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Assessment of Genetic Variability and Diversity in Pole Type French Bean under Mid-Hill Conditions of Himachal Pradesh

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ABSTRACT

An attempt was made to determine the extent of genetic variability and divergence in 29 genotypes to identify superior lines in French bean having pole type growth habit. PCV was slightly higher in magnitude than GCV for all the traits proposing occurrence of environmental stimulus. A wide range of variability was recorded for all the traits. Wide genetic variability and high heritability coupled with moderate to high genetic gain was depicted for seed yield per plant followed by 100 seed weight, pods per plant, pod yield per plant, pod width, plant height and harvest duration. The D^2 analysis grouped the genotypes into three clusters consists maximum genotypes in cluster I. An analysis of percentage contribution of each trait towards diversity concluded that seed yield per plant, pod yield per plant, pods per plant and days to 1st picking were the chief characters contributing to genetic diversity in French bean. The maximum inter cluster distance was reported between cluster II and III (784.03) which specified wide diversity between these two clusters. Therefore, the hybridization between the genotypes of cluster II and III can be carried out for getting superior hybrids or recombinants in filial generations.

Keywords D^2 analysis, Divergence, Genetic advance, Heritability, Variability.

INTRODUCTION

French bean (*Phaseolus vulgaris* L. 2n= 2x= 22), a member of Fabaceae family, is one most popular and short duration of the principal legume vegetable crops grown throughout the world. It is derived from wild ancestors which are distributed from northern Mexico to north western Argentina. It is a nutritional vegetable that includes 1.7 g protein, 4.5 g carbohydrate, 1.8 g fiber and 0.1 g fat per 100 g of green pods and plays an important function as a dietary legume (Salehi *et al*. 2010). Beans, also known as "poor meat," provide essential protein to the starving people who live in the hills. It is utilized as tender pods, pulses, shelled beans, pickles, canned, frozen, or dehydrated foods, making it a vital food source during lean times.

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Being a short duration crop French bean can be grown in a variety of cropping patterns in India's hills and plains, providing farmers with lucrative economic returns. High yield, broader adaptability, quick plant growth habits, short duration, short pods for whole processing, sloughing-free cultivars for the canning industry and fresh produce quality are the primary standards being considered for genetic development. During the crop season, French bean is susceptible to a variety of diseases, including root rot, anthracnose, and the common bean mosaic virus, all of which have a significant impact on pod yield. As a result, high yields of tender, long, dark green pods, as well as resistance to pests and diseases, are priority attributes for genetic improvement. In Himachal Pradesh, French bean is grown as a fresh vegetable throughout the summer and rainy seasons and it fetches off-season prices during the spring and autumn, making it a profitable crop for farmers. Most of the cultivars of French bean does not match in the quality and productivity level of pods to the modern day cultivars as introduced or developed a long time ago. Because of the narrow genetic base of French bean cultivars, breeders must gather wild common beans, landraces and exotic cultivars to increase genetic variety.

To combine many desirable features such as long and lush green pods with high production potential, breeders need thorough knowledge on variation present in existing germplasm. Several authors have studied the genetic variability in French bean (Noopur *et al*. 2019, Singh *et al*. 2020). Knowledge of the magnitude of variation in the existing germplasm, extent of environmental effects on the traits and heritability of the characters is a prerequisite for the improvement of yield and other desirable traits (Saifullah and Rabbani 2009). Greater variety improves genetic potential and provides greater choices for selection, resulting in the successful completion of a breeding program. The availability of reliable information on the nature and extent of gene effects in the population for boosting yield potential influences the selection of suitable plant breeding. There are several approaches to study genetic diversity using morphological, cytological and biochemical markers and more newly through DNA based technologies (Akbar *et al*. 2010), but the knowledge of phenotype gained from morphological and agronomical procedures is regarded a good source of information for breeders (Yadeta *et al*. 2011). Further, studies of genetic divergence offers a reliable practice to evaluate the divergence prevailing in the population and measures the forces of differentiation at intra-cluster and inter-cluster cluster levels in order to choose more diverse parents for hybridization programs. Therefore, the goal of this study was to determine the genetic diversity of pole type French beans so that variance in different attributes may be used in future breeding programs to improve the crop.

MATERIALS AND METHODS

The present investigation was carried out in the experimental farm of the Department of Vegetable Science, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, H.P. during the *kharif* season of the year 2020. The experiment field is situated at 30^{o}86' North of latitude and 77^{o}17' East of longitude with an altitude of 1,275 m above mean sea level. Twenty - nine indigenous genotypes of pole type French bean were collected from districts viz., Shimla, Solan and Sirmour. Samples collected comprised of freshly harvested seeds (1 kg each or less depending upon the availability). These collected genotypes were grown at the spacing of 90 cm between the rows and 60 cm between plants with three replications in Randomized Complete Block Design (RCBD). All the recommended cultural practices were followed to raise the crop. The observations were recorded on five randomly selected plants from each replication for yield and its attributing traits viz., days to 50% flowering, days to 1st picking, harvest duration (in days), pods per plant, pod length (cm), pod width (mm), pod weight (g), pod yield per plant (g), plant height (cm), seeds per pod, seed length (mm), seed width (mm), 100 seed weight (g) and seed yield per plant (g). Analysis of variance was carried out as per the method given by Panse and Sukhatme (1967). The data were analyzed for estimation of genotypic and phenotypic coefficient of variation following Burton and De Vane (1953). Heritability in broad sense and genetic advance were calculated according to Allard (1960). Genetic advance as percentage over mean as worked out as suggested by Johnson *et al*. (1955). The genetic divergence was estimated using D^2 statistics

Table 1. Analysis of variance for yield and yield contributing traits in pole French bean. [1]*Significant at 5% level of significance (DT50% F= Days to 50% flowering, DTFP= Days to first picking, HD= Harvest duration, NPPP= Number of pods per plant, PL= Pod length, PW= Pod width, PWt.= Pod weight, PH= Plant height, NSPP= Number of seeds per pod, SL= Seed length, SW= Seed width, 100 SW= Hundred seed weight, SYPP= Seed yield per plant, PYPP= Pod yield per plant).

Characters		Mean sum of square (MSS)						
source	df	DT50%F	DTFP	HD	NPPP	PL (cm)	PW (mm)	PWt. (g)
Replications	2	24.24	6.43	1.74	1.25	1.81	0.47	0.19
Genotypes	28	135.76*	218.49*	139.90*	134.90*	12.61*	10.74*	1.08*
Error	56	2.66	1.37	0.69	3.61	0.73	0.13	0.06
F_{cal}		51.07	159.97	203.34	37.33	17.34	82.07	18.33

Table 1. Continued.

Characters		Mean sum of square (MSS)						
source	df	PH (cm)	NSPP	SL (mm)	SW (mm)	100 SW(g)	SYPP (g)	PYPP (g)
Replications	2	12.03	0.93	0.63	1.28	5.50	2.36	14.26
Genotypes	28	2519.93*	3.16*	12.99*	0.75*	274.45*	1257.71*	4789.37*
Error	56	66.18	0.15	0.19	0.14	2.16	4.12	18.72
F_{cal}		38.08	21.61	67.32	5.29	126.95	305.52	255.89

of Mahanalobis and the population was grouped into clusters by following the method suggested by Rao (1952).

RESULTS AND DISCUSSION

Genetic variability, heritability and genetic advance

The genotypes involved in the study significantly differed for all the traits which clearly recommended the validation of studying genetic variability employing these genotypes and traits. The range mean and other genetic parameters estimated are present a large variation in vegetative growth and yield performance was observed among the 29 genotypes of pole type French bean (Tables 1 and 2). Genotypes vary highest mean performance range (92.89-220.50) of green pod yield (g/plant) and the lowest mean performance range (5.41-7.43) of seed width. The phenotypic coefficient of variation was higher than the genotypic coefficient of variation (Table 2) indicated that the environment

Table 2. Estimates of range, mean and components of genetic variability for various characters in twenty nine genotypes of French bean.

Characters	Range	Mean	Coefficients of variability (%) Phenotypic	Coefficients of variability (%) Genotypic	Heritability (%)	Genetic advance	Genetic gain (%)
Days to 50% flowering	42.67-64.67	50.62	13.55	13.16	94.35	13.33	26.33
Days to 1st picking	56.67-83.00	69.26	12.40	12.28	98.15	17.36	25.07
Harvest duration (in days)	24.00-46.67	36.09	19.01	18.87	98.54	13.93	38.60
Number of pods per plant	15.56-42.33	28.86	23.85	22.92	92.37	13.10	45.38
Pod length (cm)	9.47-17.56	13.05	16.58	15.24	84.49	3.77	28.86
Pod width (mm)	5.26-13.39	9.37	20.43	20.07	96.43	3.80	40.59
Pod weight (g)	5.17-7.53	6.15	10.27	9.49	85.25	1.11	18.04
Plant height (cm)	98.67-204.00	152.76	19.47	18.72	92.52	56.67	37.10
Number of seeds per pod	4.44-8.22	6.46	16.61	15.52	87.30	1.93	29.86
Seed length (mm)	8.28-17.01	13.14	16.07	15.72	95.67	4.16	31.67
Seed width (mm)	5.41-7.43	6.55	8.95	6.86	58.82	0.71	10.85
100 seed weight (g)	13.79-49.15	31.31	30.79	30.43	97.67	19.40	61.95
Seed yield per plant (g)	25.58-100.76	54.29	37.84	37.65	99.02	41.90	77.19
Pod yield per plant (g)	92.89-220.50	175.47	22.86	22.73	98.84	81.67	46.54

influenced the majority of the yield attributes.

The traits showing wide range of variability have ample scope of selections for the desirable types phenotypic coefficient of variation ranged from (8.95%) for seed width to (37.84%) for seed yield/plant. Genotypic coefficient of variation ranged from 6.86% for seed width to 37.65% for seed yield/plant. High phenotypic and genotypic coefficient variation was observed for seed yield/plant (37.84 and 37.65%) and 100-seeds weight (30.79 and 30.43%) signifying high potential of these characters for effective selection. However, GCV and PCV estimates were also found to be moderately high to high for number of pods per plant, pod yield per plant, pod width, plant height, harvest duration, number of seeds per pod, pod length and seed length which proposed comparatively high genetic variation among the genotypes for these traits. Similarly, high value of PCV and GCV were recorded by Panchbhaiya *et al*. (2017) for 100 seed weight and seed yield per plant. Rai *et al*. (2010) detected moderate PCV and GCV for pod length and number of seeds per pod and Thirugnanavel *et al*. (2019) recorded for plant height.

Heritability is a measure of the importance of selection for a given characteristic as well as an index of character transmission from parent to offspring. High heritability (broad sense) was observed for seed yield per plant (99.02%) followed by pod yield per plant (98.84%), harvest duration (98.54%), days to 1st picking (98.15%), 100 seed weight (97.67%), pod width (96.43%), seed length (95.67%), days to 50% flowering (94.35%), plant height (92.52%), number of pods per plant (92.37%), number of seeds per pod (87.30%), pod weight (85.25%) and pod length (84.49%), indicating the least effect of environment in their expression, hence signifying that selection for these characters based on phenotypic appearance would be reliable. Though, heritability (broad sense) values are likely to be over-estimated as in this calculation it was not possible to eliminate variation due to dissimilar genetic component and their interrelation. High genetic advance as percentage of mean (> 50%) was recorded for seed yield per plant (77.19%) and 100 seed weight (61.95%), moderate (25-50%) for pod yield per plant (46.54%), pods per plant (45.38%), pod width (40.59%), harvest duration (38.60%), plant height (37.10%), seed length (31.67%), seeds per pod (29.86%), pod length (28.86%), days to 50% flowering (26.33%) and days to 1st picking (25.07%) and low to moderately low for other characters like pod weight (18.04%) and seed width (10.85%).

Table 3. Clustering pattern of 29 genotypes based on genetic divergence.

Cluster	Number of genotypes	Genotypes
I	18	LCPB-4, LCPB-5, LCPB-6, LCPB-7, LCPB-9, LCPB-10, LCPB-11, LCPB-12, LCPB-13, LCPB-16, LCPB-19, LCPB-20, LCPB-24, LCPB-25, SVM-1, Pusa Himlata, Kentucky Wonder and Lakshmi
II	4	LCPB-1, LCPB-2, LCPB-3 and LCPB-17
III	7	LCPB-8, LCPB-14, LCPB-15, LCPB-18, LCPB-21, LCPB-22 and LCPB-23

Divergence study

Genetic diversity is important in all cross breeding programs because crossing genetically different parents results in a large number of required segregants. The clustering pattern of 29 genotypes of pole type French bean has been presented in Table 3 and fig. 1. Twenty nine diverse genotypes of French bean were assembled into three clusters by estimating D^2 values in all the groupings of genotypes. Maximum eighteen genotypes were received by cluster I, therefore making it the largest cluster. The second biggest cluster was cluster III having seven genotypes each. Minimum four genotype were received by cluster II. Purpose is to group individuals or objects based on the characteristics they possess, so that individuals with similar descriptions are mathematically gathered into the same cluster.

The estimates of average intra- and inter-cluster distances for three clusters (Table 4 and fig. 2) revealed that the genotypes present within a cluster have little genetic divergence from each other with respect to aggregate effect of fourteen characters under study, while greater genetic diversity was observed between the genotypes belonging to different clusters. Similar findings were also supported by Panda *et al*. (2016), Haralayya *et al*. (2017) and Panchbhaiya

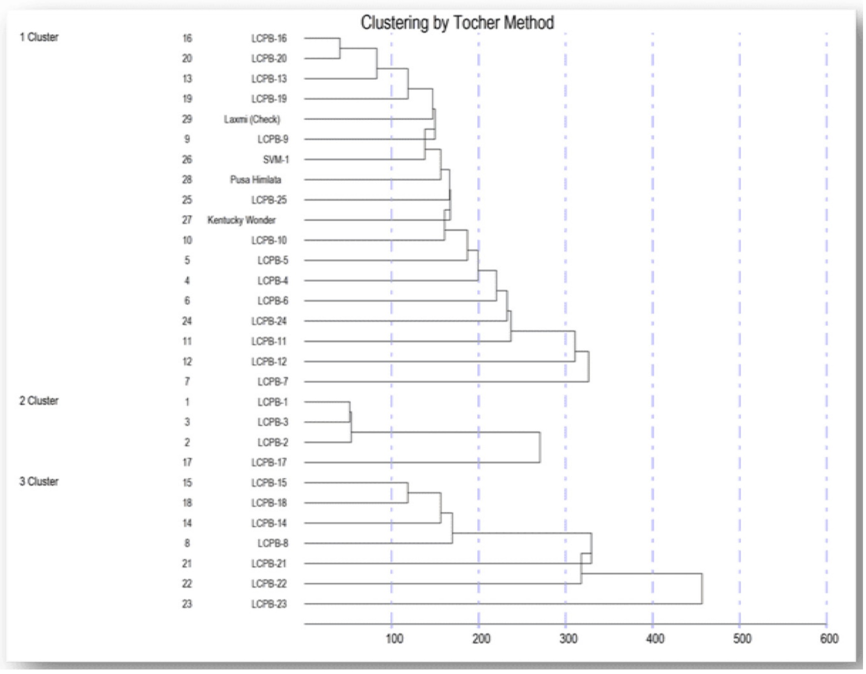

Fig. 1. Clustering pattern of 29 French bean genotypes drawn according to Tocher's method.

et al. (2017). The cluster III is having maximum intra cluster distance (382.00) followed by cluster I (234.87). Maximum intra-cluster distance in clusters denotes that genotypes present in these clusters were genetically heterogeneous to a greater extent. Maximum inter cluster distance was observed between cluster II and III (784.03) while, the minimum inter cluster distance was noticed between cluster I and II (438.76). The genotypes in the clusters with the greatest inter-cluster distances had the highest genetic variance, and hybridization between genotypes in these clusters could result in increased heterotic progenies due to convergence of unique genes in the F_1 that were scattered in the parents.

Cluster means agrees the moderate performance of all the genotype present in a particular cluster for a particular trait. The cluster means for all the characters are mentioned in Table 5. Maximum cluster mean for days to 50% flowering (46.25 days), days to 1st picking (60.75), harvest duration (39.42 days), pods per plant (33.91), pod length (13.48 cm), pod width (10.11 mm), plant height (167.50 cm), seeds per pod (7.25), 100 seed weight (45.69 g), seed yield per

Table 4. Average distance of inter and intra cluster centroids.

Cluster	I	II	III
I	234.87	438.76	444.39
II		215.92	784.03
III			382.00

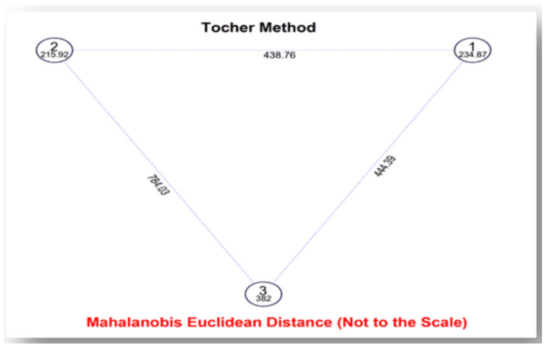

Fig. 2. Average distance of intra and inter-cluster centroids based on various traits in 29 French bean genotypes.

Table 5. Cluster mean for different economic traits in French bean genotypes.

Characters	Cluster means I	II	III
Days to 50% flowering	48.87	46.25	57.62
Days to 1st picking	68.52	60.75	76.05
Harvest duration	37.48	39.42	30.62
Number of pods per plant	29.32	33.91	24.81
Pod length (cm)	13.27	13.48	12.26
Pod width (mm)	9.48	10.11	8.68
Pod weight (g)	6.34	5.93	5.78
Plant height (cm)	155.93	167.50	136.19
Number of seeds per pod	6.54	7.25	5.81
Seed length (mm)	13.68	13.54	11.52
Seed width (mm)	6.51	6.41	6.76
100 seed weight (g)	30.78	45.69	24.46
Seed yield per plant (g)	48.46	90.96	48.32
Pod yield per plant (g)	184.68	197.88	138.97

Table 6. Contribution of different traits to total divergence in French bean.

Sl. No.	Characters	Contribution (%)	Times ranked 1st
1.	Days to 50% flowering	0.25	1
2.	Days to first picking	9.11	36
3.	Harvest duration	0.25	1
4.	No. of pods per plant	13.05	52
5.	Pod length (cm)	5.00	20
6.	Pod width (mm)	6.16	25
7.	Pod weight (g)	7.00	28
8.	Plant height (cm)	1.48	6
9.	No. of seeds per pod	3.94	16
10.	Seed length (mm)	2.96	12
11.	Seed width (mm)	8.00	32
12.	100 seed weight (g)	8.36	33
13.	Seed yield per plant (g)	19.56	78
14.	Pod yield per plant (g)	14.88	60

plant (90.96 g) and pod yield per plant (197.88 g) was observed for cluster II. Cluster I exhibited maximum mean for pod weight (6.34 g) and seed length (13.68 mm). Cluster III reported maximum cluster mean for seed width (6.76 mm). The genotypes with high mean values of any cluster can be used for hybridization for further selection and improvement (Gangadhara *et al*. 2014).

The selection and choice of parents mainly de-

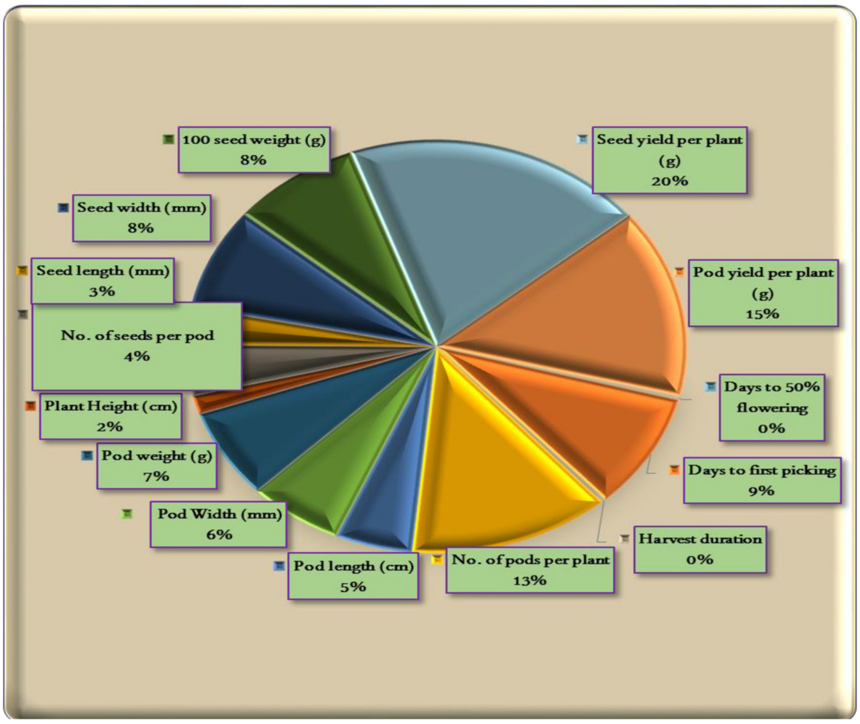

Fig. 3. Relative contribution of different characters to total divergence.

Table 7. Principal component analysis for different traits in French bean.

	Canonical roots analysis (P. C. A.)				
	1 Vector	2 Vector	3 Vector	4 Vector	5 Vector
Eigen Value (Root)	4.38	2.95	1.84	1.25	0.98
% Var. Exp.	31.30	21.09	13.17	8.95	6.98
Cum. Var. Exp.	31.30	52.38	65.55	74.50	81.48
Days to 50% flowering	0.36	0.27	0.14	0.02	0.25
Days to first picking	0.37	0.28	0.03	-0.06	0.18
Harvest duration	-0.31	0.15	-0.18	0.49	-0.13
No. of pods per plant	-0.10	0.48	0.03	-0.27	0.30
Pod length (cm)	-0.14	-0.17	-0.16	0.27	0.72
Pod width (mm)	0.01	-0.19	0.51	0.17	-0.05
Pod weight (g)	-0.24	-0.06	-0.35	-0.20	0.14
Plant height (cm)	-0.32	0.24	0.24	-0.01	-0.14
No. of seeds per pod	-0.41	-0.15	-0.08	0.13	-0.05
Seed length (mm)	-0.14	-0.38	0.16	-0.49	0.14
Seed width (mm)	-0.26	0.37	0.21	-0.16	-0.26
100 seed weight (g)	-0.16	-0.23	0.54	-0.10	0.20
Seed yield per plant (g)	-0.18	0.24	0.33	0.37	0.28
Pod yield per plant (g)	-0.36	0.23	-0.10	-0.34	0.17

pends upon role of traits towards genetic divergence. Contribution of each trait towards divergence has been assessed from the number of times that each character appeared in the first rank. The present study showed that seed yield per plant (19.56%), pod yield per plant (14.88%), pods per plant (13.05) and days to 1st picking (9.11%) were considered to be important traits contributing towards divergence as these traits become available maximum times first rank viz., 78, 60, 52 and 36 respectively (Table 6 and Fig. 3) and therefore, these traits should be discovered more while studying genetic divergence in pole type French bean. Similar findings were also supported by Jhanavi *et al.* (2018), Singh *et al.* (2018) and Al-Ballat and Al-Araby (2019).

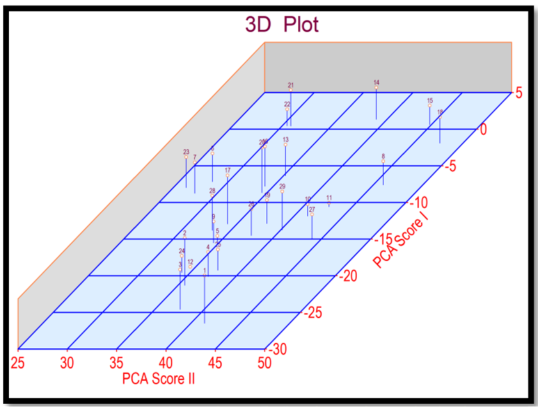

Fig. 4. 3D plot of principal component analysis (PCA) for twenty nine genotypes of French bean based on 14 characters.

The most significant causes of variance in the genotype sets were determined using principal component analysis (PCA). According to the principal component analysis, the principal components PC1, PC2, PC3, PC4 and PC5 with Eigen values of 4.38, 2.95, 1.84, 1.25 and 0.98, respectively, accounted for 81.48 % cumulative variability among genotypes. The first PC, out of the five, had the greatest impact on variability (31.30%). Days to first picking and days to 50% flowering had the highest loadings in PC1. The second major component was responsible for 21.09 % of the total variation. The most important parameters in this component were pods per plant, seed width, days to first picking, days to 50% flowering, seed yield per plant and pod yield per plant, which contributed the most to overall variability. PC3 reported for 13.17 % of overall diversity and traits such as 100 seed weight, pod width, seed yield per plant and plant height promoted higher eigen vector values in PC3. The fourth main component explained 8.95 % of total variability with harvest duration, seed yield per plant and pod length. Principal components with eigen values greater than or equal to 1.0 were considered significant (Table 7). Fig. 4 depicts a three-dimensional principal component score plot based on the two score vectors, PCA I and PCA II that account for the majority of variation. PCA I and PCA II confirmed this by grouping 29 French bean genotypes and their traits in the immediate surrounded by PCA I and PCA II.

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