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Studies of Genetic variability, heritability and genetic advance for yield and related traits in French bean (*Phaseolus vulgaris* L.)

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Abstract
The present investigation was carried out using forty French bean genotypes during January-may of 2016 to measure the extent of variability for further use in breeding programmes. Highly significant differences among the genotypes were observed for all traits under study. Phenotypic coefficient of variation was higher than that of genotypic coefficient of variation. The characters like number of pods per plant followed by green pod yield per plant (q) and green pod yield per plant (gm) showed high genotypic and phenotypic coefficient of variation with high heritability coupled with genetic advance. A positive and significant correlation of pod yield per plant (q/ha) with number of pods per plant, number of clusters per plant, green pod yield per plant (gm) and plant height was observed. Path analysis exposed that green pod yield per plant (gm) followed by number of clusters per plant, seed length and pod width have highest positive direct effect on green pod yield per plant (q). Therefore, it might be concluded that number of pods per plant, number of clusters per plant and green pod yield per plant (gm) should be given due consideration for the improvement of pod yield per plant in French bean.

Keywords: French bean, variability, heritability, genetic advance, correlation, Path coefficients

Introduction

The French bean (*Phaseolus vulgaris* L., syn. Kidney bean, haricot bean, snap bean, navy bean, string bean and also called "Raj mash" in Hindi.) is one of the most important leguminous vegetables, which is grown for fresh pod consumption and for processing as a frozen vegetable in many countries. French bean originated from Central America and Peruvian Andes in South America. It spreaded to Europe during 16th and 17th centuries and reached England by 1594. It was introduced to India during 17th century form Europe. In India, it is mainly grown in Himachal Pradesh, UKO, J&K, Punjab, Haryana, Uttar Pradesh, Bihar, Gujarat, Madhya Pradesh, Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu, India has about 137.54 thousand ha area under bean cultivation and the production is 1370.21 thousand MT with an annual productivity 9.96 MT/ha green pod (NHB, 2015). The exploitation of variability is a pre-requisite for the effective screening of superior genotypes in all crops including French bean. Improvement of crop depends on the magnitude of genetic variability in economic characters, therefore, the evaluation and utilization of genetic variability in desired direction becomes extremely important in any yield improvement programme. The assessment of variability parameters *viz.*, phenotypic and genotypic coefficient of variation, heritability and genetic gain is prerequisite for planning and execution of a breeding programme for improvement of different qualitative and quantitative traits in any crop (Atta *et al.*, 2008) [2] and the success of the programme depends upon the magnitude of these parameters (Meena and Bahadur, 2014) [10]. Phenotypic and genotypic coefficients of variation are helpful to estimate the magnitude of variability present in a population, whereas, heritability provides the degree of transmissibility of a character and indicates the effectiveness of selection. Further, estimates of heritability have to be considered in conjugation with genetic advance to find the expected genetic gain in next generation (Shukla *et al*., 2006) [21]
Correlation studies help to find the degree of interrelationship among various characters and to evolve selection criteria for improvement. Path coefficient analysis provides better index for selection than mere correlation coefficient by separating correlation coefficients of yield and its component into direct and indirect effects. For any crop improvement programme, aimed to achieve maximum productivity, a detailed knowledge of above facts such as genetic variability, genetic diversity, heritability, genetic advance, correlation and path coefficient of various quantitative traits and their contribution towards yield is essential. Studies in this direction are very less and can not to be generalized for every climatic condition and with other genetic materials. Considering all the facts described above, study was undertaken using

forty genotypes of bush type French bean to analyze the relationship between yield component, association among desired traits and their direct and indirect contributions toward the pod yield.

Materials and Methods

The present investigation was conducted at Vegetable Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar (Uttarakhand), India during Jan-May, 2016. The experimental material comprised of 40 genotypes. The experiment was laid out in randomized block design with two replications. Each genotype was sown in spacing of 90x 60 cm apart. The seeds were sown at a depth of 4-5 cm. The crop was well managed for optimum growth and yield.

The observations were recorded on randomly taken ten plants of each genotype for fifteen traits in each replication *viz.*, days to first initial flower, days to germinate, number of pods per cluster, number of pods per plant, pod length (cm), pod width (cm), seed length (cm), seed width, internodal length (cm), number of clusters per plant, test weight (gm), green pod yield per plant (gm), plant height (m), number of seeds per pod, green pod yield per plant (q). The genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were calculated as per Burton and De Vane (1953). Heritability (broad sense) and genetic advance as per cent of mean were computed by following the methods of Johnson *et al.* (1955) [9] and Robinson *et al*. (1949) respectively. Correlation and path coefficient analysis were calculated by Searle's (1961) and Dewey and Lu (1959), respectively.

$$PCV(\%) = \frac{\sqrt{Phenotypic variance\ (Vp)}}{General\ mean\ of\ population} X100$$

$$GCV\ (\%) = \frac{\sqrt{Genotypic variance\ (Vg)}}{General\ mean\ of\ population} X100$$

Heritability

$$h^2 = \frac{Vg}{Vp} X\ 100$$

Where,

Vg = Genotypic variance

Vp = Phenotypic variance

Genetic advance (GA)

The extent of genetic advance to be expected by selecting 5% of the superior was calculated as:

$$GA = i\ \sigma p\ h^2$$

Where,

i = Coefficient of selection which is 2.06 at 5 per cent selection intensity

σp = Phenotypic standard deviation

h^2 = heritability in broad sense

Genetic advance as per cent of mean

$$GA\ (as\ \%\ of\ mean) = \frac{\text{Genetic advance}}{\text{General mean of character}} X100$$

Limits used for categorizing the magnitude of different parameters are as under:

Component	High (%)	Moderate (%)	Low (%)
GCV and PCV	More than 30	15-30	Less than 15
Heritability	More than 80	50-80	Less than 50
Genetic advance	More than 50	25-50	Less than 25

Result and discussion

The variation in character of any crop species is raw material for a plant breeder and extent of variability present in the population with respect to various characters is factor for success of plant breeder in improvement of crop plant. Larger variability ensures better chances of producing desired crop variety. Highly significant differences among the genotypes were observed for all traits under study (Table1).

The general mean and the standard error along with the variability estimates such as the phenotypic coefficient of variation (PCV), the genotypic coefficient of variation (GCV), heritability, and genetic advance as percent of means are presented in Table 2. The mean estimate of genotypes for various characters revealed that the wide range was recorded for test weight and green plant yield per plant (q) while other characters showed the moderate range. Similar findings for seed width, days to first initial flower, number of pods per cluster, green plant yield per plant (q) were reported by Panchbhaiya and Singh (2015).

In the present investigation, phenotypic coefficient of variation was higher than that of genotypic coefficient of variation for all the characters under study. It may be because of the reason that the variability at phenotypic level includes both genotypic and environmental variability. For most of the characters, the differences in estimates of PCV and GCV were less, indicating that these characters were less affected by environment and therefore they were stable (Rai *et al*., 2006; Singh and Singh, 2013; Prakash and Ram, 2014; Prakash *et al*., 2015) [15, 16]. Highest genotypic as well as phenotypic coefficient of variations were exhibited by number of pods per plant followed by green pod yield per plant (q) and green pod yield per plant (gm) while lowest in days to germinate followed by days to first initial flower and pod length. Heritability in broad sense is a parameter of tremendous significance to the breeders as its magnitude indicates the reliability with which a genotype can be recognized by its phenotypic expression. The estimates of range of heritability in broad sense varied from 82.94-99.59. Because the estimate of heritability for all the characters under study were more than 80 per cent in most of the characters indicated that there is good scope of selection in this crop on the basis of these traits. Similar result is also mentioned by Rai *et al*. (2010) in their study. Higher magnitude of heritability suggests the major role of genotypic factors in the expression of the characters. The most important function of the heritability in the genetic study of quantitative characters is its predictive role to indicate the reliability of the phenotypic value as a guide to breeding value (Dabholkar, 1992; Falconer and Mackay 1996) [5, 8]. Number of pods per plant (99.59 %) showed highest per cent of heritability followed by green pod yield per plant (q) (99.56 %) and green pod yield per plant (gm) (99.43 %). In present investigation, characters namely number of pods per plant followed by green pod yield per plant (q) and green pod yield per plant (gm) showed high GCV accompanied with high heritability indicating good scope for selection. Earlier, Johnson *et al*. (1955) [9] suggested that high GCV along with high heritability and genetic advance gave better picture for the selection of genotypes. The magnitude of heritable variability is the most important aspect of genetic constitution of the genetic material which has close bearing on the response to selection. (Panse, 1957) [14].

Genetic advance is the improvement over the base population that can potentially be made from selection for a character. It is a function of the heritability of the trait, the amount of phenotypic variation and the selection differential that is used by breeders. The genetic advance depends on the extent of genetic variability, the magnitude of masking effect of genetic expression (environment influence) and the intensity of selection. High genetic advances in per cent of mean was estimated for number of pods per plant (111.18 %), green pod yield per plant (104.73 %) (q) And green pod yield per plant (101.23 %) (gm).

High heritability coupled with high genetic advance provides better information rather than the heritability alone and considerable improvement could be made in characters by predicting the results and selecting the best individual as mentioned by Johnson *et al.* (1949). In present study high genetic advance coupled with high heritability was observed for pods per plant, green pod yield per plant (q) and green pod yield per plant (gm). High heritability coupled with high genetic advance as expressed by the above mentioned characters indicated that the germplasm could be evaluated in multi location trial and selected as direct introduction as a variety or incorporated in hybridization programmes as a parent. High heritability coupled with high genetic advance and low heritability with low genetic advance might be due to additive and non additive components of genetic variance respectively (Padi, 2003) [12]. Those traits that are governed by additive genetic components in that case selection will be useful for improvement of these traits. Therefore these traits could be improved more easily than other characters which have low heritability and low genetic advance. High heritability coupled with moderate genetic advance was observed for days to first initial flower implies equal importance of additive and non additive gene actions and considerable influence of environment on the expression of this trait and the same could be improved through reciprocal recurrent selection. Similar observations were reported by Singh and Singh (2013). Moreover, days to germinate showed a low genetic advance along with high heritability reflecting the regulation of non-additive gene which could be exploited through heterosis breeding. In present study low heritability coupled with low genetic advance was found for none of characters which mean that character is not highly influenced by environment and therefore selection for traits would be effective.

Table 1: Analysis of variance for different characters of French bean

	Days of First Initial Flower	Days to Germinate	Number of Pods per cluster	Number of pods per plant	Pod length (cm)	Pod width (cm)	Seed length (cm)	Seed width (cm)
Replication	1.063	0.393	0.017	0.296	0.004	0.002	0.001	0.001
Treatment	100.431**	2.691**	113.697**	996.085**	7.637**	0.078**	0.337**	0.089**
Error	2.865	0.173	0.632	1.378	0.092	0.001	0.002	0.001

	Internodal length (cm)	Number of Clusters per plant	Number of seeds per pod	Plant Height (m)	Test Weight (gm)	Green Pod Yield per Plant (gm)	Green Pod yield per Plant (q/ha)
Replication	0.003	0.008	0.020	0.003	44.056	0.000	3.425
Treatment	18.707**	61.816**	3.223**	2.137**	46018.281**	0.019**	12305.313**
Error	0.121	0.144	0.022	0.000	99.908	0.000	17.907

**= Significant at 1% level of probability

Table 2: Estimation of coefficient of variation and other genetic parameters in French bean

S. No.	Characters	Range	GM	Coefficient of variability			Heritability	Genetic advance	Genetic advance as % of mean
				GCV	PCV	ECV			
1.	Days to first initial flower	56.00-82.00	69.10	8.25	8.61	2.45	91.90	14.43	20.89
2	Days to germinate	14.00-18.00	16.23	5.65	6.20	2.56	82.94	2.20	13.58
3.	Number of Pods per cluster	2.00-6.00	3.55	27.73	27.84	2.54	99.17	2.59	72.90
4.	Number of pods per plant	11.00-83.00	43.15	42.19	42.87	2.72	99.59	47.97	111.18
5.	Pod length (cm)	9.79-16.80	12.99	12.21	12.43	2.34	96.45	4.11	31.65
6.	Pod width (cm)	1.00-1.80	1.27	12.65	12.88	2.45	96.37	0.41	32.78
7.	Seed length (cm)	0.90-2.40	1.59	21.01	21.17	2.63	98.46	0.88	55.04
8.	Seed width (cm)	0.60-1.30	0.90	18.96	19.15	2.65	98.09	0.45	49.58
9.	Internodal length (cm)	10.10-20.80	14.53	17.14	17.30	2.39	98.09	6.51	44.81
10.	Number of Clusters per plant	5.00-23.00	14.40	31.49	31.59	2.64	99.30	11.93	82.83
11.	Test weight (gm)	180.00-650.00	408.75	30.27	30.37	2.45	99.35	325.55	79.65
12.	Green pod yield per plant (gm)	0.08-0.40	0.21	38.45	38.56	2.91	99.43	0.21	101.23
13.	Plant height (m)	0.50-3.30	2.43	34.75	34.89	3.11	99.20	2.22	91.38
14.	Number of seeds per pod	4.00-9.00	5.55	18.61	18.80	2.65	98.01	2.69	48.65
15.	Green pod yield per plant (q)	62.16-296.74	160.98	39.76	39.84	2.63	99.56	168.59	104.73

Table 3: Phenotypic correlation coefficient between different characters

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}
X_1	1.0000	0.1337	0.0131	0.0580	-0.4884**	-0.3356**	-0.5095 **	-0.0890	0.0820	0.3271**	-0.5967**	0.1215	0.3641**	0.2973**	0.1036
X_2		1.0000	-0.2039*	0.0280	-0.0842	-0.0415	-0.2368**	-0.2367**	0.0055	-0.1223	-0.2438**	-0.0144	0.1000	-0.2236*	-0.0353
X_3			1.0000	0.2358 **	0.2071*	-0.0525	0.2954**	0.0072	0.0340	0.1902*	0.1286	0.2278*	0.1955 *	0.3142**	0.1603
X_4				1.0000	-0.0205	0.1016	0.1247	-0.0053	0.1550	0.7293**	0.0362	0.6809**	0.1169	0.6825 **	0.6181**
X_5					1.0000	0.5011**	0.6968**	0.3404**	0.0389	-0.1757	0.6305 **	0.1106	-0.1076	-0.0420	0.0649
X_6						1.0000	0.4265**	0.5928**	0.3169**	0.0492	0.5685**	0.1090	-0.3972**	0.1642	0.0667
X_7							1.0000	0.5948**	-0.0668	-0.1203	0.6482**	0.0604	-0.3044 **	0.1279	0.0138
X_8								1.0000	-0.0124	-0.0752	0.4155 **	-0.1103	-0.2764**	0.1438	-0.1686
X_9									1.0000	0.2163*	0.1508	0.0563	0.1073	0.2115 *	0.0303
X_{10}										1.0000	-0.1032	0.635**	0.1779	0.7316**	0.6181**
X_{11}											1.0000	0.1585	-0.3530 **	-0.0090	0.1385
X_{12}												1.0000	-0.0141	0.5136**	0.9516**
X_{13}													1.0000	0.4391**	0.4391**
X_{14}														1.0000	-0.0099
X_{15}															1.0000

X_1= Days to first initial flower, X_2= Days to germinate, X_3= number of pods per cluster, X_4= number of pods per plant, X_5= Pod length (cm), X_6= Pod width (cm), X_7=Seed length (cm), X_8=Seed width, X_9= Internodal length (cm), X_{10}= number of clusters per plant, X_{11}= Test weight (gm), X_{12}= Green pod yield per plant (gm), X_{13} =Plant height (m), X_{14}= number of seeds per pod, X_{15}= Green pod yield per plant (q)

Table 4: Path coefficient analysis for different pairs on yield per plant (q/ha)

Character	**Days of First Initial Flower**	**Days to Germinate**	**Number of Pods per cluster**	**Number of pods per plant**	**Pod Length (cm)**	**Pod Width (cm)**	**Seed Length (cm)**	**Seed Width (cm)**	**Internodal Length (cm)**	**Number of Clusters per plant**	**Test Weight (gm)**	**Green Pod Yield/ Plant gm**	**Plant Height (m)**	**Number of Seeds per Pod**
Days to first initial flower	0.0070	0.0009	0.0001	0.0004	-0.0034	-0.0023	-0.0036	-0.0006	0.0006	0.0023	-0.0042	0.0008	0.0021	0.0025
Days to germinate	-0.0064	-0.0476	0.0097	-0.0013	0.0040	0.0020	0.0113	0.0113	-0.0003	0.0058	0.0116	0.0007	0.0106	-0.0048
Number of Pods per cluster	-0.0008	0.0127	-0.0622	-0.0147	-0.0129	0.0033	-0.0184	-0.0004	-0.0021	-0.0118	-0.0080	-0.0142	-0.0196	-0.0122
Number of pods per plant	-0.0033	-0.0016	-0.0132	-0.0561	0.0012	-0.0057	-0.0070	0.0003	-0.0087	-0.0409	-0.0020	-0.0382	-0.0383	-0.0066
Pod length (cm)	0.0333	0.0057	-0.0141	0.0014	-0.0682	-0.0342	-0.0475	-0.0232	-0.0027	0.0120	-0.0430	-0.0075	0.0029	0.0073
Pod width (cm)	-0.0148	-0.0018	-0.0023	0.0045	0.0222	0.0442	0.0189	0.0262	0.0140	0.0022	0.0251	0.0048	0.0073	-0.0176
Seed length (cm)	-0.0412	-0.0191	0.0239	0.0101	0.0563	0.0345	0.0808	0.0481	-0.0054	-0.0097	0.0524	0.0049	0.0103	-0.0246
Seed width (cm)	0.0092	0.0245	-0.0007	0.0006	-0.0353	-0.0614	-0.0617	-0.1037	0.0013	0.0078	-0.0431	0.0114	-0.0149	0.0286
Internodal length (cm)	-0.0026	-0.0002	-0.0011	-0.0048	-0.0012	-0.0099	0.0021	0.0004	-0.0313	-0.0068	-0.0047	-0.0018	-0.0066	-0.0034
Number of Clusters per plant	0.0353	-0.0132	0.0206	0.0788	-0.0190	0.0053	-0.0130	-0.0081	0.0234	0.1081	-0.0112	0.0686	0.0791	0.0192
Test weight (gm)	-0.0131	-0.0053	0.0028	0.0008	0.0138	0.0125	0.0142	0.0091	0.0033	-0.0023	0.0219	0.0035	-0.0002	-0.0077
Green pod yield per plant (gm)	0.1174	-0.0139	0.2201	0.6579	0.1068	0.1053	0.0584	-0.1065	0.0544	0.6135	0.1532	0.9661	0.4962	-0.0136
Plant height (m)	-0.0273	0.0206	-0.0289	-0.0627	0.0039	-0.0151	-0.0118	-0.0132	-0.0194	-0.0672	0.0008	-0.0472	-0.0919	-0.0067
Number of seeds per pod	0.0107	0.0029	0.0057	0.0034	-0.0032	-0.0116	-0.0089	-0.0081	0.0031	0.0052	-0.0103	-0.0004	0.0021	0.0293
Green pod yield per plant (q)	0.1036	-0.0353	0.1603	0.6181	0.0649	0.0667	0.0138	-0.1686	0.0303	0.6181	0.1385	0.9516	0.4391	-0.0099
Partial R^2	0.0007	0.0017	-0.0100	-0.0347	-0.0044	0.0029	0.0011	0.0175	-0.0009	0.0668	0.0030	0.9193	-0.0404	-0.0003

R square=0.9224, Residual effect=0.2785

Correlation study for pod yield per plant (q) (Table 3) showed a positive and significant correlation with number of pods per plant (0.6181), number of clusters per plant (0.6181), green pod yield per plant (0.9516) (gm), and plant height (0.4391) suggesting improvement of yield by giving special focus to these traits. Mishra *et al*. (2008) and Devi *et al.* (2015) also reported high correlation of pod yield with number of pods per plant. Number of pods per plant showed positive and highly significant correlation with number of clusters per plant, green pod yield per plant, number of seeds per pod. Similar results were also reported by Bhushan *et al*. (2007) [13] and Panchbhaiya and Singh (2015) [13].

The characters showing significant correlation were subjected to estimation of direct and indirect effects (Table 4). Path analysis exposed that green pod yield per plant (gm) followed by number of clusters per plant, seed length and pod width have highest positive direct effect on green pod yield per plant (q), suggesting the importance of these traits in selection programme for improving yield The study showed that number of pods per plant had maximum indirect contribution on total association of days to flowering and plant height which resulted into significant positive correlation of these traits with pod yield per plant. The low magnitude of residual effects indicated that the traits included in the present investigation accounted for most of the variation present in the dependent variable. Similar study has been done by Devi *et al*. (2015) [7]. For characters, namely, number of pods per cluster, pod length and internodal length, the value of direct effect is negative but the correlation was positive. So the selection should be based on both direct and indirect effect simultaneously. Similar findings were also reported by Singh *et al*., (2009).

Conclusion

The experimental studies revealed substantial amount of genetic variability among the genotypes under study. Genetic parameters in association with correlation study indicated that for selection of superior genotypes primary emphasis should be given on number of pods per plant, number of clusters per plant and green pod yield per plant (g). Thre fore it is further concluded that during crop improvement programme the character like - Internodal length no. of nodes per plant, no. of flowers per cluster, no. of cluster per plant will be helpful for developing high yielding varieties.

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