.75 to 40.01%, Mistry et al. (2018) and Abdelkader et al. (2022). The heterobeltiosis ranged from 34.59 to 82.43%. Significant positive heterobeltiosis was observed in all families *viz*., AB 20-19×GAOB 2 (34.59%), AB 20-13×CO 2 (60.02%), Anand Harit×GJB 3 (82.43%) and GPBRJ 204×Arka Harshitha (41.84%). These results align with findings by Shafeeq et al. (2007), Naresh et al. (2014), Balwani et al. (2017), Mistry et al. (2018) and Abdelkader et al. (2022). Positive heterosis in this trait is desirable, indicating a higher potential for hybrids to produce greater fruit yield plant^{-1}.

The inbreeding depression fluctuated from -4.92 to 16.98%. Non-significant inbreeding depression was observed in AB 20-19 × GAOB 2 (8.75%), AB 20-13×CO 2 (-4.92 %), Anand Harit× GJB 3 (9.09%) and GPBRJ 204×Arka Harshitha (16.98%). These findings do not align with those of Rai et al. (2007), Kamani and Monpara (2009), Sao and Mehta (2011), Savaliya et al.

(2017), Mistry et al. (2018), Verma et al. (2020) and Barik et al. (2022). The significantly positive magnitude of inbreeding depression for this trait is not desirable, as it suggests that further generations will have reduced fruit yield plant^{-1}, making self-pollination unsuitable for improving this trait.

3.12. Total soluble solids

Relative heterosis and heterobeltiosis for total soluble solids ranged from -3.85 to 3.69% and -2.29 to 9.44%. Non-significant relative heterosis and heterobeltiosis were observed in all families *viz*., AB 20-19×GAOB 2 (2.74% and 4.67%), AB 20-13×CO 2 (3.69% and 9.44%), Anand Harit×GJB 3 (-3.85% and -2.29%) and GPBRJ 204×Arka Harshitha (1.38% and 5.64%). These findings do not align with those obtained by Savaliya et al. (2017) and Mishra et al. (2023).

The inbreeding depression fluctuated from -4.47 to 0.26%. Non-significant inbreeding depression was found in AB 20-19×GAOB 2 (0.26%), AB 20-13×CO 2 (-3.83%), Anand Harit ×GJB 3 (-4.47%) and GPBRJ 204×Arka Harshitha (-4.38%). Similar findings were reported by Savaliya et al. (2017) who depicted -0.18 to 0.24%.

3.13. Shoot and fruit borer incidence

Relative heterosis and heterobeltiosis for shoot and fruit borer incidence ranged from -17.15 to 2.15% and -2.98 to 12.61%. Non-significant relative heterosis and heterobeltiosis were observed in AB 20-19×GAOB 2 (-6.44% and -2.19%), Anand Harit×GJB 3 (2.15% and 7.24%) and GPBRJ 204×Arka Harshitha (0.75% and 12.61%). These results were discordant with findings by Savaliya et al. (2017) who depicted 3.68 to 6.87% and Rameshkumar and Vethamonai (2020). Significant and negative relative heterosis was found in AB 20-13×CO 2 (-17.15%) and non-significant heterobeltiosis was depicted in AB 20-13×CO 2 (-2.98%). These findings align with those obtained by Savaliya et al. (2017) who recorded 5.12 to 7.61%.

The inbreeding depression fluctuated from -30.96 to 14.35%. Significant inbreeding depression was exhibited in AB 20-19×GAOB 2 (-30.96%) and GPBRJ 204×Arka Harshitha (14.35%). Non-significant inbreeding depression was revealed in AB 20-13 × CO 2 (-11.87%) and Anand Harit × GJB 3 (-5.15%). These findings are not in agreement with those obtained by Savaliya et al. (2017) who recorded -8.31 to 0.41% and -1.40 to 0.93%.

4. Conclusion

Certain genotypes exhibited a stronger heterotic capacity than others during hybridization. The performance of the F_1 hybrids is influenced by the genetic diversity of the parental lines used in the crossing programme. Based on superior performance over the better parent and reduced inbreeding depression, the families AB 20-19×GAOB 2 and GPBRJ 204×Arka Harshitha have been identified as promising F_1 hybrids for fruit yield and other important fruit traits, making them suitable for commercial exploitation.

5. Acknowledgment

We express our gratitude to the Main Vegetable Research Station, Anand Agricultural University, Anand, Gujarat, India for providing the facilities for this study.

6. References

Abdelkader, M.F.M., Awad-Allah, M.M.A., El-Diasty, M.Z., Rashed, S.M.F., Azad, A., Abdein, M.A.E., 2022. Gene action, analysis of combining ability and heterosis effects for yield, yield components and quality traits in eggplant (*solanum melongena* L.). The Seybold Report 17(12), 1329–1346.

Al-Hubaity, A., Teli, J., 2013. Combining ability and heterosis in eggplant (*Solanum melongena* L.). Mesopotamia Journal of Agriculture 41(1), 326–338.

Anonymous, 2020. Agricultural statistics at a glance 2020. Retrieved from: http:// eands.dacnet.nic.in. Accessed on 20th December, 2022.

Anonymous, 2024. Area, production and productivity of brinjal in India (2023-24) advance estimate. Available at https:// www.indastat.com. Accessed on 15th April, 2024.

Ansari, A.M., Ahmad, E., Sah, A., Ali, M.D.N.A., Bhagat, B.K., 2009. Studies of heterosis in brinjal (*Solanum melongena* L.). Green Farming 2, 211–214.

Balwani, A.K., Patel, J.N., Acharya, R.R., Gohil, D.P., Dhruve, J.J., 2017. Heterosis for fruit yield and its component traits in brinjal (*Solanum melongena* L.). Journal of Pharmacognosy and Phytochemistry 6(5), 187–190.

Barik, S., Ponnam, N., Acharya, G., Singh, T.H., Kumari, M., Dash, M., 2022. Genetics of growth and yield attributing traits of brinjal (*Solanum melongena* L.) through six generations mean analysis. Journal of Horticultural Sciences 17(1), 41–50.

Das, S., Mandal, A.B., Hazra, P., 2009. Study of heterosis in brinjal (*Solanum melongena* L.) for yield attributing traits. Journal of Crop and Weed 5, 25–30.

Kamani, J.M., Monpara, B.A., 2009. Genetic analysis for the traits associated with fruit yield in brinjal (*Solanum melongena* L.) III. Heterosis and inbreeding depression. National Journal of Plant Improvement 11, 69–71.

Kaushik, P., 2019. Line×tester analysis for morphological and fruit biochemical traits in eggplant (*Solanum melongena* L.) using wild relatives as testers. Agronomy 9(4), 185.

Mishra, S.L., Tripathy, P., Sahu, G.S., Lenka, D., Mishra, M.K., Tripathy, S.K., Padhiary, G.G., Mohanty, A., Das, S., 2023. Study of heterosis, combining ability and gene action in brinjal (*Solanum melongena* L.) landraces of Odisha. Electronic Journal of Plant Breeding 14(2), 572–583.

Mistry, C., Kathiria, K.B., Sabolu, S., Kumar, S., 2018. Heterosis and inbreeding depression or fruit yield attributing traits in brinjal. Current Plant Biology 16, 27–31.

Nagai, K., Kida, M., 1926. An experiment with some varietal crosses of eggplants. Journal of Genetics Japanese 4, 10–30.

Naresh, B.V., Dubey, A.K., Tiwari, P.K., Avani, P., 2013. Heterosis studies for yield components and cercospora leaf spot resistance in brinjal (*Solanum melongena* L.). Progressive Research 8, 410–412. cabidigitallibrary.org/doi/ full/10.5555/20143-417-386.

Patidar, D., Shitap, M.S., Patel, N.A., 2017. Heterosis studies for fruit yield and its component in long type brinjal (*Solanum melongena* L.). Electronic Journal of Plant Breeding 8(4), 1169–1176.

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

Rameshkumar, D., Swarna, P.R., Savitha, B.K., Ravikesavan, R., 2022. Genetic variability and correlation analysis in F_2 segregating population in brinjal (*Solanum melongena* L.). Journal of Applied and Natural Science 14(S1), 151–154.

Rani, M., Kumar, S., Kumar, M., 2018. Estimation of heterosis for yield and its contributing traits in brinjal. Journal of Environmental Biology 39, 710–718.

Sabolu, S., Kathiria, K.B., Mistry, C.R., Kumar, S., 2014. Generation mean analysis of fruit quality traits in eggplant (*Solanum melongena* L.). Australian Journal of Crop Science 8(2), 243–250.

Sao, A., Mehta, N., 2010. Heterosis and inbreeding depression for fruit yield and its components in brinjal (*Solanum melongena* L.). Dirasat Agricultural Sciences 37, 36–45.

Savaliya, P.G., Patel, N.B., Mungala, R.A., Sharma, L.K., 2017. Study on heterosis and inbreeding depression for fruit yield and its components in brinjal (*Solanum melongena* L.). Frontiers in Crop Improvement 5, 101–105.

Shafeeq, A., Madhusudan, K., Hanchinal, R.R., Vijayakumar, A.G., Salimath P.M., 2007. Heterosis in brinjal (*Solanum melongena* L.). Karnataka Journal of Agricultural Science 20(1), 33–40.

Sharma, T.K., Chandra Pant, S.C., Kumar, K., Kurrey, V.K., Pandey, P.K., Bairwa P.L., 2016. Studies on heterosis in brinjal (*Solanum melongena* L.). International Journal of Bio-resource and Stress Management 7(5), 964–969.

Suneetha, Y., Kathiria, K.B., Patel, J.S., Srinivas, T., 2008. Studies on heterosis and combining ability in late summer brinjal. Indian Journal of Agricultural Research 42, 171–176.

Varma, D.D., Jivani, L.L., Purohit, V.L., Vadavia, A.T., Rathod, R.K., 2020. Heterosis and inbreeding depression for fruit yield and its component characters in brinjal (*Solanum melongena* L.). Electronic Journal of Plant Breeding 11(4), 1143–1147.