Received: 21 Aug 2019 | Revised: 28 Sep 2020 | Accepted: 05 Oct 2020

Electronic Journal of Plant Breeding

Research Article

Heterosis and inbreeding depression for fruit yield and its component characters in brinjal (*Solanum melongena* L.)

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

Keywords
Brinjal (*Solanum melongena* L.), Heterosis, Inbreeding depression, F_1 hybrids, F_2 hybrids, generations.

INTRODUCTION

Vegetables are certain parts of plants that are consumed by humans as food and as part of a savoury meal. They can be eaten either raw or cooked and plays an important role in human nutrition. Vegetables are mostly low in fat and carbohydrates, but high in vitamins, minerals and dietary fiber. India is the second largest producer of vegetables in the world, next to China. Brinjal is one of the most important tender fruit vegetable crops of our country grown during rainy (*kharif*), winter (*rabi*) and spring (*summer*) seasons.

Brinjal or eggplant *(Solanum melongena* L.) originated in India, which is also considered as center of diversity (Genebus, 1963). It is an important solanaceous vegetable crop widely grown in the tropical and sub- tropical regions of the world. Brinjal shares 8.1 per cent in total vegetable production of India, it is grown in an area of 7.29 lakh ha with a production of 12.61 million tons and productivity of 18868 kg/ha (Anon., 2017). The crop has a somatic chromosome number of 2n=2x=24 and comprises of three botanical varieties *viz*., var. *esculentum*, with round or egg shaped fruits; var. *serpentinum* with long slender fruits and var. *depressum* having dwarf stature. Brinjal is highly productive and usually finds its place as the poor man's vegetable (Som and Maity, 2002). It is popular among people of all social strata and hence, it is rightly called as vegetable of masses (Patel and Sarnaik, 2003). Its immature fruits are used as vegetable and extensively used in various culinary preparations. Due to its quick growth, short duration and photo insensitive in nature, it enables the geneticists and plant breeders to raise two crops in a year, thereby reducing the period for improvement of yield. India being a center of origin, brinjal has a huge genetic diversity in our country itself which offers much scope for improvement through heterosis breeding. The ultimate aim in most brinjal breeding programme is to improve the genetic potential for fruit yield. Realizing the economic potential of brinjal crop in India, there is a need to identify suitable cross combinations which have desirable traits with high yield. Heterosis of brinjal crop has been exploited since past century.

Heterosis breeding is expected to make a quantum increase in production to cope up with the increasing demand for domestic and export purposes. However, hybrid seed production is a high level technology and cost intensive venture. Only well organized seed companies with good scientific manpower and well equipped research facilities can afford hybrid seed production.The public sector in developing countries frequently does not have sufficient capacity to supply adequate quantities of good quality vegetable seeds to poor farmers and at present, there are few private sector seed companies adapting cultivars to local environments, especially in the poorer countries.

Inbreeding is the basic mechanism for providing the raw (base) material for selection. The information regarding nature and magnitude of inbreeding depression is helpful in determining the effectiveness of selection. Thus, the role of inbreeding in the genetic improvement of brinjal crop is essentially of great consequence. Farmers themselves often produce seeds of locally preferred or traditional landraces, as the individual markets are too small and private companies have little interest in producing open pollinated cultivars. Therefore, residual heterosis if manifested in the F_2 generation would offer further scope as the grower need not to get the highly priced F_1 seeds every year. Manifestation of hybrid vigour in F_1 and its retention in F_2 generation of brinjal has been reported earlier. Hence, the present study was undertaken to study the desirable heterosis in yield and its component traits to develop superior F_1 hybrids and to study the inbreeding depression for better understanding of the plant behaviour in hybrid and selfed condition.

MATERIALS AND METHODS

The experimental materials comprised of six basic generations *viz.*, P_1, P_2, F_1 and F_2 of four crosses of brinjal namely AB-8-14 x S.Mani Black, AB-15-07 x Pant Rituraj, JB-12-06 x GJB-3 and NBR-14-1 x GJLB-4 which were raised at Vegetable Research Station, Junagadh Agricultural University, Junagadh, Gujarat during late *kharif/rabi*2018-19 to study heterosis and inbreeding depression for fruit yield and its component traits. Experiment was laid-out in Compact Family Block Design (CFBD) with three replications. The observations were recorded on twelve characters *viz.,* days to opening of first flower, days to first picking, fruit length (cm), fruit girth (cm), fruit weight (g), the number of fruits per plant, the number of primary branches per plant, plant height (cm), fruit yield per plant (kg), plant spread (cm), total soluble solids (TSS)(^{0}B) and fruit borer infestation(%). 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 crop. The heterotic effects in term of superiority of F_1 over better parent (heterobeltiosis) as per Fonseca and Patterson (1968) was worked out as under;

$$Heterobeltiosis(H\%) = \frac{\overline{F_1} - \overline{B}}{\overline{B}} \; x\,100$$

Where,

$\bar{F}_1$ = Mean value of the F_1 hybrid

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

The standard error and calculated 't' values for heterobeltiosis (H%) was computed as below;

$$\text{S.E. of H \%} = \sqrt{V_{\overline{F}_1} + V_{\overline{B}}}$$

The test of significance for heterobeltiosis was done by usual t-test.

Inbreeding depression

Inbreeding depression in F_2 generation was estimated as under,

$$\text{Inbreeding depression (\%)} = \frac{\overline{F_1} - \overline{F_2}}{\overline{F_1}} \; x\,100$$

Where,

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

$\overline{F_2}$ = mean value of F_2 generation

$$\text{S. E. for inbreeding depression} = \sqrt{V_{\overline{F}_1} + V_{\overline{F}_2}}$$

The test of significance for inbreeding depression was done by usual t-test.

RESULTS AND DISCUSSION

Results of heterosis and inbreeding depression were depicted in **table 1**. Magnitudes of heterotic effects were high for plant height, fruit weight and plant spread. The cross JB-12-06 x GJLB-3 also expressed significant and positive heterobeltiosis for fruit borer infestation, fruit girth, fruit length, plant spread and the number of fruits per plant. The highest positive heterobeltiosis for fruit weight was observed in AB-15-07 x Pant Rituraj, which was followed by high positive heterobeltiosis for a number of plant height in JB-12-06 x GJLB-3. The higher magnitude of inbreeding depression was noted in fruit weight in cross AB-8-14 x S. Mani Black. The hybrid AB-8-14 x S. Mani Black showed a significant and positive inbreeding depression for days to first flowering, thereby suggesting that F_2 flowered earlier than their respective F_1. The hybrid JB-12-06 x GJB-3 exhibited a significant and positive inbreeding depression for days to first picking, thereby suggesting that F_2 mature earlier than their respective F_1.

Heterobeltiosis is calculated by taking early maturing parent as better parent. Heterosis over better parent ranged from 0.27% (AB 15-07 x Pant Rituraj) (cross 2) to -1.60 % (AB-8-14 x S.Mani Black) (cross 1). Heterosis over better parent was non-significant in all the crosses. The estimates of inbreeding depression ranged from -0.63% (NBR-14-01 x GJLB-4) (cross 4) to 2.47% (AB-8-14 x S. Mani Black) (cross 1). The inbreeding depression was significant and positive in crosses; (AB-8-14 x S. Mani Black) (cross 1) and significant and negative in (AB 15-07 x Pant Rituraj) (cross 2). Similar results were observed by Indiresh and Kulkarni (2002) that wide range of heterosis and heterobeltiosis for days to first flowering.

Table 1. Heterosis and Inbreeding depression for yield and yield attributing traits in brinjal

Crosses	Heterosis (%) over BP	ID (%)	Heterosis (%) over BP	ID (%)
	Days to opening of first flower		Days to first picking	
AB-8-14 x S.Mani Black (Cross 1)	-1.60±0.83	2.47**±0.28	3.13**±0.47	-0.28±0.40
AB 15-07 x Pant Rituraj (Cross 2)	0.27±0.85	-1.23**±0.40	-1.27±1.14	-0.33±0.88
JB 12-06 x GJB -3 (Cross 3)	0.80±0.73	-0.72±0.56	0.20±0.88	1.03*±0.80
NBR-14-1 x GJLB-4 (Cross 4)	0.80±0.63	-0.63±0.56	0.13±0.68	0.60±0.64
	Fruit length (cm)		Fruit girth (cm)	
AB-8-14 x S.Mani Black (Cross 1)	-0.07±0.21	-0.07±0.15	0.53*±0.24	-0.46*±0.21
AB 15-07 x Pant Rituraj (Cross 2)	-0.06±0.16	-0.67*±015	-0.05±0.14	-0.07±0.09
JB 12-06 x GJB -3 (Cross 3)	0.18**±0.17	0.07±0.15	01.2**±0.14	-0.23±0.23
NBR-14-1 x GJLB-4 (Cross 4)	-0.13±0.21	-0.01±0.19	-0.25±0.15	-0.13±0.12
	Fruit weight (g)		Number of fruits per plant	
AB-8-14 x S.Mani Black (Cross 1)	-7.61±5.76	71.18**±10.50	-0.17±0.19	0.09±0.09
AB 15-07 x Pant Rituraj (Cross 2)	51.83**±15.67	44.59**±15.35	0.13*±0.28	0.69**±0.20
JB 12-06 x GJB -3 (Cross 3)	21.69±9.04	28.01**±9.07	0.74**±0.17	0.77±0.17
NBR-14-1 x GJLB-4 (Cross 4)	4.68±8.32	-1.13±7.77	0.41*±0.16	0.09±0.12

*, ** Significant at 5 and 1 per cent level, respectively (*Contd.*)

Table 1. (*Contd.*)

Crosses	Heterosis (%) over BP	ID (%)	Heterosis (%) over BP	ID (%)
	Number of primary branches per plant		Plant height (cm)	
AB-8-14 x S.Mani Black (Cross 1)	0.33 ± 0.32	-.10 ± 0.25	-2.27 ± 1.74	-.072 ± 1.57
AB 15-07 x Pant Rituraj (Cross 2)	-0.27 ± 0.24	-.043* ± 0.20	-11.13 ± 1.40	8.92** ± 1.32
JB 12-06 x GJB -3 (Cross 3)	-.40 ± 0.25	-.048* ± 0.20	7.33** ± 1.60	4.33** ± 1.63
NBR-14-1 x GJLB-4 (Cross 4)	0.13 ± 0.25	-.038** ± 0.19	-0.33 ± 1.58	3.57** ± 1.23
	Fruit yield per plant (kg)		Plant spread (cm)	
AB-8-14 x S.Mani Black (Cross 1)	-0.17 ± 0.19	0.09 ± 0.09	8.47**± 1.98	2.98* ± 1.35
AB 15-07 x Pant Rituraj (Cross 2)	0.13 ± 0.28	0.69* ± 0.20	-0.13 ± 1.77	-4.22** ± 1.48
JB 12-06 x GJB -3 (Cross 3)	0.74 ± 0.17	0.77**± 0.17	0.53** ± 1.35	-3.75** ±1.21
NBR-14-1 x GJLB-4 (Cross 4)	0.41 ± 0.16	0.09 ± 0.12	-4.87** ± 1.73	-4.57** ± 1.22
	Total soluble solids (TSS) (^{0}B)		Fruit borer infestation (%)	
AB-8-14 x S.Mani Black (Cross 1)	-0.29** ± 0.14	-0.29** ± 0.10	0.73 ± 0.36	0.93** ± 0.28
AB 15-07 x Pant Rituraj (Cross 2)	-0.19 ± 0.16	0.08 ± 0.11	-1.33** ± 0.37	-1.40 ± 0.27
JB 12-06 x GJB -3 (Cross 3)	-0.07 ± 0.12	0.12 ± 0.08	0.40** ± 0.44	0.58 ± 0.28
NBR-14-1 x GJLB-4 (Cross 4)	-0.13 ± 0.07	-0.03 ± 0.06	-0.93 ± 0.46	-0.80* ± 0.31

*, ** Significant at 5 and 1 per cent level, respectively

The heterosis over better parent ranged -1.27% (AB 15-07 x Pant Rituraj) (cross 2) to 3.13% (AB-8-14 x S.Mani Black) (cross 1). The cross (AB-8-14 x S.Mani Black) (cross1) was highly significant and positive for heterobeltiosis. The inbreeding depression fluctuated from -0.33 (AB 15-07 x Pant Rituraj) to 1.03% JB 12-06 x GJB -3 (cross 3) and was significant and positive in JB 12-06 x GJB -3 (cross 3). Padaria (2003) also observed considerable heterosis and heterobeltiosis for this character.

The estimates of heterobeltiosis was ranged from -0.13% (AB 15-07 x Pant Rituraj) (cross 2) to 0.18% (JB 12-06 x GJB -3) (cross 3). Heterosis over better parent was significant and positive in (JB 12-06 x GJB -3) (cross 3). The estimates of inbreeding depression ranged from -0.01% (NBR 14-1 x GJLB-4) to -0.67% (AB 15-07 x Pant Rituraj) (cross 2) and was significant and negative in cross AB 15-07 x Pant Rituraj (cross 2). Similar results were in trend with Ingale and Paw (1996).

The estimates of heterobeltiosis was ranged from -0.25% (NBR 14-1 x GJLB-4) (cross 4) to 0.53% (AB-8-14 x S.Mani Black) (cross1). Heterosis over better parent was significant and positive in cross AB-8-14 x S. Mani Black (cross1) and in JB 12-06 x GJB -3 (cross 3).The value of inbreeding depression ranged from -0.46% (cross 1) to -0.07% (cross 2) and was significant and negative in cross AB-8-14 x S. Mani Black (cross1). Ingale and Paw (1996) recorded a significant heterosis over better parent.

The heterobeltiosis was ranged from 4.68% (NBR-14-1 x GJLB-4) (cross 4) to 51.83% (AB 15-07 x Pant Rituraj) (cross 2).Heterosis over better parent was significant and positive in AB 15-07 x Pant Rituraj (cross 2) and positive in the crosses; JB 12-06 x GJB -3 (cross 3) and (NBR-14-1 x GJLB-4) (cross 4).The inbreeding depression ranged from -1.13% (NBR-14-1 x GJLB -4) to 71.18% (AB-8-14 x S.Mani Black) and was significant and positive in three crosses; AB-8-14 x S.Mani Black (cross 1), AB-15-07 x Pant Rituraj (cross 2) and JB 12-06 x GJB-3 (cross 3).Similar results were in trend with Das and Baru (2001)
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The estimates of heterosis over better parent varied from 0.74% (JB 12-06 x GJB -3) (cross 3) to -0.17% (AB-8-14 x S.Mani Black) (cross 1) and found significant and positive in the crosses; 2, 3 and 4. The estimates of inbreeding depression ranged from 0.69% (AB 15-07 x Pant Rituraj) (cross 2) to 0.09% (AB-8-14 x S. Mani Black) (cross 1) and was significant and positive in the cross (AB 15-07 x Pant Rituraj) (cross 2).Similar results were in trend with Umaretia (2002).

The heterobeltiosis ranged from -0.40% (JB 12-06 x GJB -3) (cross 3) to 0.33% (AB-8-14 x S.Mani Black) (cross 1).The estimate of heterosis over better parent were non-significant in all the crosses. The estimates of inbreeding depression ranged from -0.10% (AB-8-14 x S.Mani Black) (cross 1) to -0.48 (JB 12-06 x GJB-3) (cross 3).The estimates of inbreeding depressions was significant in all the three crosses except the cross AB-8-14 x S.Mani Black (cross1).Similar results were in accordance with Verma *et al*. (1986).

The heterobeltiosis ranged from -0.33% (NBR-14-1 x GJLB-4) (cross 4) to -11.37% (AB 15-07 x Pant Rituraj) (cross 2). The estimate of heterosis over better parent was significant and positive in the cross JB 12-06 x GJB -3 (cross 3).The estimates of inbreeding depression varied from -0.72% (AB-8-14 x S.Mani Black (cross 1) to 8.92% (AB 15-07 x Pant Rituraj (cross 2) and was significant and positive in all the crosses except the cross AB-8-14 x S.Mani black (cross 1). Similar results are in trend with Prabhu *et al*. (2005).

The estimates of heterosis over better parent varied from 0.13% (AB 15-07 x Pant Rituraj) (Cross 2) to 0.74% (JB 12-06 x GJB-3) (Cross 3) and were non-significant and positive in all the crosses. The estimates of inbreeding depression ranged from 0.09% (AB-8-14 x S.Mani Black) (cross 1) to 0.77% (JB 12-06 x GJB -3) (cross 3) and was significant and positive in cross 2 and 3. Similar results were observed by Jivani (2005).

The heterosis over better parent ranged from-0.13% (AB 15-07 x Pant Rituraj) (cross 2) to 8.47% (AB-8-14 x S. Mani Black) (cross 1).The hybrid had negative and significant in the cross (NBR 14-01 x GJLB-4) (cross 4), it was significant and positive in the cross (AB-8-14 x S. Mani Black) (cross 1) and in (JB-12-06 x GJB-3) (cross 3).The estimates of inbreeding depression varied from 2.98% (AB-8-14 x S. Mani Black) (cross 1) to -4.57% (NBR-14-1 x GJLB-4) (cross 4) and was significant and negative in all the crosses except the cross (AB-8-14 x S.Mani black) (cross 1).These findings were in agreement with Vaddoria (2006).

Heterosis over better parent ranged from -0.07% (JB 12-06 x GJB-3 (cross 3) to -0.29% (AB-8-14 x S.Mani Black) (cross 1). Heterosis over better parent was significant and negative in the cross AB-8-14 x S. Mani Black (cross 1).The estimates of inbreeding depression ranged from -0.29% (AB-8-14 x S.Mani Black) (cross 1) to -0.03% (NBR- 14-1 x GJLB -4) (cross 4) and was non-significant and positive in cross 2 (AB-15-07 x Pant Rituraj) and (JB 12-06 x GJB-3) (cross 3).Similar results were found by Vaddoria (2006).

The estimates of observed heterosis over better parent varied from -0.93% (NBR-14-1 x GJLB-4) (cross 4) to-1.33% (AB 15-07 x Pant Rituraj) (cross 2). The estimates of heterosis was significant and negative in cross (AB 15-07 x Pant Rituraj) (cross 2). The values of inbreeding depression ranged from 0.58% (JB 12-06 x GJB-3) (cross 3) to -1.40% (AB 15-07 x Pant Rituraj) (cross 2) and was significant and positive in AB-8-14 x S.Mani Black (cross 1) in (NBR-14-1 x GJLB-4) (cross 4), where it was significant and negative. Similar results are in trend with Kanthaswamy *et al*. (2003).

From the present study it could be concluded that the magnitude of heterotic effect was high for plant height, fruit weight and plant spread. Cross JB-12-06 x GJB-3 expressed significant and positive heterobeltiosis for fruit borer infestation, fruit girth, fruit length, plant spread and the number of fruits per plant. The lowest and desirable inbreeding depression was observed by crosses AB-8-14 x S. Mani Black and NBR-14-1 x GJLB-4 for fruit yield per plant.

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