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YIELD-STABILITY DIFFERENCES AMONG FRENCH BEAN (*PHASEOLUS VULGARIS* L.) GENOTYPES UNDER NORTH-WESTERN HIMALAYAN CONDITIONS

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ABSTRACT

Selection of stable and high yielding genotypes is important not only for increasing the agricultural production but also to use in regular breeding programme. Twenty seven French bean genotypes were evaluated in three different agro-ecological zones of Himachal Pradesh comprising four environments to study their stability in performance. Genotype × environment interaction was significant for majority of the traits. The coefficient of determination was observed to be due to linear responses of each genotype to environmental fluctuations for majority of the traits. The genotypes 'DPDFB-2 (M)', 'IVFB-2', 'MFB-3' and 'VLFB-130'were stable for early flowering(*bi* d″ 1and lesser number of days to flowering than the population mean). The genotypes 'DWDFB-53', 'IVFB-2' and 'MFB-4' were the most prospective genotypes under varied environmental conditions because of their stable (*bi* d″ 1) and high fresh pod as well as seed yieldthan the population mean. Further, based upon the stability parameters, genotypes namely, 'Arka Suvidha', 'DWDFB-1', 'DWDFB-53', 'IVRFB-1', 'IVFB-1', 'MFB-3' and 'MFB-4' were foundstable across the environments for majority of traits and can be recommended for cultivation.Besides, they can be used in hybridization programme to develop high yielding varieties with stability in their performance.

INTRODUCTION

French bean (*Phaseolus vulgaris* L.) is one of the most important leguminous vegetables, which is grown for fresh pod consumption and for processing as a frozen vegetable in many countries (Biswas *et al.,* 2010).It is an annual, diploid (2n = 2x = 22) species derived from wild ancestors distributed from northern Mexico to north western Argentina (Galvan *et al*., 2003) and regarded as "grain of hope" as it is an important component of subsistence agriculture and offer an alternative for diversification of agricultural system (Sofi *et al.,* 2011). But, despite continuous breeding efforts, its average yield is low due to unsuitable cultivars, biotic and abiotic stresses, genetic drift in the cultivars and development of new pathogen races.

Further, genotype-environment interaction is a major challenging issue for plant breeders in dealing with instability and uncertainty of yield and in the development of improved cultivars for wide range of cultivation (Raffi *et al.,* 2004) and that phenotypic response to change in environment is different among genotypes (Sabah *et al*., 2007).The effect of environmental variation on genotype performance suggests that genotype selection is not possible from one environment (either year or location) but that genotypes must be evaluated in diverse environments (Ortiz and Izquierdo, 1994) and thus indicates its importance in developing improved varieties (Akhtar *et al.,* 2010). Generally, genotypes with consistent yield over many environments are preferred to those with high yield in selected environments. It is imperative to select cultivars which are adapted to unpredictable environmental fluctuations by raising them over the locations and years. The cultivars for specific purpose are determined on the basis of interaction of genotypes with predictable environment (Shree *et al.,* 2014). This allows the assessment of G×E interaction and selection of desirable germplasm.Genotypes which interact less with the environments are selected and it aids the breeders to greater extent in developing stable and high yielding genotypes. This inturn help in increasing and stabilising the agricultural production along with utilization in the regular breeding programme (Ali and Sarwar, 2008).The identification of stable and high yielding lines is of urgent need for commercial exploitation at farmer's field for boosting up the production and productivity of French bean.

The responses of genotypes to variable productivity levels among environments provide an understanding of the stability of performance. Genotype x Environment interaction parameters have been reported to be useful for measuring adaptability by various workersin French bean namely, Pan *et al*. (2006), Pan *et al*. (2009), Sharma (2010) and Razvi *et al*. (2011) besides also in other beans *e.g*. Raffi *et al*. (2004) in dry beans and Dhillon *et al*. (2009) in soybean.Keeping this in view, the present investigation was planned with the objective to evaluate different varieties of French bean in diverse environmental conditions to assess their phenotypic yield stability in different regions of Himachal Pradesh.

MATERIALS AND METHODS

Twenty seven genotypes of french bean from different public and private institutes were used in this study. These genotypes were raised in Randomized Complete Block Design with three replications in three locations constituting four environments namely, Palampur (1, 290.8 m above sea level, 32º 62 N and 76º32 E having temperate-humid climate, annual rainfall of 2500 mm, silty clay loam soil with acidic reaction pH 5.6) during 2008 and 2009, Bajaura (1,090 m above sea level, 31º 082 N and 77ºE with sub-humid temperate climate having annual precipitation of 975 mm, sandy loam soil with high water table, pH 6.6) during 2008 and Kukumseri (2,672 m above sea level, 31º442 N and 76º 412 E with dry temperate climate having 125 mm annual rainfall, sandy loam soil with near neutral soil reaction pH 6.8) during 2008. Each genotype was raised in two rows of 2.7m length with inter row spacing of 0.45m while plants with in row were spaced at 0.15m.The common agronomic management was used in each location.The data were recorded on randomly selected ten plants for yield and yield related traits *viz.,*days to 50 % flowering, pod length (cm), average pod weight (g), pods per plant, plant height (cm), seeds per pod, pod yield/plant (g), days to seed maturity, seed yield per plant (g) and 100-seed weight.

The phenotypic stability of each cultivar for yield and related traits was computed using simple linear regression (Eberhart and Russell, 1966; Finlay and Wilkinson, 1965). The determination of high- and stable yielding genotypes for podand seed yield was performed by plotting the mean of the cultivar (x-axis) vs the stability coefficient bi (y- axis). A genotype was considered to be stable if b_i (coefficient of regression) = 1 andS^2d_i(deviationfrom linearity) = 0. The stability characteristic bi was considered consistent if its standard error was not significantly different than zero. This was indicated in the analysis of variance by a non-significant deviation from linear regression mean square (S^2d_i). Cultivars having their performance better than the grand mean and b*i* d″ 1 were regarded as stable and high performing genotypes (Ortiz and Izquieardo, 1994) and ensure a greater resis-tance to environmental variation and hence, increasing specificity of adaptability to low yielding environments (Kilic *et al.,* 2010). Regres-sion coefficient (b*i*) values above 1.0 define genotypes with higher sensitivity to environmental alteration. The significance of regression coefficient (b_i) and deviations from regression (S^2d_i) were tested using t-test and F-test, respectively. The environmental index was calculated as the mean of all the twenty seven French bean genotypes at each environment by subtracting the grand mean.

RESULTS AND DISCUSSION

The mean sum of squares due to genotypes and environments were found significant for majority of the traits which revealed considerable variationamong genotypes as well as environments (Table 1). The G× E interaction was found to be significant for all the traits which indicate that the genotypes had different productivity responses across the environments. The variation in different characters may be due to differences in climatic or soil factor among environments (Alake and Ariyo, 2012). Raffi *et al.*(2004) also found significant G × E interaction for many traits in pulse bean. Temesgen *et al*. (2015) reported that G × E interaction minimizes the utility of genotypes by confounding their yield performances. The genotypes namely 'IVFB-2', 'DWDFB-53' and 'MFB-4' were found to have high and stable fresh as well as seed yields (Figure 1 & 2). However, their stability characteristic bi was regarded as inconsistent because S^2di was more than zero for these genotypes (Table 4). The coefficient of determination indicated that sum of squares due to G × E interaction from combined analysis over environments was due to linear responses of each genotype to environmental fluctuations for majority of the traits *viz.,*days to flowering, pods per plant, days to maturity, plant height, fresh pod yield and seed yield per plant (Table 1) which suggests that S^2di could not be included as stability criteria for multi-location trials (Ortiz and Izquieardo, 1994). Similarly, the variation due to pooled deviation was found highly significant for all the traits, suggesting that performance of different varieties fluctuating from their respective linear path of response to environment and thereby indicating difficulty in predicting the performance of these varieties over environments for these traits. Patel *et al*. (2009) also found similar observation for some of these traits with their genetic material. In crop improvement programmes, the best strategy is to evaluate the genotypes in different seasons and environments to determine their performance and adaptation. The growers who use limited inputs or raise their crop under unpredicted environments prefer yield stability than augmentation. Accordingly, stability is useful only when considered together with the mean performance of genotypes (Alake and Ariyo, 2012). In French bean, earliness is a highly desirable trait as the market prices are invariably high early in the season. The genotypes are classified on the basis of days to flower and days to maturity for earliness. 'DPDFB-2 (M)',

Table 1: Stability analysis of variance for yield and related traits in French bean

Source	DF	Mean sum of squares Days to flowering	Pods width (cm)	Pod length (cm)	Average pod weight (g)	Pods per plant	Days to maturity	Plant height (cm)	Seeds per pod	100-seed weight (g)	Fresh pod yield per plant (g)	Seed yield per plant (g)
Environments (E)	3	761.81*	0.18*	10.45*	27.27*	1451.41*	6364.72*	1719.40*	0.39	26.38	40815.92*	3733.62*
Genotypes (G)	26	35.28*	0.02	8.56	4.69*	82.68	88.79	117.13	1.07*	415.00*	2728.7	711.27*
G × E	78	11.36*	0.01	2.52*	2.03*	94.51*	56.97*	75.00*	0.45	56.60*	2686.83*	305.09*
E + (G× E)	81	31.86*	0.01*	1.2	1.66*	84.09*	254.03*	87.75*	0.16	19.15	2374.13*	236.02*
E (Linear)	1	2285.43+	0.54+	31.35+	81.8+	4354.23+	19094.16+	5158.15+	1.16+	79.12+	122448.1+	11200.89+
G × E (Linear)	26	7.25+	0.003	0.79	0.57	48.84+	52.09+	25.63+	0.17	23.66	1007.92+	184.72+
Pooled deviation	54	1.98*	0.003*	0.83*	0.69*	21.96*	2.37*	23.77*	0.14*	15.86*	808.33*	57.93*
Pooled error	208	0.75	0.001	0.31	0.16	0.84	0.26	1.32	0.04	2.15	7.43	3.95

Where, * Significant at $p \leq 0.05$; + Significant against pooled deviation at 5 %

Table 2: Mean performance and stability parameters of different genotypes for days to flowering, pod width, pod length and average pod weight

S. No.	Genotypes	Days to flowering			Pods width (cm)			Pod length (cm)			Average pod weight (g)		
		Mean	b_i	S^2di	Mean	b_i	S^2di	Mean	b_i	S^2di	Mean	b_i	S^2di
1.	Arka Suvidha	43.50	1.19	0.54	0.87	1.52	0.00	14.21	1.14	0.04	7.09	0.57	2.35*
2.	Arka Anoop	46.83	1.11	1.17	0.82	-0.01*	0.00	15.30	1.64	1.42*	6.37	1.19	0.18
3.	DWDFB-1	46.25	0.93	0.36	0.83	1.34	0.00	16.06	0.49	0.74	6.42	1.42	0.33
4.	DPDFB-1(M)	44.08	1.28	0.62	0.85	1.48	0.00	14.96	1.98	0.20	6.05	0.98	0.42
5.	DPDFB-2(M)	43.92	0.90	1.51	0.80	0.84	0.00	14.25	2.02	0.43	6.01	1.16	0.10
6.	DWDFB-53	47.00	1.11	2.52*	0.92	0.95	0.01	13.55	0.82	0.65	6.32	1.50	0.24
7.	DWDFB-57	47.92	0.85*	0.27	0.86	1.11	0.00	15.21	0.37	0.39	7.03	1.14	0.47
8.	HAFB-1	45.67	0.99	2.39*	0.85	1.80	0.00	14.05	0.97	0.52	6.87	1.69	2.53
9.	HAFB-2	45.58	1.43	0.14	0.81	1.10	0.01	13.46	1.57	0.62	5.92	0.36*	0.53
10.	HAFB-3	46.17	1.01	0.77	0.84	1.12	0.00	13.70	0.53	0.65	5.72	1.45	0.14
11.	HAFB-4	46.25	1.10	0.56	0.80	0.87	0.01	14.03	-0.38	1.11*	5.90	0.46	0.25
12.	IVRFB-1	48.42	1.37	12.05*	0.80	0.94	0.01	13.88	1.96	1.10*	7.34	1.63	2.10*
13.	IVFB-1	44.25	0.86	0.70	0.82	1.34	0.00	15.07	1.56	0.17	6.05	0.77*	0.00
14.	IVFB-2	45.50	0.98	1.62	0.84	0.98	0.00	15.68	1.00	0.08	6.01	0.96	0.42
15.	IVFB-3	45.08	1.11	4.50	0.79	0.86	0.00	15.15	1.36	0.49	5.55	0.92	0.02
16.	KPV-2	43.08	1.10	0.85	0.90	1.07	0.00	13.56	0.22*	0.15	4.92	0.38*	0.04
17.	MFB-2	46.83	1.28	3.28*	0.90	1.00	0.00	14.89	1.10	3.17*	5.23	0.72	0.72
18.	MFB-3	43.58	0.98	0.38	0.88	0.96	0.00	14.13	1.11	0.10	5.95	0.67	0.09
19.	MFB-4	44.25	1.10	0.67	0.84	0.57*	0.00	15.10	2.00	2.93*	6.69	1.66	2.80*
20.	MFB-5	43.25	0.59*	1.79	0.86	0.67*	0.00	15.47	0.85	0.18	6.39	1.37	1.59*
21.	VLB-8	43.17	0.28*	5.49*	0.84	0.12*	0.00	13.69	0.71	1.13*	5.89	1.51	0.28
22.	VLB-2003	42.67	0.70*	1.14	0.81	0.55*	0.00	14.07	0.52*	0.04	6.09	1.19	3.00*
23.	VLFB-130	43.42	0.91	0.34	0.86	0.94	0.00	14.92	0.85	1.74*	5.50	0.70*	0.01
24.	Aparna	45.92	1.69	3.90*	0.81	1.89	0.00	13.14	-0.47	2.37*	5.77	0.20	1.31*
25.	Falguni	46.67	1.09	1.68	0.72	0.34	0.00	12.55	-1.10*	0.54	4.58	0.53	0.38
26.	Arka Komal	42.83	0.64*	0.16	0.83	0.31	0.01	14.20	1.95	0.91	6.00	0.84	1.69
27.	Contender	42.50	0.54*	3.87*	0.88	1.14*	0.00	14.06	2.24	0.55	6.01	0.93	0.10
Population mean		44.98	-	-	0.84	-	-	14.38	-	-	6.06	-	-

Significant at $p \leq 0.05$, S^2di - Deviation of regression differed significantly from zero at $p \leq 0.05$

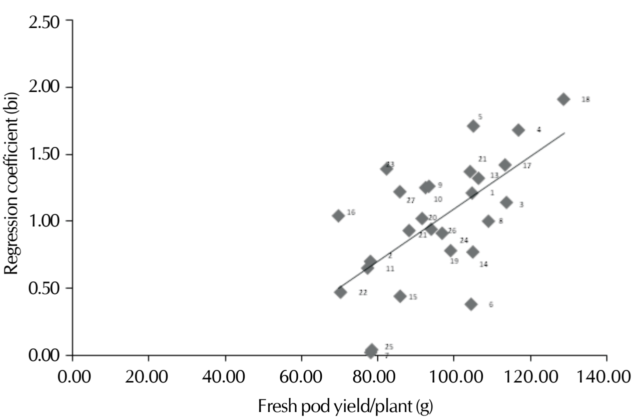

Figure 1: Relationship of regression coefficients (b*i*) and cultivar means over the environments for fresh pod yield

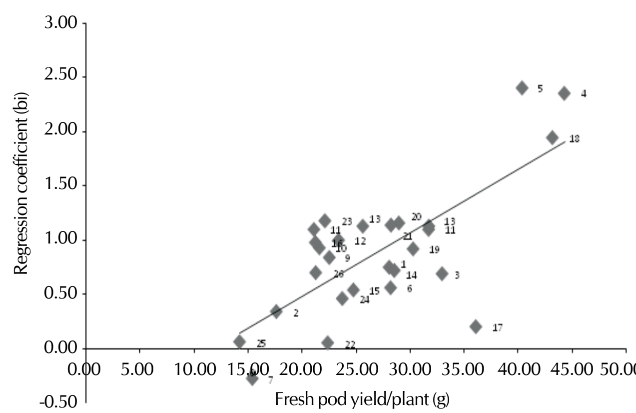

Figure 2: Relationship of regression coefficients (b*i*) and cultivar means over the environments for seed yield

'IVFB-2', 'MFB-3' and 'VLFB-130' may be selected as early genotypes as they were stable ($bi \leq 1$) and took lesser number of days to flowering than the population mean (Table 2) On the other hand, genotypes 'Arka Suvidha', 'DPDFB-1(M)', 'KPV-2'and 'MFB-4' showed their stability for early flowering under favourable environmental conditions ($bi > 1$) *i.e.* highly sensitive to environmental fluctuations. Desirable pod width depends upon the purpose whether consumed as fresh or pulse. For fresh pod consumption,slender pods are preferred by the consumers. Accordingly, minimum pod width was recorded in 'Arka Komal', 'Falguni', 'MFB-3', 'IVFB-3', 'IVFB-2', 'IVRFB-1', 'HAFB-4'and 'DPDFB-2(M)' and they also ensured greater resistance to the environmental variations. In contrary, 'DWDFB-1', 'HAFB-2', 'IVFB-1' and 'Aparna' showed sensitivity to the fluctuating environment (Table 2). Another parameter which pays greater attention of the consumers is pod length with medium or small length. Four genotypes namely, 'DWDFB-53', 'HAFB-1', 'HAFB-3', and 'VLB-8' produced stable and desirable pod length below average performance of the genotypes whereas 'Arka Suvidha',

Table 3: Mean performance and stability parameters of different genotypes for pods/plant, days to maturity and plant height

S. No.	Genotypes	Pods per plant			Days to maturity			Plant height		
		Mean	b_i	S^2di	Mean	b_i	S^2di	Mean	b_i	S^2di
1	Arka Suvidha	14.82	0.7	21.32*	88	0.74*	8.78*	34.35	0.93	45.81*
2	Arka Anoop	12.64	0.69	6.52*	87.92	0.70*	4.10*	33.69	1.19	9.66*
3	DWDFB-1	16.96	0.82	5.42	91.75	1.42	4.24*	34.9	0.57*	6.02*
4	DPDFB-1(M)	19.83	1.64	20.69*	86.33	0.76*	0.2	35.62	1.01	4.69*
5	DPDFB-2(M)	18.56	1.87	40.02*	87.25	0.77*	0.61	32.5	1.49	16.47*
6	DWDFB-53	17.63	0.57	60.16*	93.92	1.4	0.71	35.42	0.66	7.29*
7	DWDFB-57	10.98	-0.19*	12.46*	94	1.34	0.73	32.15	1.18	13.19*
8	HAFB-1	18.57	1.21	55.73*	90.08	1.39	1.01*	30.09	0.85	15.48*
9	HAFB-2	15.94	1.22	22.81*	90.75	1.41	3.53*	32.23	0.15*	12.43*
10	HAFB-3	16.57	1.28	8.98*	88.42	1.11	1.06*	32.28	1.2	6.03*
11	HAFB-4	13.73	0.87	1.09	87.67	0.85*	0.61	36.38	1.32	9.80*
12	IVRFB-1	14.84	1.19	14.80*	93	1.39	2.00*	33.93	0.81*	0.8
13	IVFB-1	18.13	1.38	13.64*	88.33	1.08	0.35	41.91	0.1	298.40*
14	IVFB-2	18.24	0.73	34.78*	86.67	0.87*	0.86	36.46	0.82	9.57*
15	IVFB-3	15.99	0.61*	1.83	86.33	0.75*	0.2	35.32	1.1	0.45
16	KPV-2	14.74	1.4	28.89*	88.75	1.11	3.25*	30.06	1.09	6.51*
17	MFB-2	21.6	1.89	21.93*	86.17	0.74*	0.63	35.08	1.46	19.25*
18	MFB-3	22.31	1.8	2.31	86.92	0.91	1.62*	34.39	0.66*	4.07*
19	MFB-4	14.87	0.61*	5.70*	87.25	0.90*	1.09*	34.73	1.08	19.35*
20	MFB-5	15.38	1.24	12.02*	86.33	0.75*	1.69*	30.98	1.05	10.70*
21	VLB-8	16.39	1.25	2.91*	86.42	0.75*	1.53*	30.01	0.73	4.06
22	VLB-2003	11.91	0.37*	11.85*	86.67	0.77	10.01*	29	1.21	1.09
23	VLFB-130	16.65	1.52	7.92*	86.75	0.74*	4.00*	34.55	1.43	40.30*
24	Aparna	17.52	0.78	100.53*	92.17	1.3	0.99*	32.45	1.34	5.29*
25	Falguni	16.89	-0.25*	11.59*	94.75	1.31	0.37	29.43	0.97	37.85*
26	ArkaKomal	15.84	0.63	54.30*	87.33	0.72*	8.64*	30.12	1.16	0.11
27	Contender	14.49	1.11	12.86*	87.08	0.90*	0.96*	26.27	0.96	37.11*
Population mean		16.37	-	-	88.78	-	-	33.12	-	-

Significant at $p \leq 0.05$, S^2di - Deviation of regression differed significantly from zero at $p \leq 0.05$

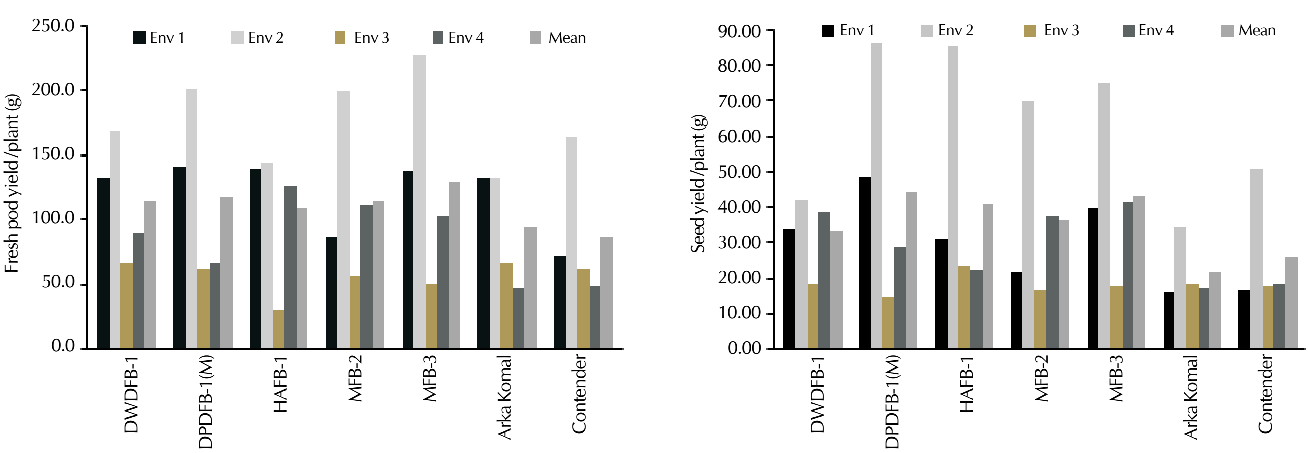

Figure 3: Performance of top ranked five genotypes for fresh pod and seed yield in comparison to Arka Komal and Contender.

'DPDFB-2 (M)', 'HAFB-2', 'IVRFB-1' and 'MFB-3' indicated better performance under favourable environments. Pan *et al.* (2006) reported genotype EC 398570 suitable for unfavourable environment for pod length and pod width.High yield is the basic objective of all crop improvement programmes. It is of immense importance to develop a genotype which has a potential to surpass a commercially adopted/adapted cultivar(s) otherwise the genotype will be of no significance even if it hasexcellent performance for other traits. Number of pods per plant has a direct bearing on the total productivity. Keeping this in view, 'DWDFB-1', 'IVFB-2' and 'Aparna' showed their stability ($bi \leq 1$) as potential genotypes with above average performance for number of pods per plant (Table 3). Shukla *et al.* (2014) also reported similar findings in chick pea. In addition, 'DPDFB-1(M)', 'DPDFB-2(M)', 'HAFB-1', 'HAFB-3', 'IVFB-1' 'MFB-2', 'MFB-3', 'VLB-8' and 'VLFB-130' may show stable performance under favourable environmental conditions ($bi > 1$). For average pod weight, only 'Arka Suvidha' revealed better adaptation to variable environments with above average pod weight of the

Table 4: Mean performance and stability parameters of different genotypes for yield and other traits in French bean

S. No.	Genotypes	Seeds per pod			100- seed weight			Fresh yield per plant			Seed yield per plant		
		Mean	b_i	S^2di	Mean	b_i	S^2di	Mean	b_i	S^2di	Mean	b_i	S^2di
1	Arka Suvidha	5.16	3.87	0.02	42.44	1.61	16.64*	104.72	1.21	591.17*	28.03	0.75	65.77*
2	Arka Anoop	5.57	2.43	0.02	30.23	6.1	0.07	78.1	0.7	356.03*	17.57	0.34*	19.52*
3	DWDFB-1	5.81	-0.5	0.05	38.81	-1.91*	4.4	113.74	1.14	76.99*	32.94	0.69	70.91*
4	DPDFB-1(M)	5.56	3.5	0.1	47.02	-2.01	46.68*	116.88	1.68	241.61*	44.27	2.36	284.22*
5	DPDFB-2(M)	5.46	2.17	0.03	44.02	-3.70*	16.83*	105.06	1.71	643.82*	40.36	2.41	149.34*
6	DWDFB-53	5.05	1.5	0.26*	35.81	-3.58*	11.46*	104.47	0.38	2112.45*	28.16	0.56	132.73*
7	DWDFB-57	5.01	2.29	0.21*	30.73	0.3	14.63*	78.19	0.02	1503.90*	15.34	-0.28*	10.12
8	HAFB-1	5.55	0.77	0.13*	34.42	2.97	0.02	109.01	1	1961.32*	31.69	1.1	83.71*
9	HAFB-2	5.33	0.06	0.03	25.31	-1.3	59.50*	92.53	1.25	1622.09*	22.48	0.84	53.70*
10	HAFB-3	5.43	-0.23	0.06	26.75	0.46	3.6	93.42	1.26	274.10*	21.56	0.93	39.71*
11	HAFB-4	5.73	1.25	0.02	29.96	-1.4	11.76*	77.37	0.65	193.73*	21.05	1.1	11.12
12	IVRFB-1	5.65	-0.49	0.07	28.28	2.71	2.76	104.21	1.37	934.08*	23.34	1	5.18
13	IVFB-1	5.5	0.45	0.05	37.19	2.95	2.24	106.41	1.32	823.58*	31.72	1.13	55.46*
14	IVFB-2	5.38	1.64	0.01	36.3	4.77	1.61	104.92	0.77	424.57*	28.51	0.72	61.66*
15	IVFB-3	5.57	0.2	0.09	35.12	1.08	0.56	85.89	0.44*	2.7	24.72	0.54*	14.49*
16	KPV-2	5.28	-2.77*	0.02	31.79	0.78	2.02	69.73	1.04	1103.40*	21.19	0.98	27.07*
17	MFB-2	5.54	2.18	0.17*	35.82	2.99	1.24	113.35	1.42	1126.30*	36.07	0.20*	9.42
18	MFB-3	5.81	-0.27	0.20*	35.83	-1.05	11.50*	128.69	1.91	129.74*	43.17	1.95	62.94*
19	MFB-4	5.81	-0.54	0.59*	37.04	0.6	5.78	99.11	0.78	1305.56*	30.26	0.92	83.40*
20	MFB-5	5.84	0.39	0.26*	36.85	-0.43	10.71*	91.62	1.02	373.82*	28.93	1.16	94.77*
21	VLB-8	5.6	3.42	0.40*	37.08	2.11	11.64*	88.22	0.93	681.26*	28.2	1.14	26.69*
22	VLB-2003	5.03	0.94	0.04	36.72	0.97	13.20*	70.28	0.47*	256.48*	22.33	0.05*	4.45
23	VLFB-130	5.08	1.2	0.52*	34.05	-1.58*	1.32	82.33	1.39	626.27*	22.07	1.18	7.9
24	Aparna	5.58	1.29	0.02	30.14	1.15	20.39*	96.87	0.91	2324.28*	23.68	0.46	143.47*
25	Falguni	6.21	-2.63*	0.09	19.42	5.46	16.44*	78.45	0.04*	1090.37*	14.15	0.06*	0.72
26	ArkaKomal	5.68	4.89	0.1	31.08	7.69	125.43*	94.03	0.94	1014.02*	21.22	0.7	14.53*
27	Contender	5.05	0.11	0.17*	39.89	-0.72	15.72*	85.81	1.22	643.29*	25.58	1.13	31.13*
Population mean		5.49			34.37	-	-	95.31	-	-	26.98	-	-

Significant at $p \leq 0.05$, S^2di* - Deviation of regression differed significantly from zero at $Pd \leq 0.05$

population whereas nine other genotypes may respond better under favourable environmental conditions. Plant height in bush bean is desirable up to the extent that it does not add to the cost of staking. Accordingly, five genotypes *viz.*, 'Arka Suvidha', 'DPDFB-1(M)', 'DWDFB-53', 'IVFB-1' and 'IVFB-2' had plant height above average and were well adapted under fluctuating environments whereas seven genotypes had shown sensitivity to the varied environments. For seeds/pod, 'HAFB-1', 'IVFB-1', 'IVFB-3' and 'MFB-5' were well adapted under unfavourable environments with above average performance (Table 4). Besides, 'Arka Anoop', 'DPDFB-1(M)', 'MFB-2', 'VLB-8' 'Aparna' and 'Arka Komal' had shown above average mean value and average regression value ($bi < 1$) indicating their sensitivity to fluctuating environments. Raffi *et al.* (2004) also reported relatively stable genotypes under fluctuating environment for seeds/pod and pods/plant in dry French bean.For 100 seed weight, only 'MFB-4' and 'VLB-2003' revealed their stability under diverse climatic conditions whereas six others were adapted to favourable environments. Earliness for seed maturity is of paramount importance in bush beans as seed maturity in spring-summer and autumn crop coincides with rainy season and low temperature in winters, respectively. This ultimately affects the seed quality and seed yield especially in hilly areas. Only two genotypes 'MFB-3' and 'VLB-2003' were early maturing for seed with stability under unfavourable environmental conditions while three others ('HAFB-3', 'IVFB-1' and KPV-2') showed their stability under favourable environments.

The genotypes 'DWDFB-53', 'HAFB-1', 'IVFB-2', 'MFB-4' and 'Aparna' may be selected as the prospective genotypes under varied environmental conditions of north-western Himalayan conditions of Himachal Pradesh because of their stable ($bi \leq 1$) and above average fresh pod yield (Table 4). Singh *et al.* (2007) also found four genotypes namely, HUR 137, CH 812, IIHR 909 and Arka Komal as most desirable and stable for pod yield over different fertility environments. Various reasonscould be used to explain the results obtained for stability of yield by taking into consideration the genetic structure of each genotype. The phenotypic stability of these genotypes could be the result of their high plasticity due to heterogeneous composition but it is more often due to the alleles that confer broad adaptation. The other genotypes namely, 'Arka Suvidha', 'DWDFB-1', 'DPDFB-1(M)', 'DPDFB-2(M)', 'IVRFB-1', 'IVFB-1', 'MFB-2' and 'MFB-3' were sensitive to environmental fluctuation ($bi > 1$) for fresh pod yield, which suggests that these genotypes yield high only under favorable environment. Similar results were also reported by Sharma (2010) for different genotypes which possessed specific adaptability for favourable environments.Pan *et al.* (2006) reported that line EC 350949 was better performing, stable and suitable for favourable environment for green pod yield and number of pods/plant while line EC 398564 was also better performing, stable and suitable for favourable environment for green pod yield, pod length, pod width, pod girth and pod weight. In another study, Pan *et al.* (2009) also revealed that line HAFB-2 was high yielding, stable and showed average response to change in environmental conditions for green pod yield, pod weight and pod girth and suitable for unfavourable environment for number of pods/plant while line HAFB-4 found suitable under favourable environment for green pod yield, pods/plant and pod girth.Similarly, Razvi *et al.* (2011) reported that genotype SAUAR 28 was stable and average responsive to the environments for yield and most of the component traits.

On the other hand, lines 'Arka Suvidha', 'DWDFB-1', 'DWDFB-53', 'IVFB-2' and 'MFB-4' achieved stability for high seed yield and may be adaptedwell by ensuring greater resistance to the varied environments. Besides, in the genotypes 'DPDFB-1(M)', 'DPDFB-2(M)', 'HAFB-1', 'IVFB-1', 'MFB-3', 'MFB-5' and 'VLB-8' seed yield recorded was above average but they showed sensitivity to the environmental variations indicating that these lines specifically adapted to favourable environments. Thakur *et al.* (2001) identified stable genotypes under high input conditions for seed yield in pulse bean.The results indicate that it is possible to select genotypes for pod and seed yield stability in French bean.It can be concluded that stability analysis helps to identify and select the most stable, high performing genotypes/varieties that are best suitable under a given set of environmental conditions. Based upon the stability parameters, genotypes namely, 'Arka Suvidha', 'DWDFB-1', 'DWDFB-53', 'IVRFB-1', 'IVFB-1', 'MFB-3' and 'MFB-4' were found suitable across all the environments for majority of the traits (Fig 3). The wider adaptability of the identified genotypes can be mainly attributed to their wider adaptability for component traits like pod weight, pods per plant, pod length, plant height, fresh and seed yield per plant. These genotypes are recommended for hybridization programme to develop high yielding varieties with stability in their performance.

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