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D^2 Studies and Determination of the Selection Criterias through Principal Component Analysis in Bush Type Vegetable French Bean Genotypes (*Phaseolus vulgaris* L.) under North-Eastern Ghat Region of India

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ABSTRACT

A thorough examination of the genetic diversity helps to make good decisions in a crossing program. Therefore, the present experiment consisted of 16 diverse germplasm of bush type vegetable French bean was conducted at Horticulture Research Farm (HRF) of MS Swaminathan School of Agriculture, Centurion University of Technology and Management, Odisha, India during *rabi* season of the year 2021-2022 to assess genetic diversity through D^2 analysis and principal component analysis (PCA). On the basis of relative magnitude of cluster distances, all the 16 genotypes of French bean were grouped into five major clusters. Cluster pattern revealed that cluster I was the largest group consisting of 9 genotypes followed by cluster II (4 genotypes). Cluster III, IV and V each had only one genotype. Maximum inter-cluster distance of 6158.36 was obtained between clusters II and IV followed by cluster IV and V (4931.45) thus the genotypes grouped under cluster II, IV and V may show maximum heterosis upon hybridization and also create wide variability including transgressive segregants in selfed generations. Cluster I had highest mean for number of seeds per pod. Cluster II had highest mean value for pod length, pod diameter, number of pods per plant, 10 pod weight and pod yield per plant. Similarly, cluster III and V showed highest plant height and 100 seed weight respectively. Cluster IV showed highest values for days to first flowering, days to 50 % flowering, protein content, total sugar and PDI of bean anthracnose. Principal component analysis revealed that the first eigen root had maximum 79% variation of total variation while the first four principal component axes together explained 98.71% variation.

Keywords French bean, Genetic divergence, D^2 analysis, Principal component analysis, Selection criteria.

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INTRODUCTION

French bean, *Phaseolus vulgaris* L. (2n=2x=22), belongs to the family 'Fabaceae', is a self-pollinated, annual, bushy or climbing type legume vegetable crop which is also known as snap bean, kidney bean, garden bean and considered as an important protein sources for many developing countries (Chatterjee 2022). The genus *Phaseolus* is large, including approximately 80 cultivated and wild species, but *Phaseolus vulgaris* is the most widely cultivated species (Porch *et al.* 2013). French bean originated from Central America and Peruvian Andes in South America (Vavilov 1951, Yarnell 1965). It is adapted to a wide variety of climatic conditions, being grown from 52° north latitude to 32° south latitude in the humid tropics, semi-arid tropics and even cold climate regions (Panchbhaiya *et al.* 2017). In India, it is cultivated in 215 thousand hectares of land with total production of 2080 thousand tonnes. The productivity is estimated to be 9.67 t/ ha (Anonymous 2020). Commonly, green pods are consumed as vegetable and dry seeds as pulse which is popularly known as 'Rajmah' especially in the northern parts of India. French bean can play an important role in nutrition. Its green pods and ripe seeds contain protein, carbohydrate, fiber, thiamin, riboflavin, calcium and iron. The pods are nutritionally rich which contain on an average 1.7% protein, 4.5% carbohydrate, 1.8% fiber and minerals like calcium 50 mg, magnesium 29 mg, phosphorus 28 mg, iron 1.7 mg per 100 g of edible portion (Shanmugavelu 1989). French bean is having immense medicinal values as well i.e. homoeopathic remedy is made from entire fresh herb and used in treatment of arthritis and disorders in urinary tract. Seed is used for treatment of cancer. The crop contains 'phaseolin' which is having fungicidal activity. French bean can also be used as carminative, diuretic and emollient. It is also used in treatment of diabetes, diarrhoea, dysentery and kidney problems (Broughton *et al.* 2003).

The present cultivars of this crop exhibit lower productivity, non-synchronous flowering and fruiting, non- responsive to high doses of inputs like fertilizers, irrigation, tillage, non-suitability of the various cropping systems, lodging and shattering susceptible, long duration, complete or partial absence of genetic resistance to major insect pest and diseases which caused considerable damage and very poor harvest indexes (Immaculee 2011). Most of the varieties which are cultivated in India are open pollinated types because hybrids are not commercially exploited in this crop due to its complex flower structure and problem in crossed fruit setting. As a result productivity of the crop is significantly low compared to the world average (Chatterjee 2022).

Genetic diversity is one of the important tools to quantify genetic variability in both cross and self-pollinated crops (Naik and Prasad 2015). The knowledge of genetic diversity, its nature and degree of variability would be useful for selecting desirable and diverse parents from available germplasm for a successful breeding program (Ullah *et al.* 2015). Diverse parents are expected to produce high yielding hybrids through manifestation of heterosis, increase the probability to obtain transgressive segregants in F_2 and in subsequent generations (Chatterjee *et al*. 2018). Cluster analysis and PC (principal component) analysis are the important genetic diversity measuring tools employed for exhibiting relative genetic differences among the genotype collection of various crop species (Jatav *et al*. 2019). However, in spite of the potential nutritive and medicinal values, a very few reports of multivariate analysis in French bean genotypes are available (Gangadhara *et al.* 2014, Kumar *et al.* 2014, Verma *et al.* 2014, Arunga *et al.* 2015, Gelaw 2017, Haralayya *et al.* 2017, Panchbhaiya *et al.* 2017, Sharma *et al.* 2019 and Reddy *et al.* 2021). In view of this, the present study was conducted to classify a set of French bean genotypes based on multivariate analysis that may be used for generating more heterotic cross combinations and finally superior useful hybrids.

MATERIALS AND METHODS

Sixteen germplasm including one check i.e. 'Anupama' of French bean (*Phaseolus vulgaris* L.) were evaluated for genetic diversity studies during November-February, 2021-22 at the Horticulture Research Farm (HRF), Ranadevi under the Department of Horticulture, MS Swaminathan School of Agriculture, Centurion University of Technology and Management, Parlakhemundi, Odisha which is

Table 1. List of genotypes used in present study.

Sl. No.	Genotypes	Sources
1.	Malgudi	Ashoka Farm Aids, Bangalore
2.	Akshara	Bhairavi Bio – Sciences Private Ltd, West Bengal
3.	Falguni	Kishan Seed Farm,West Bengal
4.	Anupama	Solar Seeds, Bangalore
5.	Anup	Ashoka Farm Aids, Bangalore
6.	Arka Komal	IIHR, Bangalore
7.	Serengeti	Syngenta India Limited, Pune
8.	NFL-35 (Suman)	Nirmal Seeds Pvt Ltd, Maharashtra
9.	Rani	Shriram Bioseed Genetics, Hyderabad
10.	Bean Roshni	Durga Seed Farm, Chandigarh
11.	Rupali	Bharat Nursery Pvt Ltd, West Bengal
12.	Fiesta	Tokita Seed India (P) Ltd, Bangalore
13.	Aishwarya	RK Seed Farms, New Delhi
14.	Arka Arjun	IIHR, Bangalore
15.	Arka Sarath	IIHR, Bangalore
16.	Harsha	DCM Shriram Limited, New Delhi

lying between 18º80´N latitude and 84º14´E longitude at an elevation of 182.9 meters above mean sea level. The experimental field at Ranadevi located in the Gajapati district which comes under the north eastern ghat agroclimatic zone with a typical sub-tropic and sub-humid climate.

The experiment was conducted in Randomized Complete Block Design (RCBD) with 3 replications to assess the performance of 16 bush type vegetable French bean genotypes (Table 1). The crop was grown in individual plots of 3.6 m × 2.4 m keeping 45 cm and 30 cm spacing between row to row and plant to plant respectively. Standard cultural practices recommended in the 'Manual on Agricultural Production Technology' (Anonymous 2008) and protective measures were followed to ensure a healthy crop stand. The data recorded on 13 quantitative characters viz., plant height (cm), days to first flowering, days to 50% flowering, pod length (cm), pod diameter (cm), number of pods per plant, pod weight (g), 100 seed weight (g), number of seeds per pod, protein content of green pod (%), total sugar content of green pod (%), PDI of bean anthracnose (%) and pod yield per plant (g). Data of ten plants from each genotype was averaged replication wise and mean data was used for statistical analysis.

Table 2. Cluster classification of French bean genotypes. *Figures in parentheses indicate number of genotypes.

Number of clusters	Name of the genotype
I (9) *	Bean Roshni, Fiesta, Falguni, Akshara, Anup, Aishwarya, Serengeti, Rani, Anupama
II (4)	NFL-35 (Suman), Arka Sharath, Arka Arjun, Malgudi
III (1)	Rupali
IV (1)	Harsha
V (1)	Arka Komal

Genetic divergence was estimated by using D^2 statistics of Mahalanobis (1936) and clustering of genotypes was done according to Tocher's method as described by Rao (1952). A dendrogram (Fig. 1) was generated using Ward's method (1963). Statistical analyses for D^2 and principal components were done using SAS 9.3 Professional Version and SPSS Professional Version 13.0.

RESULTS AND DISCUSSION

On the basis of determination of divergence, all the 16 genotypes were grouped into 5 clusters by treating estimated D^2 values as the square of the generalized distance (Table 2). Cluster I was the largest having 9 genotypes ('Bean Roshni', 'Fiesta', 'Falguni', 'Akshara', 'Anup', 'Aishwarya', 'Serengeti', 'Rani', 'Anupama'). Remaining clusters viz., cluster II contains 4 genotypes and cluster III, IV and V contained 1 genotype each. Cluster II consists of the genotypes 'NFL-35 (Suman)', 'Arka Sharath', 'Arka Arjun'

Table 3. Inter and intra-cluster distances of sixteen genotypes of French bean.

Clusters	I	II	III	IV	V
I	**420.98**	1716.72	1281.03	1829.41	2152.43
II		**83.17**	4930.76	6158.36	1828.37
III			**0.00**	229.88	4925.09
IV				**0.00**	4931.45
V					**0.00**

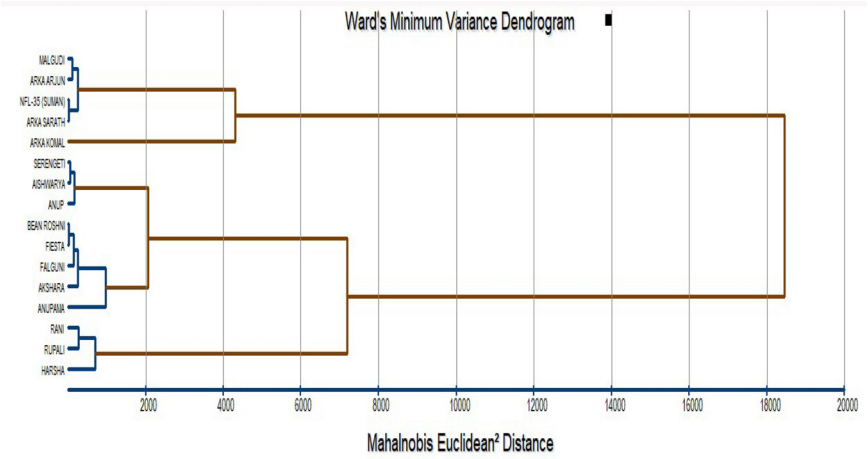

Fig. 1. Clustering pattern of different genotypes by Tocher's method.

and 'Malgudi' whereas cluster III had 'Rupali'. The genotype 'Harsha' was placed into cluster IV. Cluster V consists of genotype 'Arka Komal'. The grouping pattern of genotypes was observed to be random, indicating no direct relationship was noticed between geographical distribution and genetic distance. Hence, the selection of genotypes for hybridization should be based on genetic divergence rather than geographic diversity. Several earlier studies also reported that different set of French bean genotypes were grouped under 3-6 clusters (Arunga *et al*. 2015, Verma *et al.* 2014, Gelaw 2017, Haralayya *et al.* 2017).

Among the 5 clusters, cluster I had the maximum intra-cluster value (420.98) followed by cluster II (83.17) indicating existence of wide genetic divergence among the component genotypes in it as compared to other clusters. Minimum intra-cluster distance was noted in cluster III, IV and V (0.00). At inter-cluster level, the maximum inter-cluster value was observed between cluster II and IV (6158.36) followed by between cluster IV and V (4931.45), cluster II and III (4930.76) and cluster III and V (4925.09) indicating the genotypes included in these clusters had the maximum divergence. The minimum

Table 4. Cluster means of thirteen characters of French bean.

Character	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	% Contribution towards divergence
Plant height (cm)	39.28	44.10	44.36	35.52	41.99	15.00
Days to first flowering	35.00	31.08	39.33	40.00	31.67	10.00
Days to 50% flowering	38.41	34.67	41.33	43.00	36.33	9.17
Pod length (cm)	12.98	14.04	11.84	11.50	13.50	5.83
Pod diameter (cm)	0.67	0.92	0.58	0.55	0.80	3.33
Number of pods per plant	15.26	20.18	12.20	11.80	18.33	13.33
10 pod weight (g)	48.68	73.58	39.51	38.68	63.93	5.00
100 seed weight (g)	19.07	19.41	15.34	20.11	35.03	9.17
Number of seeds per pod	6.20	5.95	5.33	5.43	4.27	7.50
Protein content of green pod (%)	4.34	1.82	5.60	5.61	2.27	1.67
Total sugar content of green pod (%)	6.08	3.73	7.63	7.68	4.75	4.17
PDI of bean anthracnose (%)	18.11	12.26	25.40	26.75	13.76	3.33
Pod yield per plant (g)	74.06	89.58	66.05	61.39	81.17	12.50

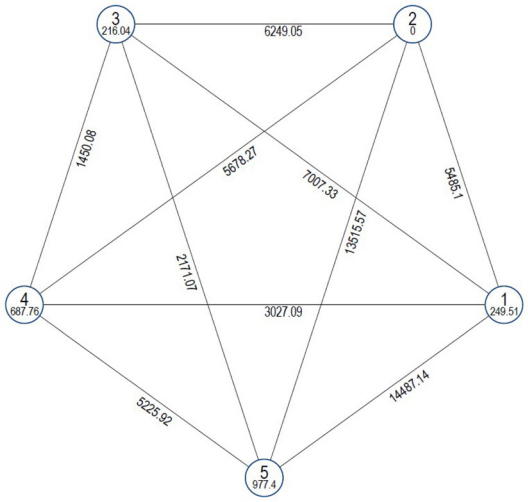

Fig. 2. Mahalanobis Euclidean distance through Tocher's method.

inter- cluster value was observed between cluster III and IV (229.88) followed by between cluster I and III (1281.03) which indicated close relationship among the genotypes included in these clusters. The average intra and inter cluster distances have been presented in Table 3. Cluster dendogram and Mahalanobis distance depicted in Figs. 1–2. Maximum inter-cluster value between cluster II and IV followed by between cluster IV and V, II and III and III and V indicated that the genotypes in these clusters can be used as parents in hybridization program to develop higher heterotic hybrids and segregating population will expect to give transgressive segregates in the advanced generation. This result corroborated with the finding of Gangadhara *et al.* (2014), Kumar *et al*. (2014), Gelaw (2017) and Haralayya *et al*. (2017) who suggested that the crosses between selected varieties from widely separated clusters are most likely to give desirable recombinants in French bean.

Table 5. Results of principal component analysis (PCA) for characters contributing to divergence in French bean.

Principal components	Eigenvalue (Root)	% Variance	% Cumulative variance
Eigenvalues and variance accounted for (%) by PCA based on correlation matrix			
PC_1	10.270	79.000	79.000
PC_2	1.275	9.812	88.812
PC_3	1.030	7.926	96.738
PC_4	0.256	1.973	98.711

The selection and choice of parents mainly depends upon contribution of characters towards divergence. Among the 13 characters, plant height (15 %) expressed the maximum contribution towards the diversity followed by number of pods per plant (13.33 %), green pod yield per plant (12.50 %), days to first flowering (10 %), days to 50 % flowering (9.17 %), 100 seed weight (9.17 %), number of seeds per pod (7.50 %), pod length (5.83 %), 10 pod weight (5 %), total sugar of green pod (4.17 %), pod diameter (3.33%), PDI of bean anthracnose (3.33%) and protein content of green pod (1.67%) presented in Table 4. Therefore, plant height, number of pods per plant, pod yield per plant, days to first flowering and days to 50% flowering would be most rewarding characters for selecting divergent genotypes in breeding program. Similarly, high contribution towards the

Table 6. Contribution of diverse traits in the principal components of French bean.

Variables	PC_1	PC_2	PC_3	PC_4
Factor loadings due to PCs with eigenvalues greater than 1				
Plant height (cm)	0.304	0.056	0.014	0.186
Days to first flowering	-0.301	-0.157	-0.114	-0.139
Days to 50% flowering	-0.305	-0.054	-0.111	0.023
Pod length (cm)	0.283	0.012	0.142	0.759
Pod diameter (cm)	0.301	0.004	-0.130	-0.292
Number of pods per plant	0.309	0.046	0.046	-0.123
10 pod weight (g)	0.303	0.040	-0.059	-0.386
100 seed weight (g)	0.099	0.777	-0.347	0.049
Number of seeds per pod	-0.104	0.318	0.852	-0.178
Protein content of green pod (%)	-0.305	-0.067	0.111	0.223
Total sugar content of green pod (%)	-0.286	0.282	-0.203	0.166
PDI of bean anthracnose (%)	-0.305	-0.054	-0.156	-0.024
Pod yield per plant (g)	0.273	-0.414	-0.068	0.078

divergence through plant height and green pod yield per plant was reported by Haralayya *et al.* (2017). On the other hand, Gangadhara *et al.* (2014) reported significant contribution of the character days to 50 % flowering towards the divergence. From the result of the present study in French bean, it is pretty clear that qualitative trait is as important as some morphological traits for measurement of genetic diversity. Similar type of results was also documented previously by Kumar *et al.* (2014).

Cluster means of 13 yield, yield contributing and quality characters were assessed and presented in Table 4. The maximum cluster mean was in cluster II for pod yield per plant (89.58) followed by 10 pod weight (73.58), number of pods per plant (20.18), pod length (14.04) and pod diameter (0.92). The trait plant height had highest (44.36) cluster mean in cluster III. The trait 100 seed weight showed highest (35.03) cluster mean in cluster V. In cluster I, the trait number of seeds per pod had highest (6.20) cluster mean. The traits protein content (5.61) and total sugar content of green pod (7.68) had highest cluster mean in cluster IV. However, minimum values regarding days to first flowering (31.08), days to 50% flowering (34.67) and PDI of bean anthracnose (12.26) revealed by the cluster II. These clusters could be useful sources of genes for simultaneous improvement of earliness, pod yield and pod quality characters. A high yielding, early flowering type with better pod quality could be breed by utilizing genotypes from cluster II and IV as parents. Similarly divergence studies were previously carried out by Mishra *et al.* (2010), Molosiwa *et al*. (2014), Walling and Chturvedi (2014), Haralayya *et al*. (2017) and Panchbhaiya *et al.* (2017).

Principal component analysis (PCA), which is a size reduction method using the data set of the studied horticultural characteristics, applied. All of the total variation has been derived from 4 principal component axis and eigen values, % variance and % cumulative variance presented in Table 5. Principal component analysis revealed highest eigen value (10.270) of first principal axis. The first principal component had 79.000 % of the total variation (PC1). The second principle component (PC2) explained 9.812% of the total variation. The third and fourth principle component had 7.926% and 1.973% of the total variation respectively. The cumulative ratio of the four primary components in total variation was 98.711%. It suggested that first four principal components are adequate to explain the variance in reduced dimension. These were interpreted as relative weight of the variables in each component. The important variables are those which have positive or negative relative weight values. Girgel (2021) reported that if the eigen values are above 1, it indicates that the evaluated principal component weight values are reliable. The first component (PC1) had high positive weight to number of pods per plant (0.309) followed by plant height (0.304), 10 pod weight (0.303) and pod diameter (0.301), while high negative weight to days to 50% flowering (-0.305), protein content of green pod (-0.305) and PDI of bean anthracnose (-0.305) followed by days to first flowering (-0.301) and total sugar content of green pods (-0.286). The second component (PC2) had high positive weight to 100 seed weight (0.777) followed by number of seeds per pod (0.318), while high negative weight to pod yield per plant (-0.414) and days to first flowering (-0.157). The third component (PC3) exhibited high positive weight to number of seeds per pod (0.852) and pod length (0.142), while negatively associated with 100 seed weight (-0.347) and total sugar content of green pod (-0.203). The contribution of diverse traits in principal components of French bean is depicted in Table 6.

It could be concluded from the principal component analysis that important variables in French bean genotypes with respect to yield contributing and quality traits were number of pods per plant, plant height, 10 pod weight, pod diameter, days to 50 % flowering, protein content of green pod, PDI of bean anthracnose, days to first flowering and total sugar content of green pods. The above variables might be taken into consideration for effective selection of parents during hybridization program. Similar kind of selection indices for French bean improvement is previously reported by Sharma *et al.* (2019), Reddy *et al.* (2021) and Girgel (2021).

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REFERENCES

Anonymous (2008) Manual on Agricultural Production Technology. Published by 'Directorate of Agriculture and Food Production, Bhubaneswar, Odisha' with technical support from Odisha University of Agriculture and Technology, Bhubaneswar, pp 69—70.

Anonymous (2020) Indian Horticulture Database. National Horticulture Board, Gurgaon, Haryana.

Arunga EE, Kinyua M, Ochuodho J, Owuoche J, Chepkoech E (2015) Genetic diversity of determinate French beans grown in Kenya based on morpho-agronomic and simple sequence repeat variation. *J Pl Breed Crop Sci* 7 (8) : 240—250.

Broughton WJ, Hernandez G, Blair NI, Beebe S, Gepts P, Vanderleyden J (2003) Beans (*Phaseolus* spp.) –Model food legumes. *Pl Soil* 252 (1) : 55—128.

Chatterjee S (2022) Yield components, nodulation and gene action in French bean (*Phaseolus vulgaris* L.). PhD thesis. Department of Vegetable Science, Bidhan Chandra Krishi Viswavidyalaya, West Bengal, pp 1—191.

Chatterjee S, Sharma S, Mukherjee D, Patil S (2018) Estimation of genetic divergence in some mid late and late cauliflower (*Brassica oleracea* var. *botrytis* L.) germplasm. *The Bioscan* 13 (2) : 459—462.

Gangadhara K, Jagadeesaha RC, Anushma PL (2014) Genetic divergence studies in French bean (*Phaseolus vulgaris* L). *Pl Arch* 14 (1) : 225—227.

Gelaw YM (2017) Genetic diversity in speckled bean (Phaseolus vulgaris L.) genotypes in Ethiopia. *J Pl Breed Crop Sci* 9 (11) : 200—207.

Girgel U (2021) Principle component analysis (PCA) of bean genotypes (*Phaseolus vulgaris* L.) concerning agronomic, morphological and biochemical characteristics. *Appl Ecol Environ Res* 19 (3) : 1999—2011.

Haralayya B, Salimath PM, Aghora TS, Adivappar N, Ganga Prasad S (2017) Genetic diversity analysis by D^2 clustering of yield and yield attributing traits in French bean (*Phaseolus vulgaris* L.). *J Pharmacog Phytochem* 6 (6) : 1331—1335.

Immaculee N (2011) Genetic diversity in French bean (*Phaseolus vulgaris* L.) germplasm lines. MSc thesis. Department of Genetics and Plant Breeding, University of Agricultural Sc Bengaluru, pp 145.

Jatav V, Singh DK, Singh NK, Panchbhaiya A (2019) Principal Component Analysis in Bitter Gourd (*Momordica charantia* L.). *Environ Ecol* 37 (1A) : 287—292.

Kumar AP, Reddy RVSK, Pandravada S, Durga RCV, Chaitanya V (2014) Genetic divergence studies in indigenous French bean (*Phaseolus vulgaris* L.) germplasm. *Pl Arch* 14 (1) : 189—192.

Mahalanobis PC (1936) On the generalized distance in statistics. *Proc Nat Inst Sci Ind* 2 : 49—55.

Mishra S, Sharma MK, Singh M, Yadav SK (2010) Genetic diversity of French bean (Bush type) genotypes in North-West Himalayas. *Ind J Pl Genet Resour* 23 (3) : 285—287.

Molosiwa OO, Kgokong SB, Makwala B, Gwafila C, Ramokapane MG (2014) Genetic diversity in terapy bean (*Phaseolus acutifolius*) landraces grown in Botswana. *J Pl Breed Crop Sci* 6 (12) : 194—199.

Naik ML, Prasad VM (2015) Studies on genetic divergence in pumpkin. *The Bioscan* 10 (4) : 2085—2088.

Panchbhaiya A, Singh DK, Verma P, Jatav V, Maurya AK (2017) Genetic analysis of French bean (*Phaseolus vulgaris* L.) germplasm through principal component analysis and D^2 cluster analysis. *J Pharmacog Phytochem* 6 (3) : 537—542.

Porch TG, Beaver JS, Debouck DG, Jackson SA, Kelly JD, Dempewolf H (2013) Use of Wild Relatives and Closely Related Species to Adapt Common Bean to Climate Change. *Agronomy* 3 (2) : 433–461.

Rao CR (1952) Advanced Statistical Methods in Biometrical Research. John Wiley and Sons, Inc Macmillan Publishing Company, New York, pp 460.

Reddy BR, Pandey M, Singh J, Rai N (2021) Principal component analysis and stability of genotypes in French bean (*Phaseolus vulgaris* L.). *Legume Res* (Online First Article) DOI: 10.18805/LR-4569.

Shanmugavelu KG (1989) Production Technology of Vegetable Crops. Oxford and IBH Publishing Co Pvt Ltd, New Delhi, pp 461.

Sharma R, Jabeen N, Sofi PA (2019) Principal component analysis for assessment of variability in phonological and morphological traits in French bean (*Phaseolus vulgaris* L.). *Elect J Plant Breed* 10 (4) : 1569—1575.

Ullah MZ, Hassan L, Singha T, Patwary AK (2015) Genetic divergence in tomato lines (*Solanum lycopersicum* L.). *J Bangladesh Agric Univ* 13 (1) : 61—64.

Vavilov NI (1951) The Origin, Variation, Immunity and Breeding of Cultivated Plants. *Chron Bot* 13 : 1—366.

Walling B, Chaturvedi HP (2014) Genetic diversity in French bean (*Phaseolus vulgaris* L.) genotypes of Nagaland. *Ind Res J Genet Biot* 6 (3) : 535—538.

Ward JH (1963) Hierarchical Grouping to Optimize an Objective Function. *J Am Stat Assoc* 58 (301) : 236—244.

Yarnell SH (1965) Cytogenetics of vegetable crops IV. legumes. *Bot Rev* 31 : 247—303.