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Principal component based agro-morphological performance analysis of French bean (*Phaseolus vulgaris*)

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Abstract
On the basis of principle component analysis 15 genotypes of French bean were evaluated to assess the contribution of quantitative traits in genetic variability. The principal component analysis showed that the two principal components explained 64.27% of the total variation. The first Principle component accounted for 39.768% of variation mostly influenced yield, pod length, average pod weight and number of seeds per pod. The second component accounted for 24.502% of the variance and is mostly influenced by plant height and number of seeds per pod. With respect to PC_1 and PC_2 the distance of each variable showed the contribution of this variable in the variation of genotypes. Cluster analysis of French bean genotypes using distance between cluster and UPGMA, produce two major cluster and two sub cluster in each major cluster.

Keywords: French bean, PCA, agro-morphological performance, Eigen value

Introduction
French bean (*Phaseolus vulgaris* L., 2n=2x=22) is an important legume crop, used as green pod vegetable (known by various names as snap bean, string bean, garden bean, fresh bean) or dry seeds (known as dry beans) [1]. French bean (*Phaseolus vulgaris* L.), a native of central and South America [2] has one of the longest histories of cultivated plants and is widely cultivated in the temperate and subtropical regions and in many parts of the tropics [3]. Spanish and Portuguese explorers introduced the legume to Europe and Africa, and by the nineteenth century the slim pods became a common vegetable in France, hence being called "French" beans. Today, French beans are a common alternative to green beans and other legumes, and are grown around the world including India and Africa where they are a staple food. The dry seed type varieties are known as 'Rajmash' in India. Snap bean seeds can also be used in dry state like the dry bean types, in that case pinto, kidney, pink, small red, etc., terms can also be used. In India, green pods as well as dry seed consumption is conspicuous and is primarily grown in Jammu and Kashmir, Himachal Pradesh and hills of Uttaranchal [4]. North East region India is one of the world's richest centres of crop genetic diversity because of diverse agro-climatic conditions and socioeconomic and cultural variation [5]. French bean is a good source of protein, carbohydrate, calcium, iron, phosphorus and vitamins [6], particularly, Vitamin B. India has about 217 thousand ha area under bean cultivation and the production is 2135 thousand MT with an annual productivity 9.83MT/ha [7].
French bean had evolved from a wild growing vine *viz., Phaseolus aborigineus* distributed in the highlands of middle America and Andes [8]. The knowledge of genetic diversity is an important pre-requisite to any breeding programme aimed to exploit hybrid vigour. For estimation of diversity within the germplasm, several workers have postulated principal component analysis and clustering of genotypes [9]. Multivariate methods such as principle component analysis (PCA) have proven to be useful for evaluating and classifying germplasm when a large number of accession are assessed for several characteristics of agronomic importance. Principal component analysis or simply PCA is a statistical procedure concerned with elucidating the covariance structure of a set of variables. In particular it allows us to identify the principal directions in which the data varies [3]. Therefore the present study was undertaken to identify the most divergent genotypes in terms of genetic variability for use in efficient breeding programs using principle component analysis based on five yield attributing characters.

Materials and Methods

The experimental material for the present study was comprised of 15 genotypes of French bean (*Phaseolus vulgaris* L.), the list of genotypes is given in Table 1. All the genotypes mention in table 1 are grown in the month of July, 2016 and July, 2017. The experiment was laid out in Completely Randomized Design (CRD) with three replications. The soil used for this study was collected from Vegetable Research Farm of College of Horticulture and Forestry, Pasighat. Plastic pots sized 30 cm x 30 cm were used and filled with the experimental soil of 10 kg. Pots were kept in medium-tech polyhouse. Seven seed of each genotype was sterilized with 1 % sodium hypochlorite and soaked overnight in water and sown in each pot. Observation were recorded for five agro morphological characters at different growth stages of the plant for two consecutive years as Plant height (cm), Average Pod weight (g), Pod length (cm), number of seed per pod and Yield (g/plant). The data is the mean of five randomly selected plants for each replications and was used for statistical analysis.

Table 1: List of French bean genotypes with source of collection

Sl. No	Genotype	Source
1	G_1	Lakshmi (IIVR, Varanasi)
2	G_2	Swarna Lata (IIVR, Varanasi)
3	G_3	RCMFB-1 (IIVR, Varanasi)
4	G_4	Mizoram
5	G_5	Meghalaya
6	G_6	Tripura
7	G_7	Pasighat (Arunachal Pradesh)
8	G_8	Mao (Manipur)
9	G_9	Mao (Manipur)
10	G_{10}	Choinu village (Manipur)
11	G_{11}	Chandel District (Manipur)
12	G_{12}	Mayangkhang village (Manipur)
13	G_{13}	Mayangkhang village (Manipur)
14	G_{14}	Senapati (Manipur)
15	G_{15}	Senapati (Manipur)

The data were analyzed using R3.0.3. The PC was used to determine the extent of genetic variation. Eigen- values were obtained from the PC, which were used to determine the relative discriminative power of the axes and their associated characters.

Results & Discussion

Based on five agronomic characters the Principle component analysis (PCA) was analyzed through one of the most frequently used multivariate methods using SPSS (version 16.0, 2007). Based on the five yield attributing characters the results of PCA revealed a wide range of diversity among the French bean genotypes. In table 2, the Eigen values representing the variance of the principle components and the cumulative percent of the Eigen values indicating percentage contribution to the total variance attributable to each principle component is given.

Table 2: Eigen values and percentage of variation for corresponding two component characters in 15 genotypes of French bean.

Component	PC_1	PC_2
Eigen value	1.988	1.225
% Variance	39.768	24.502
Characters	**Eigen vectors**	
Plant height (cm)	-0.028	0.832
Average pod weight (g)	0.672	-0.473
Pod length (cm)	0.688	-0.142
Number of seeds per pod	0.522	0.500
Yield (g/plant)	0.889	0.199

The Eigen value for first Principle component accounted for 39.768% of total variation and the second Principle component accounted for 24.502%. The two PC axes explained 64.27% of the variation, the first Principle component accounted for 39.768% of variation mostly influenced yield, pod length, average pod weight and number of seeds per pod. The second component accounted for 24.502% of the variance and is mostly influenced by plant height and number of seeds per pod. The characters with the largest coefficient and which contributed to it is number of seeds per pod and yield.

The plot of PCA_1 and PCA_2 is shown in Figure 1 which shows the relationship among the observation per genotype. Results shows that G_4 and G_7 were the most disperse and diverse of all the accession considered in this study. G_4 and G_7 are mostly described by characters average pod weight, pod length, number of seeds per pod and yield, whereas plant height in the PC_2 is best described by G_{14}.

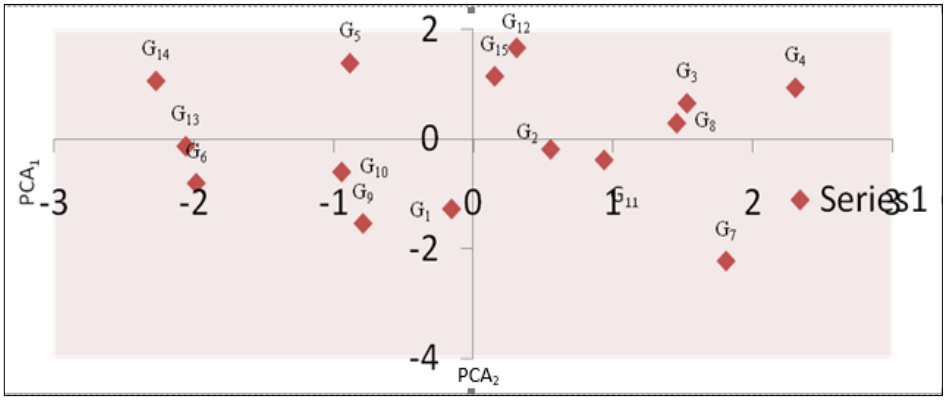

Fig 1: Arrangement of 15 French bean genotypes under PCA_1 and PCA

Screen plot explained the percentage variance associated with each principal component obtained by drawing graph between eigen values and principal component numbers (Fig. 2). PC_1 showed 39.768% with eigen value 1.988 in genotypes which then reduced gradually. Little variance is observed in each PC and it ended at 5th PC. From the graph it is clear that maximum variation is present in first PC, so selection of genotypes from this PC will be useful.

The Principle component plot showed that variables were super imposed on the plot as vectors. With respect to PC_1 and PC_2 the distance of each variable showed the contribution of this variable in the variation of genotypes (Fig. 3).

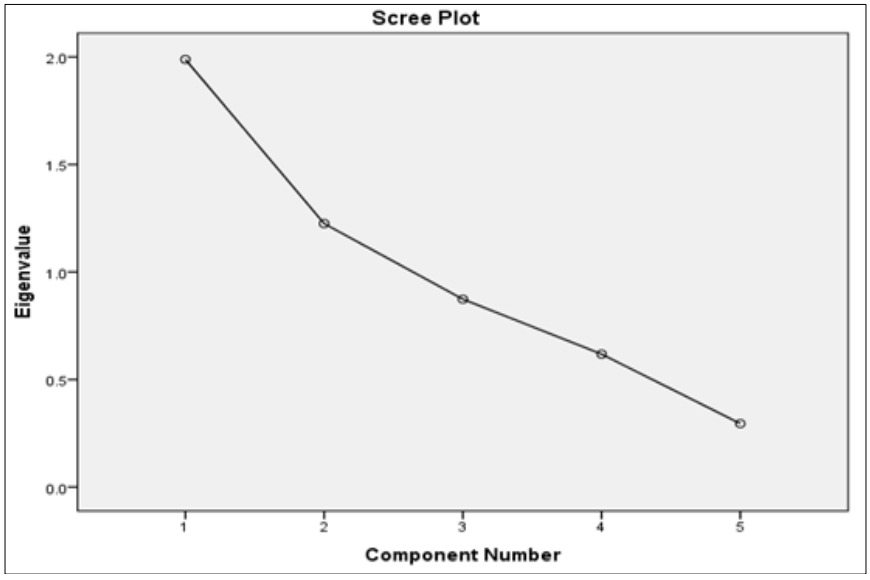

Fig 2: Scree plot showing eigen values in response to number of components for the estimated variables.

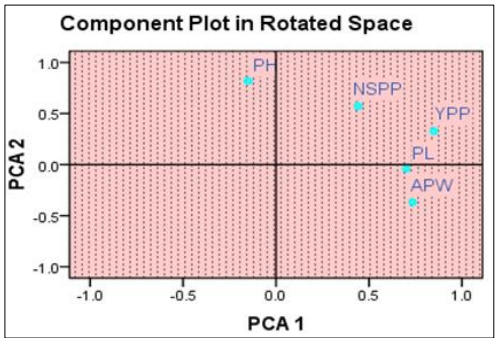

Fig 3: Principal component plot based on correlation of each character with two principle components

Agro-morphological variability of 15 genotypes of French bean was studied based on five principle yield attributing characters using cluster analysis. Based on the agro-morphological data, single linked hierarchical clustering was taken into consideration for all genotypes (Figure 4). Cluster analysis of French bean genotypes using distance between cluster and UPGMA, produce two major cluster and two sub cluster in each major cluster. Cluster I contained the genotypes G_2, G_6, G_7, G_9, G_{10} and G_{11}, the cluster II was found to incorporate 9 genotypes *viz*., G_1, G_3, G_4, G_5, G_8, G_{12}, G_{13}, G_{14} and G_{15}. Dendrogram summarized the existing genetic similarity/dissimilarity among French bean genotypes within the cluster based on agro-morphological characters.

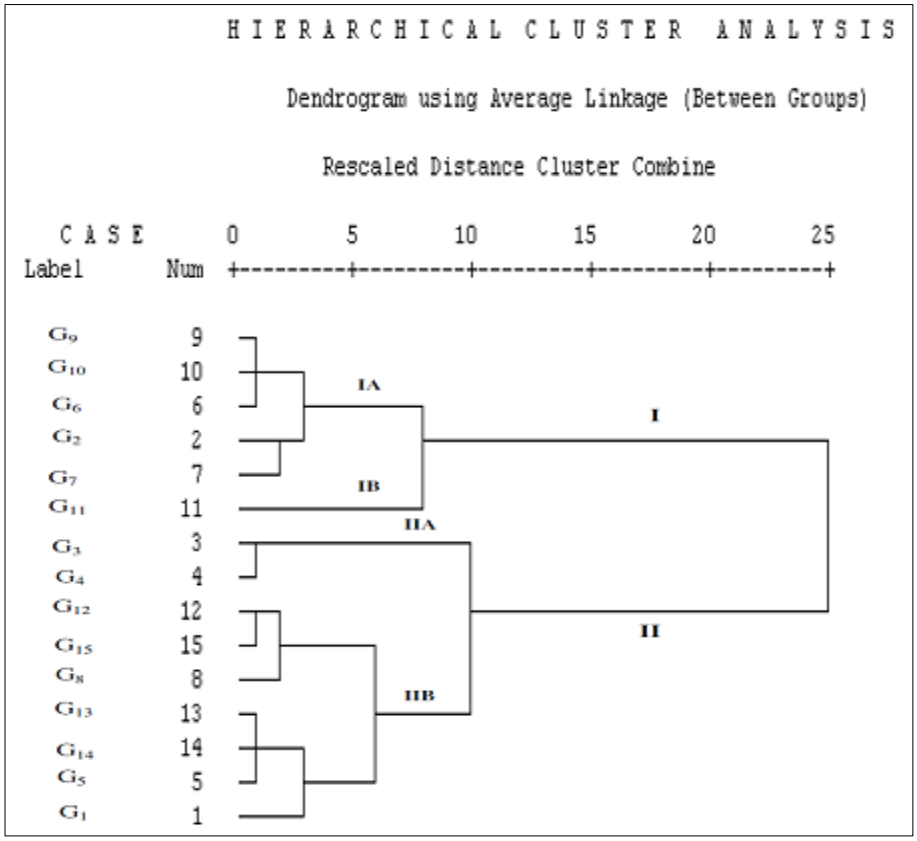

Fig 4: Dendrogram showing relationship of French bean genotypes based on Euclidian distance and UPGMA clustering using five yield attributing characters**.**

Conclusion

The Eigen value of first principal component was accounted approximately 39.768% of total variation and the second Principle component accounted for 24.502%. The two PC axes explained 64.27% of the variation suggesting considerable diversity among the characters. Cluster analysis for yield and yield contributing traits classified all fifteen genotypes into two major clusters and two sub cluster in each major cluster. The analysis revealed the maximum inter-cluster distance was found between G_1 and G_9 which can be could be utilized for crossing programme to create more genetic diversity or segregants of desired characteristics through French bean breeding programmes.

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