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Genetic Characterization for Quantitative and Qualitative Traits and its Relationship in French Bean (*Phaseolus vulgaris* L.)

D. R. Jhanavi*, H. B. Patil, R. W. Anuradha and Shasikala Ruli

Department of Vegetable Science, College of Horticulture, Bidar -585403, India

**Corresponding author*

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A B S T R A C T

An experiment comprising of thirty six diverse French bean genotypes were evaluated for genetic variability, correlation and path analysis for pod yield and its contributing traits. The analysis of variance was significant (p=0.01) for all characters indicated higher magnitude of variability. High heritability coupled with high genetic advance was recorded for the pod width, number of pods/plant, weight of ten pods, yield /plant and protein content. Total yield per plant was found to be positively and significantly associated with plant height, 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. Positive association at genotypic level among the traits viz., number of clusters per plant, number of pods per cluster, weight of ten pods and pod length had exhibited true association with direct effect on yield per plant. The inter cluster D2 value was maximum (395.94) between cluster II and Cluster V indicating that these genotypes could be used in hybridization programme to obtain transgressive segregants.

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. According to Vavilov (1931) the primary centre of origin of french bean is Southern Mexico and Central America. It is originated from wild species *Phaseolus aborigineus* L. Beans are essentially 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 diabetics (Prajapati, 2003).

The nutritive value of the crop per100 g of green pod is 1.7 g protein, 0.1 g fat, 4.5g 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 programme primarily dependent

on the nature and magnitude of genetic variability existing in the breeding material, with which breeder is working. 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 to predict the efficiency of selection. Yield is a complex character controlled by large number of contributing characters and their interactions.

A study of correlation between different quantitative characters provides an idea of association that could be effectively exploited to formulate selection strategies for improving yield and quality of a crop. In order to have clear picture of yield components for effective selection programme, it would be desirable to consider the relative magnitude of association of various characters with yield.

The technique of path coefficient analysis facilitates in partitioning the correlation coefficients into direct and indirect contribution of various characters on yield. It is a standardised by partial regression coefficient analysis

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 programme. 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 programme.

Materials and Methods

The material consists of thirty six 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*, 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 hectare and recommended dose of fertilizers (63:100:75 NPK/ ha) were incorporated. In each replication, five plants were selected randomly for recording observation. The characters *viz.,* plant height, number of primary branches per plant, plant spread, days to first flowering, days to 50 per cent 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 and pod yield 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 correlation co-efficient among all important character combinations at phenotypic (rp) and genotypic (rg) level were estimated by employing formula given by Al-Jibouri *et al.,* (1958).

Path co-efficient analysis suggested by Wright (1921) and Dewey and Lu (1957) was carried out to know the direct and indirect effect of the morphological traits on plant yield. 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 (1977).

Results and Discussion

The analysis of variance (Tables 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 per cent 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, weight of ten pods, pod yield per plant, pod yield per ha 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.,* (2014b); and Jayprakash *et al.,* (2015) in french bean, Chaitanya *et al.,* (2014) and Prashanth and Sreelatha (2014) in dolicos bean are in same line.

High heritability (>60%) along with high genetic advance as per cent over mean (>20%) was recorded for the plant height, pod width, number of pods per plant, weight of ten pods, yield per plant, yield per hectare and protein content. These results suggested the presence of additive gene effects.

Thus, there is an ample scope for improving these characters with direct selection. Rai *et al.,* (2010); Kumar *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 dolicos bean also indicated the same findings in their research.

Total yield per plant was found to be positively and significantly (p=0.01) associated with plant height at 25 and 50 DAS, number of primary branches at 50 DAS, plant spread (N- S) at 50 DAS, plant spread (E-W) at 50 DAS, plant spread (N- S) at 25 DAS, plant spread (E-W) at 25 DAS, 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 pod and number of root nodules per plant.

Table.1 Analysis of variance (mean sum of squares) for growth, earliness and yield parameters in French bean genotypes

Sl. no	Source of variation/ Character	Replication	Genotype (treatment)	Error	CD @ 5%	CD @1%
	Degrees of freedom	1	35	35		
Growth Parameters						
1.	Plant height at 50 DAS (cm)	105.12	77.57**	11.92	7.01	9.40
2.	Number of primary branches at 50 DAS	0.21	1.03**	0.199	0.90	1.21
3.	Plant spread (N-S) at 50 DAS	62.94	40.69**	4.95	5.13	6.88
4.	Plant spread (E-W) at 50 DAS	1.30	33.70**	4.76	4.43	5.94
Earliness Parameters						
5.	Days to first flowering	17.01	14.26**	2.87	3.43	4.61
6.	Days to 50 percent flowering	22.89	26.47**	3.61	3.86	5.18
7.	Days to first pod picking	24.15	30.56**	5.02	4.54	6.10
Yield Parameters						
8.	Pod length (cm)	9.46	4.21**	0.94	1.97	2.64
9.	Pod width (cm)	0.001	0.019**	0.001	0.08	0.12
10.	Pod flesh thickness (cm)	0.005	0.010**	0.001	0.08	0.11
11.	Number of clusters per plant	12.33	5.49**	0.94	1.97	2.64
12.	Number of seeds/ pod	0.22	0.70**	0.10	0.64	0.86
13.	Number of pods per cluster	0.055	0.19**	0.04	0.41	0.56
14.	Number of pods per plant	169.17	67.12**	13.09	7.34	9.86
15.	Weight of ten pods (g)	90.74	103.92**	21.83	9.47	12.73
16.	Yield per plant (g/plant)	8867.922	3481.91**	377.55	39.38	52.93
17.	Yield per hectare (t/ha)	109.69	42.96**	4.64	4.37	5.87
18.	Number of root nodules per plant	17.11	18.14**	1.43	2.43	3.26
19.	Dry matter content of pod (g)	6.67	16.21**	2.546	3.23	4.34
Quality Parameters						
20.	Protein content (g/100g)	0.040	0.275**	0.001	5.47	4.07

Table.2 Estimates of range, mean, components of variance, heritability and genetic advance for growth, earliness and yield parameters in French bean

Sl. no	Character	Range	Mean ±S.Em	PV	GV	PCV (%)	GCV (%)	h^2 (%)	GA	GAM (%)
A.	**Growth parameters**									
1.	Plant 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
2.	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
3.	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
4.	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**									
5.	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
6.	Days to 50 percent flowering	34.50-48.50	40.41±1.34	15.04	11.43	9.59	8.36	75.96	6.07	15.02
7.	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**									
8.	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
9.	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
10.	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
11.	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
12.	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
13.	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
14.	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
15.	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
16.	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
17.	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
18.	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
19.	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
D.	**Quality parameters**									
20.	Protein content	0.94-2.42	1.62±0.03	0.1385	0.1365	22.88	22.72	98.56	0.75	46.46

GV = Genotypic variance; PV = Phenotypic 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

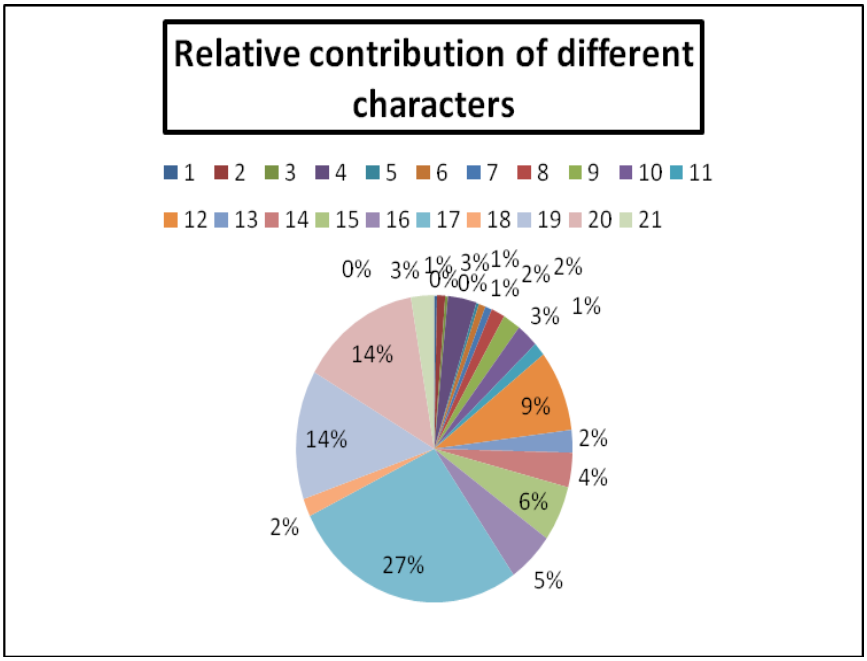
Table.3 Cluster composition based on D^2 statistics in french bean**.**

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	**1**	IIHR-37
IV	**1**	IIHR- 67
V	**1**	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

Figure.1 Relative contribution of different characters to the total divergence in french bean Genotypes



Number of pods (27.46%) , 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 per cent flowering (2.06%), weight of ten pods (1.90%), days to first flowering (1.59%) and pod length (1.43%).

Table.5 Genotypic correlation coefficient among growth, earliness and yield parameters in french bean genotypes 4

6	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	1.000	0.957**	0.645**	0.553**	0.613**	0.622**	0.685**	-0.492**	-0.692**	-0.575**	0.794**	-0.485**	0.661**	0.621**	0.374**	-0.177	0.198	0.793**	0.576**	0.496**	0.585**
2		1.000	0.447**	0.342**	0.486**	0.582**	0.552**	-0.422**	-0.684**	-0.530**	0.682**	-0.304**	0.448**	0.537**	0.421**	-0.030	0.314**	0.573**	0.673**	0.471**	0.552**
3			1.000	0.661**	0.641**	0.584**	0.642**	-0.341**	-0.184	-0.342**	0.298*	-0.151	0.519**	0.462**	0.389**	-0.100	0.236*	0.622**	0.465**	0.707**	0.525**
4				1.000	0.895**	0.822**	0.830**	-0.370**	-0.465**	-0.428**	0.328**	-0.266*	0.470**	0.429**	0.371**	0.448**	0.596**	0.465**	0.617**	0.543**	0.707**
5					1.000	0.917**	0.904**	-0.431**	-0.490**	-0.304**	0.376**	-0.176	0.551**	0.386**	0.639**	0.441**	0.793**	0.493**	0.802**	0.665**	0.857**
6						1.000	0.997**	-0.477**	-0.483**	-0.310**	0.470**	-0.212	0.571**	0.568**	0.542**	0.329**	0.631**	0.625**	0.694**	0.774**	0.815**
7							1.000	-0.396**	-0.503**	-0.374**	0.469**	-0.244*	0.532**	0.499**	0.413**	0.433**	0.603**	0.631**	0.679**	0.757**	0.807**
8								1.000	0.479**	0.476**	-0.022	0.023	-0.407**	-0.292*	-0.272*	-0.230	-0.373**	-0.377**	-0.677**	-0.416**	-0.499**
9									1.000	0.452**	-0.507**	0.390**	-0.277*	-0.438**	-0.243*	-0.231*	-0.375**	-0.510**	-0.743*	-0.324**	-0.573**
10										1.000	-0.020	0.109	-0.096	-0.268*	-0.291*	-0.315**	-0.426**	-0.363**	-0.447**	-0.478**	-0.517**
11											1.000	-0.539**	0.612**	0.536**	0.247*	-0.196	0.107	0.796**	0.614**	0.110	0.499**
12												1.000	-0.436**	-0.477**	-0.210	0.140	-0.092	-0.549**	-0.189	0.108	-0.354**

13												1.000	0.641**	0.253*	-0.079	0.149	0.885**	0.315**	0.293*	0.594**
14													1.000	0.227	0.085	0.240*	0.790**	0.493**	0.317**	0.614**
15														1.000	0.031	0.760**	0.153	0.366**	0.410**	0.648**
16															1.000	0.667**	0.038	0.269*	0.234*	0.481**
17																1.000	0.164	0.484**	0.465**	0.809**
18																	1.000	0.611**	0.433**	0.717**
19																		1.000	0.639**	0.700**
20																			1.000	0.601**
21																				1.000

Critical r_g value at 1 percent - 0.301 critical r_g value at 5 percent – 0.231 **- indicates significant at P=0.01 *- indicates significant at P= 0.05

1.	Plant height at 25 DAS	8. Days to first flowering	15. No. of clusters per plant
2.	Plant height at 50 DAS	9. Days to 50 per cent flowering	16. No. of pods per cluster
3.	No. of primary branches at 50 DAS	10. Days to first pod picking	17. No. of pods per plant
4.	Plant spread (N-S) at 50 DAS	11. Pod length	18. Weight of ten pods
5.	Plant spread (E-W) at 50 DAS	12. Pod width	19. Dry matter content of pods
6.	Plant spread (N-S) at 25 DAS	13. Pod flesh thickness	20. No. of root nodules per plant
7.	Plant spread (E-W) at 25 DAS	14. No. of seeds per pod	21. Pod yield per plant

Table.6 Genotypic path coefficient analysis among growth, earliness and yield parameters in french bean genotypes

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	rG
1	0.144	0.138	0.093	0.079	0.088	0.089	0.098	-0.071	-0.099	-0.083	0.114	-0.070	0.095	0.089	0.054	-0.025	0.028	0.114	0.083	0.071	0.585**
2	-0.337	-0.352	-0.157	-0.120	-0.171	-0.205	-0.194	0.149	0.241	0.187	-0.240	0.107	-0.158	-0.189	-0.148	0.010	-0.111	-0.202	-0.237	-0.166	0.552**
3	0.019	0.013	0.030	0.020	0.019	0.018	0.019	-0.010	-0.005	-0.010	0.009	-0.004	0.016	0.014	0.012	-0.003	0.007	0.019	0.014	0.021	0.525**
4	-0.088	-0.055	-0.106	-0.160	-0.143	-0.131	-0.133	0.059	0.074	0.068	-0.052	0.042	-0.075	-0.068	-0.059	-0.071	-0.095	-0.074	-0.099	-0.087	0.707**
5	0.007	0.005	0.007	0.010	0.011	0.011	0.010	-0.005	-0.005	-0.003	0.004	-0.002	0.006	0.004	0.007	0.005	0.009	0.005	0.009	0.008	0.857**
6	-0.063	-0.059	-0.059	-0.083	-0.093	-0.102	-0.101	0.048	0.049	0.031	-0.048	0.0216	-0.058	-0.058	-0.055	-0.033	-0.064	-0.063	0.070	-0.079	0.815**
7	0.151	0.121	0.141	0.183	0.199	0.219	0.220	-0.087	-0.110	-0.082	0.103	-0.053	0.117	0.110	0.091	0.095	0.133	0.139	0.149	0.166	0.807**
8	0.002	0.002	0.001	0.001	0.002	0.002	0.002	-0.005	-0.002	-0.002	0.0001	-0.0001	0.002	0.001	0.001	0.001	0.001	0.001	0.003	0.002	-0.499**
9	0.089	0.088	0.023	0.060	0.063	0.062	0.064	-0.061	-0.128	-0.058	0.065	-0.050	0.035	0.056	0.031	0.029	0.048	0.065	0.095	0.041	-0.573**
10	0.056	0.052	0.033	0.042	0.029	0.030	0.036	-0.046	-0.044	-0.098	0.002	-0.010	0.009	0.026	0.028	0.031	0.041	0.035	0.0440	0.047	-0.517**
11	0.096	0.082	0.036	0.039	0.045	0.056	0.056	-0.002	-0.061	-0.002	0.121	-0.065	0.074	0.064	0.029	-0.023	0.013	0.096	0.074	0.013	0.499**
12	-0.027	-0.017	-0.008	-0.015	-0.009	-0.011	-0.013	0.001	0.022	0.006	-0.030	0.056	-0.024	-0.026	-0.01	0.007	-0.005	-0.030	-0.010	0.006	-0.354**
13	0.047	0.032	0.037	0.033	0.039	0.040	0.038	-0.029	-0.019	-0.006	0.043	-0.031	0.071	0.045	0.018	-0.005	0.010	0.063	0.022	0.021	0.594**
14	0.051	0.044	0.038	0.035	0.031	0.047	0.041	-0.024	-0.036	-0.022	0.044	-0.039	0.053	0.082	0.018	0.007	0.019	0.065	0.040	0.026	0.614**
15	0.252	0.283	0.262	0.250	0.430	0.364	0.278	-0.183	-0.164	-0.195	0.166	-0.141	0.170	0.153	0.673	0.020	0.511	0.103	0.246	0.276	0.648**
16	-0.092	-0.016	-0.052	0.234	0.231	0.172	0.226	-0.120	-0.120	-0.164	-0.102	0.073	-0.041	0.044	0.016	0.523	0.349	0.020	0.141	0.122	0.481**

17	-0.035	-0.056	-0.042	-0.106	-0.142	-0.113	-0.108	0.066	0.067	0.076	-0.019	0.016	-0.026	-0.043	-0.136	-0.119	-0.179	-0.029	-0.086	-0.083	0.809**
18	0.274	0.197	0.215	0.160	0.170	0.216	0.218	-0.130	-0.176	-0.125	0.275	-0.189	0.305	0.273	0.053	0.013	0.056	0.345	0.211	0.149	0.717**
19	0.040	0.047	0.032	0.043	0.056	0.048	0.047	-0.047	-0.052	-0.031	0.043	-0.013	0.022	0.034	0.025	0.018	0.034	0.042 9	0.070	0.044	0.700**
20	-0.001	-0.0009	-0.001	-0.001	-0.001	-0.001	-0.001	0.008	0.0006	0.0009	-0.000	-0.0002	-0.000	-0.000	-0.0008	-0.0005	-0.0009	-0.000	-0.001	-0.001	0.601**

Residual effect (R) = 0.04 Bold and diagonal values indicate direct effect.

1.	Plant height at 25 DAS	8. Days to first flowering	15. No. of clusters per plant
2.	Plant height at 50 DAS	9. Days to 50 per cent flowering	16. No. of pods per cluster
3.	No. of primary branches at 50 DAS	10. Days to first pod picking	17. No. of pods per plant
4.	Plant spread (N-S) at 50 DAS	11. Pod length	18. Weight of ten pods
5.	Plant spread (E-W) at 50 DAS	12. Pod width	19. Dry matter content of pods
6.	Plant spread (N-S) at 25 DAS	13. Pod flesh thickness	20. No. of root nodules per plant
7.	Plant spread (E-W) at 25 DAS	14. No. of seeds per pod	21. Pod yield per plant

Whereas days to first flowering, days to 50 per cent flowering, days to first pod maturity and pod width showed negative and significant association at both genotypic level and phenotypic level. The findings of Syed mudasir *et al.,* (2012) and Jayprakash *et al.,* (2015) in French bean, are in conformity with present findings.

Path analysis studies revealed that significant positive association at genotypic level among the traits viz., number of clusters per plant (0.673), number of pods per cluster (0.523), weight of ten pods (0.345), plant spread (E-W) at 50 DAS (0.220), plant height at 50 DAS (0.144) and pod length (0.121) had exhibited true association with direct effect on yield per plant. Number of pods per plant had low and direct negative effect on total yield per plant. It had low and indirect negative effect through weight of ten pods.

Similar results were recorded by Verma *et al.,* (2014b) and Singh *et al.,* (2014b) in french bean. The direct selection for these traits would be rewarding for improvement in the total yield per plant. 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 clusters is given in (Table 3).

Among the five clusters, cluster I contained 24 genotypes followed by cluster II (9) and remaining three had solitary genotype. 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) in dolicos 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 (D2=395.94). This indicates that genotypes can be further used as parents in hybridization programme to obtain superior segregants.

The minimum inter cluster distance was noticed between cluster III and cluster V. Cluster I showed higher intracluster distance (D2= 69.06). This indicated the existence of wider genetic divergence among the constituent genotypes. The selection and choice of parents mainly depends upon contribution of characters towards divergence (Figure 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 per cent 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 dolicos bean, Panigrahi *et al.,* (2014) in black gram are in accordance with results.

From this Genetic variability study can be concluded that the characters like plant height, pod width, number of pods per plant, weight of ten pods, yield per plant, yield per hectare 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 programmes for the development of french bean for better yield and quality characters.

Plant spread, number of clusters per plant, number of pods per cluster per plant and weight of ten pods had high direct and indirect effects on total yield per plant at genotypic level. Diversity studies the genotypes having clusters with maximum inter cluster distance are genetically more divergent and these genotypes could be used in hybridization programme to obtain promising segregants.

The high yielding genotypes IIHR-62, Arka Arjun, IIHR-53, IIHR-232 and Arka Anoop are high yielders having desirable quality characters. Hence there need to be assessed further for their performance in different environments.

Author Contribution

D. R. Jhanavi: Investigation, formal analysis, writing—original draft. H. B. Patil: Validation, methodology, writing—reviewing. R. W. Anuradha:—Formal analysis, writing—review and editing. Shasikala Ruli: Investigation, writing—reviewing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval: Not applicable.

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