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Studies on genetic variability components and character association of french bean (*Phaseolus vulgaris* L.) for growth, yield and quality attributes under the Gangetic alluvial plains of West Bengal

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Abstract
Twelve genotypes of bush type french bean were evaluated to study the genetic variability, correlation and path analysis for twenty- three yield and yield contributing parameters. Significant differences were observed among all the genotypes. Both GCV and PCV corresponded closely for all the characters which indicate low environmental influence. Higher phenotypic and genotypic co-efficient of variability were observed for leaf fresh weight, leaf dry weight, pod weight, ascorbic acid, total chlorophyll, reducing sugar, total sugar and pod protein. Characters like primary branches/plant (no.), leaf fresh weight (g), leaf dry weight (g), flowers/Inflorescence (no.), pod set/Inflorescence (no.), pods/plant (no.), pod girth (cm), pod weight (g), ascorbic acid (mg/100g), total chlorophyll (mg/100g), reducing sugar (%), total sugar (%), pod protein (mg/100g) and green pod yield/plant (g) exhibited high heritability coupled with high genetic advance as percent over mean indicating the presence of additive gene action and thus selection based on phenotypic performance may prove useful. Pod weight and pods/plant exhibited high positive significant correlation with green pod yield/plant as well as high positive direct effect on green pod yield/plant. Hence, these traits can be directly considered for yield improvement programme in french bean.

Keywords: French bean (*Phaseolus vulgaris* L.), Genetic variability, correlation, path analysis, yield and quality attributes

Introduction
Legumes constitute to be a cheap source of nutrients as they are rich in proteins, vitamins and minerals. One such important legume is the French bean (*Phaseolus vulgaris* L.), belonging to Leguminosae (Fabaceae), native to Latin America containing 1.7 g protein, 4.5 g carbohydrates, vitamins and minerals per 100g of green pods (Gopalakrishnan, 2007) [8]. It covers an area of 0.23 million hectares with a production of 2.27 million tonnes and a productivity of 9.9 t/ha in India (Anonymous, 2017) [2]. Although its cultivation is becoming an integral part of general cropping system in terai region of West Bengal due to having higher suitability during winter (Das *et al*., 2018) [4], successful cultivation of French bean is hindered in West Bengal due to exclusive cultivation of local genotypes (low yield), non-adoption of suitable agronomic practices (Saini and Negi, 1998 and Ujjammanavar *et al*., 2006) [22, 28] and various diseases including bacterial, fungal and viral diseases. While Gujarat is the forerunner in french bean production (7.19 lakh tonnes) with 10.42 t/ha productivity, productivity in West Bengal is only 5.6 t/ha (Anonymous, 2017) [2].
Being a short duration and nutritious legume crop, it is becoming popular among the farmers in hilly regions as well as the plains of India. Therefore, evaluation of French bean genotypes possessing higher yield with good quality traits, resistant to diseases suitable for the growing environment to replace the low yielding local types is important. The improvement of such traits for breeding purposes largely depends on the amount of variability present in various characters of the genotypes. The expression of characters is influenced by genotypic, phenotypic and environmental factors.

Hence, it is important to check the extent of variability parameters like genotypic and phenotypic coefficient of variations, heritability and genetic advance to identify reliable, maximum and accurate effect of character for selection. Assessing the degree of association between the various characters and direct effect of yield contributing characters on total yield is of paramount importance, as it gives the idea to breeders about the nature and relationship between different pairs of characters (degree and cause) as one trait can have positive or negative effects on other associated traits. Dhillon *et al.* (2017) [7] had reported negative correlation between green pod yields per plant with days to 50% germination, days to 50% flowering and total sugar content at both genotypic and phenotypic level. As an important nutritious crop, identifying true relationship and reliable quality parameters contributing to yield for direct selection in crop improvement is crucial. Hence, the present comprehensive genetic study was carried out to know the extent of variability parameters for important growth, quality and yield component characters that influence the tender pod yield existing in the genotypes.

Materials and methods

The present investigation was carried out during *rabi* season of 2016 in New Alluvial Zone of West Bengal, at Horticultural Research Station, Mondouri, Bidhan Chandra Krishi Viswavidyalaya. The research station is located approximately at 23.5°N latitude, 89°E longitude having an average altitude of 9.75 m from the sea level. Topographical situation of the experimental site belongs to the Gangetic New Alluvial plains of West Bengal with sandy loam soil which is slightly acidic in nature. The average temperature ranges from 25º- 36.5ºC during summer months and between 12ºC and 25ºC during winter months.

Twelve genotypes of bush type French bean comprising of 11 varieties and 1 indigenous genotype (Table 1) employed for the study were collected from different sources and established in Randomized Block Design with three replications. Raised beds of 2.4 x 1.8 m size, 20 cm high with block to block distance of 60 cm and plot to plot distance of 30 cm were prepared. Each experimental plot accommodated 24 plants at a spacing of 60 x 30 cm. A fertilizer dose of 50 kg N (urea), 60 kg P (single super phosphate) and 50 kg K (Muriate of Potash) along with 10 tons of FYM/ha were incorporated in the soil as per schedule. Seeds, after treatment with *Rhizobium phaseoli* (100 g kg^{-1} seed) and shade dried for two hours were sown during last week of November, 2016 at a depth of 1 cm by dibbling two to three seeds per hill and covered with finely sieved soil. *Rhizobium* culture is very much essential to encourage good nodulation and better nitrogen fixation in a shy nodulator like french bean. The weak seedlings were thinned out leaving only one vigorous seedling per hill after 25 days of sowing.

Several growth parameters such as plant height (cm), primary branches/plant (no.), leaves/plant (no.), leaf width (cm), leaf length (cm), leaf fresh weight (g), leaf dry weight (g), days to first flowering (no.), days to 50% flowering (no.), flowers per inflorescence (no.), pod set/inflorescence (no.), pods/plant (no.), pod length (cm), pod girth (cm), pericarp thickness (mm), pod weight (g), ascorbic acid (mg/100g), total chlorophyll (mg/100g), reducing sugar (%), total sugar (%), total soluble solids (%), pod protein (mg/100g) and green pod yield/plant (g). Mean values of genotypes were computed for determining analysis of variance. Analysis of variance for the studied traits was analyzed as per Panse and Sukhatme (1967) [16]. The genotypic and phenotypic coefficients of variation were calculated using the formulae of Burton (1952) [3]. Furthermore, broad sense heritability was calculated as per Lush (1940) [13] and genetic advance was also estimated by the method of Johnson *et al.*, (1955) [11]. Categorization of genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV) and genetic advance (GA) were done as per Sivasubramanian and Menon (1973) [26] and heritability by Johnson *et al.*, (1955) [11]. Phenotypic and genotypic correlation coefficients were computed as per Johnson *et al.*, (1955) [11]. Path coefficient analysis (Dewey and Lu, 1859) was used to partition the genotypic correlation into components of direct and indirect effects. Scale for path coefficient analysis was given as per Lenka and Mishra (1973) [12].

Table 1: Preliminary information of 12 genotypes.

S. No	Genotypes	Sources
1.	Arka Anoop	IIHR, Bangalore
2.	Arka Komal	IIHR, Bangalore
3.	Arka Sharat	IIHR, Bangalore
4.	Arka Suvidha	IIHR, Bangalore
5.	Arjun	Debgiri Seeds
6.	Falguni	Loknath Seeds
7.	Fagun	B.K Seeds
8.	Anupama	Hindustan Seeds
9.	Saguni	Patel Seeds
10.	Pencil Beans	Durga Seeds
11.	Palguna	Puja Seeds
12.	Manipur Local	Tentha, Manipur

Results and discussion

The genotypes varied significantly for all the twenty-three characters studied which is presented in Table 2. The mean squares due to genotype were highly significant for all the characters indicating varietal differences for all the characters studied. The coefficient of variation was below 10%, for all characters (Tables 2) confirming the reliability of the experiment and indicating less genotype by environment interactions for expression of characters, which was expected for a self-pollinated crop.

Estimates of genotypic coefficient of variation (GCV) helps to measure the range of genetic variability in a character and provides a measure to compare genetic variability present in various characters. High expression of GCV and PCV was recorded for characters like leaf fresh weight (g), leaf dry weight (g), pod weight (g), ascorbic acid (mg/100g), total chlorophyll (mg/100g), reducing sugar (%), total sugar (%) and pod protein (mg/100g) indicating lesser.

Table 2: Analysis of variance for the 23 characters of french bean

Source of variation (df)	Mean sum of squares											
	PH (cm)	NB (no.)	LP (no.)	LW (cm)	LL (cm)	FLW (g)	DLW (g)	DFF (no.)	DF (no.)	FI (no.)	PSI (no.)	PP (no.)
Replication (2)	81.12	0.12	14.78	0.04	0.28	0.09	0.001	0.64	0.05	0.25	1.33	42.12
Genotype (11)**	33.54	0.95	29.97	3.34	23.22	3.70	0.13	4.59	4.29	3.22	2.09	51.13
Error (22)	8.84	0.13	9.32	0.02	0.33	0.25	0.001	0.348	0.195	0.800	0.281	5.273

CV (%)	7.834	8.895	10.58	1.487	2.611	11.58	1.207	1.413	0.964	15.20	10.54	7.115
	Mean sum of squares											
	PL (cm)	PG (cm)	PT (mm)	PW (g)	AA (mg/100g)	TC (mg/100g)	RS (%)	TS (%)	TSS (%)	PP (mg/100g)	GPYP (g)	
Replication (2)	0.034	0.206	0.014	0.644	0.024	0.021	0.004	0.118	0.064	0.011	0.469	
Genotype (11)**	1.387	0.405	0.490	7.947	7.795	5.890	0.277	7.701	0.722	1.906	2,569.457	
Error (22)	0.040	0.049	0.010	1.294	0.028	0.063	0.003	0.113	0.079	0.001	131.163	
CV (%)	1.32	9.457	6.046	16.55	3.293	3.992	3.513	4.355	4.012	1.62	5.144	

****** significant at $P<0.01$

PH (cm)= Plant height; NB (no.)= Primary branches/plant; LP (No.)= No. of leaves/plant; LW (cm)= Leaf width; LL (cm)= Leaf length; FLW (g)= Fresh leaf weight; DLW (g)= Dry leaf weight; DFF (no.)= Days to first flowering; DF (no.) = Days to 50% flowering; FI (no.)= Flowers/inflorescence; PSI (no.)= Pod set/inflorescence; PP (no.)= Pods/plant; PL (cm)= Pod length; PG (cm)= Pod girth; PT (mm)= Pericarp thickness; PW (g)= Pod weight; AA (mg/100g)= Ascorbic acid; TC (mg/100g)= Total chlorophyll; RS (%)= reducing sugar; TS (%)= Total sugar; TSS (%)= Total soluble solids; PP (mg/100g)= pod protein; GPYP (g)= Green pod yield/plant(g).

Table 3: Mean of 23 different characters of frenchbean genotypes.

Genotypes	PH (cm)	NB (no.)	NL (no.)	LW (cm)	LL (cm)	FLW (g)	DLW (g)	DFF (no.)	DF (no.)	FI (no.)	PSI (no.)	PP (no.)
Arka Anoop	35.43	3.27	25.67	10.60	26.30	6.43	1.32	40.23	44.23	4.34	4.20	28.76
Arka Komal	42.11	4.40	29.33	8.50	24.39	4.76	0.94	41.10	44.77	6.27	5.67	34.88
Arka Sharath	35.13	4.83	27.33	9.87	25.41	5.73	1.31	43.23	46.90	7.23	6.33	38.33
Arka Suvidha	36.03	3.80	28.33	9.00	22.87	4.81	1.01	40.03	44.00	7.03	4.33	25.94
Arjun	40.53	3.70	31.33	8.07	24.93	3.83	0.84	40.43	44.43	6.05	5.00	32.09
Falguni	35.30	3.53	23.67	7.13	17.63	2.57	0.61	41.93	45.93	5.71	4.86	30.45
Fagun	36.53	4.30	34.67	7.90	21.79	3.62	0.94	43.30	47.37	6.33	5.50	34.09
Manipur local	34.80	4.77	29.67	7.73	20.67	3.71	0.85	41.17	45.17	6.56	6.00	30.11
Anupama	44.34	4.33	30.00	8.63	20.80	4.16	0.98	41.20	45.50	6.82	5.87	37.02
Saguni	40.90	3.33	32.00	9.40	20.37	5.07	1.11	42.70	46.60	4.06	3.89	26.22
Pencil Bean	39.50	3.47	24.67	7.17	18.47	2.96	0.71	42.87	46.83	4.99	4.00	36.67
Palguna	34.77	4.47	29.67	8.17	20.43	4.08	0.88	43.17	46.93	5.22	4.67	33.67

Table 3: Conti….

Genotypes	PP (no.)	PL (cm)	PG (cm)	PT (mm)	PW (g)	AA (mg/100g)	TC (mg/100g)	RS (%)	TS (%)	TSS (%)	PP (mg/100g)	GPYP (g)
Arka Anoop	28.76	15.93	2.10	4.48	8.29	6.933	5.40	1.67	9.83	6.43	1.39	244.95
Arka Komal	34.88	14.96	2.27	3.64	7.74	5.8	6.87	0.92	9.42	6.77	1.03	254.64
Arka Sharath	38.33	15.60	2.20	4.50	6.81	3.9	8.17	1.30	9.50	6.73	1.48	260.67
Arka Suvidha	25.94	15.83	2.33	4.25	10.02	6.7333	7.10	1.37	7.66	6.57	1.08	235.66
Arjun	32.09	15.74	1.93	3.90	6.70	4.367	5.23	1.99	8.11	6.43	1.17	224.12
Falguni	30.45	16.07	2.17	4.04	6.25	4.433	6.97	1.28	5.73	7.43	3.68	197.83
Fagun	34.09	14.57	2.30	4.18	4.95	5.167	4.63	1.61	5.60	7.73	2.62	198.17
Manipur local	30.11	14.98	3.37	3.07	7.50	1.113	5.50	1.20	5.92	7.03	1.97	211.81
Anupama	37.02	14.73	2.63	4.36	8.62	6.4	8.10	1.89	6.84	6.57	1.06	256.23
Saguni	26.22	14.52	2.31	4.02	4.64	4.367	6.93	1.57	9.36	7.83	1.34	160.74
Pencil Bean	36.67	14.43	2.36	3.71	5.69	5.2	7.07	1.49	8.37	7.17	1.12	215.84
Palguna	33.67	14.08	2.09	4.01	5.27	6.333	3.63	1.70	6.30	7.23	1.36	213.06

influence of environment. However, the magnitude of PCV was higher than GCV for all characters (Table 4). This indicates the existence of inherent variability that remains unaltered by environmental conditions among genotypes, which is more useful for exploitation in selection and hybridization. These results corroborate the findings of Aklade *et al.* (2018) [1], Patil *et al*. (2018) [18] and Lyngdoh *et al.* (2017) [14] for pod weight.

Moderate GCV and PCV values occurred for primary branches/plant (no.), leaf width (cm), leaf length (cm), pod set/inflorescence (no.), pods/plant (no.), pod girth (cm) and green pod yield/plant (g) indicating the potential of simple selection for improvement of these characters. These results corroborate the findings of Jhanavi *et al.* (2018) [10] for primary branches/plant (no.) and pods/plant (no.) and Rai *et al.* (2006) [21] for primary branches/plant. Burton (1952) [3] stated that genetic variability, along with heritability, should be considered to assess the maximum and accurate effect of selection. The estimate of heritability is a useful guide to breeders as it gives relative proportion of variation due to genes and environments on total phenotypic variability.

Broad sense heritability values were recorded high (> 60%) for primary branches/plant (no.), leaf width (cm), leaf length (cm), leaf fresh weight (g), leaf dry weight (g), days to first flowering, days to 50% flowering, pod set/inflorescence (no.), pods/plant (no.), pod length (cm), pod girth (cm), pod weight (g), ascorbic acid (mg/100g), total chlorophyll (mg/100g), reducing sugar (%), total sugar (%), total soluble solids (%), pod protein (mg/100g) and green pod yield/plant (g). These results are in agreement with Prakash and Ram (2014) [19] and Prakash *et al.* (2015) [20] for pods/plant (no.), yield/plant and pod protein (%); Topwal and Gaur (2016) for number of pods, pod length and yield/plant; Bhaganna *et al*. (2015) for number of pods/plant and pod length. Jhanavi *et al.* (2018) [10] also reported high heritability for pods/plant (no.), pod weight (g) and yield/plant. High heritability indicates the presence of additive gene effects resulting in minimal environmental influence on characters. Plant height (cm), leaves/plant (no.) and flowers/inflorescence (no.) showed moderate heritability. Low heritability implies that the characters were under the influence of predominantly non-additive gene action and are comparatively less reliable for direct selection in crop

improvement. However, no characters under study had shown low heritability.

The genetic advance (GA) is another important parameter which serves to determine the expected response to selection (Shukla *et al*., 2004) [24]. In the present study, genetic advance (GA) expressed as percentage of mean was high for primary branches/plant (no.), leaf width (cm), leaf length (cm), leaf fresh weight (g), leaf dry weight (g), flowers/Inflorescence (no.), pod set/Inflorescence (no.), pods/plant (no.), pod girth (cm), pod weight(g), ascorbic acid (mg/100g), total chlorophyll (mg/100g), reducing sugar (%), total sugar (%), pod protein (mg/100g) and green pod yield/plant (g) (Table 4). Johnson *et al.* (1955) [11] stated that heritability in combination with genetic advance would be more reliable for predicting the effects of selection because genetic advance depends on the amount of genetic variability, magnitude of masking effect of genetic expression (environmental influence), and intensity of selection. High to moderate heritability coupled with high genetic advance registered in primary branches/plant (no.), leaf width (cm), leaf length (cm), leaf fresh weight (g), leaf dry weight (g), flowers/inflorescence (no.), pod set/inflorescence (no.), pods/plant (no.), pod girth (cm), pod weight (g), ascorbic acid (mg/100g), total chlorophyll (mg/100g), reducing sugar (%), total sugar (%), pod protein (mg/100g) and green pod yield/plant(g) offer opportunities for selection, and is attributed by additive gene action controlling the concerned characters (Panse, 1957) [17], so early generation selection would be helpful for improving these characters. Lyngdoh *et al.* (2017) [14], Panchbhaiya *et al.* (2017) [15], Devi *et al.* (2015) [5] had also recorded high heritability coupled with high genetic advance estimates in number of pods/plant, pod yield/plant, pod weight and Singh *et al.* (2013) [25] for pod length. Moderate heritability, coupled with moderate genetic advance for plant height (cm) and leaves/plant (no.) indicate that these traits were moderately influenced by environmental effects, and selection will not be as effective as in case of the characters showing high GCV coupled with high broad sense heritability and genetic advance. Furthermore, high heritability coupled with low genetic advance is recorded in days to first flowering (no.), days to 50% flowering (no.) and pod length (cm) indicating that these characters are governed by non-additive genes and heterosis breeding may be helpful.

Table 4: Estimation of different genetic parameters of growth, yield and quality characters.

Characters	Mean	Range	PCV[a] (%)	GCV[b] (%)	h^2 (%) in b.s	GA	GA as percent of Mean
Plant height(cm)	37.95	32.77- 42.11	10.88	7.56	48.23	4.11	10.82
Primary branches/plant (no.)	4.02	3.27- 4.83	15.76	13.01	68.15	0.89	22.13
Leaves/plant (no.)	28.86	24.67- 34.67	13.94	9.09	42.47	3.52	12.20
Leaf width (cm)	8.51	7.13- 10.60	12.45	12.36	98.57	2.15	25.29
Leaf length (cm)	22.00	17.63- 26.30	12.82	12.55	95.85	5.57	25.32
Leaf fresh weight (g)	4.31	2.57- 5.73	27.42	24.86	82.16	2.00	46.42
Leaf dry weight (g)	0.96	0.61- 1.32	22.06	22.03	99.70	0.43	45.32
Days to first flowering (no.)	41.78	40.03- 43.30	3.17	2.85	80.23	2.19	5.25
Days to 50% flowering (no.)	45.72	44.00- 47.37	2.73	2.56	87.47	2.25	4.92
Flowers/Inflorescence (no.)	5.88	4.06- 7.23	21.54	15.27	50.25	1.31	22.30
Pod set/Inflorescence (no.)	5.03	3.89- 6.33	18.70	15.45	68.26	1.32	26.30
Pods/plant (no.)	32.36	25.94- 38.33	14.01	12.08	74.351	6.95	21.46
Pod length (cm)	15.12	14.08- 16.07	4.62	4.43	91.88	1.32	8.75
Pod girth (cm)	2.34	1.93- 3.37	17.5	14.72	70.80	0.60	25.52
Pericarp thickness (mm)	4.01	3.07- 4.50	10.28	9.97	94.11	0.8	19.93
Pod weight(g)	6.87	4.64- 10.02	27.26	21.66	63.15	2.44	35.47
Ascorbic acid (mg/100g)	5.062	1.11- 6.93	31.955	31.785	98.937	3.30	65.13
Total chlorophyll (mg/100g)	6.3	3.63- 8.17	22.478	22.121	96.846	2.83	44.844
Reducing sugar (%)	1.498	0.92- 1.99	20.472	20.169	97.056	0.61	40.931
Total sugar (%)	7.721	5.60- 9.83	21.054	20.599	95.721	3.21	41.516
Total soluble solids (%)	6.994	6.43- 7.83	7.74	6.619	73.126	0.82	11.659
Pod protein (mg/100g)	1.607	1.03- 2.62	49.63	49.603	99.893	1.64	102.128
Green pod yield/plant(g)	222.64	160.4-260.67	13.79	12.81	86.11	54.50	24.48

[a]PCV=Phenotypic coefficient of variation; [b]GCV = Genotypic coefficient of variation; h^2 = Heritability; GA = Genetic Advance

Most correlation coefficients at the genotypic level were greater than the corresponding phenotypic ones (Table 5). The higher values of genotypic, than phenotypic, correlation indicated that the genotypic effects were more important that environmental factors (Falconer, 1988). In the presence of high environmental influence on expression of characters, there is the possibility of over estimation of the genotypic correlation coefficient. Characters like pod weight (rg = 0.754, rp = 0.659), flowers/inflorescence (rg = 0.653, rp = 0.433), leaf length (rg = 0.620, rp = 0.567), pods/plant (rg = 0.521, rp = 0.445), pod set/inflorescence (rg = 0.527, rp = 0.429), fresh leaf weight (rg = 0.426, rp = 0.366), leaf width (rg = 0.362, rp = 0.337) and dry leaf weight (rg = 0.360, rp = 0.336) exhibited significantly positive correlation with green pod yield/plant (Table- 4). The results are in conformity with the findings of Lyndoh *et al*. (2018) and Devi *et al*., (2015) [5] for number of pods per plant and pod set per inflorescence. However, green pod yield/plant was also recorded negatively and significantly correlated with total soluble solids (rg = -0.959, rp = -0.687), primary branches/plant (rg = -0.661, rp = -0.557), pod protein (rg = -0.447, rp = -0.414), days to 50% flowering (rg = -0.442, rp = -0.413) and days to first flowering (rg = -0.405, rp = -0.398). Savita *et al*. (2017) also reported highly significant, positive, correlation of green pod yield with number of marketable pods per plant, number of pods per plant, and was negatively correlated with days to 50% flowering.

The direct and indirect contribution of various characters to green pod yield/plant through path coefficient analysis indicated that seven characters *viz.*, leaf width (0.955), leaf length (0.791), pods/plant (0.473), days to 50% flowering (0.344), pod girth (0.339), pericarp thickness (0.533) and pod

weight (0.357) showed high and positive direct effect on green pod yield/plant indicating the importance of these traits in selection programme for improving yield (Table 5). These results are in conformity with the findings of Lyndoh *et al.* (2018) for number of pods/plant on pod yield; Devi *et al.* (2015) [5] for pods/plant and pod weight on pod yield and Rai *et al*. (2010) for pods/plant on pod yield. However, leaves/plant (-0.374), days to first flowering (-0.31), total sugar (-0.384) and pod protein (-0.38) have high and negative direct effect on green pod yield/plant suggesting that minimum days to first flowering, decrease in leaves/plant (no.), low total sugar and low pod protein results in higher green pod yield/plant. The low magnitude of residual effect (0.06) indicated that the traits included in the present investigation accounted for most of the variation present in the dependent variable. The higher magnitude for positive direct effects as well as positive significant correlation for pod weight and pods/plant indicates true, significant, positive, beneficial association and these traits could be used for direct selection for improvement of pod yield/plant. However, quality parameters such as pod protein (mg/100g) and total sugar (%) have high negative direct effect on green pod yield/plant.

Conclusion

There exists a significant amount of variability in frenchbean germplasms for yield and yield related components. Priority should be given for characters pods/plant, pod weight, green pod yield/plant for selecting high yielding genotypes in frenchbean. Moreover, quality parameters such as pod protein (mg/100g) and total sugar (%) should also be considered carefully by breeders for improving pod and quality characters conjointly with green pod yield/plant due to their negative direct effects on green pod yield/plant. Based on overall performances of different genotypes, for pod yield/plant as well as days to 50% flowering and pods/plant, Arka Suvidha, Arka Anoop, Arka Komal, Anupama and Arka Sharath are expected to perform better if used in frenchbean breeding programme for development of early and high yielding variety for Gangetic New Alluvial plains of West Bengal. Hence, such genotypes can be used for further improvement of yield and other yield contributing characters.

Table 5: Genotypic and phenotypic correlation and direct effects of 23 characters at phenotypic level on green pod yield/plant.

Characters		rg with green pod yield/plant[a]	rp with green pod yield/plant[b]	Phenotypic correlation with green pod yield/plant
1	Plant height(cm)	0.125	0.142	0.194
2	Primary branches/plant (no.)	-0.661**	-0.557**	-0.2
3	Leaves/plant (no.)	-0.356*	-0.168	-0.374
4	Leaf width(cm)	0.362*	0.337*	0.955
5	Leaf length(cm)	0.620**	0.567**	0.791
6	Leaf fresh weight(g)	0.426**	0.366*	0.183
7	Leaf dry weight(g)	0.360*	0.336*	-1.366
8	Days to first flowering	-0.405*	-0.398*	-0.31
9	Days to 50% flowering	-0.442**	-0.413*	0.344
10	Flowers/Inflorescence (no.)	0.653**	0.433**	0.049
11	Pod set/Inflorescence (no.)	0.527**	0.429**	-0.018
12	Pods/plant (no.)	0.521**	0.445*	0.473
13	Pod length (cm)	0.334*	0.303	-0.152
14	Pod girth (cm)	-0.042	-0.050	0.339
15	Pericarp thickness (mm)	0.3	0.277	0.533
16	Pod weight(g)	0.754**	0.659**	0.357
17	Ascorbic acid (mg/100g)	0.347*	0.318	-0.198
18	Total chlorophyll (mg/100g)	0.337*	0.317	-0.115
19	Reducing sugar (%)	-0.101	-0.103	-0.236
20	Total sugar (%)	0.329*	0.302	-0.384
21	Total soluble solids (%)	-0.959**	-0.687**	0.187
22	Pod protein (mg/100g)	-0.447**	-0.414*	-0.38

*, ** significant at P<0.05 and P<0.01, respectively; [a] rg = Genotypic correlation coefficient;
[b] rp = Phenotypic correlation coefficient. [c] Residual effect: 0.06

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