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Analysis of Combining Ability and Gene Action in Indian bean [*Lablab purpureus* (L.) Sweet]

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A B S T R A C T

An experiment was conducted involving 10 diverse parents and their 24 hybrids obtained by line x tester mating design laid out in randomized block design with three replications. The analysis of variance revealed presence of ample variability for fifteen quantitative traits studied. The genotypes Katargam, GP-167, GP-158 and GP-kh-64 were found to be good general combiners for one or more yield attributes. The cross combination GP-167 x Katargam exhibited highest mean values and standard heterosis over check variety Gujarat Papadi-1 for green pod yield per plant followed by GP-167 x GNIB-21 and GP-189 x GNIB-21. These hybrids had good general combining parents, high sca effects and heterotic effects over better parent as well as standard check. Both additive and non-additive gene actions played important role for the inheritance of most of the traits. While, only non-additive gene action was responsible for days to flowering, plant height, primary branches per plant, seeds per pod and straw yield per plant. The ratio of $\sigma^2 gca / \sigma^2 sca$ indicated the preponderance of non-additive gene action for all the traits except green pod yield per plant. The superior hybrids may be advanced to obtain transgressive segregants and purelines for higher green pod yield per plant. As the development of hybrid variety is not possible in Indian bean, diallel selective mating system may be adopted for improvement of remaining traits followed by some sort of biparental mating and recurrent selection.

Introduction

Indian bean [*Dolichos lablab* (L.), syn. *Lablab purpureus* (L.) Sweet], belongs to Fabaceae family (2n = 22), is an important pulse crop grown for its nutritious tender pods, while dry seeds are used as a split pulse. Green pod has a high nutritive value as it contains 25 per cent proteins, 2.7 per cent fats, 62.2 per cent carbohydrates, 16.1 per cent fiber and 7.1 per cent ash (Kay, 1973). It is grown as grain and green vegetables as well as fodder throughout the tropics and sub-tropics. It is considered as a minor pulse crop in India. Indian bean fits well in a variety of cropping systems such as cover crop, mix crop and catch crop as pulses have unique property of maintaining and restoring soil fertility through biological nitrogen fixation as well as conserving and improving physical properties of soil by addition of organic matter through leaf drop towards maturity and deep root system.

Average yield of Indian bean is very low and year to year yield variation is remarkably high. Poor yield potentiality of Indian bean may be due to the genotypes adapted to poor management practices as it is constantly grown under marginal lands, residual moisture or stress conditions. It is believed that pulses may have lower genetic potential than cereals, however, the available evidences indicates that the pulse crops have higher genetic potential for yield than cereals (Jain, 1975).

Development of high yielding hybrid or improved variety is the main objective of almost all crop improvement programmes. As the research work done for genetic evaluation and improvement of Indian bean is very scanty, attempts in Indian bean varietal improvement would, therefore, need development and execution of very sound-breeding programmes. Hybridization is frequently used in any breeding programme to improve the yield. Yield is a complex genetic phenomenon which depends upon the balance of additive, dominance and epistatic components of the genetic variance. Due to this, the presence or absence of heterosis is not itself indicative of the presence or absence of any particular type of gene effects. The nature of gene effects varies with the genetic structure and the divergence between populations. Consequently, a high yielding line may not be able to transmit its superiority to its progeny. A distinct knowledge about the type of gene effect, its magnitude and probable future breeding consequences is of fundamental importance to a plant breeder.

The line x tester analysis technique has been extensively used as compared to other methods because it provides a more systematic approach to assess the combining ability of parents and crosses for different quantitative characters as well as to study the extent of heterosis for yield and yield contributing characters. Besides, it gives over all genetic picture of the materials under investigation in a single generation. The present investigation is, therefore, proposed to estimate combining ability of parents and nature of gene actions involved in the inheritance of yield and its components through Line x Tester design in Indian bean.

Materials and Methods

The experimental material for the present investigation comprised of 10 parents and their 24 hybrids developed through Line X Tester mating design. Genotypes used as lines were GP-189, GP-158, GP-KH-120, GP-16, GP-KH-64 and GP-1, and the testers were GNIB-21, Katargam, Kapasi and Manchhi. GNIB-21 is recently released variety for vegetable purpose which is determinate, pole type and photo-insensitive. While, Katargam, Kapasi and Manchhi are landraces with marketable pod qualities. Crossing programme for present investigation was carried out in Late-*Kharif*, 2014-15 at College Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari. F_1 seeds were produced by hand emasculation and pollen transfer. The mature dry pods from female parents were harvested cross-wise, separately. For parental lines, flower buds of different parents were selfed and seeds were collected accordingly. Evaluation of parents along with F_1s was carried out during Late-*Kharif*, 2015-16 at same location for genetic parameters like combining ability and gene actions. Twenty four F_1 hybrids along with 10 parents including check variety Gujarat Papadi-1 were evaluated in a randomized block design with three replications. Each plot consisted of a single row of 10 plants. Inter- and intra-row spacing was kept 90 cm and 45 cm, respectively. All the recommended package of practices was adopted to raise a healthy crop.

Five random and competitive plants were selected from each row in each replication to

record the observations. Remaining five plants were utilized to observe green pod yield per plant and related traits. The data was recorded for the characters like days to 50% flowering, days to maturity, plant height, primary branches per plant, pods per plant, pod length, pod width, pod weight, seeds per pod, green pod yield per plant, seed yield per plant, harvest index, straw yield, 100 dry seed weight and protein content. The observations on days to 50 % flowering and days to maturity were recorded on population basis. The data obtained for each character was analyzed by the usual standard statistical procedure suggested by Panse and Sukhatme (1978). The variation among the hybrids was partitioned further into sources attributable to general and specific combining ability components in accordance with the procedure suggested by Kempthorne (1957) and modified by Arunachalam (1974).

Results and Discussion

The character-wise mean data of parents and F₁s were subjected to analysis of variance for green pod yield per plant and its attributes. The results of analysis of variance of parents and their hybrids for various traits are given in Table 1. Mean squares due to genotypic differences were found significant for all the traits studied which indicated that experimental material under study had sufficient genetic diversity.

Further, partitioning of sum of squares due to genotypes indicated that the differences among parents were significant for all the traits. In case of hybrids, significant differences were obtained for all the traits studied. While, mean squares due to parents vs. hybrids were significant for all the traits studied except pod length, pod weight and seeds per pods. This indicated that the hybrids were significantly different among themselves and from the parents for mentioned traits.

The genetic variances were estimated from the analysis of variance for combining ability for fifteen characters as suggested by Kempthorne (1957). The results are presented in Table 2, the estimates of combining ability of hybrids were highly significant for all the traits. Mean squares due to lines' effects were non-significant for pods per plant, pod length and harvest index, whereas it was highly significant for pod width, pod weight, green pod yield per plant and 100 dry seed weight. While, significant estimates of testers' mean squares were observed for days to maturity, pods per plant, pod length, pod width, green pod yield per plant and seed yield per plant.

Line x tester effects were also highly significant for all the characters except days to flowering, primary branches per plant and green pod yield per plant. The ratio of σ^2gca / σ^2sca indicated the preponderance of additive gene effects for the inheritance of green pod yield per plant. Whereas, the ratio suggested preponderance of non-additive gene actions for remaining traits. The results are in accordance with Srinivasan and Das (1996), Valu *et al.,* (1999), Bagade (2001), Bagade *et al.,* (2003), Vashi *et al.,* (2001), Tukadiya *et al.,* (2006), Modha *et al.,* (2007), Rahman *et al.,* (2009), Patil *et al.,* (2013), Das *et al.,* (2014) and Kumar *et al.,*(2015).

The parents were classified as good, average and poor general combiners based on estimates of general combining ability effects (Table 3). The analysis revealed that the genotype Katargam was found to be good general combiner for pods per plant, pod length, pod width, pod weight, seed yield per plant, straw yield and 100- dry seed weight; GP-167 for days to 50% flowering, plant height, pod width, pod weight, green pod yield per plant, straw yield and 100 dry seed weight; GP-158 for pod length, pod width, pod weight, seeds per pod, seed yield per plant, straw yield and 100 dry seed weight; GP-kh-64 for pods

per plant, green pod yield per plant, seed yield per plant and harvest index; Manchhi for plant height, pod length, pod width, straw yield and 100-dry seed weight; Kapasi for pods per plant, pod weight, seed yield per plant and harvest index; GP-189 for plant height, pod length, pod weight, green pod yield per plant and straw yield; GP-1 for pods per plant, seed yield per plant and harvest index; GP-kh-120 for pods per plant, green pod yield per plant and harvest index; GNIB-21 for days to maturity, seeds per pod and green pod yield per plant Therefore, parents Katargam, GP-167 and GP-158 may be utilized for future breeding programme in Indian bean. While, recently released variety GNIB-21 can be utilized for genetic improvement of earliness and green pod yield per plant (Table 4).

Table.1 Analysis of variance for various characters in Indian bean

	Sources of variation	replication	genotypes	parents	Females	males	Female vs males	Parents vs hybrids	hybrids	error
M E A N	d.f	2	33	9	5	3	1	1	23	66
	Days to 50% flowering	2.14	32.85***	69.07***	20.32*	136.0***	112.0***	34.12*	18.62*	7.28
S U M	Days to maturity	4.32	222.8***	355.1***	146.3***	808.5***	39.20**	23.71*	179.7***	4.70
O F	Plant height (cm)	28.73	284.7***	165.5***	134.1***	252.4***	62.18	952.7***	302.3***	22.43
	Primary branches per plant	0.34	0.71***	1.23***	0.30	2.32***	2.59***	4.11***	0.36*	0.19
S Q U A R E S	Pods per plant	4090.6***	7758.1***	5258.8***	94.21	11583.0***	12109.7***	36658.9***	7479.5***	73.53
	Pod length (mm)	63.32***	427.23***	794.7***	575.9***	112.0***	3936.8***	0.19	302.2***	2.90
	Pod width (mm)	5.93***	32.16***	48.93***	46.92***	6.99***	184.83***	66.63***	24.09***	0.67
	Pod weight (g)	0.61***	0.95***	1.32***	1.15	1.41***	1.88***	0.029	0.85***	0.031
	Seeds per pods	0.085	0.24***	0.20***	0.27***	0.065	0.33*	0.19	0.26***	0.057
	Green pod yield per plant	4.09	2899.5***	4892.0***	2073.3***	1699.8***	28561.6***	12173.9***	1716.6***	39.6
	Seed yield per plant (g)	4496.4***	3868.2***	2085.9***	500.6***	5315.9*	322.1	31890.8***	3347.3***	101.9
	Harvest index (%)	241.2***	265.3***	380.9***	61.8***	733.3***	919.0***	183.7***	223.7***	5.40
	Straw yield (g)	83.37	13919.7***	19620.6***	15474.0***	26468.9***	19808.4***	40819.4***	10519.4***	75.85
	100 seed weight (g)	0.59	71.55***	87.61***	78.13***	5.31***	381.9***	6.92***	68.08***	0.20
	Protein content (%)	0.62	36.96***	90.57***	108.2***	12.82***	235.5***	42.18***	15.76***	0.64

*, **, *** significance at 5 per cent, 1 per cent and 0.1 percent levels of probability, respectively

Table.2 Mean squares due to general and specific combining ability for different characters in Indian bean

parents	LINES							TESTERS				
	GP -189	GP -158	GP-Kh-120	GP-167	GP-kh-64	GP-1	S.E.(gi)	GNIB-21	Katargam	kapasi	Manchhi	S.E.(gj)
Days to 50% flowering	0.73	1.23	-0.76	-2.01*	0.81	0.014	0.77	-0.98	1.79**	0.45	-1.26	0.63
Days to maturity	-0.87	0.042	1.12	0.70	0.12	-1.12	0.62	-9.54***	2.95***	-0.81	7.40***	0.51
Plant height (cm)	7.67***	-9.75***	0.95	5.11***	2.42	-6.42***	1.36	-2.93*	-1.04	1.04	2.92*	1.11
Primary branches per plant	-0.097	-0.18	0.23	-0.11	0.13	0.019	0.12	-0.13	-0.014	0.042	0.10	0.10
Pods per plant	-47.10***	-20.36***	32.43***	-15.25***	41.76***	8.51**	2.47	-30.20***	13.68***	37.42***	-20.91***	2.02
Pod length (mm)	11.60***	4.76***	-7.10***	0.00	-4.10***	-5.16***	0.49	-0.52	5.11***	-8.22***	3.63***	0.40
Pod width (mm)	0.06	2.66***	-2.16***	1.58***	-2.54***	0.38	0.23	-1.42***	1.18***	-1.44***	1.68***	0.19
Pod weight (g)	0.36***	0.49***	-0.43***	0.29***	-0.36***	-0.35***	0.05	-0.24***	0.20***	0.17***	-0.13**	0.04
Seeds per pods	-0.042	0.25***	-0.17***	0.12	-0.19**	0.025	0.06	0.24**	-0.14*	-0.064	-0.042	0.05
Green pod yield per plant (g)	15.38***	-29.43***	10.71***	27.11***	8.48***	-32.26***	1.81	6.92***	-0.45	-3.07*	-3.40*	1.48
Seed yield per plant (g)	-39.45***	10.54***	-2.14	5.70	14.14***	11.20***	2.91	-24.51***	15.63***	18.36***	-9.48***	2.38
Harvest index (%)	-12.09***	-0.027	4.59***	-1.26	3.68***	5.11***	0.67	-1.58**	0.75	4.19***	-3.37***	0.54
Straw yield (g)	40.14***	24.87***	-48.11***	27.99***	-17.44***	-27.44***	2.51	-32.15***	26.79***	-6.78**	12.14***	2.05
100 seed weight	-0.22	4.90***	-4.87***	3.55***	-3.32***	-0.042	0.13	-1.39***	1.58***	-1.91***	1.71***	0.10
Protein content (%)	0.85***	0.84***	-3.62***	-0.44	1.82***	0.54***	0.23	0.88***	0.36	-0.50*	-0.73***	0.18

*, **, *** Significant at 5 %, 1 % and 0.1 % levels of probability, respectively.

Table.3 Estimation of gca effects of parents for various characters in Indian bean

	Days to 50% flowering	Days to maturity	Plant height (cm)	Primary branches per plant	Pods per plant	Pod length (mm)	Pod width (mm)	Pod weight (g)	Seeds per pods	Green Pod yield per plant(g)	Seed yield per plant (g)	Harvest index (%)	Straw yield (g)	100-seed weight (g)	Protein content (%)
Lines															
GP-189	0.73	-0.87	7.67***	-0.097	-47.10***	11.60***	0.06	0.36***	-0.042	15.38***	-39.45***	-12.09***	40.14***	-0.22	0.85***
GP-158	1.23	0.042	-9.75***	-0.18	-20.36***	4.76***	2.66***	0.49***	0.25***	-29.43***	10.54***	-0.027	24.87***	4.90***	0.84***
GP-kh-120	-0.76	1.12	0.95	0.23	32.43***	-7.10***	-2.16***	-0.43***	-0.17***	10.71***	-2.14	4.59***	-48.11***	-4.87***	-3.62***
GP-167	-2.01*	0.70	5.11***	-0.11	-15.25***	0.00	1.58***	0.29***	0.12	27.11***	5.70	-1.26	27.99***	3.55***	-0.44
GP-kh-64	0.81	0.12	2.42	0.13	41.76***	-4.10***	-2.54***	-0.36***	-0.19**	8.48***	14.14***	3.68***	-17.44***	-3.32***	1.82***
GP-1	0.014	-1.12	-6.42***	0.019	8.51**	-5.16***	0.38	-0.35***	0.025	-32.26***	11.20***	5.11***	-27.44***	-0.042	0.54***
S.E. (gi)	0.77	0.62	1.36	0.12	2.47	0.49	0.23	0.05	0.06	1.81	2.91	0.67	2.51	0.13	0.23
Testers															
GNIB-21	-0.98	-9.54***	-2.93*	-0.13	-30.20***	-0.52	-1.42***	-0.24***	0.24***	6.92***	-24.51***	-1.58**	-32.15***	-1.39***	0.88***
Katargam	1.79**	2.95***	-1.04	-0.014	13.68***	5.11***	1.18***	0.20***	-0.14*	-0.45	15.63***	0.75	26.79***	1.58***	0.36
Kapasi	0.45	-0.81	1.04	0.042	37.42***	-8.22***	-1.44***	0.17***	-0.064	-3.07*	18.36***	4.19***	-6.78**	-1.91***	-0.50*
Manchhi	-1.26	7.40***	2.92*	0.10	-20.91***	3.63***	1.68***	-0.13**	-0.042	-3.40*	-9.48***	-3.37***	12.14***	1.71***	-0.73***
S.E. (gj)	0.63	0.51	1.11	0.10	2.02	0.40	0.19	0.04	0.05	1.48	2.38	0.54	2.05	0.10	0.18

*, **, *** Significant at 5 %, 1 % and 0.1 % levels of probability, respectively.

Table.4 Summary of top three parents and hybrids with respect to their *per se* performance and combining ability effects for various characters in Indian bean

Characters	*Per se* performance		Combining ability effects	
	Parents	**F₁s**	**GCA**	**SCA**
Days to 50% flowering	GNIB-21	GP-kh-120 x Manchhi	GP-167	**GP-kh-120 x Manchhi**
	GP-kh-120	GP-167 x GNIB-21	Manchhi	**GP-kh-64 x Kapasi**
	GP-167	GP-167 x Kapasi	GNIB-21	**GP-189 x Katargam**
Days to maturity	GNIB-21	GP-kh-64 x GNIB-21	GNIB-21	**GP-1 x Katargam**
	GP-kh-64	GP-1 x GNIB-21	GP-1	**GP-kh-64 x GNIB-21**
	GP-167	GP-167 x GNIB-21	GP-189	**GP-158 x Manchhi**
Plant height (cm)	GP-kh-120	GP-189 x GNIB-21	GP-189	**GP-189 x GNIB-21**
	Katargam	GP-189 X Manchhi	GP-167	**GP-167 x Kapasi**
	GP-189	GP-167 x Kapasi	Manchhi	**GP-kh-64 x Kapasi**
Primary branches per plant	Katargam	GP-kh-64 x Kapasi	GP-kh-120	**GP-kh-64 x Kapasi**
	Manchhi	GP-kh-120 x Katargam	GP-kh-64	**GP-158 x Manchhi**
	GP-kh-120	GP-158 x Manchhi	Manchhi	**GP-158 x Katargam**
Pods per plant	Katargam	GP-kh-120 x Kapasi	GP-kh-64	**GP-158 x Manchhi**
	Manchhi	GP-kh-64 x Kapasi	Kapasi	**GP-167 x GNIB-21**
	GP-kh-120	GP-kh-64 x Katargam	GP-kh-120	**GP-kh-64 x Katargam**
Pod length (mm)	GP-189	GP-189 x Katargam	GP-189	**GP-189 x Katargam**
	GP-158	GP-189 x Manchhi	Katargam	**GP-kh-64 x Kapasi**
	Katargam	GP-167 x Katargam	GP-158	**GP-189 x Manchhi**
Pod width (mm)	GP-158	GP-167 x Katargam	GP-158	**GP-167 x Katargam**
	GP-1	GP-1 x Manchhi	Manchhi	**GP-158 x Kapasi**
	Katargam	GP-189 x Manchh	GP-167	**GP-189 x Katargam**
Pod weight (g)	GP-158	GP-158 x Kapasi	GP-158	**GP-158 x Kapasi**
	Katargam	GP-167 x Katargam	GP-189	**GP-kh-120 x Katargam**
	GP-189	GP-167 x Kapasi	Katargam	**GP-kh-64 x GNIB-21**
Seeds per pod	GP-1	GP-158 x GNIB-21	GP-158	**GP-189 x Kapasi**
	GP-167	GP-189 x Kapasi	GNIB-21	**GP-158 x GNIB-21**
	Manchhi	GP-1 x GNIB-21	GP-1	**GP-1 x Katargam**
Green pod yield perplant (g)	GP-167	GP-167 x Katargam	GP-167	**GP-167 x Katargam**
	GP-189	GP-167 x GNIB-21	GP-189	**GP-kh-120 x GNIB-21**
	Katargam	GP-189 x GNIB-21	GNIB-21	**GP-kh-64 x Kapasi**
Seed yield per plant (g)	Katargam	GP-kh-64 x Kapasi	Kapasi	**GP-158 x Manchhi**
	GP-189	GP-kh-120 x Kataragam	Katargam	**GP-kh-64 x Kapasi**
	GP-158	GP-158 x Manchhi	GP-kh-64	**GP-kh-120 x Katargam**
Harvest index (%)	GNIB-21	GP-kh-64 x Katargam	GP-1	**GP-kh-64 x Katargam**
	Katargam	GP-kh-120 x Kapasi	GP-kh-120	**GP-1 x GNIB-21**
	GP-1	GP-kh-120 x Katargam	Kapasi	**GP-167 x Manchhi**
Straw yield (g)	GP-158	GP-158 x Katargam	GP-189	**GP-kh-64 x Kapasi**
	GP-189	GP-189 x Katargam	GP-167	**GP-167 x GNIB-21**
	Kapasi	GP-189 x Manchhi	Katargam	**GP-kh-120 x Manchhi**
100 dry seed weight (g)	GP-158	GP-167 x Katargam	GP-158	**GP-167 x Katargam**
	GP-167	GP-189 x Manchhi	GP-167	**GP-189 x Manchhi**
	Katargam	GP-158 x Katargam	Katargam	**GP-158 x Manchhi**
Protein content (%)	GNIB-21	GP-kh-64 x GNIB-21	GP-kh-64	**GP-kh-120 x Katargam**
	Kapasi	GP-158 x GNIB-21	GNIB-21	**GP-1 x Manchhi**
	GP-1	**GP-189 x Kapasi**	**GP-189**	**GP-189 x Kapasi**

A comparative study of the most promising hybrids having high sca effect for green pod yield per plant and for various characters along with gca effects of the parents revealed that the best performing parents may not always be a best general combiners. Significant and high sca effect in desirable direction was observed for days to maturity in the crosses GP-1 x Katargam (-9.875), GNIB-21 x GP-kh-64 (-7.292) and GP-158 x Manchhi (-3.819); for plant height in the crosses GNIB-21 x GP-189 (13.432), Kapasi x GP-167 (8.821) and Kapasi x GP-kh-64 (8.704); for primary branches per plant in the

cross Kapasi x GP-kh-64 (0.542); for pods per plant in the crosses GP-158 x Manchhi (49.011), GNIB-21 GP-167 (44.250) and GP-kh-64 x Katargam (32.811); for pod length in the crosses GP-189 x Katargam (9.800), Kapasi x GP-kh-64 (6.978) and GP-189 x Manchhi (6.211); for pod width in the crosses GP-167 x Katargam (2.614), Kapasi x GP-158 (2.097) and GP-189 x Katargam (1.864); for pod weight in the crosses Kapasi x GP-158 (0.893), GP-kh-120 x Katargam (0.459) and GNIB-21 x GP-kh-64 (0.296); for seeds per pod in the cross Kapasi x GP-189 (0.464).

The cross combination GP-167 x Katargam (10.317) manifested significant sca effect in desirable direction for green pod yield per plant; GP-158 x Manchhi (38.083), Kapasi x GP-kh-64 (24.703) and GP-kh-120 x Katargam (26.008) for seed yield per plant; GP-kh-64 x Katargam (9.139), GNIB-21 x GP-1 (7.274) and GP-167 x Manchhi (6.596) for harvest index; Kapasi x GP-kh-64 (56.732), GNIB-21 x GP-167 (56.295) and GP-kh-120 x Manchhi (55.437) for straw yield; GP-167 x Katargam (7.531), GP-189 x Manchhi (5.781) and GNIB-21 x GP-158 (2.692) for 100 dry seed weight. For majority of the yield attributes the genotypes Kapasi, Katargam, GNIB-21 and GP-167 are involved for producing top ranking hybrids in relation to *per se* performance and sca effects. The cross combination Kapasi x GP-kh-64 exhibited highest mean for green pod yield per plant followed by GP-kh-120 x Katargam and GP-158 x Manchhi. The cross Kapasi x GP-kh-64 possessed significant sca effects in desirable direction for days to flowering, plant height, primary branches per plant, pod length, green pod yield per plant, seed yield per plant and straw yield.

Whereas, the cross GP-158 x Manchhi had significant sca effects for days to maturity, primary branches per plant, pods per plant and seed yield per plant. General combining ability of these parents were reflected in their hybrids in terms of higher *per se* performance and sca effects for most of the traits. A perusal of these observations revealed that genotypes GNIB-21, GP-167, GP-kh-64 and GP-kh-120 were early flowering. The worth of these genotypes was reflected in estimates of combining ability. The hybrid GNIB-21 x GP-167 was best hybrid in relation to *per se* performance and sca effect considering earliness for flowering and maturity. For days to maturity, top three crosses had either GNIB-21 or GP-167 as one of the parents.

As non-additive gene action was predominant for most of the traits and due to non-feasibility of hybrid variety in Indian bean, diallel selective mating system may be adopted followed by some sort of biparental mating and recurrent selection for improvement of these traits. Considering genetic improvement of Indian bean, recently, harvest index, photo-insensitivity, pole type plant stature and determinate habit is getting attention in relation to crop geometry. Recombinant Inbred Lines (RILs) may be developed from these hybrids and QTL analysis for pod quality traits, protein content and harvest index may be carried out. Saturated linkage maps may be developed utilizing recent Next Generation Sequencing (NGS) platforms / SNP discovery methods and segregating generations of above hybrids followed by QTL analysis and association mapping.

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