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Genetic divergence, path coefficient and cluster analysis of French bean (*Phaseolus vulgaris*) genotypes

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ABSTRACT

Thirty four pole type French bean (*Phaseolus vulgaris* L.) genotypes were evaluated to assess their genetic variability to identify desirable ones for yield and quality traits. The genotypic variance was moderate to high for the all the 14 traits studied, which resulted in high heritability and moderate to high genetic advance values. Pod yield/plant was positively correlated with all traits except days to 50% flowering, pod diameter and vitamin C content. High heritability and genetic advance of leaf width, first flowering node, number of seeds/pod, number of pods per plant, average pod weight and dry matter content vis-a-vis their positive association and direct positive effect on pod yield per plant suggested for their improvement through simple selection method. All the French bean genotypes were grouped into five distinct clusters. An analysis of the percentage contribution of individual characters towards genetic diversity revealed that vitamin C content, number of pods/plant and dry matter content were the major characters contributing to genetic diversity in French bean. Based on the finding it can concluded that French bean genotypes exhibited a wide range of variability for most of the traits. Some genotypes possessed desirable genes for more than one characters, hence may be utilized directly or included in hybridization programme.

Key words: Crude fibre, French bean (pole type), Genetic diversity, Vitamin C

French bean (*Phaseolus vulgaris* L.), a native of central and South America (Swaider *et al*. 1992) has one of the longest histories of cultivated plants and is widely cultivated in the temperate and subtropical regions and in many parts of the tropics. It is the most important legume worldwide for human consumption (Singh 1999). North East region of India is one of the world's richest centres of crop genetic diversity because of diverse agro-climatic conditions and socioeconomic and cultural variation (Pandey *et al*. 2012).

Beans, the "meat of the poor", contribute essential protein to the undernourished people living in the hills. In North-Eastern India, French bean is used both as fresh vegetable (green pod) and pulse (dried seed). Pole type French beans are cultivated for green pods in the hills during summer to autumn. Farmers regard beans as a cash-generating crop in the hills and grow a number of landraces with varying morphologies. Most of the genotypes/landraces are grown not only to get higher yield but due to their specific colour and taste, thus the productivity remains low. Therefore, to improve the genetic gain under low or no input conditions, there is a need to explore the existing genetic diversity as knowledge and use of diversity available in cultivated landraces are essential for broadening the genetic base of cultivars to sustain improvement. To breed new cultivars possessing desirable yield and quality traits in the present day context, the breeder requires a comprehensive knowledge of variability present in the existing germplasm. The objective of this study was to evaluate pole type French bean genotypes, to study yield attributing components, their heritability and genetic advance.

MATERIALS AND METHODS

Thirty-four genotypes of French bean (pole type) were evaluated during August to November in two consecutive years of 2010-11 and 2011-12 at the ICAR Research Complex for NEH Region, Umiam, Meghalaya. The experiment was laid out in a randomized block design (RBD) with three replications, at a spacing of 30 cm × 20 cm, and a gross plot size measuring 2.7m × 5.0m. The recommended agronomic practices and plant protection measures were followed to ensure a normal crop growth. The weeds were controlled by manual weeding twice at 30-35 and 60-65 days after planting. Staking was done with bamboo sticks between 15-20 days after planting. The nutrients were applied as FYM 10 tonnes/ha and the NPK 60: 60:40 kg/ha. Full dose of FYM, P and K and half dose

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Table 1 Components of variation in French bean genotypes for agro morphological and quality traits

Trait	Range	Mean	GCV %	PCV%	h²b	GAM (5%)
Leaf length (cm)	2.45-9.04	5.69	22.99	24.78	0.86	43.94
Leaf width (cm)	4.87- 11.47	7.85	20.36	21.11	0.93	40.46
Days to flowering	28.05- 42.00	37.72	8.68	8.76	0.98	17.73
First flowering node	2.33-6.00	4.57	17.29	17.86	0.94	34.48
Pod length (cm)	8.14- 17.15	11.01	16.38	16.55	0.98	33.37
Pod diameter(cm)	0.72- 1.56	1.02	18.72	19.23	0.95	37.56
No of seeds/pod	3.08- 7.77	5.64	24.29	25.03	0.94	48.58
No of pods/plant	5.30- 27.00	15.61	43.32	43.43	0.99	89.02
Average pod wt. (g)	4.45- 12.19	7.31	28.29	28.60	0.98	57.65
Plant height (cm)	102.64- 282.00	171.66	23.42	23.62	0.98	47.84
Dry matter (%)	11.13- 30.83	19.87	29.13	29.29	0.99	59.67
Crude fibre (%)	12.66 -34.17	19.94	25.82	26.03	0.98	52.73
Vitamin C (mg)	13.69- 54.14	30.63	35.92	35.99	0.99	73.83
Yield/plant (g)	22.52- 128.53	68.68	33.63	41.36	0.66	56.35

of N were applied in the rows two weeks before planting. The remaining nitrogen dose was applied 30 days after planting. The pods were harvested at fully developed tender stage. Observations were recorded for 14 characters, viz. days to 50% flowering, plant height (cm), leaf length (cm), leaf width (cm), first flowering node, pod length (cm), pod diameter (cm), number of seeds per pod, number of pods per plants, average pod weight (g), dry matter content (%), crude fibre (%), vitamin C (mg/100 g) and yield (g/plant) on ten randomly selected plants in each replication. Mean values were taken for analysis of variance as per Panse and Sukhatme (1978). Phenotypic and genotypic variances of the genotypes were estimated as described by Burton and Devane (1953), heritability as described by Hanson *et al.* (1956) and genetic advance was estimated using the formula suggested by Johnson *et al*. (1955). The genotypic and phenotypic correlation coefficient and path coefficient were estimated as suggested by Dewey and Lu (1959). The data were subjected to analysis of genetic divergence through D^2 statistic (Mahalanobis 1936) to measure genetic divergence as suggested by Rao (1952), while Tocher's method was used to form clusters. Principal component analysis (PCA), based on the all the 14 traits studied, was done by using SAS 9.2 software (SAS Institute Inc., Cary, NC, USA).

RESULTS AND DISCUSSION

Genetic variability, heritability and genetic advance

The exploitation of variability is a pre-requisite for the effective screening of superior genotypes in any crop. The progress in breeding for the yield and its contributing characters is determined by the magnitude and nature of their genetic variability. Hence, it is essential to partition the overall variability into its heritable and non-heritable components with the help of genetic parameters like genetic coefficient of variation, heritiability and genetic advance. Response to selection for quantitative traits is directly proportional to the function of its heritability, genetic advance and its genotypic variance. Heritability enables the plant breeder to recognize the genetic differences among traits and genotypic variance reveals the potential for improvement of a particular trait. Analysis of variance revealed significant genotypic differences for all the characters. The estimates of genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability and genetic advance are presented in Table 1. Considerable variability was observed for all the traits under study indicating enough scope for bringing about improvement in the desired direction. Plant height was recorded maximum in RCMFB1 (282 cm) and minimum in RCMFB19 (102.64 cm). The number of pods per plant ranged from 5.3 – 27. A range of 3.08 - 7.77 was observed among genotypes for number of seeds per pod. Data on crude fibre in seeds varied from 12.66 to 34.17 whereas for vitamin C content a range of 13.69-54.14 was observed. FB-9 which had maximum vitamin C content may be used as parent in future varietal development programme for improvement in this trait.

The PCV for traits, viz. leaf length, leaf width, no of seeds/pod, no of pods/plants, average pod weight, yield per plant, plant height , dry matter content, crude fibre % and vitamin C was high (>20%) but moderate for days to 50% flowering, first flowering node, pod length and pod diameter (10-20%). Highest coefficients of variation were observed for number of pods per plant followed by yield per plant. Days to 50% flowering has shown lowest (8.76%) PCV. Genotypic coefficients of variation closely followed the phenotypic coefficients of variation in all the characters except yield per plant. It show yield was highly influenced by environment, hence selection for this trait may not be effective. High heritability was observed in all the characters except yield per plant. Genetic advance over mean was also found to be high (> 40%) for majority of the characters except days to 50% flowering, first flowering node, pod length and pod diameter. Pod/plant showed high heritability and genetic advance for the traits suggest the least effect of

Table 2 Correlation coefficients among the fifteen characters of French bean (Significance Levels: 0.05= *; 0.01=**)

		Leaf Width (cm)	Days to flowering	First flowering node	Pod length (cm)	Pod diameter (cm)	No. of seeds/ pod	No. of pods/ plant	Average pod wt. (g)	Plant height (cm)	Dry matter (%)	Crude fibre (%)	Vitamin C (mg)	Yield/ plant (g)
Leaf length (cm)	G	0.920**	–0.101	0.243*	0.250*	–0.326**	0.250**	0.502**	0.370**	0.400**	–0.036	–0.233*	–0.136	0.792**
	P	0.881**	–0.091	0.208*	0.230*	–0.294**	0.225**	0.463**	0.327**	0.369**	–0.038	–0.203*	–0.129	0.513**
Leaf width (cm)	G		–0.188	0.239*	0.359**	–0.290**	0.292**	0.471**	0.447**	0.375**	–0.036	–0.058	–0.158	0.751**
	P		–0.175	0.209*	0.337**	–0.266**	0.280**	0.453**	0.418**	0.357**	–0.038	–0.051	–0.154	0.584**
Days to flowering	G			0.054	–0.110	0.274**	–0.276**	–0.380**	0.223*	–0.068	0.497**	0.128	–0.337**	–0.180
	P			0.055	–0.116	0.268**	–0.256**	–0.377**	0.219*	–0.064	0.489**	0.123	–0.335**	–0.145
First flowering node	G				0.155	–0.178	0.138	0.131	0.445**	0.272**	0.130	0.071	–0.366**	0.436**
	P				0.137	–0.166	0.137	0.127	0.431**	0.265**	0.121	0.061	–0.355**	0.342**
Pod length (cm)	G					0.118	0.658**	0.257**	0.600**	0.629**	0.043	–0.054	0.067	0.837**
	P					0.113	0.628**	0.255**	0.586**	0.614**	0.044	–0.048	0.068	0.668**
Pod diameter (cm)	G						–0.280**	–0.422**	0.068	–0.061	0.245*	0.132	–0.137	–0.215
	P						–0.265**	–0.411**	0.065	–0.064	0.234*	0.126	–0.134	–0.167
No of seeds/pod	G							0.470**	0.453**	0.297**	0.062	0.281**	0.023	0.894**
	P							0.453	0.439**	0.288**	0.060	0.263**	0.019	0.713**
No of pods/plant	G								0.018**	0.245*	–0.116	–0.004	–0.259**	0.816**
	P								0.019**	0.241*	–0.115	–0.004	–0.258**	0.662**
Average pod wt. (g)	G									0.501**	0.195*	0.112	–0.097	0.887**
	P									0.491**	0.195*	0.104	–0.094	0.725**
Plant height (cm)	G										0.113	–0.183	0.042	0.676**
	P										0.112	–0.186	0.039	0.548**
Dry matter (%)	G											0.531**	–0.293**	0.019
	P											0.523**	–0.290**	0.015
Crude fibre (%)	G												–0.341**	0.135
	P												–0.335**	0.103
Vitamin C (mg)	G													–0.220*
	P													–0.176

Table 3 Path coefficient showing direct (bold) and indirect effect of observed characters on grain yield per plant in French bean

	Leaf length (cm)	Leaf width (cm)	Days to flower-ing	First flower-ing node	Pod length (cm)	Pod diameter (cm)	No. of seeds/ pod	No of pods/ plant	Average pod wt. (g)	Plant height (cm)	Dry matter (%)	Crude fibre (%)	Vitamin C (mg)	Yield/ plant (g)
Leaf length (cm)	–0.034	–0.030	0.003	–0.007	–0.008	0.010	–0.008	–0.016	–0.011	–0.012	0.001	0.007	0.004	0.513**
Leaf width (cm)	0.064	0.073	–0.013	0.015	0.024	–0.019	0.020	0.033	0.030	0.026	–0.003	–0.004	–0.011	0.584**
Days to flowering	–0.006	–0.011	0.063	0.003	–0.007	0.017	–0.016	–0.024	0.014	–0.004	0.031	0.008	–0.021	–0.145
First flowering node	0.003	0.003	0.001	0.015	0.002	–0.002	0.002	0.002	0.006	0.004	0.002	0.001	–0.005	0.342**
Pod length(cm)	–0.008	–0.012	0.004	–0.005	–0.035	–0.004	–0.022	–0.009	–0.020	–0.021	–0.002	0.002	–0.002	0.668**
Pod diameter (cm)	–0.040	–0.036	0.036	–0.022	0.015	0.134	–0.036	–0.055	0.009	–0.009	0.031	0.017	–0.018	–0.167
No of seeds/pod	0.047	0.058	–0.053	0.029	0.131	–0.055	0.208	0.094	0.091	0.060	0.012	0.055	0.004	0.713**
No of pods/plant	0.278	0.272	–0.226	0.076	0.153	–0.247	0.272	0.601	0.012	0.145	–0.069	–0.002	–0.155	0.662**
Average pod wt. (g)	0.185	0.236	0.124	0.244	0.331	0.037	0.248	0.011	0.565	0.277	0.110	0.059	–0.053	0.725**
Plant height (cm)	0.040	0.039	–0.007	0.029	0.066	–0.007	0.031	0.026	0.053	0.108	0.012	–0.020	0.004	0.548**
Dry matter (%)	0.005	0.005	–0.064	–0.016	–0.006	–0.030	–0.008	0.015	–0.025	–0.015	–0.130	–0.068	0.038	0.015
Crude fibre (%)	–0.014	–0.004	0.009	0.004	–0.003	0.009	0.019	0.000	0.007	–0.013	0.037	0.071	–0.024	0.103
Vitamin C (mg)	–0.008	–0.010	–0.021	–0.022	0.004	–0.008	0.001	–0.016	–0.006	0.003	–0.018	–0.021	0.063	–0.176
Partial R^2	–0.017	0.042	–0.009	0.005	–0.023	–0.022	0.148	0.398	0.410	0.059	–0.002	0.007	–0.011	

R Square = 0.9845 Residual effect = 0.1247

environment and probably prevalence of additive gene action. Such characters would be responsive to direct selection (Burton 1952, Johnson *et al.* 1955). High heritability for pod related characters in French bean were also reported by Rai *et al.* (2006).

Correlation and path coefficient analysis

Correlations coefficients estimated among fourteen traits, indicated the inherent association between any two variables, which might have occurred due to the pleiotropic action of genes, linkage or more likely both (Table 2). Pod yield per plant was positively correlated with all traits except days to 50% flowering, pod diameter and vitamin C content. The association of number of seeds per pod has significant positive correlation with pod length while it was significantly negative with pod diameter. Significant negative associations of vitamin C content with days to flowering, first flowering node, number of pods per plant, crude fibre %, dry matter content and yield per plant were observed. Pod diameter has positive association with crude fibre % and negative association with vitamin C content. French bean pods with less fibre are generally preferred and so in future crop improvement programme negative selection for pod diameter (round seeds) may be effective.

In the present investigation the path coefficient analysis was performed to estimate the direct and indirect contribution of various plant characters to grain yield per plant. Further compartmentalization of correlation coefficients into direct and indirect effects discerned the true nature of association between observed characters. Except for leaf length, pod length and dry matter content all other characters exhibited positive direct effect on yield per plant (Table 3).

Number of pods per plant exhibited maximum direct effect followed by average pod weight and number of seeds per pod. Number of pods per plant had not only the maximum direct effect, but its indirect effect on average pod weight and number of seeds per pod was high. Except for days to flowering, pod diameter and vitamin C, all the characters had positive correlation with yield per plant. Pod diameter had positive direct effect on yield per plant but its negative effect through number of seeds per pod and number of pods per plant made its association with yield per plant significantly negative. The negative association of pod diameter with yield per plant also reported by Rai *et al.* (2010) but it is in contradiction to the result earlier reported by Rai *et al.* (2006). Leaf length and pod length had negative direct effect on yield per plant but its positive effect through number of pods per plant, average pod weight and number of seeds per pod made its association with yield per plant significantly positive. The correlation between yield per plant and a character due to the direct effect of the character reflects a true relationship between them and selection may be practised for such a character for improvement. If the correlation is mainly due to the indirect effect of the character through another component trait, the selection should be practised for that trait through which indirect effect is

Table 4 Inter- and intra- (bold) cluster distances (D^2) and distribution of thirty four genotypes of French bean to different clusters

Clusters	I	II	III	IV	V	No. of genotypes	Genotypes
I	**389**	1109	677	879	1275	15	RCMFB1A, RCMFB5, RCMFB11, RCMFB18, RCMFB37, RCMFB76, RCMFB78, RCMFB84, RCMFB87, Megha local-2, FB3, FB4, FB7, Fb13, NLC2
II		**447**	1308	1009	1653	8	RCMFB1, RCMFB60, RCMFB62, RCMFB75, RCMFB79, RCMFB85, FB9, NLC1
III			**532**	1512	1168	9	RCMFB19, RCMFB31, RCMFB61, RCMFB63, RCMFB67, RCMFB70, RCMFB74, RCMFB88, FB8
IV				**0**	1270	1	RCMFB80
V					**0**	1	RCMFB42-A

Table 5 Mean performance of different characters for yield and yield contributing traits in French bean

Characters	Cluster				
	I	II	III	IV	V
Leaf length (cm)	6.18	5.46	4.92	6.57	6.26
Leaf width (cm)	8.28	7.44	7.29	9.46	8.13
Days to flowering	37.91	36.07	39.74	28.05	39.66
First flowering node	4.7	3.86	4.78	5	6
Pod length(cm)	11.18	10.55	10.14	13.88	17.15
Pod diameter(cm)	0.97	0.98	1.13	1.04	1.17
No of seeds/pod	5.84	5.36	5.26	6.83	7.33
No of pod/plant	20.44	12.01	10.48	25	8.52
Average pod wt. (g)	7.13	6.44	7.56	9.85	12.19
Plant height (cm)	179.77	155.92	152.37	239.32	282
Dry matter (%)	19.41	15.2	25.09	11.13	25.86
Crude fibre (%)	18.56	16.6	25.87	17.34	16.77
Vitamin C (mg)	24.1	46.24	26.33	39.05	33.99
Yield per plant (g)	78.39	52.7	56.84	128.53	97.53

exerted. Results of the correlation and path analysis suggested that selection of genotypes may reliably be done based on leaf width, number of seeds per pod, number of pods per plant, average pod weight and plant height as these traits having positive association with yield are also directly contributing to yield.

Genetic divergence analysis

All the 34 French bean genotypes were grouped into five clusters (Table 4) based on D^2 analysis. Maximum number of genotypes were retained in cluster I (15) followed by cluster III (9). Cluster I exhibited maximum mean values for leaf width and minimum mean value for pod width (Table 5). Cluster II had the highest mean value for vitamin C content. Cluster III had the highest mean value for days to 50% flowering and crude fibre percentage. The maximum contribution towards divergence was due to vitamin C followed by number of pods per plant and dry matter content. The results of D^2 analysis may be useful in identifying the best parental combination for generating variability with respect to various traits under study. For creating wide spectrum of variability and improving the grain yield the genotypes from cluster II and III may be crossed with genotypes of cluster IV and V, since both

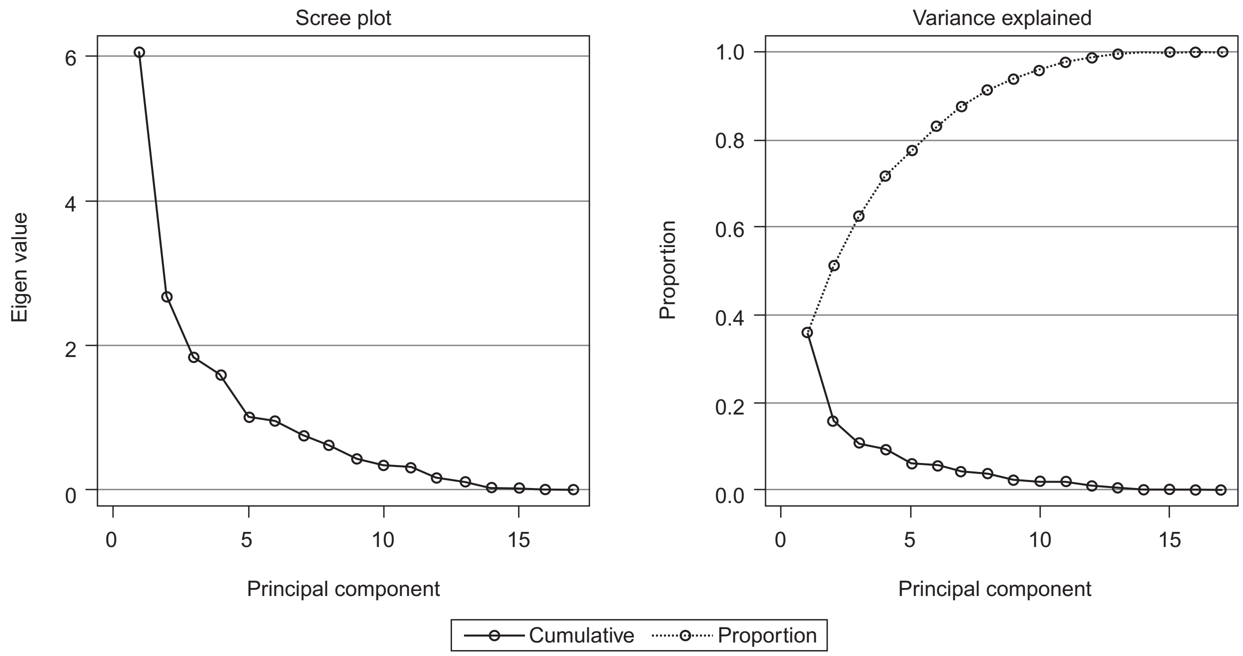

Fig 1 A Scree plot of French bean genotypes based on fifteen studied traits

cluster IV and V contained only one genotype and both genotypes were suitable for most of the characters, another option of crossing genotypes of cluster II with genotypes of cluster III may be explored for creating wide spectrum of variability.

PCA is a powerful technique for data reduction which removes interrelationships among components. Results reported by various researchers showed multivariate analysis as a valid system to deal with germplasm collection. Smith *et al*. (1995) conducted average linkage cluster and principal component analyses, and reported the utility of these results in preservation and utilization of germplasm. In present study, principal components analysis performed on quantitative traits revealed that the first three most informative components accounted for 62.26% variance among thirty-four genotypes of French bean (Fig 1).

Important characters with greater weightings in principal component axis I include yield (q/ha), average pod weight, number of pods per plant and number of seeds per pod. Important characters with greater weightings in principal component axis II include dry matter content, days to 50% flowering and crude fibre.

In present study French bean genotypes exhibited a wide range of variability for most of the traits. Some genotypes possessed desirable genes for more than one character and hence could be utilized directly or included in hybridization programme for the development of variety suitable for mid altitude region of Meghalaya.

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