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Genetic Variability and Genotypic × Environment Interaction for Seed Yield and Related Traits in French Bean Germplasm

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Thirty-three accessions of bush type French bean were evaluated in Randomized Complete Block Design with three replications for two seasons during summer 2008 and 2009 at Vegetable Farm, H.P. Agricultural University, Palampur to explore the genetic variability and G × E interaction for yield and yield related traits. High genotypic and phenotypic coefficients of variations were observed for seed yield/plant followed by moderate for majority of the traits. A positive correlation was observed for seed yield/plant with fresh pod yield/plant, pods/plant, 100-seed weight, average pod weight, plant height, pod length, biological yield/plant and branches/plant. On the basis of correlation and path coefficient analysis, selection on the basis of pods/plant, fresh pod yield/plant, 100-seed weight, plant height and branches/plant would be a paying proposition for evolving high yielding genotypes. A significant association between seed yield/plant and fresh pod yield is of significance to explore the possibilities to develop dual purpose French bean variety(ies) both for vegetable and dry bean.

Key Words: Attributes, Correlation, Genetic variation, Path analysis, *Phaseolus vulgaris* L., Yield

Introduction

French bean (*Phaseolus vulgaris* L.), being legume crop, is an important source of protein, calcium, iron and vitamins in human diet. It finds very coveted position in the hill states of India for its off-season cultivation and quality pods which in turn results in high remuneration to the vegetable growers. The age old variety 'Contender' is still cultivated by the farmers due to lack of suitable cultivars with desirable horticultural traits. The variety is prone to plethora of diseases and has curved pods which have the tendency to break in transit and thereby, results in heavy losses. So, genetic restructuring of French bean germplasm is required to develop high yielding varieties with desirable traits. The improvement potential of any crop is proportional to the magnitude of genetic variability in the germplasm (Singh *et al.* 2009) and a wide range of variability for various traits is available in *Phaseolus* spp. This provides the possibility to improve the yield and quality through strategic breeding programme. Selection of one trait invariably affects number of associated traits, which evokes the need to find out the interrelationship of various yield components among themselves and with yield. The knowledge of the interrelationship between different traits is important in breeding for direct and indirect selection of traits that are not easily measured and have low heritability. The consistent association of yield characters over environment is of immense importance to explore the breeding efficiency (Adunga and Labuschangne 2003). Therefore, it is necessary to examine the magnitude of correlation between characters for achieving the higher yield. However, the correlation studies do not provide the exact picture of relative importance of direct and indirect effects of each of the component character. Moreover, when more and more variables are included, the indirect association becomes more complex. Under such situations, path coefficient analysis helps in partitioning the correlation into direct and indirect effects. Keeping this in view, a study was undertaken to analyse the relationship between yield components, association amongst the desired traits and their direct and indirect contribution toward the seed yield in 33 potential genotypes of bush type french bean. The information shall enable the breeders to make informed decisions about suitable parents while planning french bean breeding programme for high yield along with desirable horticulture traits.

Materials and Methods

The experiment was undertaken at the experimental farm of the Department of Vegetable Science and Floriculture,

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CSK HPKV, Palampur (1290.8 m amsl, with latitude 32^0 6' N, longitude 76^0 3' E). The 33 genotypes (Table 1) were laid in Randomized Complete Block Design for two seasons during March-June 2008 and 2009. The sowings were done at spacing of 0.45m between rows and 0.15m between plants within rows in two rows of 2.7m length. Data were recorded on ten competitive plants taken at random in each entry for twelve yield and other related traits *viz*., days to 50% flowering, average pod weight (g), branches/plant, pods/plant, fresh pod yield/plant (g), days to seed maturity, pod length (cm), seeds/pod, biological yield/plant (g), plant height (cm), 100-seed weight (g) and seed yield/plant (g).

The crop was well managed for optimum growth and yield. The seeds were sown at a depth of 4-5 cm. The fertilizers were applied at the time of sowing @ 50 kg N: 90 kg P_2O_5 and 60 kg K_2O/ha. Weeds were controlled with Pendimethalin @ 1 kg a.i./ha as pre-emergence application at the initial stages of growth followed by two manual weedings at 40 and 60 days after sowing. The irrigation was applied at 15 days interval depending upon the requirement.

Analysis of variance was performed for individual season and error variance was tested for homogeneity (Gomez and Gomez 1983). The combined analysis of variance of two season's data was done for each trait for 33 French bean accessions. The genotypic, phenotypic and environmental coefficients of variations were estimated following the method of Burton and De Vane (1953). Heritability and expected genetic advance (GA) were calculated as per Burton and De Vane (1953) and Johnson *et al.* (1955), respectively. Coefficients of correlation were calculated as suggested by Al-Jibouri *et al.* (1958) and path coefficients of different traits with seed yield /plant were carried out as per the method of Dewey and Lu (1959).

Results and Discussion

Seasons were significantly different for majority of the traits except number of branches/plant, pods/plant, pod length and seeds/pod. This indicates that these traits were more stable than the other across the seasons (Table 2). This uniformity is very useful for selection of parents for high pod yield. The French bean genotypes were significantly different for almost all the characters and there were significant genotypic and environmental interactions for these yield and related traits except for branches/plant, pod length and seeds/pod. The results showed genetic variability for these characters and also indicated the need for multi-location trials to identify the superior genotypes. The contribution of G×E interaction was lower than the contribution of genotypic differences in all the traits. A wide range in means (Table 3) of the

Table 1. List of genotypes used in the experiment and their source

S. No.	Genotypes	Source	S. No.	Genotypes	Source
1	Arka Suvidha	IIHR, Hasarghata	18	KPV-2	CSKHPKV, Palampur
2	Arka Anoop	IIHR, Hasarghata	19	MFB-1	NEH, ICAR, Barapani
3	DPDFB-1	CSKHPKV, Palampur	20	MFB-2	NEH, ICAR, Barapani
4	DPDFB-1(M)	CSKHPKV, Palampur	21	MFB-3	NEH, ICAR, Barapani
5	DPDFB-2(M)	CSKHPKV, Palampur	22	MFB-4	NEH, ICAR, Barapani
6	DWDFB-I	UAS, Dharwad	23	MFB-5	NEH, ICAR, Barapani
7	DWDFB-53	UAS, Dharwad	24	VLB-8	VPKAS, Almora
8	DWDFB-57	UAS, Dharwad	25	VLB-9	VPKAS, Almora
9	HAFB-1	HARP, Ranchi	26	VLB-2003	VPKAS, Almora
10	HAFB-2	HARP, Ranchi	27	VLFB-130	VPKAS, Almora
11	HAFB-3	HARP, Ranchi	28	Aparna	Prabhakar Hybrid Seed Company, Hyderabad
12	HAFB-4	HARP, Ranchi	29	Chandini	Sutton and Sons (India) Pvt. Ltd.
13	IVRFB-1	IIVR, Varanasi	30	Falguni	Seminis Vegetable Seeds (India) Ltd.
14	IVFB-1	IIVR, Varanasi	31	Surya	Solar Seeds
15	IVFB-2	IIVR, Varanasi	32	Arka Komal	IIHR, Hasarghata
16	IVFB-3	IIVR, Varanasi	33	Contender	CSKHPKV, Palampur
17	JFB-97-1	GAU, Junagadh			

Table 2. Pooled analysis of variance over two years for different characters in French bean

Traits	Mean Squares				
	Source	Genotypes	Environment	Genotype × Environment Interactions	Pooled error
	df	32	1	32	128
Days to 50 % flowering		16.65*	8.91*	6.91*	1.81*
Days to first marketable picking		15.83*	2.44*	6.47*	2.85*
Average pod weight (g)		3.28*	213.72*	1.62*	0.38
Branches/plant		0.99	0.21	0.99	0.15
Pods /plant		112.21*	0.703	38.31*	3.45*
Fresh pod yield/plant (g)		3806.07*	50345.38*	1330.8*	25.45*
Days to seed maturity		15.69*	861.5*	9.33*	1.03
Pod length (cm)		16.89*	0.39	1.40	0.72
Seeds / pod		1.30	0.633	0.23	0.14
Biological yield/plant (g)		362.23*	5083.97*	203.55*	5.049*
Plant height (cm)		40.12*	145.19*	16.30*	4.94*
100-seed weight(g)		389.31*	57.89*	35.26*	7.04*
Seed yield/plant (g)		399.87*	477.71*	126.65*	17.47*

*Significant at P≤0.05

Table 3. Estimates of coefficient of variations and other genetic parameters for different seed traits in French bean pooled over two years

Traits	Range	Mean	Coefficients of variation			Heritab-ility (h^2) (%)	Genetic advance	Genetic advance (%) of mean
			Phenot-ypic (PCV)	Genotypic (GCV)	Environmental (ECV)			
Days to 50 % flowering	40.00-46.67	42.42	4.88	3.71	3.17	57.74	2.46	5.81
Average pod weight (g)	4.52-8.23	5.96	15.63	11.66	10.40	55.69	1.07	17.93
Branches /plant	2.68-4.27	3.29	17.60	13.12	11.73	55.57	0.66	20.15
Pods /plant	9.13-26.7	14.96	31.05	28.46	12.41	84.01	8.04	57.72
Fresh pod yield/plant (g)	43.65-141.5	87.93	29.15	28.58	5.74	96.12	57.72	53.74
Days to seed maturity	78.50-84.5	81.44	2.29	1.92	1.24	70.40	2.70	3.32
Pod length (cm)	10.55-16.10	13.82	13.38	11.89	6.14	78.91	3.00	21.75
Seeds/ pod	4.03-6.33	5.59	10.33	7.87	6.69	58.00	0.69	12.34
Biological yield/plant (g)	14.95-50.67	29.23	27.49	26.40	7.69	92.18	15.26	52.21
Plant height (cm)	29.37-39.57	35.47	9.27	6.83	6.27	54.28	3.68	10.36
100 -seed weight (g)	14.88-48.95	33.00	25.48	24.18	8.04	90.06	15.60	47.27
Seed yield/plant (g)	12.58-38.57	22.26	40.50	35.88	18.78	78.49	14.57	65.48

traits was observed for fresh pod yield/plant, pods/plant, 100-seed weight, days to first marketable picking and days to 50% flowering. High estimates of PCV and GCV for seed yield/plant indicates that selection and breeding initiatives can be taken up immediately (Ordonez *et al.* 2005). On the other hand, fresh pod yield/plant, pods/plant, biological yield/plant, 100-seed weight, branches/plant, pod length and average pod weight had moderate estimates of PCV and GCV suggesting that these traits should be considered cautiously for direct selection. Singh *et al.* (2007) and Raffi and Nath (2004) also supported this theory for pod length. High PCV with moderate GCV was recorded for pods /plant.

High heritability estimates were observed for fresh pod yield/plant, biological yield/plant, 100-seed weight, pods/plant, pod length, seed yield/plant and days to seed maturity (Table 3). This reveals the presence of additive gene action and the characters can be fixed by resorting to selection. High heritability estimates were also recorded by Mishra *et al.* (2008) for 100-seed weight and fresh pod yield/plant, Junaif *et al.* (2010) for number of pods/plant and Salgotra and Gupta (2005) for 100-seed weight and seed yield/plant in their respective studies with different french bean germplasm under variable environments. Johnson *et al.* (1955) stressed that for estimating the actual effects of selection, heritability alone

cannot be the sole indicator for improvement since high heritability does not mean high expected genetic advance. Hence, prediction on the basis of both heritability and genetic advance simultaneously could be more useful. High heritability along with high genetic advance was recorded for seed yield/plant, fresh pod yield/plant, biological yield/plant and 100-seed weight (Table 3). This suggested the presence of additive gene action and hence, these characters are likely to respond better to selection. The manifestation of additive gene action for pods/plant and seed yield/plant was also advocated by Singh *et al*. (2007) and Walling and Chaturvedi (2014).

Correlation studies revealed that seed yield/plant was positively and significantly correlated with fresh pod yield/plant, pods/plant, 100-seed weight, average pod weight, plant height, pod length, biological yield/plant and branches/plant (Table 4). From different sets of genetic material and environmental conditions, Karasu and Oz (2010) and Bezaweletaw *et al*. (2006) also observed positive association of seed yield with some of these traits. In contrary, Shukla *et al*. (2006) observed a negative correlation between plant height and seed yield. On the other hand, seed yield/plant was negatively associated with days to seed maturity which was also observed by Sofi *et al*. (2011). This association signifies that early maturing genotypes tend to have high pod yield which is quite relevant under those conditions where seed maturity coincided with early onset of monsoons and thereby affected the total seed yield.

Table 4. Estimates of phenotypic (P) and genotypic (G) correlation coefficients for different pairs of horticultural traits in French bean pooled over two years

Traits		Average pod weight (g)	Branches/ plant	Pods/ plant	Fresh pod yield/ plant (g)	Days to seed maturity	Pod length (cm)	Seeds/ pod	Biological yield/ plant (g)	Plant height (cm)	100-seed weight (g)	Seed yield/ plant (g)
Days to 50 % flowering	P	0.086	0.238*	0.146	0.229*	0.254*	-0.045	-0.002	0.347*	0.220*	-0.325*	-0.111
	G	0.307*	0.360*	0.277*	0.370*	0.462*	-0.05	0.084	0.394*	0.409*	-0.475*	-0.068
Average pod weight (g)	P		-0.009	-0.183	0.290*	-0.006	0.326*	-0.071	0.156	0.032	0.301*	0.094
	G		-0.262*	-0.065	0.332*	-0.019	0.610*	-0.179	0.325*	0.231*	0.449*	0.474*
Branches/plant	P			0.423*	0.397*	0.276*	-0.412*	0.18	0.393*	0.268*	-0.298*	0.119
	G			0.697*	0.595*	0.446*	-0.602*	0.315*	0.558*	0.509*	-0.440*	0.203*
Pods/plant	P				0.851*	0.253*	-0.180	0.202*	0.278*	0.335*	-0.183	0.633*
	G				0.915*	0.381*	-0.335*	0.343*	0.349*	0.417*	-0.268*	0.582*
Fresh pod yield/ plant (g)	P					0.246*	-0.002	0.210*	0.389*	0.344*	-0.020	0.672*
	G					0.272*	-0.077	0.316*	0.472*	0.506*	-0.065	0.763*
Days to seed maturity	P						-0.313*	-0.130	0.203*	0.201*	-0.350*	-0.174
	G						-0.583*	0.347*	0.245*	0.422*	-0.603*	-0.248*
Pod length (cm)	P								-0.058	0.007	0.539*	0.283*
	G								-0.059	-0.008	0.660*	0.356*
Seeds/ pod	P								0.151	0.192	-0.323*	0.144
	G								0.236*	0.260*	-0.449*	0.103
Biological yield/ plant (g)	P									0.261*	-0.202*	0.127
	G									0.414*	-0.187	0.223*
Plant height (cm)	P										-0.086	0.273*
	G										-0.007	0.386*
100-seed weight (g)	P											0.474*
	G											0.527*

*Significant at P≤0.05

Pods/plant, branches/plant, fresh pod yield/plant, days to seed maturity, biological yield/plant, seeds/ pod and plant height showed a positive and significant association with each other. This reflects that the performance of these traits is inter-dependable and a due consideration must be paid towards these traits for improvement in French bean. Angadi et al. (2012) also observed positive association among these traits. A significant and positive correlation between seed yield/ plant and fresh pod yield is of significance as it indicated the possibilities of development of dual purpose French bean variety(ies) which would be suitable for both vegetable and dry bean as per suitability and preference of consumers.

The path analysis study revealed that the direct effects obtained at genotypic level were markedly different from those at phenotypic level (Table 5) which might be due to varying degree of influence of environment on various traits studied. This fact was also revealed from the results of component variance analysis and correlation at the environmental level. In few cases, like the direct effect of average pod weight, number of branches/plant, fresh pod yield/plant and biological yield/plant on seed yield/ plant were observed to be of opposite sign (positive to negative and vice-versa) at corresponding phenotypic and genotypic levels. Such a change in direction and magnitude of direct and indirect effects might be due to the environmental factors influencing various traits under study.

Pods/plant and average pod weight exhibited maximum positive direct effect at genotypic level followed by 100-seed weight, seeds/ pod, number of branches/plant and plant height on seed yield/plant. Salehi *et al.* (2010) and Roy *et al.* (2006) also observed direct contribution of these traits on seed yield. Further, it was observed that number of pods/plant had the maximum indirect contribution on the total association of number of branches/plant, fresh pod yield/plant, biological yield/ plant and plant height at both phenotypic and genotypic levels, which resulted into positive and significant association of these traits with seed yield.

The low magnitude of residual effects at phenotypic and genotypic levels indicated that the traits included in the present investigation accounted for most of the variation present in the dependent variable. In view of the direct and indirect contributions of component traits, selection on the basis of pods/plant, average pod weight, 100-seed weight, seeds/pod and branches/plant for seed yield/plant would be a paying proposition for evolving high yielding genotypes.

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Table 5. Direct and indirect effects of yield traits on seed yield in French bean in pooled over two years

Trait		Days to 50 % flowering	Average pod weight (g)	Branches/ plant	Pods/plant	Fresh pod yield/plant (g)	Days to seed maturity	Pod length (cm)	Seeds/ pod	Biological yield/plant (g)	Plant height (cm)	100-seed weight (g)
Days to 50 % flowering	P	**-0.032**	-0.003	-0.006	-0.005	-0.007	-0.008	0.001	0.000	-0.011	-0.007	0.010
	G	**-0.071**	-0.022	-0.025	-0.020	-0.026	-0.033	0.004	-0.006	-0.028	-0.029	0.034
Average pod weight (g)	P	-0.009	**-0.099**	0.009	0.018	-0.029	0.001	-0.032	0.007	-0.015	-0.003	-0.029
	G	0.201	**0.654**	-0.171	-0.043	0.217	-0.126	0.399	-0.117	0.213	0.151	0.294
Branches /plant	P	-0.005	0.002	**-0.021**	-0.009	-0.008	-0.006	0.008	-0.004	-0.008	-0.006	0.006
	G	0.075	-0.054	**0.209**	0.146	0.125	0.093	-0.126	0.066	0.117	0.107	-0.092
Pods/plant	P	0.064	-0.080	0.185	**0.438**	0.372	0.111	-0.079	0.088	0.122	0.147	-0.080
	G	0.374	-0.088	0.940	**1.348**	1.233	0.513	-0.452	0.462	0.470	0.563	-0.361
Fresh pod yield/plant (g)	P	0.076	0.096	0.132	0.283	**0.333**	0.082	-0.001	0.070	0.130	0.115	-0.007
	G	-0.279	-0.251	-0.450	-0.692	**-0.756**	-0.279	0.058	-0.239	-0.357	-0.383	0.168
Days to seed maturity	P	-0.047	0.001	-0.051	-0.047	-0.046	**-0.185**	0.058	-0.023	-0.038	-0.037	0.065
	G	-0.129	0.054	-0.124	-0.106	-0.076	**-0.012**	0.163	-0.105	-0.068	-0.118	0.049
Pod length (cm)	P	-0.003	0.018	-0.023	-0.010	0.000	-0.018	**0.056**	-0.007	-0.003	0.000	0.030
	G	-0.001	0.012	-0.012	-0.001	-0.002	0.109	**0.020**	-0.005	-0.001	0.000	0.013
Seeds / pod	P	0.000	-0.012	0.031	0.035	0.036	0.022	-0.023	**0.174**	0.026	0.033	-0.056
	G	0.024	-0.052	0.091	0.099	0.091	-0.034	-0.069	**0.289**	0.068	0.075	-0.130
Biological yield/plant (g)	P	0.001	0.003	0.006	0.004	0.006	0.003	-0.001	0.002	**0.016**	0.004	-0.003
	G	-0.054	-0.045	-0.077	-0.048	-0.065	0.048	0.008	-0.033	**-0.138**	-0.058	0.026
Plant height (cm)	P	0.016	0.002	0.020	0.025	0.025	0.015	0.001	0.014	0.019	0.073	-0.006
	G	0.046	0.026	0.058	0.047	0.057	0.322	-0.001	0.029	0.047	**0.113**	-0.007
100-seed weight(g)	P	-0.177	0.164	-0.162	-0.100	-0.010	-0.191	0.294	-0.176	-0.110	-0.047	**0.545**
	G	-0.254	0.240	-0.235	-0.143	-0.035	-0.206	0.353	-0.240	-0.100	-0.036	**0.534**
Correlation	P	-0.111	0.094	0.119	0.633*	0.672*	-0.174	0.283*	0.144	0.127	0.273*	0.474*
	G	-0.068	0.474*	0.203*	0.582*	0.763*	-0.248*	0.356*	0.103	0.223*	0.386*	0.527*

Significance at P≤0.05; Residual effect at phenotypic level=0.249 and at genotypic level=0.19; bold digits corresponds to direct effects

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