The Pharma Innovation Journal 2023; 12(12): 3476-3482

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(12): 3476-3482

www.thepharmajournal.com
Received: 06-09-2023
Accepted: 10-10-2023

Kalpana V Rathava
Department of Genetics and Plant Breeding, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat, India

RR Acharya
Main Vegetable Research Station, Anand Agricultural University, Anand, Gujarat, India

Corresponding Author:
Kalpana V Rathava
Department of Genetics and Plant Breeding, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat, India

Estimation of heterosis and inbreeding depression for fruit yield and its components traits in brinjal (*Solanum melongena* L.)

Kalpana V Rathava and RR Acharya

Abstract
A study was conducted to estimate the extent of relative heterosis, heterobeltiosis and inbreeding depression for various quantitative and qualitative traits using generation mean analysis from four crosses of eight diversified cultivars of brinjal (*Solanum melongena* L). The present study revealed high magnitude of heterobeltiosis in desirable direction in cross ABSR 2 × NSP 1 for plant height, cross KS 224 × CHBR 1 for fruit yield per plant and total soluble solids, cross JBGR 1 × GP BRJ 204 for number of fruits per plant, total soluble sugar, days to first picking and days to first flowering as well as in cross DOLI 5 × PN 1) for total phenol content. These crosses also had better overall performance in respect of important attributes related to yield. Hence, these hybrids could be commercially exploited after due investigation. Similarly, significant and positive inbreeding depression was exhibited in fruit yield per plant in cross KS 224 × CHBR 1 followed by cross ABSR 2 × NSP 1 and cross JBGR 1 × GP BRJ 204, number of fruits per plant in cross JBGR 1 × GP BRJ 204 followed by cross KS 224 × CHBR 1, fruit weight in cross ABSR 2 × NSP 1, total phenol content in cross DOLI 5 × PN 1 indicating the early generation selection for all these traits in brinjal, whereas highly significant heterosis with low inbreeding depression was exhibited for total soluble sugar in cross KS 224 × CHBR 1 and cross JBGR 1 × GP BRJ 204.

Keywords: Brinjal, generation mean analysis, relative heterosis, heterobeltiosis, inbreeding depression

Introduction
Brinjal or eggplant (*Solanum melongena* L.) is an important commercial vegetable crop in India and having chromosome number 2n = 24. It is self-pollinated crop belonging to the family Solanaceae. India considered as the primary centre of origin of brinjal. Brinjal crop is a versatile crop adapted to different agro-climatic regions and can be grown throughout the year. It is a perennial but grown commercially as an annual crop. The varieties of brinjal exhibit a wide range of fruit size, shapes and colors. Brinjal is a common and popular major vegetable crop in the subtropics and tropics mainly for its immature fruits as vegetables and since ancient time the human society has social and economical relationship with this crop. Many local cultivars are popular in different locations and cultivated in large area for their qualitative traits but is characterized by very low productivity due to lack of high yielding varieties adapted to different seasons and agronomic conditions at different parts of country. It is also susceptible to various pests and diseases. As we know, yield is a complex end product of a number of components most of which are under polygenic control. So, all changes in yield must be accompanied by changes in one or more of the components as have been pointed out by Grafius (1959) [10].

The ultimate goal of any plant breeding programme is to develop improved genotypes which are better than their existing ones in one or more traits which producing the economic yield. Sufficient understanding of the inheritance of quantitative traits and information about heritability of fruit yield, its components and quality traits are essential to develop an efficient breeding strategy. The scope for the improvement of the crop plants through proper breeding method depends on the amount of genetic variability available. Luckily a great genetic variation is available in brinjal throughout the country with regard to fruit size, shape, colour, growth habit, canopy fruit bearing habit, yield, diseases and insect-pests resistance, as well as quality and adaptability for different localities and for different growing seasons.

The heterosis expresses the superiority of F1 hybrid over its parents in term of yield and other traits. On the other hand, the inbreeding depression reflects on reduction or loss in vigour, fertility and yield as a result of inbreeding.

The magnitude of heterosis helps in the identification of potential cross combinations to be used in conventional breeding programme to enable create wide array of variability in segregating generations. The knowledge of heterosis accompanied by the extent of inbreeding depression in subsequent generations is essential for maximum exploitation of such heterosis by adopting appropriate breeding methodology. In crop improvement, only the genetic component of variation is important since only this component is transmitted to next generation.

The application of heterosis breeding is considered to be an outstanding application of principles of genetics to agriculture. Existence of a significant amount of dominance variance is essential for undertaking heterosis breeding programme. The dominance effects are associated with heterozygosity. For a successful heterosis breeding programme in any crop, there are two important strategies involved (1) There must be presence of significant heterotic effect in the hybrids that can be exploited easily and (2) The feasibility of the hybrid seed production on commercial base. Heterosis is useful to decide the direction of future breeding programme and to identify the cross combinations which are promising in conventional breeding programme. In this study several cross combinations exhibited conspicuous relative heterosis and heterobeltiosis for different traits.

Materials and Methods

The material comprising of eight genetically diverse parents of brinjal (ABSR 2, NSP 1, KS 224, CHBR 1, JBGR 1, GP BRJ 204, DOLI 5 and PN 1) selected on the basis of their geographic origin and variation in morphological characters and based on their mineral nutrient content. four crosses (ABSR 2 × NSP 1, KS 224 × CHBR 1, JBGR 1 × GP BRJ 204 and DOLI 5× PN 1) obtained by crossing of diverse parents during *Kharif-rabi*-2014-15 which was produced by the department at Main Vegetable Research Station, Anand Agricultural University, Anand. Backcrossing was done in *Kharif-rabi*-2016-17 with its respective parents. Selfing of F1s was done in the same season (*Kharif-rabi*-2016-17) to get F2s. The evaluation trial was conducted in *Kharif-rabi*-2017-18 at Main Vegetable Research Station, Anand Agricultural University, Anand. The experimental material consisting of six generations (P1, P2, F1, F2, BC1 and BC2) of each of the four crosses were sown during *Kharif-rabi*-2017-18 in compact family block design with three replications. Each replication was divided in four compact blocks. Each four crosses consisting of six generations were randomly allotted to each plot within a block. Each plot consisted of two rows of parents and F1s, four rows of the backcrosses and eight rows of the F2 generations of each cross. Inter and intra row spacing was 90 cm and 60 cm respectively. The standard agronomical practices were followed to raise the good experimental crop.

In this study observations for twelve different characters under study were recorded in each experimental unit. *i.e.,* generation as five plants in each P1, P2 and F1, ten plants in each B1 and B2 and twenty plats in F2 *viz.,* days to first flowering, days to first fruit picking, plant height, number of fruits per plant, fruit length, fruit girth, fruit weight, fruit yield per plant, total phenol content, total soluble sugars, moisture content and total soluble solids. The plants for recording observations were selected randomly from the competitive plants. The selected plants were tagged and numbered for recording different observations. An individual observation of each generation of each family was considered for statistical analysis.

Statistical Analysis

Heterosis: Heterosis, expressed as per cent increase or decrease in the mean value of F1 hybrid over the mid and better parent (heterobeltiosis) was computed for

Relative heterosis

$$(RH)\ (\%) = \frac{\bar{F}_1 - \bar{M}\bar{P} \times 100}{M}$$

$$\bar{M}P = \frac{P_1 + P_2 \times 100}{2}$$

Where,

$\bar{P}1$ = Mean performance of first parent i.e. (female), $\bar{P}2$ = Mean performance of second

parent i.e. (male), $\bar{F}1$ = Mean value of F1 hybrid i.e. F1

Heterobeltiosis (Hb) (%) = $\bar{F}1 - \bar{\bar{B}}\bar{P} \times 100$

Where,

$\bar{\bar{B}}\bar{P}$ = Mean performance of better parent, $\bar{F}1$ = Mean value of F1 hybrid i.e. F1

Inbreeding depression: Reduction in vigour, reproductive capacity and productivity due to

fixation of unfavourable recessive gene in F2 as a result of inbreeding was computed by using the following formulae:

Where,

$$\text{Inbreeding depression } (\%) = \frac{F1 - F2}{F1} \times 100$$

$\bar{F}1$ = Mean value of F1 hybrid, $\bar{F}2$ = Mean value of F2 generation of respective F1

Results and Discussion

The degree of heterosis over mid parent and over better parent varied from cross to cross for all the twelve characters. The highest estimate of relative heterosis was obtained for fruit yield per plant in cross KS 224 × CHBR 1 (147.77%), total soluble sugar in cross JBGR 1 × GP BRJ 204 (71.71%), number of fruits per plant in cross JBGR 1 × GP BRJ 204 (67.40%), total phenol content in cross DOLI 5 × PN 1 (57.24%), fruit weight in cross ABSR 2 × NSP 1 (35.53%), fruit girth in cross I (16.24%), fruit length in cross JBGR 1 × GP BRJ 204 (15.17%), plant height in cross IV (6.35%), moisture content in cross DOLI 5 × PN 1 (2.13%), days to first flowering in cross JBGR 1 × GP BRJ 204 (-7.94%) and days to first picking in cross JBGR 1 × GP BRJ 204 (-9.46%). The highest estimate of heterobeltiosis was obtained for fruit yield per plant in cross KS 224 × CHBR 1 (97.23%), number of fruits per plant in cross JBGR 1 × GP BRJ 204 (47.80%), total phenol content in cross DOLI 5 × PN 1 (44.96%), total soluble sugar in cross JBGR 1 × GP BRJ 204 (36.64%), total soluble solids in cross KS 224 × CHBR 1 (10.63%), plant height in cross ABSR 2 × NSP 1 (6.35%), days to first picking in cross JBGR 1 × GP BRJ 204 (-11.36%) and days to first flowering in cross JBGR 1 × GP BRJ 204 (-12.15%).

In the present study, low to high amount of inbreeding depression (ID) in desirable direction was found in most of the traits. With few expectations, the higher magnitude of inbreeding depression was noted in fruit yield per plant in cross KS 224 × CHBR 1 (58.40%) followed by cross ABSR 2 × NSP 1 (32.13%) and cross JBGR 1 × GP BRJ 204 (28.28%), number of fruits per plant in cross JBGR 1 × GP BRJ 204 (40.64%) and cross KS 224 × CHBR 1 (29.56%), fruit weight in cross ABSR 2 × NSP 1 (35.11%), total phenol content in cross DOLI 5 × PN 1 (27.01%). The characters which manifested low heterosis in F1 also showed low inbreeding depression in F2. All the crosses exhibited significant and positive inbreeding depression for plant height suggesting that F2s had lower estimate than their respective F1s for these characters except cross KS 224 × CHBR 1, which exhibited non-significant and positive inbreeding depression. Close examination of data on inbreeding depression for fruit yield indicated that, in general, crosses showing moderate to high heterotic effect also displayed significant inbreeding depression. Further, the values obtained for relative heterosis was generally greater than the values for inbreeding depression. This was anticipated since the estimates of inbreeding depression, theoretically account for only 50% of the expected change and consequently they will usually be much less than the estimates of heterosis. The results were in agreement with the findings of Kheradanam *et al.* (1975) [18] who reported parallel relationship between heterosis and inbreeding depression. For practical utility, it would be worthwhile to compare the performance of hybrids with the best available pure line.

The estimates of heterosis expressed as percentage over mid parent (relative heterosis) and over better parent (heterobeltiosis) in F1 hybrid and inbreeding depression in F2 generation estimated in comparison to F1 mean value for various characters in four crosses of brinjal are presented in Table 1 and 2. For days to first flowering, relative heterosis and heterobeltiosis in negative direction always desirable for early blooming, so that the early flowering of a cross can be considered to be desirable. The magnitude of various heterotic effects and inbreeding depression were lower in all the crosses. Only one cross JBGR 1 × GP BRJ 204 exhibited significant negative relative heterosis (-7.94%) as well as heterobeltiosis (-12.15%) which was desirable for this trait (Table 1). The results was in accordance with findings of Das and Barua (2001) [6], Singh *et al*. (2003) [30], Chowdhury *et al.* (2010) [5], Hubaity *et al*. (2013) [12], who exhibited significant negative to positive range of heterobeltiosis for days to first flowering. Pandey *et al.* (2018) [22] and Dharwad *et al*. (2011) [7] who observed frequency and magnitude of heterosis was low for days to first flowering. None of the crosses depicted significant positive inbreeding depression. Out of four crosses KS 224 × CHBR 1 (-8.29%) and JBGR 1 × GP BRJ 204 (-6.75%) were depicted significant negative inbreeding depression. Hence these crosses revealed possibilities for undesirable transgressive sergeants. Sao and Mehta (2010b) [26] reported the significant inbreeding depression for days to first flowering in brinjal.

With regard to days to first fruit picking relative heterosis and heterobeltiosis in negative direction are desirable for early harvesting, so that the early picking of a cross can be considered to be desirable. The magnitude of various heterotic effects and inbreeding depression were lower in all the crosses. Out of four crosses, only one cross JBGR 1 × GP BRJ 204 exhibited significant negative relative heterosis (-9.46%) as well as heterobeltiosis (-11.36%), which was desirable for this trait.The results are in agreement with the findings of Makani *et al*. (2013) [20], Biswas *et al*. (2013) [4], Dishri *et al.* (2018) [8] and Pandey *et al.* (2018) [22] who reported significant and the highest negative heterobeltiosis. The estimates of inbreeding depression ranged from -7.33 to 0.98 per cent. None of the crosses depicted significant positive inbreeding depression. Out of four crosses KS 224 × CHBR 1(-7.33%) and JBGR 1 × GP BRJ 204 (-5.98%) were depicted significant and negative inbreeding depression. Hence these crosses revealed possibilities for undesirable transgressive sergeants. Gopinath and Madalageri (1986) [34] reported significant inbreeding depression for days to first picking in brinjal.

For plant height, relative heterosis and heterobeltiosis in negative direction were considered to be desirable. Among all four crosses, only one cross Doli 5 × PN 1 (11.98%) exhibited significant positive and the highest relative heterosis followed by ABSR 2 × NSP 1 (9.27) as well as heterobeltiosis (6.35%). Only one cross JBGR 1 × GP BRJ 204 exhibited non-significant negative relative heterosis (-0.81%) as well as heterobeltiosis (-10.55%), which was undesirable for this trait. Similar results were recorded by Singh *et al*. (2003) [30], Biswas *et al*. (2013) [4], Makani *et al*. (2013) [20], Dubey *et al*. (2014) [9] and Dishri *et al.* (2018) [8] who reported positive significant heterobeltiosis. Inbreeding depression was found positive and highly significant in all crosses *viz.*, ABSR 2 × NSP 1 (5.80%), JBGR 1 × GP BRJ 204 (9.55%) and Doli 5 × PN 1 (9.11%) except in cross KS 224 × CHBR 1(4.66%).

In case of number of fruits per plant, relative heterosis and heterobeltiosis in positive direction was considered to be desirable. The magnitudes of various heterotic effects were moderate to high, whereas, the estimates of inbreeding depression were high for most of crosses. All the crosses *viz.*, ABSR 2 × NSP 1 (11.72%), KS 224 × CHBR 1 (54.58%), JBGR 1 × GP BRJ 204 (67.40%) except Doli 5 × PN 1 (-13.55%) showed significantly positive relative heterosis, indicating significant increase in number of fruits per plant of F1 over their respective mid parent values, which was desirable for this trait. Whereas, the highly significant positive heterobeltiosis was registered in cross JBGR 1 × GP BRJ 204 (47.80%) followed by KS 224 × CHBR 1 (30.79%) which was desirable for this trait. The results are in agreement with the findings of Singh *et al.* (2003) [30], Chowdhury *et al.* (2010) [5], Dharwad *et al*. (2011) [7], Hubaity *et al*. (2013) [12], Biswas *et al*. (2013) [4], Makani *et al*. (2013) [20], Shahjahan *et al.* (2016) [16] and Dishri *et al.* (2018) [8] who reported significant positive heterobeltiosis. Out of four crosses, KS 224 × CHBR 1 (29.56%) and JBGR 1 × GP BRJ 204 (40.64%) were depicted significant positive inbreeding depression, which is not preferred for beneficial transgressive segregants. None of the hybrids found desirable for transgressive segregants. Joarder *et al.* (1981) [16] and Gopinath and Madalageri (1986) [34] reported high inbreeding depression for fruit number per plant in brinjal.

For fruits length, relative heterosis and heterobeltiosis in positive direction was considered to be desirable. In general, the magnitude of various heterotic effects was low to moderate in fruit length; however some crosses exhibited positive and highly significant estimates of heterotic effects. Among all the four crosses, the highly significant relative heterosis was observed in cross JBGR 1 × GP BRJ 204 (15.17%), which was desirable for more fruit length. Only one cross Doli 5 × PN 1 (-9.73%) depicted significant and negative estimates of heterobeltiosis, which was undesirable for this trait. However, none of the crosses exhibited significant heterobeltiosis in desired direction. The results are in agreement with the findings of Singh *et al*. (2003) [30], Biswas *et al*. (2013) [4], Makani *et al*. (2013) [20], Dubey *et al*. (2014) [9], Ansari and Singh (2016) [1], Shahjahan *et al.* (2016) [16] and Dishri *et al.* (2018) [8] who exhibited significant highest relative heterosis and heterobeltiosis. The cross ABSR 2 × NSP 1 (8.51%) depicted significant and positive estimate of inbreeding depression, which is not preferred for beneficial transgressive segregants. None of the hybrids is likely to yield desirable transgressive segregants. Gopinath and Madalageri (1986) [34] reported significant inbreeding depression for fruit length in brinjal.

Relative heterosis and heterobeltiosis in negative direction was considered to be desirable for fruit girth. The magnitudes of various heterotic effects were low to moderate, whereas the estimates of inbreeding depression were moderate to high for most of crosses. Only one cross ABSR 2 × NSP 1 (16.24%) showed significant positive relative heterosis, which was undesirable for this trait. None of the cross exhibited negative and significant estimate of heterosis. Out of all the four crosses, only one cross Doli 5 × PN 1 (-19.82%) depicted significantly negative heterobeltiosis and found desired for the uniform fruit girth. The results of present study are akin with finding of Biswas *et al*. (2013) [4], Makani *et al*. (2013) [20], Balwani *et.al* (2017) [2] and Dishri *et al.* (2018) [8]. Out of four crosses, the highest significantly positive inbreeding depression was depicted by the cross ABSR 2 × NSP 1 (15.37%), which is useful for isolation of transgressive segregants.

In case of fruit weight, Relative heterosis and heterobeltiosis in positive direction was considered to be desirable for fruit girth. The magnitudes of various heterotic effects were low to high, whereas the estimates of inbreeding depression were low to high for most of crosses. Out of four crosses, only one cross ABSR 2 × NSP 1 (31.53%) depicted significant and positive relative heterosis, which was desirable for this trait. Whereas, all the crosses had negative heterobeltiosis, out of which the cross Doli 5 × PN 1 (-32.26%) manifested significant negative heterobeltiosis, which was undesirable for this trait. The size of the fruit always preferred for higher yield. The results are in agreement with the findings of Dharwad *et al*. (2011) [8], Biswas *et al*. (2013) [4], Makani *et al*. (2013) [20], Dubey *et al*. (2014) [9], Reddy and Patel (2014) [25], Ansari and Singh (2016) [1], Shahjahan *et al.* (2016) [16], Balwani *et.al* (2017) [2] and Dishri *et al.* (2018) [8]. Out of four crosses, only one cross JBGR 1 × GP BRJ 204 (-18.19%) was depicted significantly negative inbreeding depression while, cross ABSR 2 × NSP 1 (35.11%) was depicted significantly positive inbreeding depression. Hence this cross revealed possibilities for transgressive segregants. Joarder *et al.* (1981) [16] reported high inbreeding depression for fruit yield, fruit weight and fruit number per plant in brinjal.

For fruit yield per plant, relative heterosis and heterobeltiosis in positive direction were considered to be desirable. The estimates of various heterotic effects and inbreeding depression were high and positive for majority of crosses. All the crosses depict significant and positive relative heterosis. The highest relative heterosis recorded by cross KS 224 × CHBR 1 (147.77%) followed by JBGR 1 × GP BRJ 204 (70.42%), ABSR 2 × NSP 1 (64.96%) and Doli 5 × PN1 (10.46%), which was desirable for yield in brinjal. For the purpose of estimation of heterosis over better parent, the parent having higher fruit yield per plant was considered as better parent. All the crosses *viz.,* KS 224 × CHBR 1 (97.23%), ABSR 2 × NSP 1 (59.77%) and JBGR 1 × GP BRJ 204 (44.36%) were significantly superior to their respective better parent except cross Doli 5 × PN 1(-0.05%). The higher magnitude of heterobeltiosis for fruit yield suggested presence of over dominance; hence heterosis breeding would be most effective to take advantage of dominance gene effect. The results of present study are akin with finding of Singh *et al*. (2003) [30], Sao and Mehta (2010b) [26], Chowdhury *et al*. (2010) [5], Dharwad *et al*. (2011) [8], Pachiyappan *et al*. (2012), Hubaity *et al*. (2013) [12], Biswas *et al*. (2013) [4], Makani *et al*. (2013) [20], Dubey *et al*. (2014) [9], Reddy and Patel (2014) [25], Ansari and Singh (2016) [1], Singh *et al.* (2016), Shahjahan *et al.* (2016) [27], Balwani *et.al* (2017) [2], Kumar *et al*., (2017)b, Patel *et al.*(2017) [24] and Dishri *et al.* (2018) [8] who reported highest significant positive relative heterosis and heterobeltiosis. Among all the crosses *viz.,* KS 224 × CHBR 1(58.40%), ABSR 2 × NSP 1 (32.13%) and JBGR 1 × GP BRJ 204%) were depicted significantly positive inbreeding depression and it is not preferred for beneficial transgressive segregants. Whereas, the cross Doli 5 × PN 1 (-8.68%) were depicted significantly negative inbreeding depression. Hence this cross revealed possibilities for desirable transgressive segregants. Joarder *et al.* (1981) [16], Gopinath and Madalageri (1986) [34] reported inbreeding depression for fruit yield in brinjal. Sao and Mehta (2010b) [26] reported the high degree of inbreeding depression for fruit yield per plant and its related traits in brinjal. The higher estimates of various heterotic effects in positive direction and presence of undesirable inbreeding depression suggested that heterosis breeding would be of immense value for improvement of fruit yield per plant in brinjal.

The magnitude of various heterotic effects were low to high, whereas the estimates of inbreeding depression were low to high for most of crosses for total phenol content. Significantly negative relative heterosis was observed with cross JBGR 1 × GP BRJ 204 (-59.05%) and ABSR 2 × NSP 1 (-19.36%), which revealed significant decrease in phenol content of these hybrids as compared to their mid parent value, which was desirable for this trait. For the purpose of estimation of heterosis over better parent, the parent having lower phenol content was considered as better parent. The significantly negative heterobeltiosis was registered in cross JBGR 1 × GP BRJ 204 (-73.18%), KS 224 × CHBR 1 (-65.37%) and ABSR 2 × NSP 1 (-30.58%) which revealed significant decrease in phenol content of these hybrids as compared to their better parent value, which was desirable for this trait. However, only cross Doli 5 × PN 1 (44.96%) depicted significantly positive heterobeltiosis. The higher magnitude of heterobeltiosis for phenol content suggested existence of over dominance gene effect. The results of present study are akin with finding of Makani *et al.* (2013) [20] who reported significant relative heterosis and heterobeltiosis. Three crosses JBGR 1 × GP BRJ 204 (-263.13%), KS 224 × CHBR 1(-116.86%) and ABSR 2 × NSP 1 (-17.78%) were depicted significantly negative inbreeding depression, whereas cross Doli 5 × PN 1 (27.01%) registered significantly positive inbreeding depression. Hence, this cross revealed possibilities of desirable transgressive segregants.

For total soluble sugars, the magnitude of various heterotic effects were low to high, whereas, the estimates of inbreeding depression were low to high for most of crosses. Significantly positive heterosis was observed with cross JBGR 1 × GP BRJ 204 (71.71%) and KS 224 × CHBR 1 (41.60%), which revealed significant increase in total soluble content of these hybrids as compared to their mid parent value, which was desirable for this trait. For the purpose of estimation of heterosis over better parent, the parent having higher total soluble sugar content was considered as better parent. The significantly positive heterobeltiosis was registered in cross KS 224 × CHBR 1 (-65.37%) which revealed significant increase in total soluble sugar content of these hybrids as compared to their better parent value, which was desirable for this trait. The crosses Doli 5 × PN 1 (-49.50%) and ABSR 2 × NSP 1 (-76.69%) depicted significantly negative heterobeltiosis. The negative estimate of heterobeltiosis for total soluble sugar content could not be preferred for this trait. The results are in agreement with the findings of Makani *et al*. (2013) [20] whereas Patel *et al.* (2017) estimated heterotic effects were low to moderate for total soluble sugar. Among all the crosses, ABSR 2 × NSP 1 (14.75%) registered significantly positive inbreeding depression, whereas crosses KS 224 × CHBR 1(- 16.32%), Doli 5 × PN 1 (-64.66%) and JBGR 1 × GP BRJ 204 (-111.41%) were depicted significantly negative inbreeding depression. Hence, this cross revealed possibilities of desirable transgressive segregants for this trait.

For moisture content, relative heterosis and heterobeltiosis in positive direction were considered to be desirable. The magnitudes of various heterotic effects were low whereas, the estimates of inbreeding depression were low for most of crosses. Among all the crosses, ABSR 2× NSP 1 (1.72%) and Doli 5 × PN 1 (2.13%) showed significant positive and the highest relative heterosis, indicating significant increase in moisture content of F1 over their respective mid parent values, which was desirable for this trait. The cross KS 224 × CHBR 1 (-0.12%) was registered highly significant negative heterobeltiosis followed by Doli 5 × PN 1 (-0.46%) which were undesirable for this trait. The results of present study are akin with finding of Makani *et al*. (2013) [20] whereas, Patel *et al.* (2017) estimated heterotic effects were low to moderate for moisture content. Out of four crosses ABSR 2 × NSP 1(10.37%), KS 224 × CHBR 1 (4.49%) and Doli 5× PN 1 (2.54%) were depicted significant positive inbreeding depression and it is not preferred for beneficial transgressive segregants.

In case of total soluble solids, relative heterosis and heterobeltiosis in positive direction were considered to be desirable. The magnitudes of various heterotic effects were low to moderate whereas, the estimates of inbreeding depression were low for most of crosses. Among all the crosses *viz.*, KS 224 × CHBR 1 (10.63%) and JBGR 1 × GP BRJ 204 (9.87%) showed highly significant positive relative heterosis, indicating significant increase in total soluble solids of F1 over their respective mid parent values, which were desirable for this trait. The cross ABSR 2 × NSP 1 (-2.68%) and Doli 5 × PN 1 (-2.68%) exhibited significant and negative relative heterosis. The highly significant negative heterobeltiosis was registered in cross ABSR 2 × NSP 1(-11.81%) which was undesirable for this trait. These results corroborate with findings of Biswas *et al.* (2013) [4] and Balwani *et.al* (2017) [2] whereas, Patel *et al.* (2017) [24] who estimated heterotic effects were low to moderate for total soluble solids. Out of four crosses, only one cross KS 224 × CHBR 1 (9.11%) depicted significant positive inbreeding depression and it is not preferred for beneficial transgressive segregants. The crosses ABSR 2 × NSP 1 (-1.15%) and Doli 5 × PN 1 (-1.15%) were exhibited significant and negative inbreeding depression. Hence, this cross revealed possibilities of desirable transgressive segregants for this trait.

The results on inbreeding depression revealed that high inbreeding depression for fruit yield was mainly due to the inbreeding depression for its components. Relationship between heterotic response and inbreeding depression (*i.e.* crosses showing high heterosis also show high inbreeding depression) suggests the importance of non- additive gene in cowpea. The result is in close agreement with those of Kheradanam *et al.* (1975) [18].

It is pertinent to note that some hybrids of low x low and low x high yielding parents manifested relatively high heterobeltiosis while some hybrids involving high x high yielding parents exhibited low heterobeltiosis. The probable explanation for this type of behaviour is that poor yielding parents might have different constellations of genes with complementary action when brought together in a hybrid combination. It is therefore, desirable to select hybrid based on their mean performance rather than heterotic effect. These results are in agreement with the finding of Singh (1983) [32] who observed high heterosis in high x High and high x low yielding parental combination. While Bhaskaraish *et al.* (1980) [3] did not observed high heterosis in low x low yielding parents.

Table 1: Estimates of relative heterosis (RH%), heterobeltiosis (HB%) and inbreeding depression (ID%) for days to first flowering, days to first fruit picking, plant height, number of fruits per plant, fruit length and fruit girth in four crosses of brinjal.

Estimates (%)	Days to first flowering	Days to first fruit picking	Plant height	Number of fruits per plant	Fruit length	Fruit girth
Cross I (ABSR 2 × NSP 1)						
RH%	2.32*	3.92**	9.27**	11.72**	8.05	16.24**
HB%	-1.97	0.76	5.64	-20.07**	1.62	0.74
ID%	-2.35	-2.52	5.80*	-14.97**	8.51*	15.37**
Cross II (KS 224 × CHBR 1)						
RH%	-1.92	-1.70	6.55	54.58**	7.76	8.15
HB%	-2.23	-1.98	1.60	30.79**	-0.27	2.60
ID%	-8.29**	-7.33**	4.66	29.56**	-3.67	2.87
Cross III (JBGR 1 × GP BRJ 204)						
RH%	-7.94**	-9.46**	-0.81	67.40**	15.17*	6.21
HB%	-12.15**	-11.36**	-10.55	47.80**	1.09	-5.28
ID%	-6.75**	-5.98**	9.55*	40.64**	-4.44	-6.27
Cross IV (DOLI 5 × PN 1)						
RH%	-0.58	0.09	11.98**	-13.55**	-2.21	2.89
HB%	-2.49	-2.20	6.35**	-45.79**	-9.73**	-19.82**
ID%	-1.49	0.98	9.11**	-0.22	2.13	3.56

Table 2: Estimates of relative heterosis (RH%), heterobeltiosis (HB%) and inbreeding depression (ID%) for fruit weight, fruit yield per plant, total phenol content, total soluble sugars, moisture content and total soluble solids in four crosses of brinjal.

Estimates (%)	Fruit weight	Fruit yield per plant	Total phenol content	Total soluble sugars	Moisture content	Total soluble solids
Cross I (ABSR 2 × NSP 1)						
RH%	31.53*	64.96**	-19.36**	-66.74**	1.72**	-2.68**
HB%	-13.50	59.77**	-30.58**	-76.69**	0.01	-11.81**
ID%	35.11**	32.13**	-17.78**	14.75**	10.37**	-1.15*
Cross II (KS 224 × CHBR 1)						
RH%	-13.49	147.77**	-60.75	41.60**	0.01	10.63**
HB%	-17.94	97.23**	-65.37**	36.64**	-0.12**	0.98
ID%	-13.52	58.40**	-116.86**	-16.32**	4.49**	9.11**
Cross III (JBGR 1 × GP BRJ 204)						
RH%	-2.54	-29.22	-18.19*	71.71**	-8.47	9.87**
HB%	70.42**	44.36**	28.28**	-2.72	-10.26	-0.90
ID%	-59.05**	-73.18**	-263.13**	-111.41**	-8.08**	-4.00
Cross IV (DOLI 5 × PN 1)						
RH%	-4.70	10.46**	57.24**	-42.01**	2.13**	-2.68**
HB%	-32.26**	-0.05	44.96**	-49.50**	-0.46**	-11.81
ID%	2.69	-8.68**	27.01**	-64.66**	2.54**	-1.15*

Conclusion

From present investigation it is concluded that heterosis in both positive and negative direction is important based on character under study. For characters *viz.,* days to first flowering, days to first fruit picking, plant height and total phenol content negative heterosis is desirable whereas for characters *viz.*, number of fruits per plant, fruit length, fruit girth, fruit weight, fruit yield per plant, total soluble sugars, moisture content and total soluble solids positive heterosis is desirable. All the promising hybrids developed from 8 parents showed positive heterosis over their respective mid and better parents which supporting high relative heterosis and heterobeltiosis for yield and its components in brinjal.

From this results and discussion, it can be clear that the highest extent of heterosis for fruit yield per plant over mid parent was recorded in the hybrid KS 224 × CHBR 1 followed by JBGR 1 × GP BRJ 204, ABSR 2 × NSP 1 and Doli 5 × PN 1 and over better parent was recorded in the hybrid KS 224 × CHBR 1 followed by ABSR 2 × NSP 1 and JBGR 1 × GP BRJ 204. The hybrids which registered higher values of various heterotic effects for fruit yield also exerted higher amount of heterotic effect for at least two yield contributing component characters, which support the combinational heterosis theory for fruit yield in brinjal. In the present investigation, the expression of heterosis in high heterotic crosses for fruit yield could be attributed to combined effect of heterosis for its major component characters. It is desirable to have highly significant and positive heterosis with low inbreeding depression. Highly significant heterosis with low inbreeding depression exhibited for total soluble sugar in cross KS 224 × CHBR 1 and cross JBGR 1 × GP BRJ 204. The magnitude of inbreeding depression in the present investigation varied from cross to cross indicating influence of genetic constitution of cross.

The significant relative heterosis and/or heterobeltiosis in desired direction were observed for number of fruits per plant, fruit girth, fruit weight, fruit yield per plant, total phenol content, total soluble sugars, moisture content and total soluble solids there by heterosis breeding would be more practical approach for higher fruit yield in brinjal. Though the traits *viz.,* days to first flowering, days to first fruit picking had negative estimates in those crosses that showed significantly positive relative heterosis and/or heterobeltiosis for fruit yield, revealed the negative association among fruit yield and its component traits. For improvement of such traits along with high fruit yield, population improvement methods such as reciprocal recurrent selection would be beneficial and it was too much easy in crop like brinjal. The crosses which depicted significantly positive heterosis for total soluble sugars, moisture content, total soluble solids and significantly negative heterosis for total phenol content had less Fruit yield, the quality of brinjal could be improved by heterosis breeding but it might resulted into lower yields therefore population improvement is a good option to improve all these traits.

References

1. Ansari AM, Singh YV. Heterosis studies for fruit characters in brinjal (*Solanum melongena* L.). Electron J Plant Breed. 2016;7(2):197-208.
2. Balwani AK, Patel JN, Acharya RR, Gohil DP, Dhruve JJ. Heterosis for fruit yield and its component traits in brinjal (*Solanum melongena* L.). J Pharmacogn Phytochem. 2017;6(5):187-190.
3. Bhaskaraish KB, Shivshanker G, Virupakshappa K. Hybrid vigour in cowpea. Indian J Genet. 1980;40(2):334-337.
4. Biswas L, Mehta N, Ansari SF. Hybrid vigour studies in brinjal (*Solanum melongena* L.). Global J Sci Frontier Res. 2013;13(9):9-11.
5. Chowdhury MJ, Ahmad S, Uddin MN, Quamruzzaman AKM, Patwary MMA. Expression of Heterosis for Productive Traits in F1 Brinjal (*Solanum melongena* L.) Hybrids. Agriculturists. 2010;8(2):8-13.
6. Das G, Barua SN. Heterosis and combining ability for yield and its components in brinjal. Ann Agric Res New Ser. 2001;22(3):399-403.
7. Dharwad NA, Patil SA, Salimath PM. Heterosis and combining ability analysis for productivity traits in brinjal (*Solanum melongena* L.). Karnataka J Agric Sci. 2011;24(5):622-625.
8. Dishri M, Mishra HN, Senapati N, Talekar NS, Sahu GS. Estimation of heterosis for earliness, yield and its components in brinjal (*Solanum melongena* L.). Plant Archives. 2018;18(2):1405-1410.
9. Dubey R, Das A, Ojha MD, Saha B, Ranjan A, Singh PK. Heterosis and combining ability studies for yield and yield attributing traits in brinjal (*Solanum melongena* L.). Bioscan. 2014;9(2):889-894.

10. Grafius JE. Heterosis in barley. Agron J. 1959;51:551-554.
11. Hanson CH, Robinson HF, Comstock RE. Biometrical studies of yield in segregating populations of Korean Lespedeza. Agron J. 1956;48:268-272.
12. Hubaity AI, Teli JA. Combining ability and heterosis in eggplant (*Solanum melongena* L.). Mesopotamia J Agric. 2013;41(1):23-35.
13. Jinks JL. A survey of the genetical basis of heterosis in varieties of diallel crosses. Heredity. 1955;9:225-238.
14. Jinks JL. Biometrical genetics of heterosis. In: Frankel R, editor. Heterosis reappraisal of theory and practices, monograph of theoretical and applied genetics. Heidelberg: Berlin, New York; 1983. p. 1-46.
15. Jinks JL, Jones RM. Estimation of the components of heterosis. Genetics. 1958;43:223-234.
16. Joarder OL, Islam QN, Salehyzzaman M, Alam MS. Inheritance of some quantitative characters in eggplant (*Solanum melongena* L.). Genet Pol. 1981;22:91-102.
17. Johnson HW, Robinson HF, Comstock RE. Genotypic and phenotypic correlations in soybean and their implications in selection. Agron J. 1955;47:477-483.
18. Kheradanam M, Bassiri A, Nikhejad M. Heterosis, inbreeding depression and reciprocal effects for yield and some yield components in a cowpea cross. Crop Sci. 1975;15(5):689-691.
19. Kumar R, Kumar R, Kumar A, Bharati DK. Estimation of heterosis for yield attributing traits and fruit borer incidence in round brinjal (*Solanum melongena* L.). Adv Res. 2017a;11(3):1-9.
20. Makani AY, Patel AL, Bhatt MM, Patel PC. Heterosis for yield and its contributing attributes in brinjal (*Solanum melongena* L.). Bioscan. 2013;8(4):1369-1371.
21. Pachiyappan R, Saravanan K, Kumar R. Heterosis in yield and yield components in eggplant (*Solanum melongena* L.). Int J Current Agric Sci. 2012;2(6):17-19.
22. Pandey M, Yadav GC. Heterosis for earliness and yield contributing traits in brinjal (*Solanum melongena* L.). Int J Chem Stud. 2018;6(4):232-234.
23. Panse VG, Sukhatme PV. Statistical methods for agricultural workers. New Delhi: Indian Council of Agricultural Research; 1985.
24. Patel AA, Gohil DP, Dhruve JJ, Damor HI. Heterosis for fruit yield and its quality characters in brinjal (*Solanum melongena* L.). J Pharmacogn Phytochem. 2017;6(6):975-978.
25. Reddy EEP, Patel AI. Heterosis studies for yield and yield attributing characters in brinjal (*Solanum melongena* L.). J Recent Advances Agric. 2014;2(2):175-180.
26. Sao A, Mehta N. Heterosis and inbreeding depression for fruit yield and its components in brinjal (*Solanum melongena* L.). Agric Sci. 2010b;37:95-101.
27. Shahjahan M, Kabir K, Zomo SA, Sarkar MD, Fazlullah MU. Evaluation of heterosis in exotic eggplant (*Solanum melongena* L.). Prudent Journals. 2016;1(2):23-32.
28. Singh RK, Chaudhary BD. Biometrical methods in quantitative genetics analysis. Ludhiana: Kalyani publishers; c2004.
29. Singh AP, Naik MR, Prasad I, Dapke JS, Patel NM. Heterosis for fruit yield in diverse brinjal (*Solanum melongena* L.) germplasm. Int J Appl Pure Sci Agric. 2016;2(7):211-215.
30. Singh HV, Singh SP, Singh S, Rajput CBS. Heterosis in relation to combining ability in brinjal (*Solanum melongena* L.). Veg Sci. 2003;30(1):38-41.
31. Singh RK, Chaudhary BD. Biometrical methods in quantitative genetics analysis. Ludhiana: Kalyani publishers; c2004.
32. Singh RP. Heterosis in cowpea. J Res Assam Agric Univ. 1983;4(1):12-14.
33. Wright S. The effects of inbreeding and cross breeding in guinea pigs. U. S. dept. Agric. Bull; c1922. p. 1121-1125.
34. Gopinath G, Madalageri BB. Bacterial wilt (*Pseudomonas solanacearum* E. F. Smith) resistance in eggplant. Veg. Sci. 1986;13:189-195.