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Research Article

Genetic variability, character association and path coefficient analysis in determinate F_5 progenies of Indian bean [*Lablab purpureus* (L.) Sweet]

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Abstract
The experiment was carried out to determine the genetic variability parameters and character associations for eleven quantitative traits in Indian bean genotypes. It revealed a significant amount of variability present among these genotypes. Seed yield per plant had high Genotypic coefficient of variation (GCV) and Phenotypic coefficient of variation (PCV) values, showing the potential for improvement by selection. Racemes per plant, pods per raceme, pods per plant, and pod weight had moderate GCV and PCV values. There was high heritability combined with a high genetic advance for pod weight and seed yield per plant. Plant height, pods per plant, and pod weight were significantly and positively associated with seed yield per plant. Pods per plant had the most positive direct effect on seed yield per plant, followed by racemes per plant, plant height, pod weight, pod length, and seeds per pod. Therefore, selection for such traits is advised to bring about improvement in Indian beans.

Keywords: Variability, Heritability, Correlation, Path analysis, Dolichos bean, Indian bean

INTRODUCTION

The Indian bean [*Lablab purpureus* (L.) Sweet], is among the oldest legume crops and is widely grown in dry, semi-arid, and sub-tropical regions of Africa, West Indies, Central and South America, and Southeast Asia including Indonesia (Ayyangar and Nambiar, 1935; Naeem *et al.*, 2020). In rainfed areas, it is cultivated either in a pure stand or grown along with cereals such as finger millet, maize, sorghum and bajra, as well as with other crops such as peanut and castor (Raghu *et al.*, 2018). It is referred to be a “natural N-fertilizer” since it delivers nitrogen to the soil, which may support small farmers in improving soil fertility (Sheahan, 2012). As a result, this crop can be grown in rotation with cereals to fix nitrogen in the soil (Naeem *et al.*, 2020). Because the seeds and pods of the Indian bean contain 20-28 % protein, it is a rich source of vegetable protein (Naeem *et al.*, 2020). It also contains a good amount of carbohydrates, lipids, and fiber, as well as minerals (phosphorus, iron and calcium) (Naeem *et al.*, 2020). Indian bean’s tolerance to stressed environments has been demonstrated in different studies (D’Souza and Devaraj, 2011; Rai *et al.*, 2015), so it can be grown in drought-prone areas or areas of a limited amount of rainfall. Moreover, there are very few determinate and photo-insensitive varieties available for cultivation. Such characteristics make possible the cultivation of the crops in any season and one can take more than one season

per year. In Gujarat, based on pod characteristics Indian bean genotypes are locally classified as '*Wal*' (short and flat shape, bitter in taste, high fiber content), '*Valor*' (long and narrow shape, bitter/sweet in taste, medium fiber content) and '*Papdi*' (short and narrow shape, sweet in taste, less fiber content). '*Papdi*' type of pods have high marketable quality used in daily diet as green pods for cooking vegetables or famous items like "*Undhiyu*" and "*Ubadiyu*", especially in Gujarat and adjoining areas.

Variability is essential for any improvement in any crop to do the selection. Heritability is also required to determine the trait transmissibility to the following generation. Because yield is a quantitative trait and it is heavily influenced by the environment, it is difficult to select for it directly (Allard, 1999). As a result, understanding character association is required to achieve successful yield improvement via a visual selection of yield-associated characters. Path analysis divides correlation coefficients into direct and indirect effects, allowing for the investigation of the key force that produces a given association as well as the relative significance of each causal factor. Hence, this experiment was conducted to investigate the variability among *'Papdi'* type Indian bean genotypes, as well as to assess the correlation and effects of various yield component traits on seed yield.

MATERIALS AND METHODS

The experiment was conducted during *Rabi,* 2019-20, at College Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari (Gujarat). The experimental material consisted of forty-seven "*Papdi*" type determinate genotypes out of which, forty-five were F_5 progenies and two were check varieties (GNIB-21 and GNIB-22). F_5 progenies were obtained from four crosses i.e., GNIB-21 × GP-1, GNIB-21 × GP-189, GNIB-21 × GP-167 and GNIB-21 × GPKH-120. All 47 progenies were evaluated in three replications using a randomized block design (RBD). Each row was comprised of fifteen plants with a spacing of 60 cm x 20 cm. For a successful crop raising, all advised agronomic measures were followed. A total of eleven quantitative traits were investigated *i.e*., days to 50 per cent flowering, days to maturity, plant height (cm), racemes per plant, pods per plant, pods per raceme, pod length (cm), pod width (cm), seeds per pod, pod weight (g) and seed yield per plant (g). Except for days to 50 per cent flowering and days to maturity, which were recorded on a population basis, for all the traits the data were collected on ten randomly selected plants from each progeny from each replication, and their means were used in statistical analysis.

The analysis of variance was done using the procedure suggested by Panse and Sukhatme (1978). The methodology by Allard (1999) was used to determine heritability in a broad sense (h^2_{bs}) and genetic advance. The approach described by Miller *et al.* (1958) was used to obtain genotypic correlation coefficients. Genotypic path coefficients were calculated as per Dewey and Lu (1959).

RESULTS AND DISCUSSION

For all of the characters in F_5 progenies, analysis of variance indicated significant mean square values, showing that there was enough variability among the progenies for all the characters **(Table 1).** Patel *et al*. (2022) and Hadavani *et al*. (2018) reported similar findings.

The outcome of the variability parameters is shown in **Table 2**. Mean values revealed a vast range for days to 50 per cent flowering (38-50), days to maturity (81.33-96.67), plant height (41.58-64.46 cm), racemes per plant (3.83-11.76), pods per plant (20.00-48.49), pod weight (0.56-1.28 g), pods per raceme (5.08-8.88), pod length (4.33-7.10 cm), pod width (0.99-1.66 cm), seeds per pod (3.44-4.00) and seed yield per plant (4.41-22.24 g). Based on mean values, the progenies R-2-35-2 (22.24 g), R-1-35-4 (18.75 g) and R-1-37-1 (17.07 g) recorded significantly higher seed yield per plant over check varieties GNIB 21 and GNIB 22 and were identified as elite genotypes.

Progenies had greater GCV and PCV values for seed yield per plant (25.26 % and 29.29 %, respectively) and a less difference between GCV and PCV, indicating that the environment had very little impact on this trait and the scope of improving this character by applying selection (**Table 2**). GCV and PCV levels were moderate in racemes per plant (15.12 % and 19.85 %, respectively), pods per plant (13.15 % and 17.01 %, respectively), pod weight (13.21 % and 16.87 %, respectively) and pods per raceme

Table 1. Analysis of variance for the traits under study in Indian bean

Source of variation	d.f.	Mean sum of square										
		DFF	DM	PH	RPP	PPP	PW	PPR	PL	PWD	SPP	SYPP
Replication	2	4.170*	6.645	32.685	3.014	44.502	0.006	0.645	0.029	0.006*	0.000	6.921
Progenies	46	7.665**	14.499**	78.268**	5.645**	89.922**	0.044**	1.640**	0.715**	0.037**	0.033**	33.035**
Error	92	1.054	2.653	13.075	1.096	16.481	0.008	0.268	0.102	0.002	0.004	3.407

** - Significant at 1.0 % level of probability, * - Significant at 5.0 % level of probability

DFF=Days to 50% flowering DM=Days to maturity PH=Plant height RPP=Racemes per plant
PPP=Pods per plant PW=Pod weight PPR=Pods per raceme PL=Pod length
PWD=Pod width SPP=Seeds per pod SYPP=Seed yield per plant

Table 2. Measures of variability parameters of all the characters studied in Indian bean

Character	Range		Grand mean	GCV (%)	PCV (%)	h^2_{bs}(%)	GA	GAM (%)
	Minimum	Maximum						
Days to 50 % flowering	38.00	50.00	43.40	3.42	4.16	67.64	2.52	5.79
Days to maturity	81.33	96.67	87.35	2.27	2.94	59.82	3.17	3.62
Plant height (cm)	41.58	64.46	56.58	8.24	10.43	62.43	7.59	13.41
Racemes per plant	3.83	11.76	8.14	15.12	19.85	58.04	1.93	23.73
Pods per plant	20.00	48.49	37.62	13.15	17.01	59.76	7.88	20.95
Pod weight (g)	0.56	1.28	0.84	13.21	16.87	61.31	0.18	21.31
Pods per raceme	5.08	8.88	6.66	10.16	12.79	63.06	1.11	16.61
Pod length (cm)	4.33	7.10	5.66	7.99	9.78	66.76	0.76	13.44
Pod width (cm)	0.99	1.66	1.24	8.75	9.36	87.31	0.21	16.84
Seeds per pod	3.44	4.00	3.80	2.62	3.07	72.79	0.17	4.60
Seed yield per plant (g)	4.41	22.24	12.44	25.26	29.29	74.35	5.58	44.86

(10.16 % and 12.79 %, respectively), which indicated that these characters are less responsive to selection. While, low GCV and PCV values were recorded for days to 50 per cent flowering (3.42 % and 4.16 %, respectively), days to maturity (2.27 % and 2.94 %, respectively), pod length (7.99 % and 9.78 %, respectively), pod width (8.75 % and 9.36 %, respectively) and seeds per pod (2.62 % and 3.07 %, respectively) except plant height (8.24 % and 10.43 %, respectively) which showed moderate PCV value suggesting a limited range of variability for these traits and limited scope of selection for them. Similar results were also obtained for seed yield per plant by Peer *et al*. (2018); for pods per raceme by Singh *et al*. (2011); for racemes per plant and days to 50 per cent flowering by Patel *et al*. (2022); for pods per plant and pod weight by Afsan and Roy (2020); for seeds per pod and pod length by Gnanesh *et al*. (2006) and for days to maturity by Patel *et al*. (2022).

High heritability estimates were recorded for days to 50 per cent flowering (67.64 %), plant height (62.43 %), pod weight (61.31 %), pods per raceme (63.06 %), pod length (66.76 %), pod width (87.31 %), seeds per pod (72.79 %) and seed yield per plant (74.35 %) indicating these traits might be controlled by additive gene effects and that phenotype could offer a reliable measure of genotypic effect, and simple phenotypic selection can help to improve these traits (**Table 2**). Whereas, moderate heritability was observed for days to maturity (59.82 %), racemes per plant (58.04 %), and pods per plant (59.76 %) indicating the moderate influence of environment in the expression of these characters showing limited scope for phenotypic selection. Similar results were obtained for days to 50 per cent flowering, pod weight, pod length, pod width and seed yield per plant by Hadavani *et al*. (2018); for plant height and pods per raceme by Magalingam *et al*. (2013) and for seeds per pod by Peer *et al*. (2018).

In the present study, high genetic advance as per cent of mean was observed for racemes per plant (23.73 %), pods per plant (20.95 %), pod weight (21.31 %) and seed yield per plant (44.86 %) (**Table 2**). Moderate genetic advance as per cent of mean was recorded for plant height (13.41 %), pods per raceme (16.61 %), pod length (13.44 %) and pod width (16.84 %), while days to 50 per cent flowering (5.79 %), days to maturity (3.62 %) and seeds per pod (4.60%) had low estimates of genetic advance as per cent of mean. Similar findings were obtained for racemes per plant, pods per plant and pod weight by Peer *et al*. (2018); for seed yield per plant by Hadavani *et al*. (2018); for pod length and seeds per pod by Gnanesh *et al*. (2006); for days to maturity and days to 50 per cent flowering by Mohan *et al.* (2014); for pods per raceme by Sharma *et al*. (2014), and for pod width by Verma *et al*. (2015).

In general, heritability combined with genetic advance as per cent of mean is preferable to heritability alone in estimating selection response. The heritability of pod weight (61.31 %) and seed yield per plant (74.35 %) was high, with high genetic advance as per cent of mean (21.31 % and 44.86 %, respectively), indicating the role of additive gene effects and less influence of environment on the expression of these traits. As a result, direct phenotypic selection could be used to improve these characters. High heritability and moderate genetic advance as per cent of mean were observed for plant height (62.43 % and 13.41 %, respectively), pods per raceme (63.06 % and 16.61 %, respectively), pod length (66.76 % and 13.44 %, respectively) and pod width (87.31 % and 16.84 %, respectively) indicating these traits are governed by non-additive gene effects and have limited scope of improvement of these traits by selection. Moderate heritability coupled with high genetic advance was recorded for racemes per plant (58.04 % and 23.73 %, respectively) and pods per plant (59.76 % and 20.95

%, respectively) indicating the role of additive gene effects on the expression of these traits. High genetic advance as per cent of mean indicated that these traits can be improved through direct selection. High heritability and low genetic advance as per cent of mean were observed for seeds per pod (72.79 % and 4.60%, respectively) and days to 50 per cent flowering (67.64 % and 5.79 %, respectively) while moderate heritability with low genetic advance was recorded for days to maturity (59.82 % and 3.62 %, respectively) indicative of non-additive gene effects for these characters.

According to correlation analysis, seed yield per plant was observed to be significantly and positively correlated at the genotypic level with plant height (0.609**), pods per plant (0.411**) and pod weight (0.357*), which suggested that these characters can be improved simultaneously with seed yield per plant by direct selection (**Table 3**). A similar trend was found for plant height by Choudhary *et al*. (2016) and for pod weight by Ali *et al*. (2005). While it was non-significantly and positively correlated with racemes per plant (0.284), pods per raceme (0.034) and pod length (0.161) indicated less significance of these traits for yield improvement. Plant height had a negative significant correlation and negative non-significant correlation with days to fifty per cent flowering (-0.460**) and days to maturity (-0.012), respectively, which indicated that simultaneous improvement of plant height and seed yield per plant may result in indirect selection for early flowering and early maturity, which is desirable in Indian bean. Pods per plant were significantly and negatively correlated with seeds per pod (-0.412**) (**Table 3**). Therefore, while selecting the seed yield, pods per plant cannot be improved simultaneously with seeds per pod. Pods per plant (0.671**) with pods per raceme and (0.828**) with racemes per plant), pods per raceme (0.545**) with racemes per plant) and racemes per plant were significantly and positively associated with each other. Pod weight had a significant and positive correlation with pod length (0.360*), while pod length was significantly and positively correlated with pod width (0.485**). This indicated that such traits can be improved indirectly through direct selection for high seed yield.

The genotypic path analysis unveiled that the highest positive direct effects on seed yield per plant were exhibited by pods per plant (0.409) followed by racemes per plant (0.383), plant height (0.355), pod weight (0.199), pod length (0.131) and seeds per pod (0.038) (**Table 4**). Therefore, selection for such traits in F_5 and the subsequent generations will be easy and would be useful to bring about the improvement in Indian bean. Similar results were also recorded by Rubya *et al.* (2017) for racemes per plant; by Singh *et al.* (2011) for pods per plant and pod length, and by Chaitanya *et al.* (2014) for seeds per pod. The highest negative direct effects on seed yield per plant were recorded by pods per raceme (-0.465) followed by days to maturity (-0.450), pod width (-0.222) and days to 50 % flowering (-0.150) indicating less significance of these traits in selection for higher seed yield. The pods per plant had the highest positive indirect effects through racemes per plant on seed yield per plant. In general, it was observed that most of the characters exhibited a high magnitude of indirect effects on seed yield per plant *via* racemes per plant, pods per plant and pods per raceme. Path coefficient analysis for seed yield showed a residual effect of 0.283, which indicated that a few more traits need to be included in future studies to cover most of the available variation.

Table 3. Genotypic correlation coefficients of seed yield per plant with other characters in F_5 progenies of Indian bean

Characters	DFF	DM	PH	RPP	PPP	PW	PPR	PL	PWD	SPP	SYPP
DFF	1.000										
DM	0.260	1.000									
PH	-0.460**	-0.012	1.000								
RPP	0.322*	0.374**	0.037	1.000							
PPP	0.034	0.329*	0.371*	0.828**	1.000						
PW	-0.249	0.358*	0.400**	0.136	0.246	1.000					
PPR	0.067	0.063	0.122	0.545**	0.671**	0.081	1.000				
PL	-0.151	-0.024	0.173	-0.014	0.040	0.360*	0.096	1.000			
PWD	0.137	-0.082	0.118	-0.042	0.088	0.090	0.089	0.485**	1.000		
SPP	0.070	-0.179	-0.155	-0.413**	-0.412**	-0.071	0.046	0.129	0.124	1.000	
SYPP	-0.421**	-0.166	0.609**	0.284	0.411**	0.357*	0.034	0.161	-0.099	-0.320*	1.000

** - Significant at 1.0 % level of probability, * - Significant at 5.0 % level of probability

DFF=Days to 50% flowering DM=Days to maturity PH=Plant height RPP=Racemes per plant
PPP=Pods per plant PW=Pod weight PPR=Pods per raceme PL=Pod length
PWD=Pod width SPP=Seeds per pod SYPP=Seed yield per plant

Table 4. Genotypic path coefficient analysis of component characters towards seed yield per plant in F_5 progenies of Indian bean

Characters	DFF	DM	PH	RPP	PPP	PW	PPR	PL	PWD	SPP	Correlation with SYPP
DFF	-0.150	-0.117	-0.163	0.123	0.014	-0.049	-0.031	-0.020	-0.030	0.003	-0.421**
DM	-0.039	-0.450	-0.004	0.143	0.135	0.071	-0.029	-0.003	0.018	-0.007	-0.166
PH	0.069	0.005	0.355	0.014	0.152	0.080	-0.057	0.023	-0.026	-0.006	0.609**
RPP	-0.048	-0.168	0.013	0.383	0.339	0.027	-0.253	-0.002	0.009	-0.016	0.284
PPP	-0.005	-0.148	0.132	0.317	0.409	0.049	-0.312	0.005	-0.019	-0.016	0.411**
PW	0.037	-0.161	0.142	0.052	0.101	0.199	-0.037	0.047	-0.020	-0.003	0.357*
PPR	-0.010	-0.028	0.043	0.208	0.275	0.016	-0.465	0.012	-0.020	0.002	0.034
PL	0.023	0.011	0.061	-0.005	0.016	0.072	-0.044	0.131	-0.108	0.005	0.161
PWD	-0.021	0.037	0.042	-0.016	0.036	0.018	-0.041	0.063	-0.222	0.005	-0.099
SPP	-0.010	0.081	-0.055	-0.158	-0.169	-0.014	-0.021	0.017	-0.027	0.038	-0.320*

** - Significant at 1.0 per cent level of probability, * - significant at 5.0 per cent level of probability,

Residual = 0.283, Diagonal figures are the direct effects

DFF=Days to 50% flowering
DM=Days to maturity
PH=Plant height
RPP=Racemes per plant
PPP=Pods per plant
PW=Pod weight
PPR=Pods per raceme
PL=Pod length
PWD=Pod width
SPP=Seeds per pod
SYPP=Seed yield per plant

The overall study indicated that ample variability is present among the progenies for all the traits. The selection for pods per plant, racemes per plant, plant height, pod weight, pod length and seeds per pod will be easy and would be useful in a further breeding program for improving seed yield in Indian beans.

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