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Genetic Variability and Diversity Studies in French Bean (*Phaseolus vulgaris* L.)

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Abstract The investigation was carried out with 36 genotypes of French bean (*Phaseolus vulgaris* L.) to know the genetic variability and diversity during 2015-2016. The analysis of variance was significant (p=0.01) for all characters indicated higher magnitude of variability. Moderate GCV and PCV were observed for the traits. High heritability coupled with high genetic advance was recorded for the pod width, number of pods/plant, weight of ten pods, yield/plant, number of root nodules/plant, dry mattet content of pods, roots and protein content. It indicated the presence of additive gene effects. Genetic diversity among the genotypes was worked out using Mahalanobis D^2 statistics. On the basics of Tocher's method, these genotypes were broadly grouped in to fiveclusters. Cluster I was the largest having 24 genotypes followed by cluster II (9), cluster III, cluster IV and cluster V had solitary genotype each. The inter cluster D^2 value was maximum (395.94) between cluster II and cluster V indicating that these genotypes could be used in hybridization program to obtain transgressive segregants.Whereas, cluster I showed maximum intra cluster distance.

Keywords French bean, Variability, Heritability, Genetic advance, Diversity.

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Introduction

French bean (*Phaseolus vulgaris* L., 2n = 2x = 22) is an important legume vegetable belonging to family Fabaceae. It has many synonyms like snap bean, kidney bean, haricot bean and also called raj mash in hindi. The primary center of origin of French bean is Southern Mexico and Central America. It is originated from wild species *Phaseolus aborigineus* L.Beans are essential used for their tender green pods. The dried pods are used as pulse and provide valuable protein to the human diet. Immature pods are marketed fresh, canned or frozen (Abate 2006). These pods are dried and fried like potato chips and can be cooked. Green pods can be used to strengthen diuretic, flushing of toxins from the body and also infused in the treatment of diabeties (Prajapati 2003).

The nutritive value of the crop per 100 g of green pod is 1.7 g protein, 0.1 g fat, 4.5 g carbohydrate, 1.8 g fiber and is also rich in minerals and vitamins. French bean possesses medicinal properties which are useful against diabetes, certain cardiac problems and a good natural cure for bladder burn. It has both carminative and reparative properties against constipation and diarrhoea respectively.

The success of any crop improvement program primarily dependent on the nature and magnitude of genetic variability existing in the breeding material, with which breeder is working. Further, variance in any quantitative trait depends on additive variance (heritable)and non-additive variance (non- heritable), which include dominance and epistatis (non allelic interaction). Therefore, it becomes necessary to partition the observed phenotypic variability into genotypic (partly heritable) and environmental (non heritable) components with suitable parameters, such as phenotypic and genotypic co-efficient of variation and heritability in broad sense. Furthermore, genetic advance can be used predict the efficiency of selection. Considering its use as a vegetable which fits well in different cropping systems, there is need for improvement and development of cultivars to specific agro ecological conditions.

Generally diverse plants of compatible texa are expected to give high hybrid vigor and hence, it is necessary to study the genetic divergence among the existing varieties and germplasm collection for identification of more diverse parents for hybridization program. The information of genetic divergence of various traits particularly of those that contribute to yield and quality would be most useful in planning the breeding program. The D^2 statistics developed by Mahalanobis (1936) provides a measure of magnitude of divergence between two groups under comparison. Grouping of genotypes based on D^2 analysis will be useful in choosing suitable parent lines for hybridization program.

Materials and Methods

The material consists of 36 bush type genotypes of French bean collected from Indian Institute of Horticultural Research, Hesaraghatta, Bangalore. The experiment was conducted in a RCBD with two replications during *rabi,* 2015-2016 at Department of Vegetable Science, College of Horticulture, Bagalkot. Fifty plants of each genotype were grown per replication with a spacing of 60 cm between rows and 15 cm between plants. About 25 tonnes of FYM per hectatre and recommended dose of fertilizers (63:100:75 NPK/ha) were incorporated as per the package of practices of UHS, Bagalkot. In each replication, five plants were selected randomly for recording observation. The character viz., plant height, number of primary branches per plant, plant spread, days to first flowering, days to 50% flowering, days to first pod picking, pod length, pod width, pod flesh thickness, number of seeds per pod, number of clusters per plant, number of pods per cluster, number of pods per plant, weight of ten pods, dry matter content of pods, pod yield per plant and number of root nodules per plant. Analysis of variance was carried out as per the procedure given by Panse and Sukhatme (1967). Genotypic and phenotypic coefficients of variations were computed according to Burton and Devane (1953). Broad sense heritability was estimated as the ratio of genotypic variance to the phenotypic variance and expressed in percentage (Falconer 1981). Genetic advance (GA) was computed using the formula given by Robinson et al. (1949). Genetic advance as percentage over mean was worked out as suggested by Johnson et al. (1955). The genetic divergence was estimated using D^2 statistics of Mahanalobis and the population was grouped into cluster by following the method suggested by Toucher (Rao 1952). The intra and inter-cluster distances were calculated by the formula described by Singh and Choudhary (1979).

Results and Discussion

The analysis of variance (Table 1) indicated highly significant (at p=0.01) difference among genotypes for most of the traits viz., plant height, plant spread, number of primary branches, days to first flowering, days to 50% flowering, days to first pod maturity, pod length, pod width, pod flesh thickness, number of seeds per pod, number of clusters per plant, number of pods per cluster, number of pods per plant,

Table 1. Analysis of variance (mean sum of squares) for growth, earliness and yield parameters in French bean genotypes. **-Significant at p=0.01.

Sl. No.	Source of variation/ Character	Replication	Genotype (treatment)	Error	CD @ 5%	CD @ 1%
	Degrees of freedom	1	35	35		
A.	**Growth parameters**					
1.	Plant height at 25 DAS (cm)	24.85	44.89**	7.82	5.67	7.61
2.	Plant height at 50 DAS (cm)	105.12	77.57**	11.92	7.01	9.40
3.	Number of primary branches at 50 DAS	0.21	1.03**	0.199	0.90	1.21
4.	Plant spread (N-S) at 25 DAS	7.36	29.21**	3.21	4.51	6.06
5.	Plant spread (N-S) at 50 DAS	62.94	40.69**	4.95	5.13	6.88
6.	Plant spread (E-W) at 25 DAS	4.06	33.29**	3.52	4.88	6.26
7.	Plant spread (E-W) at 50 DAS	1.30	33.70**	4.76	4.43	5.94
B.	**Earliness parameters**					
8.	Days to first flowering	17.01	14.26**	2.87	3.43	4.61
9.	Days to 50% flowering	22.89	26.47**	3.61	3.86	5.18
10.	Days to first pod picking	24.15	30.56**	5.02	4.54	6.10
C.	**Yield parameters**					
11.	Pod length (cm)	9.46	4.21**	0.94	1.97	2.64
12.	Pod width (cm)	0.001	0.019**	0.001	0.08	0.12
13.	Pod flesh thickness (cm)	0.005	0.010**	0.001	0.08	0.11
14.	Number of clusters per plant	12.33	5.49**	0.94	1.97	2.64
15.	Number of seeds/pod	0.22	0.70**	0.10	0.64	0.86
16.	Number of pods per cluster	0.055	0.19**	0.04	0.41	0.56
17.	Number of pods per plant	169.17	67.12**	13.09	7.34	9.86
18.	Weight of ten pods (g)	90.74	103.92**	21.83	9.47	12.73
19.	Yield per plant (g/plant)	8867.922	3481.91**	377.55	39.38	52.93
20.	Yield per hectare (t/ha)	109.69	42.96**	4.64	4.37	5.87
21.	Number of root nodules per plant	17.11	18.14**	1.43	2.43	3.26
22.	Dry matter content of pod (g)	6.67	16.21**	2.546	3.23	4.34
23.	Dry matter content of Leaves (g)	8.92	16.89**	2.82	3.41	4.58
24.	Dry mater content of Stem (g)	15.35	100.41**	18.62	8.75	11.76
25.	Drtmatter content of Roots (g)	0.01	2.99**	0.35	1.21	1.63
D.	**Quality parameters**					
26.	Protein content (g/100g)	0.040	0.275**	0.001	5.47	4.07

weight of ten pods, pod yield per plant, pod yield per ha, number of root nodules per plant, dry matter content (leaves, stem, pod and roots) and protein content. The results indicated that sufficient variability existed for all the characters.

The estimates of range, mean, components of variance, heritability and genetic advance for growth, earliness and yield parameters in French bean genotypes (Table 2). High (>20%) GCV and PCV were observed for most of yield traits viz., yield per plant, protein content in pods and yield per hectare. The results indicated the existence of sufficient variability in genetic stock studied and the traits are governed by additive genes. Hence, there exists ample scope for improving these characters through direct selection. The findings of Kumar et al. (2014), Singh et al. (2014), Verma et al. (2014) and Jayprakash et al. (2015) in French bean, Chaitanya et al. (2014) and Prashanth and Sreelatha (2014) in dolichos bean are in same line.

Table 2. Estimates of range, mean, components of variance, heritability and genetic advancefor growth, earliness and yield parameters in French bean. GV=Genotypic variance, PV=Phenotype variance, GCV=Genotypic coefficient of variance, GA= Genetic advance, h^2= Heritability (broad sense), PCV=Phenotypic coefficient of variance, GAM = Genetic advance (per cent mean), DAS = Days after sowing.

Sl. No.	Character	Range	Mean±SEm	PV	GV	PCV (%)	GCV (%)	h^2 (%)	GA	GAM (%)
A.	**Growth parameters**									
1.	Plant height at 25 DAS (cm)	18.75-37.90	29.83±1.97	26.35	18.53	17.20	14.43	70.33	7.43	24.93
2.	Plan height at 50 DAS (cm)	31.50-53.50	44.87±2.44	44.75	32.82	14.90	12.76	73.35	10.10	22.52
3.	Number of primary branches at 50 DAS	4.80-7.10	6.09±0.31	0.61	0.41	12.91	10.63	67.78	1.09	18.03
4.	Plant spread (N-S) at 25 DAS	29.50-48.00	37.27±1.57	22.79	17.83	12.80	11.32	78.26	7.69	20.64
5.	Plant spread (N-S) at 50 DAS	38.25-60.00	45.94±1.7	28.10	21.72	11.53	10.14	77.27	8.43	18.36
6.	Plant spread (E-W) at 25 DAS	26.50-48.00	33.75±1.54	19.23	14.46	12.99	11.26	75.23	6.79	20.13
7.	Plant spread (E-W) at 50 DAS	29.50-47.00	38.87±1.62	18.62	13.33	11.10	9.39	71.59	6.36	16.37
B.	**Earliness parameters**									
8.	Days to first flowering	28.50-39.50	33.04±1.19	8.56	5.69	8.85	7.22	66.50	4.01	12.13
9.	Days to 50% flowering	34.50-48.50	40.41±1.34	15.04	11.43	9.59	8.36	75.96	6.07	15.02
10.	Days to first pod picking	43.50-59.00	51.62±1.58	17.79	12.77	8.17	6.92	71.77	6.23	12.07
C.	**Yield parameters**									
11.	Pod length (cm)	8.25-15.50	13.39±0.68	2.57	1.63	11.99	10.00	63.32	2.09	15.64
12.	Pod width (cm)	0.61-1.27	0.82±0.03	0.010	0.008	12.42	11.21	81.37	0.17	20.83
13.	Pod flesh thickness (cm)	0.42-0.73	0.61±0.030	0.006	0.004	13.01	10.47	71.08	0.11	19.05
14.	Number of seeds per pod	4.40-7.20	6.02±0.22	0.40	0.29	10.50	9.09	74.84	0.97	16.20
15.	Number of clusters per plant	10.50-15.90	13.67±0.69	2.27	3.21	13.12	11.03	70.74	2.61	19.12
16.	Number of pods per cluster	1.95-3.13	2.61±0.14	0.11	0.075	13.14	10.55	64.48	0.45	17.45
17.	Number of pods per plant	20.93-46.29	35.77±2.56	27.01	40.11	17.70	14.52	67.35	8.78	24.56
18.	Average pod weight	30.65-66.00	51.97±3.30	41.04	62.87	15.25	12.32	65.27	10.66	20.51
19.	Yield per plant	110.65-268.50	185.09±13.74	1552.18	1929.73	23.73	21.28	80.43	72.78	39.32
20.	Yield per hectare	12.29-29.83	20.56±1.52	19.15	23.80	23.72	21.28	80.48	8.08	39.33
21.	Number of root nodules per plant	11.40-22.60	16.16±0.84	9.79	8.35	19.38	17.87	85.36	5.50	34.02
22.	Dry matter content of pods	15.95-26.25	19.40±1.13	6.83	9.38	15.48	13.47	72.85	4.59	23.68
23.	Dry matter content of Leaves	18.85-32.75	27.58±1.19	7.03	9.85	11.38	9.61	71.36	4.61	16.73
24.	Dry matter content of Stem	60.60-86.50	71.45±3.05	40.89	59.52	10.79	8.95	68.71	10.91	15.28
25.	Dry matter content of roots	7.15-11.75	9.54±0.42	1.31	1.61	13.57	12.03	78.68	2.09	21.99
D.	**Quality parameters**									
26.	Protein content	0.94-2.42	1.62±0.03	0.1385	0.1365	22.88	22.72	98.56	0.75	46.46

Moderate (11-20%) GCV and PCV were observed for plant height (25 and 50 days), no of primary branches (50 days), pod width, pod flesh thickness, number of clusters per plant, number of pods per cluster, number of pods per plant, weight of ten pods, number of root nodules per plant, dry matter content in pods and roots. It implied equal importance of additive and non additive gene action and substantial amount of variability for these traits. These results are in accordance with Kumar et al. (2014), Prakash and Ram (2014), Prashanth and Sreelatha (2014), Singh et al. (2014). Verma et al. (2014) and Jayprakash et al. (2015) in French bean.

High heritability (>60%) along with high genetic advance as per cent over mean (>20%) was recorded for the plant height (25 and 50 DAS), pod width, number of pods per plant, weight of ten pods, yield per

Table 3. Cluster composition based on D^2 statistics in French bean.

Cluster number	Number of genotypes	Name of the genotypes
I	24	IIHR-9, IIHR-23, IIHR-6, IIHR-7, IIHR-40, IIHR-44, IIHR-34, IIHR-245, IIHR-237, IIHR-119, Arka Anup, IIHR-32, IIHR-234, IIHR-16, IIHR-76, IIHR-67, IIHR-29, IIHR-36, IIHR-35, Bagalkot local, IIHR-13, IIHR-47, IIHR-87 and Arka Suvidha
II	9	IIHR-48, IIHR-62, IIHR-232, Arka Arjun, IIHR-53, Arka Sharath, IIHR-21, IIHR-27 and Arka komal
III	I	IIHR-37
IV	I	IIHR-67
V	I	IIHR-244

Table 4. Average intra and inter cluster D^2 values for 5 clusters for 21 characters formed by 36 genotypes of French bean.

Clusters	I	II	III	IV	V
I	69.06	146.06	116.20	127.39	241.08
II		48.21	223.39	171.48	395.94
III			0.00	133.13	102.98
IV				0.00	158.28
V					0.00

plant, yield per hectare, number of root nodules per plant, dry matter content of pods and roots and protein content. These results suggested the presence of additive gene effects. Thue, there is an ample scope for improving these characters with direct selection. Rai et al. (2010), Kunar et al. (2014), Prakash and Ram (2014) and Jayprakash et al. (2015) in French bean. Islam et al. (2011) and Chaitanya et al. (2014) in dolichos bean also indicated the same findings in their research.

By following Tocher's method, 36 genotypes were grouped in to five clusters by treating estimated D^2 values as the square of the generalized distance. The distribution of entries into various cluster is given in (Table 3). Among the five clusterts, cluster I contained 24 genotypes followed by cluster II (9) and remaining three had solitary genotype. Genotypes usually didn't cluster according to their geographical distributions. The findings of Mishra et al. (2010), Syed mudasir et al. (2012) and Gangadhara et al. (2014) in French bean, Patel et al. (2011) and Salim et al. (2013)

Table 5. Mean values of 21 characters for 5 clusters formed by 36 genotypes in French bean.

Sl. No.	Character	Clusters I	II	III	IV	V
1.	Plant height at 25 DAS (cm)	28.91	35.03	19.25	27.00	18.75
2.	Plant height at 50 DAS (cm)	43.28	51.33	37.75	41.25	35.80
3.	Number of primary branches at 50 DAS	5.94	6.65	5.00	7.05	4.85
4.	Plant spread (N-S) at 50 DAS (cm)	44.52	51.46	41.50	40.25	40.75
5.	Plant spread (E-W) at 50 DAS (cm)	37.61	43.83	34.80	34.00	33.50
6.	Plant spread (N-S) at 25 DAS (cm)	35.74	42.93	32.45	33.50	29.00
7.	Plant spread (E-W) at 25 DAS (cm)	32.21	39.17	30.00	30.50	29.00
8.	Days to first flowering	34.15	30.28	35.50	31.00	31.00
9.	Days to 50% flowering	41.50	36.48	41.50	43.50	45.50
10.	Days to first pod maturity	52.91	48.52	48.50	49.75	54.00
11.	Pod length (cm)	13.37	14.46	11.85	11.00	8.25
12.	Pod width (cm)	0.81	0.80	0.88	0.91	1.28
13.	Pod flesh thickness (cm)	0.62	0.65	0.55	0.54	0.43
14.	Number of seeds per pod	5.94	6.44	6.30	5.50	4.40
15.	Number of clusters per plant	13.64	14.27	10.50	12.75	11.63
16.	Number of pods per cluster	2.52	2.80	3.13	2.00	3.10
17.	Number of pods per plant	34.42	40.83	32.75	25.65	35.98
18.	Weight of ten pods (g)	50.33	58.98	51.91	49.54	30.65
19.	Dry matter content of pods (g)	18.30	23.10	16.75	18.25	16.65
20.	Pod yield per plant (g/plant)	172.38	235.94	169.99	125.64	110.66
21.	Number of root nodules per plant	14.86	19.46	13.55	21.40	15.35

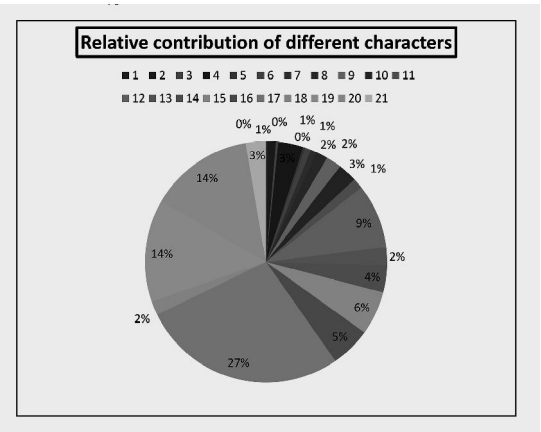

Fig. 1. Relative contribution of different characters to the total divergence in French bean genotypes. 1. Plant height at 25 DAS (cm), 2. Plant height at 50 DAS (cm), 3. Number of primary branches at 50 DAS, 4. Plant spread (N-S) at 50 DAS, 5. Plant spread (E-W) at 50 DAS, 6. Plant spread (N-S) at 25 DAS, 7. Plant spread (E-W) at 25 DAS, 8. Days to first flowering, 9. Days to 50% flowering, 10. Days to first pod maturity, 11. Pod length, 12. Pod width, 13. Pod flesh thickness, 14. Number of seeds per pod, 15. Number of clusters per plant, 16. Number of pods per cluster, 17. Number of pods per plant, 18. Weight of ten pods, 19. Dry matter content of pods, 20. Pod yield per plant (g/plant), 21. Number of root nodules per plant.

in dolichos bean, Panigrahi et al. (2014). In black gram and Kutty et al. (2003) in cowpea were similar.

In general, intercluster distances were higher than the intra cluster D^2 values (Table 4). Maximum intercluster distance was observed between cluster II and cluster V (D^2 395.94) This indicates that genotypes can be further used as parents in hybridization program to obtain superior segregants. The minimum intercluster distance was noticed between cluster III and cluster V. Cluster I showed higher intracluster distance (D^2 69.06). This indicated the existence of wider genetic divergence among the constituent genotypes.

A wide range of variation was observed in cluster means for all the characters studied (Table 5).The maximum mean values for plant height, plant spread, pod length, pod flesh thickness, number of seeds per pod, number of clusters per plant, number of pods per cluster, number of pods per plant, weight of ten pods, dry matter content of pods and pod yield per plant was observed in cluster II followed by cluster I. Therefore, it would be logical to attempt crossing among the genotypes belonging to these cluster for further improvement.

The selection and choice of parents mainly depends upon contribution of characters towards divergence (Fig. 1). i.e., number of pods (27.46%) contributed maximum to the genetic diversity followed by total yield per plant (13.97%), dry matter content of pods (13.65%), pod width (8.57%), number of clusters per plant (5.87%), number of pods per cluster (5.45%), number of seeds per pod (3.65%), plant spread (N-S) at 50 DAS (3.33%), number of root nodules (2.70%), days to first pod maturity (2.54%), pod flesh thickness (2.38%), days to 50% flowering (2.06%), weight of ten pods (1.90%), days to first flowering (1.59%) and pod length (1.43%). The findings of Syed Mudasir et al. (2012) and in French bean, Chaitanya et al. (2013) and Salim et al. (2013) in dolichos bean, Panigrahi et al.(2014) in black gram are in accordance with results.

Conclusion

From this genetic variability study can be concluded that the characters like plant height (25 and 50 DAS), pod width, number of pods per plant, weight of ten pods, yield per plant, yield per hectare, number of root nodules per plant, dry matter content of pods and roots and protein content showed high heritability (<60%) along with high genetic advance as per cent over mean (>20%) could be effectively used in selection indices and also to take up further crop improvement programs for the development of French bean for better yield and quality characters. Where as in diversity studies the genotypes having cluster with maximum inter cluster distance are genetically more divergent and these genotypes could be used in hybridization program to obtain promising segregants.

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