The Bioscan 12(1): 317-322, 2017 (Supplement on Agronomy)
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
www.thebioscan.com

STUDIES ON DIVERGENCE AND STABILITY IN FRENCH BEAN (*PHASEOLUS VULGARIS* L.) UNDER EAST AND SOUTH EASTERN COASTAL PLAIN ZONE OF ODISHA

AMITABH PANDA[1]*, AMITAVA PAUL[1] AND PREMANANDA MOHAPATRA[2]
[1,2]Department of CIHAB,
Palli Siksha Bhavana (Institute of Agriculture), Visva-Bharati, Sriniketan,West Bengal - 731 236, INDIA
[2]Department of Vegetable Science, O.U.A.T., Bhubaneswar, Odisha - 751 003, INDIA
e-mail: amitabhp70@gmail.com

KEYWORDS
Divergence
Stability
French bean
Genotype × environment interactions

Received on : 10.11.2016

Accepted on : 19.02.2017

***Corresponding author**

ABSTRACT

Twenty eight genotypes of French bean were evaluated during Rabi seasons of 2011 and 2012 at four locations of district Nayagarh in Odisha under eight environments for analysis of diversity and stability analysis for green pod yield and other yield contributing traits using Mahalanobis D^2 model and Eberhart and Russel model. The genotypes were grouped into seven clusters based on D^2 model indicating that the genetic diversity was not fully associated with geographic diversity. Among the clusters, maximum number of genotypes (9) were included in cluster I followed by cluster II (8). The study revealed that plant height contributed maximum towards total divergence. The genotype X environment interaction was significant for the traits such as plant height, number of pods per plant and pod yield per plant. Genotype Arka Anoop was found stable for three traits *i.e.* number of pods per plant, single pod weight and pod yield per plant. Considering the D^2 analysis and stability , crossing among the genotypes of cluster II (Arka Anoop, FB-53) and the genotypes of cluster IV (HAFB-1, HAFB-5, HAFB-6) may be made to produce stable segregants.

INTRODUCTION

French bean (*Phaseolus vulgaris* L.2n=2X=22), family Fabaceae, also known as snap bean, kidney bean, garden bean or string bean is the most important leguminous vegetable crop (Singh, 1999) grown for its tender fleshy green pods, shelled green seeds and also dry bean (Rajmash). It originated from a wild form, of which *P. aborigineus* is a modern survivor (Evans, 1976). It is native to Central America and Peruvian Andes in South America (Kaplan, 1965). As per FAO estimates, it is cultivated in an area of 28 mha, with annual production of 20 mt., with average productivity of 0.72t ha^{-1}in world (FAO STAT. 2008). In India, it is mainly grown in Jharkhand, Maharashtra, Karnataka, West Bengal, Himachal Pradesh, Odisha, Uttar Pradesh, Punjab, Haryana, Andhra Pradesh, Tamil Nadu in an area of 0.15 mha with annual production of 0.42mt and productivity of 2.8t ha^{-1} compared to China (26t ha^{-1}) (FAO, 2002). In Odisha, it is cultivated in 11.01'000ha area, production 50.9'000mt, productivity 4.52tha^{-1} (Anonymous, 2012).

French bean otherwise called as "the meat of the poor" provides a wide range of variability, diversity with a tremendous scope for genetic studies and improvement. Diversity in the genotypes is essential in order to create variability. Further, selection of parents for the purpose of breeding depends upon the existence of genetic diversity and its assessment is very much helpful in improvement of quantitative traits (Govankoppa *et al.,* 2002). In this regard, D^2 statistics has been extensively used to measure the genetic divergence in breeding programmes (Mahalanobis, 1928). Selection for yield is based on phenotype, which is highly influenced by genotype X environment (GXE) interaction (Reddy *et al.*, 2011). GXE interaction plays a key role for stabilizing genotypes across the environments with high yield potential. The present study was undertaken to identify diverse genotypes with stable performance for yield and other morphological traits for breeding and to obtain desirable segregants through selection in the advance generations.

MATERIALS AND METHODS

The present investigation was undertaken during Rabi seasons of 2011 and 2012 at four locations of district Nayagarh in Odisha (20°24'N,85°12'E,90m above msl) in a total of eight environments. The experimental material comprised of twenty eight genotypes of french bean consisting of released and pre-released lines obtained from five states of India. The experiment was laid out in a randomized block design with three replications in each of the four environments over both the growing seasons. The seeds of each genotype were sown on 2 rows of 3 m. long keeping plant to plant and row to row spacing of 15 cm. and 50 cm. respectively. All the recommended package of practices was followed during the crop season for raising a healthy crop. Harvesting of pods was done at tender stage in three pickings.

The data on horticultural traits like days to 50% flowering (number), days to 1st green pod picking (number), plant height (cm.), number of primary branches per plant (number), number of secondary branches per plant (number), basal internodal length (cm.), basal internodal diameter (cm.), green pod length (cm.), green pod width (cm.), green pod breadth (cm.), number of pods per plant, single pod weight (g.), pod yield per plant (g.) were recorded using standard procedures.

Genetic diversity was studied using D^2 statistics of Mahalanobis (1928) and populations were grouped into clusters by following the method as suggested by Rao (1952). The stability analysis was done as per Eberhart and Russel model (1966). This model has three parameters namely mean (X), regression coefficient (b_i), and mean square deviation from regression (S^2d_i).While X provides a measure of performance of the genotypes as compared to other entries, b_i is a measure of responsiveness to environment and S^2d_i as a measure of stability. The data collected on different parameters were subjected to appropriate statistical analysis using SPAR programme.

RESULTS AND DISCUSSION

Diversity

The total list of genotypes along with their sources of collection is depicted in Table 1. The details of morphological features are described in table 2. Analysis of variance (ANOVA) showed highly significant differences among the 28 genotypes for all the thirteen traits studied. The genotypes were grouped into seven clusters. Among the clusters, maximum number of genotypes (9) were included in cluster I followed by cluster II (8), cluster III (4), cluster IV (3), cluster V (2). Cluster VI & VII were monogenotypic cluster consisting of one genotype each indicating their independent identity and importance due to various unique characters possessed by them. The formation of largest cluster I comprising 9 genotypes might be due to a free flow (or) exchange of breeding material from one place to another (Suneetha *et al.*, 2013).

The present pattern of grouping of genotypes indicated that the genotypes have grouped or diverged into different clusters irrespective of their geographical origin which means that the genetic constitution of the varieties was more dominant than their geographical origin while forming a cluster (Choubey *et al.,* 2003, Singh, 2006).This kind of genetic diversity was recorded among the genotypes belonging to the same geographic origin might be due to differences in adoption, selection pressure and selection criteria, and environmental condition (Gokulkrishnan *et al.*, 2012). Therefore, choice of the parents for hybridization should be decided on the basis of genetic diversity rather than geographic diversity (Nance *et al.,* 2013).Inter cluster distance values were greater than intra-cluster distance value suggesting heterogeneous and homogeneous nature of the strains between and within the clusters respectively(Isha *et al.*, 2015) (Table 3). The highest inter cluster distance value was observed between cluster V and VII, followed by IV andVI. Based on the above studies, it could be suggested that crosses involving genotypes from divergent clusters (V and VII, IV and VI, IV and VII, III and V) are likely to exhibit high heterotic expression for yield components and wider segregation in fillial

Table 1: List of genotypes along with sources of collection

Sl No.	Name of genotypes	Source
01	HAFB-1	ICAR RES.COMPLEX FOR EASTERN REGION, Ranchi
02	FAB Var-2	UAS, Dharwad
03	FAB Var-3	UAS, Dharwad
04	HAFB-2	ICAR RES.COMPLEX FOR EASTERN REGION, Ranchi
05	HAFB-5	ICAR RES.COMPLEX FOR EASTERN REGION, Ranchi
06	FAB Var-6	UAS, Dharwad
07	HAFB-6	ICAR RES.COMPLEX FOR EASTERN REGION, Ranchi
08	PDR-14	IIVR, Varanasi
09	FB-53	UAS, Dharwad
10	Arka Anoop	IIHR, Bangalore
11	Arka Suvidha	IIHR, Bangalore
12	VL Bean-2	VPKAS, Almora
13	Pant Anupam	GBPUAT, Pantnagar
14	VL Bean-1	VPKAS, Almora
15	Contender	VPKAS, Almora
16	Almora Local -1	VPKAS, Almora
17	Almora Local -2	VPKAS, Almora
18	VL Bean-3	VPKAS, Almora
19	HAPB-4	ICAR RES.COMPLEX FOR EASTERN REGION, Ranchi
20	Swarna Lata	ICAR RES.COMPLEX FOR EASTERN REGION, Ranchi
21	HAFB-4	ICAR RES.COMPLEX FOR EASTERN REGION, Ranchi
22	Swarna Priya	ICAR RES.COMPLEX FOR EASTERN REGION, Ranchi
23	HAFB-3	ICAR RES.COMPLEX FOR EASTERN REGION, Ranchi
24	Arka Sharat	IIHR, Bangalore
25	Kashi Param	IIVR, Varanasi
26	IIHR-4	IIHR, Bangalore
27	HUR-137	IIVR, Varanasi
28	Arka Komal	IIHR, Bangalore

Table 2: Salient features of genotypes

Sl No.	Name of genotypes	Growth Habit	Leaf Colour	Leaf Size	Flower Colour	Tender Pod Colour	Green Pod Shape	Green Pod Curvature	Green Pod texture	Green Pod Stringiness
1	HAFB-1	Bush	Green	Medium	White	Light Green	Round	Straight	Smooth	Present
2	FAB Var-2	Bush	Light Green	Medium	White	Light Green	Round	Straight	Smooth	Absent
3	FAB Var-3	Bush	Green	Medium	White	Light Green	Round	Straight	Rough	Present
4	HAFB-2	Bush	Green	Medium	White	Light Green	Round	Straight	Rough	Absent
5	HAFB-5	Bush	Green	Medium	White	Dark Green	Flat	Curved	Smooth	Present
6	FAB Var-6	Bush	Dark Green	Medium	Pink	Light Green	Round	Straight	Smooth	Present
7	HAFB-6	Bush	Dark Green	Big	White	Green	Round	Straight	Smooth	Present
8	PDR-14	Bush	Green	Medium	Light Pink	Dark Green	Round	Straight	Smooth	Absent
9	FB-53	Bush	Green	Big	Pink	Green	Round	Straight	Rough	Absent
10	Arka Anoop	Bush	Light Green	Medium	White	Light Green	Flat	Curved	Rough	Present
11	Arka Suvidha	Bush	Light Green	Small	Light Pink	Light Green	Flat	Straight	Rough	Absent
12	VL Bean-2	Bush	Green	Medium	Pink	Green	Round	Curved	Rough	Present
13	Pant Anupam	Bush	Green	Medium	White	Light Green	Round	Straight	Smooth	Absent
14	VL Bean-1	Bush	Light Green	Medium	White	Light Green	Round	Straight	Smooth	Absent
15	Contender	Bush	Green	Small	Pink	Green	Round	Straight	Smooth	Absent
16	Almora Local -1	Bush	Green	Medium	Pink	Green	Round	Straight	Smooth	Absent
17	Almora Local -2	Bush	Green	Medium	Pink	Green	Round	Straight	Smooth	Absent
18	VL Bean-3	Bush	Light Green	Medium	Pink	Light Green	Round	Curved	Smooth	Absent
19	HAPB-4	Bush	Light Green	Medium	White	Light Green	Round	Curved	Smooth	Present
20	Swarna Lata	Pole	Green	Small	Pink	Green	Flat	Curved	Smooth	Present
21	HAFB-4	Pole	Green	Medium	Pink	Light Green	Round	Curved	Smooth	Present
22	Swarna Priya	Bush	Green	Small	Pink	Green	Round	Curved	Rough	Present
23	HAFB-3	Bush	Green	Small	Pink	Green	Round	Curved	Smooth	Absent
24	Arka Sharat	Bush	Green	Small	Light Pink	Light Green	Round	Straight	Smooth	Absent
25	Kashi Param	Bush	Green	Small	Pink	Green	Round	Straight	Smooth	Present
26	IIHR-4	Bush	Light Green	Medium	White	Light Green	Flat	Straight	Rough	Present
27	HUR-137	Bush	Dark Green	Big	Light Pink	Light Green	Flat	Curved	Rough	Present
28	Arka Komal	Bush	Dark Green	Medium	Light Pink	Green	Flat	Straight	Rough	Present

Table 3: Average intra-cluster (diagonal) and inter-cluster distance (D^2 values) among 7 clusters of 28 french bean genotypes

Cluster	I(9)	II(8)	III(4)	IV(3)	V(2)	VI(1)	VII(1)
I	71.762	175.341	90.845	448.164	627.415	158.765	157.308
II		67.446	248.683	149.606	544.938	451.540	372.457
III			67.359	557.371	712.793	127.296	140.245
IV				70.704	624.710	862.562	751.796
V					52.259	623.664	1022.579
VI						0.000	233.201
VII							0.000

Table 4: Stability analysis of variance of mean data for five traits in French bean

Source	D.F.	Plant Height	Green Pod Length	Number of Pods/ Plant	Single pod weight	Pod yield/ plant
Genotypes	27	2687.72**	34.66**	224.36**	13.06**	11829.37**
Envronments	7	657.12**	9.83**	17.22**	9.62**	4874.00**
Genotype x Environment	189	7.91**	0.90	3.29**	0.68	339.77**
Env. + Gen.xEnv.	196	31.09**	1.22	3.79**	1.0	501.71**
Environment(Linear)	1	4599.85**	68.81**	120.54**	67.36**	34118.64**
Genotypex Environment(Linear)	27	13.29**	2.87**	4.40**	2.09**	938.68**
Pooled Deviation	168	6.76**	0.56	3.0**	0.43	231.38**
Pooled Error	432	4.22	0.25	1.48	0.17	85.33

*P=0.05, **P=0.01

generations(Prajapati *et al*., 2015). Similar lines of observations were obtained by Patel *et al.,* (2011). The results also indicated that genotypes specifically from Ranchi had higher genetic distance with other genotypes.

Figures in parentheses indicate number of varieties in the respective cluster. Diagonal values indicate intra-cluster distance. Bold figures indicate maximum and minimum (inter-cluster/intra-cluster) values.

Stability

For stability analysis, promising yield contributing traits such as plant height, pod length, number of pods per plant, single pod weight and pod yield per plant were considered. The analysis of variance of pooled data (Table 4) indicated highly significant differences among the genotypes for all the characters suggesting presence of considerable amount variation among the genotypes. Mean squares due to environments were also highly significant for all the characters indicating that the environments were diverse. The genotype X environment interaction was significant for the traits such as plant height, number of pods per plant and pod yield per plant indicating that the genotypes interacted considerably to

Table 5: Stability parameters for yield and its contributing traits in French bean

Genotype	Plant Height			Green pod length			Number of pods/ plant			Single pod weight			Pod yield/plant		
	X	Bi	S2di	X	Bi	S2di	X	Bi	S2di	X	Bi	S2di	X	Bi	S2di
HAFB-1	77.43	3.44*	-0.83	17.74	-2.57*	-0.74	23.56	-0.42	3.15**	9.39	-0.56	-0.08	194.78	1.30	180.21
FAB VAR-2	63.58	-0.59	2.42	12.85	5.54**	1.00	10.60	1.95	-0.48	8.96	5.23**	0.36	87.00	1.85*	-9.93
FAB VAR-3	54.30	-3.58*	-0.75	13.51	0.46	1.58	11.09	-0.48	1.66	7.85	3.50*	-0.30	83.05	1.05	97.84
HAFB-2	49.12	-4.38**	-0.85	11.15	-0.01	2.60*	11.10	0.85	1.30	7.32	2.92*	-0.02	71.92	1.52	1.69
HAFB-5	65.40	-0.18	-0.68	16.48	-4.03**	-0.87	25.26	4.18**	-.48	7.10	1.33	-0.16	158.61	2.49**	-35.98
FAB VAR-6	59.98	2.83*	-0.76	14.99	-0.05	1.57	17.11	0.86	-0.53	7.21	-1.55	2.61*	108.70	0.51	165.46
HAFB-6	73.06	-0.60	-0.77	16.46	-2.80*	-0.66	18.96	0.14	-0.68	9.33	3.50*	1.51	154.95	2.25**	-23.38
PDR-14	57.04	-3.60*	-0.76	10.74	3.17*	-0.11	6.98	-0.49	-0.89	7.68	1.19	2.60*	47.75	0.82	-65.79
FB-53	66.71	-0.86	-0.72	14.74	0.43	-0.75	19.66	-0.65	1.75	6.40	1.32	4.63**	108.85	1.54	31.42
ARKA ANOOP	67.27	-1.21	8.04**	13.41	-1.76	-0.70	17.75	0.87	-0.52	8.26	0.94	0.35	128.47	1.65	50.89
ARKA SUVIDHA	52.05	0.07	-0.13	16.89	-3.28*	-0.85	10.54	1.79	-0.88	9.33	2.61*	-0.52	84.66	0.56	-14.76
VL BEAN-2	66.26	-1.56	0.68	12.58	-0.52	-0.97	21.87	3.89**	0.35	7.26	3.75**	-0.26	136.44	2.28	328.14**
PANT ANUPAM	46.97	-0.12	1.44	11.54	3.87**	1.32	10.27	-0.05	1.35	6.40	-0.75	1.74	59.08	-0.38	93.78
VL BEAN-1	45.80	-0.25	7.69**	12.36	-1.49	1.22	7.18	-1.97	-0.51	8.68	2.63*	1.20	62.03	0.53	204.56*
CONTENDER	61.17	4.74**	-0.70	15.08	-0.77	4.51**	13.56	-0.09	5.85	8.51	-1.09	8.36**	99.22	0.11	11**27.09
ALMORA LOCAL -1	48.32	2.57*	-0.40	12.33	-0.40	4.79**	8.42	-0.57	0.33	7.50	-1.27	5.20**	58.30	0.22	178.48
ALMORA LOCAL -2	46.15	-0.29	0.29	12.61	-2.29	-0.66	7.53	-0.65	1.10	6.61	-1.25	1.94	44.36	-0.16*	41.93
VL BEAN-3	64.16	-1.07	-0.37	13.56	0.92	4.98**	12.52	-0.36	2.12*	8.71	2.58*	-0.95	85.24	-0.15	330.00**
HAPB-4	51.87	0.67	1.23	14.39	0.59	2.06	8.26	-0.63	1.35	7.92	-1.22	3.15**	58.30	0.01	212.78*
SWARNA LATA	121.76	2.24	2.58*	16.88	-0.86	-0.69	13.90	2.94*	-0.68	8.82	1.31	0.15	108.82	1.73*	-8.89
HAFB-4	108.28	4.02**	-0.76	15.36	-0.08	3.09**	12.76	2.70*	-0.37	7.50	-1.18	5.33**	83.82	1.00	137.95
SWARNA PRIYA	46.20	-1.73	-0.71	14.40	-0.06	4.41**	13.22	0.01	0.77	6.75	-1.12	5.37**	78.88	0.43*	-32.53
HAFB-3	42.03	-0.86	3.60**	10.17	-2.01	4.50**	12.42	-0.18	7.33**	6.45	-0.63	5.03	72.77	0.31	744.20**
ARKA SHARAT	46.66	3.56**	-0.19	15.15	0.25	1.88	14.79	1.39	-0.49	5.73	0.21	-0.61	75.07	1.07	-31.98
KASI PARAM	62.37	1.35	0.50	13.77	-0.16	-0.49	22.58	0.95	1.42	4.78	-1.83	-0.27	95.08	1.08	-25.94
IIHR-4	35.94	-1.83	0.77	10.42	3.09	2.95**	10.38	-0.74	3.84**	4.67	1.04	-0.81	44.25	0.35	47.74
HUR-137	61.47	-1.51	0.34	14.89	0.24	-0.62	17.67	-0.49	2*.15	7.56	1.42	1.51	120.74	1.23	368.90**
ARKA KOMAL	62.96	-0.54	-0.43	15.89	-2.85*	-0.90	19.91	-0.65	0.44	8.70	2.87*	-0.46	154.84	1.72*	-10.00
Grand Mean				13.94			14.28			7.55					

*P=0.05, **P=0.01, X=Mean, b_i=Regression coefficient, S^2d_i=Deviation from regression

environmental conditions in different years. Similar results were reported by Pan *et al.*, 2006, Pan *et al.*, 2009.

Component analysis of environment + (genotype X environment) interactions were highly significant for all the traits except pod length and single pod weight indicating that there was significant interaction between genotype and environment. This component of variation was divided into linear and non- linear components. Highly significant mean squares due to environment (linear) for all the characters indicated considerable differences among the environments and their predominant effects on the characters. This was due to variation in weather conditions during different years and locations. The mean squares due to the (GXE) (linear) were significant for all the characters revealing that the behavior of the genotypes could be predicted over the environments more precisely and accurately as the GXE interaction was the outcome of the linear function of the environmental components. The non-linear component (pooled deviation) showed highly significance for plant height, number of pods per plant and pod yield per plant indicating non- linear response of the genotypes due to environmental changes .Thus the performance of the genotypes with respect to the characters which showed significance for pooled deviation was entirely unpredictable in nature (Reddy *et al.*, 2011).Thus, for the traits such as plant height, number of pods per plant and pod yield per plant ,both predictable (linear)and unpredictable (non-linear) components contributed significantly, for other characters only linear components were important. Further, it confirmed the contribution of the non-linear component to the total GXE interaction for them.

As per Eberhart and Russel model (1966), an ideal stable genotype is one which possesses high mean (X), unit regression coefficient (b_i), with lowest deviation from regression (S^2d_i). The stability analysis is given trait wise (Table 5).

Plant height

The mean performance of the genotypes ranged from 35.94 to 121.76 with population mean 60.87. Out of twenty eight genotypes, nineteen genotypes had $b_i=1$ *i.e.* near to unity showing average response to the environment. Seven genotypes had $b_i>1$ showing their better adaptation to favourable environment. Nineteen genotypes had $b_i<1$ indicating suitability under poor environment. Twenty four genotypes had $S^2d_i=0$ (close to zero) indicating consistent performance over all the environments. Considering high mean (more than population mean), $b_i=1$, $S^2d_i=0$, only one genotype *i.e.* Kashi Param was selected as showing stable performance over eight environments (Lal *et al.*, 2013).

Green pod length

A wide variability in the mean performance of the genotypes shown from 10.17 to 17.74 with population mean 13.94. Out of twenty eight genotypes, twenty genotypes had $b_i=1$ *i.e.* near to unity showing average response to the environment. However, four genotypes namely FAB Var-2, PDR-14, Pant Anupam and IIHR-4 had $b_i>1$ showing their better adaptation to favourable environment. Twenty four genotypes had $b_i<1$ showing their response to poor environment. Twenty genotypes had $S^2d_i=0$ (close to zero) indicating consistent performance over all the environments. As per the model, high mean (more than population mean), $b_i=1$, $S^2d_i=0$, none of the genotypes was selected as showing stable performance over eight environments.

Number of pods/plant

The genotypes showed wide variation for this trait with mean ranging from 6.98 to 25.27 with population mean 14.28. Out of twenty eight genotypes, twenty genotypes had $b_i=1$ *i.e.* near to unity showing average response to the environment. However, seven genotypes had $b_i>1$ showing their better adaptation to favourable environment. Eighteen genotypes had $b_i<1$ showing their better adaptation in unfavorable environment. Five genotypes had $S^2d_i=0$ (close to zero) indicating consistent performance over all the environments. Considering high mean (more than population mean),$b_i=1$, $S^2d_i=0$, two genotypes *i.e.* Arka Anoop and Kashi Param were selected as showing stable performance over eight environments.

Single pod weight

The mean performance of the genotypes ranged from 4.67 to 9.39 with population mean 7.55. Out of twenty eight genotypes, nineteen genotypes had $b_i=1$ *i.e.* near to unity showing average response to the environment. However, more number of lines as fourteen genotypes had $b_i>1$ showing their better adaptation to favourable environment. Thirteen genotypes had $b_i<1$ showing their response to poor environment. Twenty genotypes had $S^2d_i=0$ (close to zero) indicating consistent performance over all the environments. Considering high mean(more than population mean), $b_i=1$, $S^2d_i=0$, only one genotype *i.e.* Arka Anoop was selected as showing stable performance over eight environments for single pod weight.

Pod yield per plant

The mean performance of the genotypes ranged from 44.26 to 194.78 with population mean 95.21. Out of twenty eight genotypes, twenty one genotypes had $b_i=1$ *i.e.* near to unity showing average response to the environment. However, eleven genotypes had $b_i>1$ showing their better adaptation to favourable environment. Thirteen genotypes had $b_i<1$ showing their response to poor environment. Twenty one genotypes had $S^2d_i=0$ (close to zero) indicating consistent performance over all the environments. Considering high mean (more than population mean), $b_i=1$, $S^2d_i=0$, only two genotypes such as Arka Anoop and FB-53 were selected as showing stable performance over eight environments.

It was reported that no generalization can be made with regard to the stability of genotypes for all the characters (Singh and Singh,1980). In the present study, none of the genotypes showed uniform stability and linear response pattern for all the traits. However, the overall stability may be considered on the basis of compensation pattern of different traits (Gangopadhyay *et al*., 2012).However, Arka Anoop was found stable for three traits i.e.number of pods per plant, single pod weight and pod yield per plant. Another genotype Kashi Param was found stable for plant height and number of pods per plant and FB-53 for pod yield per plant. Since the yield stability is inherited, the stable genotypes could be utilized in future breeding programmes to incorporate genes for stability through' hybridization. The stable genotypes identified could be exploited as parents in hybridization programme for developing the suitable varieties with wider adaptability (Singh *et al*., 2015).It is noteworthy to mention that one genotype namely Almora Local-2 was found to possess lower mean than population mean, b_i value lower than 1 and $S^2d_i=0$ for all the traits indicating stability and suitability for low fertility situation. This is the case of Indian farming, where farmer generally prefers a genotype which gives him assured income under precarious situations such as drought(Reddy *et al*., 2011).

From the above study, it was revealed that none of the genotypes was found to be stable over all the environments for all the characters studied. However, Arka Anoop was found stable for three traits *i.e.* number of pods per plant, single pod weight and pod yield per plant. Another genotype Kashi Param was found stable for plant height and number of pods per plant and FB-53 for pod yield per plant. Since the stability in yield is inherited, the stable genotypes could be utilized in future breeding programmes to incorporate genes for stability through' hybridization (Singh *et al*., 2015).

D^2 and stability

The three genotypes selected on the basis of stability for different characters belong to cluster II (Arka Anoop, FB-53) and cluster III (Kashi Param) as per D^2 analysis. Among these, Arka Anoop (128.48) and FB-53(108.85) possessed higher mean pod yield per plant than population mean (95.21).

Considering the D^2 analysis , stability of yield and yield contributing traits, crossing among the genotypes of cluster II (Arka Anoop, FB-53) and the genotypes of cluster IV(HAFB-1,HAFB-5,HAFB-6) may be made to produce enough genetic variability for selecting high yielding and stable segregants in the following fillial generations(Mishra and Dash 1997).

REFERENCES

Anonymous, **2012**. NHB Database, 2011-12. National Horticulture Bold. Gurgaon (online).

Asha ,I. S., Haralayya,B., Gangaprasad, S., Netravati and Salimath,P. M.2015. Analysis of Genetic Divergence in Okra [*Abelmoschus esculentus* (L.) MOENCH], *The Ecoscan*. Special issue, Vol. **VII**: 35-39

Choubey, P. K., Singh, S. P. and Chaubey,T. 2003. Genetic divergence in Rajmash(*P.vulgaris* L.).*Vegetable Science*. **30(2):** 190-191.

Eberhart, S. A. and Russel, W. A. 1966. Stability parameters for comparing varieties. *Crop Sci*. **6:** 36-40.

Evans, A. M. 1976. Evolution of crop plants.(Ed.),N. W. Simmonds, Longmann, London,pp. 168-172.

FAO. 2002. FAO Bulletin of statistics, Food and Agricultural Organisation of the United Nations, Rome, **3(2):** 104.

FAOSTAT. 2008.Food and Agricultural Organisation Statistics. Available from http://www.faostat.org.

Gangopadhya, K. K., Tahlan, S. K., Saxena, R. P., Mishra, A. K.,Raiger, H. L.,Yadav,S. K., Kumar, G., Arivalagan,M. and Dutta, M. 2012. Stability analysis of yield and its component traits in fenugreek germplasm. *Indian J.of Horticulture*. **69(1):** 79-85.

Gokulakrishnan, J., Kumar, B. S. and Prakash, M. 2012. Studies on genetic diversity in mung bean (*Vigna radiata* L.). *Legume Research*.**35(1):** 50-52.

Govanakoppa, R. B., Hosmani, R. M. and Salimath, P. M. 2002. Genetic diversity in French bean under moisture stress condition. *Vegetable Science*. **29(1):** 37-39.

Kaplan, L. 1965. Archaeology and domestication in America *Phaseolus* bean. *Econ. Bot.*, **19**:358.

Lal, H., Rai, M., Verma, A.,Vishwanath., 2005. Analysis of genetic divergence of dolichos bean (*Lablab purpureus*) genotypes.*Vegetable science.* **32(2):** 129-132.

Lal, M., Singh, K. P. and Singh, D. 2013. Phenotypic stability for seed yield and its components characters in mungbean (*Vigna radiate*.(L) WILCZEK) *Legume Research*.**26(6):** 484-488.

Mahalanobis, P.C. 1928. A statistical study at Chinese head measurement. *J. Asiatic Society, Bengal*. **25:** 301-377.

Mishra, D. and Dash, S. K. 1997.Genetic diversity and stability in aromatic rice *(Oryza sativa). Indian J. Agricultural Sciences.* **67(l):** 27-9.

Nancee, Rana M. K., Partap, P. S. and Ranjan R. 2013. Study of genetic divergence in vegetable cowpea. *Vegetable Science*. **40(2):** 182-184.

Pan, R. S., Singh, A. K., Kumar, S. and Rai, M. 2009. Stability of yield and its components in bush type French bean under off season (summer) cultivation. *Vegetable Science*. **36(1):** 35-38.

Pan, R. S., Singh, A. K., Rai, M. and Kumar, S. 2006. Stability analysis of yield and its components in bush type French bean. *Vegetable Science*. **33(2):** 145-148.

Patel, K. L., Sharma, G. L., Mehta, N. and Sarnaik, D. A. 2011. Correlation and path analysis in Dolichos bean (*Dolichos lablab* L.) for Chhattisgarh Plains. *J. Soils and Crops*. **21(2):** 188-195.

Prajapati, S., Raghuwanshi, O. and Dangi A. S. 2015. Genetic Divergence Studies for Fruits Yield and Quality Components in Diverse Tomato (*Solanum lycopersicon* L.) Genotypes. *The Ecoscan*, Special issue, Vol. **VII:** 77-83.

Rao, C. R. 1952. Advanced Statistical Methods in Biometrical Research, *John Wiley and Sons.* New York. Hafner Press.

Reddy, D. K. R., Venkataswaralu, O., Obaiah, M. C. and Shiva Jyothi, G. L. 2011. GenotypeX Environment interaction for grain yield and its components in Red gram(*Cajanus cajan* (L.) MILLSP), *Legume Research*.**34(4):** 288-291

Singh, S. P. 1999. Improvement of small-seeded race Mesoamerican cultivars. (In) *Common Bean Improvement in the Twenty-first Century*. pp. 225-74. Singh S P, Kluwer, Dordrecht

Singh, A. K. 2006. Genetic divergence in French bean (*P. vulgaris* L.).*Vegetable Science.* **33(1):** 103-105.

Singh, J., Kumar, A. and Fiyaz, R. A. 2015. Diversity and stability analysis for yield component traits in *Cajanus cajan* under rainfed conditions. *Legume Research*.**38(2):** 169-173.

Singh, R. B. and Singh, S. V. 1980. Phenotypic stability of durum and bread wheat for grain yield. *Indian J. of Genetics*. **40:** 86-92.

Suneetha, N., Vasanthi, R. P., Sudhakar P. and Reddy, K.R. 2013. Genetic diversity analysis among released and pre released cultures in groundnut. *Legume Research.* **36(3):** 208-213.