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Heterosis and inbreeding depression for seed yield and its component traits in Indian bean (*Lablab purpureus* L. Sweet)

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Abstract
The investigation was conducted to assess the magnitude heterosis and inbreeding depression for seed yield and its component characters through non-replicated trial comprised of five parents GNIB-21, GP-1, GP-167, GP-189 and GPKH-120, four hybrids and their F_2 generations of Indian bean during *kharif* 2016. All four crosses exhibited positive and significant heterosis over mid parents for days to flowering, plant height, primary branches per plant, days to maturity, pod length, pod width, pod weight, pods per plant, seeds per pod, 100 seed weight, straw yield per plant, seed yield per plant and harvest index, except pods per plant, seeds per pod and harvest index in cross GNIB-21 X GP-1; primary branches per plant and seeds per pod in GNIB-21 X GP-189; pod width, pod weight, seeds per pod and harvest index in GNIB-21 X GPKH-120. While, positive and significant heterobeltiosis was observed for days to flowering and days to maturity in all crosses. Moreover, cross GNIB-21 X GP-167 exhibited positive and significant heterobeltiosis for pod weight and harvest index. The crosses GNIB-21 X GP-1, GNIB-21 X GP-189 and GNIB-21 X GP-167 recorded relatively lower amount of inbreeding depression for seed yield and its component traits, which could be utilized for isolating transgressive segregants for respective traits.

Keywords: Indian bean, heterosis, inbreeding depression, seed yield

Introduction

Indian bean [*Lablab purpureus* (L.) Sweet], with 2n=2x=22 chromosomes belongs to Fabaceae family originated in Central Africa, is a very important short day pulse crop of tropical countries especially the tribal area. It is strictly an autogamous annual herb in which out crossing is negligible. Indian bean can be grown on a wide variety of soil types ranging from acid to alkaline soil. It is hardy, quite drought tolerant and suitable for growing as a rainfed crop. Indian bean is grown throughout the country including major growing states Gujarat, West Bengal, Tamil Nadu, Andhra Pradesh, Kerala, Karnataka and Orissa. It is popularly known as 'Wal' in Gujarat and Maharashtra. Indian bean has multipurpose uses: green pods and tender leaves as vegetables, dried seeds as a split pulse, the haulms either green or as hay or silage, are used as livestock fodder and the dried seeds are also fed to livestock. Being a legume, it fixes atmospheric nitrogen, hence famous as intercrop to enrich soil fertility.

Further, estimation of heterosis will help in identifying genetically potential crosses for further exploitation in plant breeding. It also helps in eliminating the less productive hybrids in F_1 itself and it enables the breeder to concentrate on a few but possibly more productive hybrids. Moreover, inbreeding depression give idea about gene action which responsible for reducing the mean phenotypic performance of hybrids.

Material and Methods

The experiment was carried out at College Farm (D-Block), N. M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat. The location falls under the agro climatic zone-14, humid Gujarat plain and hills with an average rainfall of 1550 mm. The experimental material consisted of 5 parents of four crosses, 4 F_1s and their 4 F_2 populations. The parental genotypes were procured from the Pulses and Castor Research Station, Navsari Agricultural University, Navsari and crosses were made among them during the year 2014. The F_1s were grown during the year *rabi*-2015 and F_2s were generated.

The 5 parents (GNIB-21, GP-1, GP-167, GP-189 and GPKH-120) and 4 F_1 and F_2 generations derived from four crosses *viz.*, GNIB-21 x GP-1, GNIB-21 x GP-67, GNIB-21 x GP-189, and GNIB-21 x GPKH-120 were analyzed in non-replicated trial as it was segregating material, during *rabi*-2016. Each row consisted of 10 plants with spacing of 90 cm x 45 cm inter and intra row spacing. Each F_2 was raised with minimum of 300 plant population and individual plant observations were recorded from 100 randomly selected plants. While, each parent and F_1 consisted of 40 plants and observations were recorded from 20 randomly selected plants, and data was analyzed. Observations on quantitative characters *viz*., days to flowering, plant height, primary branches per plant, days to maturity, pod length, pod width, pod weight, pods per plant, seeds per pod, 100 seed weight, seed yield per plant, straw yield per plant and harvest index were recorded from parents, F_1s and their F_2 populations.

Heterosis, expressed as percent increase or decrease in the mean value of F_1 hybrid over the better parent (heterobeltiosis) and mid parent (Relative heterosis) was computed using formula given by Fonseca and Patterson (1968) [3] and Turner (1953) [9], respectively.

Result and Discussion

Heterosis

Heterosis is useful to decide the direction of future breeding programme and to identify the cross combinations which are promising in conventional breeding programme and recurrent selection to utilize additive and non-additive gene actions.

In the present investigation, heterosis over mid parent range varied from 46.67 to 71.06 percent and heterobeltiosis was from - 62.23 to 0.78 percent for seed yield per plant. All four crosses exhibited positive and significant heterosis over mid parent. The highest positive and significant mid-parent heterosis was recorded for the cross GNIB-21 X GP-167, followed by GNIB-21 X GP-189, GNIB-21 X GPKH-120 and GNIB-21 X GP-1. Whereas, out of four crosses, none of the cross exhibited positive and significant heterobeltiosis. Similar resultsfor this trait was also reported by Kant and Srivastava (2012) [4], Singh and Singh (2016) [8] and Narasimhulu *et al.* (2016) [5].

None of the hybrid recorded significant and negative mid parent heterosis and heterobeltiosis in desirable direction for day to flowering. This results are in accordance with Singh and Singh (2016) [8].

All four of the hybrids recorded significant and positive heterosis over mid parent in desirable direction for plant height. While, only single cross GNIB-21 X GP-189 showed positive and non-significant heterobeltiosis (2.32). These findings are in accordance with the results obtained by Bhuvaneshwari and Muthaih (2005) [1], Virja *et al.* (2006) [11], Yadav *et al.* (2010) [12], Kant and Srivastava (2012) [4], Patil *et al.* (2012) [6], Narasimhulu *et al.* (2016) [5] and Singh and Singh (2016) [8].

In relation to primary branches per plant, three hybrids *viz.*, GNIB-21 X GP-1, GNIB-21 X GP-167 and GNIB-21 X GPKH-120 rendered positive and significant heterosis over mid parents crosses (6.74, 9.83 and 8.54, respectively). Heterosis for this trait was reported by the earlier workers Sharma (1991) [7], Bhuvaneshwari and Muthaih (2005) [1], Valu *et al.* (2006) [10], Virja *et al.* (2006) [11], Patil *et al.* (2012) [6], Narasimhulu *et al.* (2016) [5] and Singh and Singh (2016) [8].

While, only one cross GNIB-21 X GP-1 exhibited heterobeltiosis in desirable direction for day to maturity (-0.10) which was in agreement with Sharma (1991) [7], Virja *et al.* (2006) [11], Kant and Srivastava (2012) [4], Narasimhulu *et al.* (2016) [5] and Singh and Singh (2016) [8].

Pod length showed positive and significant heterosis over mid parents was found in all the four crosses (16.78, 25.62, 28.82 and 12.08, respectively). Whereas, pod width and pod weight exhibited positive and significant heterosis over mid parents for three crosses *viz.*, GNIB-21 X GP-1 (15.38 and 19.53), GNIB-21 X GP-167 (22.99 and 33.86) and GNIB-21 X GP-189 (7.40 and 32.80) and the cross GNIB-21 X GP-167 exhibited significant and positive heterobeltiosis for pod weight (3.72). Similar results for this traits was obtained by Patil *et al.* (2012) [6], Bhuvaneshwari and Muthaih (2005) [1], Valu *et al.* (2006) [10], Virja *et al.* (2006) [11], Yadav *et al.* (2010) [12] and Singh and Singh (2016) [8].

In relation to pods per plant, significant and positive heterosis over mid parents in desirable direction was manifested by the crosses *viz.,* GNIB-21 X GP-167, GNIB-21 X GP-189 and GNIB-21 X GPKH-120 (42.81, 43.75 and 39.54, respectively). Sharma (1991) [7], Bhuvaneshwari and Muthaih (2005) [1], Valu *et al.* (2006) [10], Yadav *et al.* (2010) [12], Kant and Srivastava (2012) [4], Patil *et al.* (2012) [6], Narasimhulu *et al.* (2016) [5] and Singh and Singh (2016) [8] also found similar result for pods per plant.

The single cross GNIB-21 X GP-167 recorded significant and positive mid parents heterosis for seeds per pod (7.95) which is in agreement with those reported by Valu *et al.* (2006) [10], Yadav *et al.* (2010) [12], Patil *et al.* (2012) [6], Narasimhulu *et al.* (2016) [5] and Singh and Singh (2016) [8].

Positive and significant heterosis for 100 seed weight was only found over mid parents in desirable direction for all crosses (18.96, 33.43, 30.99 and 23.92, respectively). Sharma (1991) [7], Bhuvaneshwari and Muthaih (2005) [1], Kant and Srivastava (2012) [4], Narasimhulu *et al.* (2016) [5] and Singh and Singh (2016) [8] also found same result for 100 seed weight.

Two crosses *viz.*, GNIB-21 X GP-1and GNIB-21 X GP-189 exhibited negative significant heterobeltiosis for straw yield per plant (-74.53 and -8.90). While, all of the crosses recorded significant and positive mid parent heterosis in desirable direction for straw yield per plant (35.98, 56.26, 35.59 and 48.34, respectively). Harvest index manifested significant and positive heterosis over mid parents in desirable direction for the crosses GNIB-21 X GP-167 and GNIB-21 X GP-189 (10.84 and 10.38), while, significant and positive heterobeltiosis for only the cross GNIB-21 X GP-167 (5.51). This findings are in agreement with earlier reporter Sharma (1991) [7], Kant and Srivastava (2012) [4], Narasimhulu *et al.* (2016) [5] and Singh and Singh (2016) [8].

In general, all the crosses manifested positively significant heterosis over mid parent for the characters like plant height, days to maturity, pod length, 100 seed weight, seed yield per plant and straw yield per plant, while only cross GNIB-21 X GP-167 exhibited positively significant heterobeltiosis for pod weight and harvest index. Hence, characters *viz.*, plant height, pod length, 100 seed weight, seed yield per plant and straw yield per plant are desirable for heterosis or further breeding programme for improvement.

In the present study, several cross combinations exhibited conspicuous heterosis over mid parent and heterobeltiosis for different traits. However, commercial exploitation of heterosis in form of hybrid varieties is not possible in case of indian bean as it is highly self-pollinated crop. Nonetheless, the crosses showing higher heterotic effects over better parent may be advanced to isolate purelines which are better than parents utilizing the principle of transgressive segregation. Diallel selective mating system may be adopted followed by biparental mating.

Inbreeding depression

The inbreeding depression response of F_2 is indicative of gene action among the parents involved. In the present investigation, seed yield per plant exhibited the wide range of inbreeding depression from -159.51 to 7.67 percent. Negative and significant inbreeding depression was exhibited for the cross GNIB-21 X GP-1(-159.51) followed by GNIB-21 X GP-189 (-15.68). Similar results were recorded by Sharma (1991) [7], Bhuvaneshwari and Muthaih (2005) [1], Kant and Srivastava (2012) [4], Singh and Singh (2016) [8] and Narasimhulu *et al.* (2016) [5].

Among four crosses, only two crosses GNIB-21 X GP-167 and GNIB-21 X GPKH-120 exhibited positive and significant inbreeding depression for days to flowering (3.29 and 3.63) which was in accordance with Singh and Singh (2016) [8].

Plant height showed negative and significant inbreeding depression only for two crosses GNIB-21 X GP-1 and GNIB-21 X GP-189 (-176.30 and -107.43).Similar results for this trait was obtained by Sharma (1991) [7], Bhuvaneshwari and Muthaih (2005) [1], Yadav *et al.* (2010) [12], Kant and Srivastava (2012) [4], Narasimhulu *et al.* (2016) [5] and Singh and Singh (2016) [8]. Whereas, inbreeding depression for primary branches per plant was recorded negatively significant for cross GNIB-21 X GP-1(-18.75). Sharma (1991) [7], Bhuvaneshwari and Muthaih (2005) [1], Narasimhulu *et al.* (2016) [5] and Singh and Singh (2016) [8] also found similar result for primary branches per plant.

For days to maturity, the crosses GNIB-21 X GP-167, GNIB-21 X GP-189 and GNIB-21 X GPKH-120 exhibited positive and significant inbreeding depression (3.90, 4.69 and 7.76, respectively). These findings are in agreement with earlier reporter Sharma (1991) [7], Kant and Srivastava (2012) [4], Narasimhulu *et al.* (2016) [5] and Singh and Singh (2016) [8].

Pod length, pod width and pod weight recorded negative and significant inbreeding depression only for one cross GNIB-21 X GP-1 (-61.68, -62.40 and -74.90, respectively). For these traits similar findings were reported by Bhuvaneshwari and Muthaih (2005) [1], Yadav *et al.* (2010) [12] and Singh and Singh (2016) [8]. Pods per plant manifested significant and negative inbreeding depression in three crosses GNIB-21 X GP-167, GNIB-21 X GP-189 and GNIB-21 X GP-1 (-4.66, -18.17 and -47.33, respectively). Sharma (1991) [7], Bhuvaneshwari and Muthaih (2005) [1], Yadav *et al.* (2010) [12], Kant and Srivastava (2012) [4], Narasimhulu *et al.* (2016) [5] and Singh and Singh (2016) [8] also reported similar results.

Seeds per pod did not showed negative and significant inbreeding depression in any cross of segregating population which was in agreement with Narasimhulu *et al.* (2016) [5] and Singh and Singh (2016) [8]. For 100 seed weight, negative and significant inbreeding depression was observed only in one cross GNIB-21 X GP-1 (-78.90). This results are in agreement with Sharma (1991) [7], Bhuvaneshwari and Muthaih (2005) [1], Kant and Srivastava (2012) [4], Narasimhulu *et al.* (2016) [5] and Singh and Singh (2016) [8].

Negative and significant inbreeding depression was observed for straw yield per plant in the cross GNIB-21 X GP-1 (-226.85). Harvest index exhibited negatively and significant inbreeding depression only for single cross GNIB-21 X GP-189 (-26.07). Sharma (1991) [7], Kant and Srivastava (2012) [4], Narasimhulu *et al.* (2016) [5] and Singh and Singh (2016) [8] also reported similar results.

In general, the cross GNIB-21 X GPKH-120 showing higher magnitude of heterotic effects and also associated with higher inbreeding depression. In such cases relatively high degree of heterosis in F_1 and significant inbreeding depression could be attributed due to high magnitude of non-additive gene effects controlling the traits. All the crosses which showed maximum estimates of yield heterosis, also exhibited significant heterosis for one or more of the yield components studied. For example GNIB-21 X GP-167 having the highest (71.06%) relative heterosis for yield, also revealed significant desirable heterotic effects for plant height, pods per plant, pod length, pod weight, pod width. In addition, some crosses showed negative estimates of inbreeding depression for seed yield and its components indicating thereby the existence of transgressive segregants for respective traits. In such crosses, intensive selection should be practiced in large segregating populations for isolating several high yielding homozygous lines.

The traits *viz*, plant height, days to flowering, days to maturity, primary branches per plant, pod length, pod width, pod weight, pods per plant and 100 seed weight are desirable for heterosis or further breeding programme for improvement. As far as crosses are concerned, out of four crosses, on the basis of mean performance and mid parent heterosis, the cross GNIB-21 X GP-167 has high heterotic effects as well as relatively low or negligible inbreeding depression for seed yield per plant, could be utilized for exploiting heterosis or for further breeding program for improvement in seed yield. The crosses GNIB-21 X GP-1, GNIB-21 X GP-189 and GNIB-21 X GP-167 recorded relatively lower amount of inbreeding depression for seed yield and its component traits, which could be utilized for isolating transgressive segregants for respective traits.

Table 1: The estimation of heterosis in percentage in F_1 hybrids over mid parents (MP) and better parents (BP) for various traits in Indian bean

	Range of all four crosses		Crosses											
			GNIB-21 X GP-1			GNIB-21 X GP-167			GNIB-21 X GP-189			GNIB-21 X GPKH-120		
Traits	MP	BP	Mean	MP	BP	Mean	MP	BP	Mean	MP	BP	Mean	MP	BP
Seed yield per plant (g)	46.67 to 71.06	-62.23 to 0.78	14.88	46.67**	-62.23**	71.46	71.06**	0.73	37.15	62.89**	-5.97	54.42	49.43**	0.78
Days to flowering	3.62 to11.99	6.91 to 37.24	45.65	11.99**	6.91**	58.60	9.45**	37.24**	57.3	10.56**	34.19**	49.35	3.62**	15.57**
Plant height (cm)	34.79 to 64.40	-69.89 to 2.32	48.65	34.79**	-69.89**	130.5	45.13**	-5.09**	57.3	64.40**	2.32	142.8	41.20**	0.00
Primary branches per plant	1.42 to 9.83	-20.00 to 0.00	4.00	6.74**	-20.00**	5.00	9.83*	-2.91	5.00	1.42	-4.76	5.00	8.54**	0.00
Day to maturity	9.66 to 12.43	-0.10 to 51.36	97.35	12.43**	-0.10	139.15	11.11**	42.79**	132	9.66**	35.45**	147.50	10.90**	51.36**
Pod length (cm)	12.08 to 28.82	-44.72 to 0.00	4.29	16.78**	-44.02**	8.60	25.62**	0.70	8.67	28.82**	-1.03	5.74	12.08**	-0.09
Pod width (cm)	1.06 to 22.99	-44.72 to 0.00	1.23	15.38**	-44.72**	2.23	22.99**	-3.68*	1.46	7.40**	-1.68	1.27	1.06	0.00
Pod weight (g)	1.95 to 33.86	-49.35 to 3.72	0.74	19.53**	-49.35**	1.93	33.86**	3.72**	1.61	32.80**	-0.34	0.70	1.95	0.14
Pods per plant	39.54 to 44.25	-27.67 to -0.79	28.10	44.25	-27.67**	40.8	42.81**	-1.09	29.5	43.75**	-1.5	56.45	39.54**	-0.79
Seeds per pod	-4.29 to 7.95	-10.81 to 0.00	3.55	-4.29	-4.05	4.60	7.95**	0.00	4.00	-0.52*	0.00	3.30	-3.88	-10.81*
100 Seed weight (g)	18.96 to 33.43	-50.19 to 0.45	15.14	18.96**	-50.19**	38.48	33.43**	0.45	32.35	30.99**	-2.30*	29.39	23.92**	0.24
Straw yield per plant (g)	35.59 to 5.26	-74.53 to 1.67	70.77	35.98**	-74.53**	283.54	56.26**	-4.32	231.3	35.59**	-8.90**	285.46	48.34**	1.67
Harvest index (%)	-1.76 to 10.84	-24.04 to 5.51	20.94	-0.90**	-0.83	25.2	10.84**	5.51**	16.04	10.38**	-24.04**	19.04	-1.76*	-9.81**
* and **, significant at 5% and 1% level of probability, respectively														

Table 2: The estimation of inbreeding depression (%) in F_2 generation of hybrids for various traits in Indian bean

	Crosses			
Traits	**GNIB-21 X GP- 1**	**GNIB-21 X GP-167**	**GNIB-21 X GP-189**	**GNIB-21 X GKH-120**
Seed yield (g)	-159.51**	-0.78	-15.68**	7.67**
Days to flowering	-31.74**	3.29**	-5.01**	3.63**
Plant height (cm)	-176.30**	2.50*	-107.43**	10.69**
Primary branches per plant	-18.75**	0.6	7.2	3.4
Day to maturity	-33.01**	3.90**	4.69**	7.76**
Pod length (cm)	-61.68**	6.88**	3.64**	2.80**
Pod width (cm)	-62.40**	1.96	-0.14	0.04
Pod weight (g)	-74.90**	11.14**	4.51**	-1.99
Pods per plant	-47.33**	-4.66*	-18.17**	6.75**
Seeds per pod	5.63	2.61	4.25**	-1.21
100 Seed weight (g)	-78.90**	7.34**	2.32**	6.28**
Straw yield per plant (g)	-226.85**	1.17	7.32**	10.86**
Harvest index(%)	16.42**	1.04	-26.07**	-3.89
* and **, significant at 5% and 1% level of probability, respectively.				

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