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Genotype x environment interaction and stability analysis in Recombinant inbred lines of French bean for growth and yield components

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Abstract
The phenotypic stability of nine recombinant inbreed lines of French bean were tested for growth and yield components by growing them in four different environments. Results revealed highly significant difference among the genotypes for all the traits studied except for pod weight, days to 50 percent flowering and days to maturity. Significant variation among the environments was observed for almost all the characters studied except for pod weight and days to maturity. Genotype x environmental interaction were significant for pod length, pod weight and green pod yield per plant, which indicates differential performance of genotypes under different environments. Among the recombinant inbreed lines tested for stability, inbreed line, 6-1 had maximum green pod yield per plant and is most stable over different environments with high mean values, regression coefficient around unity and non-significant deviation from regression.

Keywords: French bean, RILs, Regression, GXE interaction, Stability analysis

Introduction
French bean (*Phaseolus vulgaris* L.) is one of the most important legume vegetables. Among the several species of *Phaseolus*, it is the most widely cultivated by the farmers in several countries for its tender pods and dry beans. French bean is originated from Central America and Peruvian Andes in South America (Vavilov, 1950 and Yarnell, 1965) [12] [13]. Hundred gram of French bean contains 1.70 g protein, 0.10 g fat, 4.50 g carbohydrate, 1.80 g fibre and is also rich in minerals and vitamins. It also possesses some medicinal properties, which is useful in controlling diabetics and certain cardiac problems and it is a good natural cure for bladder burn. It has both carminative and reparative properties against constipation and diarrhoea respectively.

French bean enriches the soil by fixing atmospheric nitrogen. It is a short duration crop can be grown under different cropping patterns of hills and plains of India. Because of its wide cultivation; they are subjected to varying environmental conditions in terms of rainfall, soil fertility status, soil acidity and management levels. The wide variation in climatic conditions from season to season and region to region implies that, no two growing conditions are similar. They may therefore perform differently depending on where they are grown. Farmers need to be availed with varieties that can perform predictably well over a wide range of environmental conditions. This would offer an opportunity for predictable yields and therefore contribute to a more stable food security situation. Keeping these things in view, present investigation was planned with the objective of estimation of G x E interaction and identification of stable recombinant inbreeds lines of French bean for yield and yield related components

Materials and Methods
French bean RIL's population comprising of 44 genotypes, which were developed by crossing of different genotypes at department of Biotechnology and Crop Improvement, KRC College of Horticulture, Arabhavi, Karnataka. These 44 RILs (F_5) were evaluated in field under RCBD design in replicated trails along with check for yield and yield related traits. Based on the performance of RILs for yield and yield related traits, nine superior RILs were identified and used in the present study. Details of RILs (F_6) used in the present study and their pedigree are presented in Table-1. These nine genotypes along with two checks *viz.*, Arka suvida and Ring Beans were used for stability analysis. The experiment was laid out in a randomized block design (RBD) with three replications. In each replication, each genotype was represented by a plot of two rows of ten plants each. Total of eleven entries were planted for recording the observations on different growth and yield parameters in four different environments namely,

E1-early *Kharif* of Arbhavi (10th May 2014), E2- late *Kharif* of Arbhavi (6th August 2014), E3-late summer of Arbhavi (2th January-2015) and E4- late *Rabi* season of Bagalkot (5th December 2014). Irrigation, weed control and other cultural practices were followed as per the packages of practices (Anon., 2010) [2]. Five plants in each genotypes of three replications were randomly chosen to record the observations on plant height (cm) at 60 days after sowing (DAS), number of branches per plant at 60 days after sowing (DAS), pod length (cm), pod width (mm), number of pods per plant, number of seeds per pod (g), days to flower and total green pod yield per plant (g). Mean data obtained was statistically analyzed and the RILs were assessed for their stability of performance across four environments following the method described by Eberhart and Russell (1966) [5].

Results and Discussion.

Genotype x environment interaction is of major importance to the plant breeders in developing improved varieties and in choosing the suitable genotypes to be grown in a specific area. Selections of genotype that interact less with the environment in which they are to be grown are known to reduce genotype and environment interaction to a considerable extent (Allard and Bradshaw, 1964) [1]. The term adaptability as related to crop plants applies not only to the ability of plants to survive but also to maintain stability in yield levels under varying environments. The results of analysis of variance for eight growth and yield related traits in recombinants inbreed lines of French bean are summarized in Table-1. Analysis of variance revealed highly significant difference among the genotypes for all the traits studied except for pod weight, days to 50 percent flowering and days to maturity. Significant variation among the environments was observed for almost all the characters studied except for pod weight and days to maturity. Such a variation in pod weight was also reported previously by Cholin *et al.* (2010) [4] in 20 genotypes of cow pea over three environments. Higher magnitude of mean squares due to environments indicates considerable differences between environments for majority of the traits (table-1). Genotype x environmental interaction were significant for pod length, pod weight and green pod yield per plant, which indicates differential performance of genotypes under different environments. Similar results of significant G x E interactions were also been observed by Pereira *et al.* (2009) [9] in 16 varieties of French bean. The partitioning of mean squares (environments + genotype x environments) revealed that environments (linear) differed significantly and were quite diverse with respect to their effects on the performance of genotypes for growth and majority of yield components. Further, the higher magnitude of mean squares due to environments (linear) as compared to genotype x environment (linear) revealed that linear response of environments accounted for the major part of total variation for majority of the characters studied. The significance of mean squares due to genotype x environment (linear) components for pod length and number of pods per plant suggested that the genotypes were diverse for their regression response to change with the environmental fluctuations. Similar results were also reported by Pan *et al*. (2007) [8] in French bean and Keerthi *et al*. (2014) [6] in Dolicus bean. Significant mean squares due to pooled deviation was observed for all the characters studied suggesting that the deviation from linear regression also contributed substantially towards the differences in stability of genotypes. Thus, both linear (predictable) and non-linear (un-predictable) components significantly contributed to genotype x environment interactions.

According to Eberhort and Russell (1966) [5] model, an ideal genotype is defined as the one, which is having high mean performance with regression coefficient around unity *(*bi=1) with non-significant deviation from regression coefficient (S^2_{di} is close to zero). The linear regression is considered as a measure of response of a particular genotype to changing environments. If regression coefficient (bi) is greater than unity, the genotype is said to highly sensitive to environmental changes and adapted to favourable environments. If regression coefficient (bi) is equal to unity, it indicates average sensitivity to environmental changes and coefficient is less than unity (bi ≤ 1), indicates less sensitivity to environmental changes and if genotype shows a higher mean value, then the genotype was adapted to widely differing conditions. If the mean is low, the genotype is considered to be poorly adapted to all environments. The mean values for growth and yield related components, regression coefficient (bi) and deviation from regression (S^2_{di}) of recombinant inbreed lines of French bean across the four environments were presented in Table 3 and 4. Genotypes *viz.*, 2-2, 6-1, 8-2 and 9-2 were found to be stable with respect to plant height as indicated by their high mean values, regression coefficient approaching unity and non-significant deviation from regression; hence these genotypes are specifically adapted to favourable environments. Such varied responsiveness of genotypes to changing environments for plant height was also reported by Pan *et al*. (2007) [8] and Singh *et al*. (2007) [8]. Genotypes *viz.*, 8-2, 10-1 and Ring Beans were found stable across the environment with higher mean values, regression coefficient around unity and deviation from regression was (S^2_{di}) non-significant at 60 DAS for number of branches per plant. Similar results were also reported by Pan *et al*. (2007) [8] in 13 different genotypes of French bean over two environments.

Recombinant inbreed line, 6-1 had maximum pod length and was stable over different environments with high mean values, regression coefficient around unity and deviation from regression was non-significant. These results were in line with results of Pan and Prasad (2000) [7] in 13 pea genotypes over two environments. The genotype 6-1 and 5-2 had maximum pod weight and were stable suitable for different environments with high mean values. The line, 9-2 and Arka suvida had maximum Pod weight but was unpredictable due to significant deviation from regression. These results were in line with results of Pan *et al*. (2007) [8]. The genotypes *viz.*, 5-3, 6-1 and 7-1 were found to be stable for number of pods per plant, where as lines 5-3, Ring Bean and Arka suvida were having maximum number of pods per plant but was unpredictable due to significant deviation from regression. Similar results were also reported by Raffi *et al.* (2004) in French bean and in pea crop by Ceyhan *et al.* (2012). The lines 7-1, 4-6, 10-1 and Ring Bean were taken minimum days for fifty per cent flowering and were stable over different environments. Recombinant inbreed line, 4-6 and Ring bean were found stable across the different environments with lesser mean values for days to maturity. Such varied responsiveness of genotypes to changing environments for days taken for maturity was also reported by Pan *et al*. (2007) [8]. The green pod yield per plant differed among different genotypes over the environments. The Recombinant inbreed line, 6-1 had maximum green pod yield per plant and is stable over different environments with high mean values, regression coefficient around unity and deviation from regression was non-significant.

In conclusion, present study demonstrated the presence of GXE interaction among the recombinant inbreed lines of French bean for growth and yield related traits. Among the recombinant inbreed lines used in the study, line 6-1 exhibited highest green pod yield and was found to be stable over the different environments, which could be used in the breeding programme for the development of high yielding stable genotypes over environments for future use.

Table 1: Details of the Recombinant Inbreed Lines (RILs, F_6) of French bean and their pedigree used for stability analysis

Sl No.	Line No.	Pedigree
1	2-2	Arka Komal x Black seed
2	4-6	Arka Suvida x Black seed
3	5-2	Arka Suvida x Gokak Local
4	5-3	Arka Suvida x Gokak Local
5	6-1	Arka Suvida x Arbhavi Local
6	7-1	Black seed x Arbhavi Local
7	8-2	Black seed x Ring beans
8	9-2	Gokak Local x Arbhavi Local
9	10-1	Gokak Local x Ring Beans
10	Arka Suvida	
11	Ring Bean	

Table 2: Pooled analysis of variance (mean square) for different growth and yield parameters in Recombinants inbreed lines of French bean

Sl. No.	Sources of variation	D. f.	Plant height at 60 DAS (cm)	Number branches at 60 DAS	Pod length (cm)	Pod weight (g)	Number of pod per plant	Days to 50 % flowering	Days to maturity	Green pod yield per plant(g)
1	Genotype(G)	10	38.62 **	2.31 **	40.39 **	33.58	31.69**	0.83	3.95	1532.02 *
2	Environment(E)	3	2083.26 **	2.72 *	69.08**	42.31	171.60 **	10.49 **	7.50	12951.58 **
3	GX E	30	7.84	0.69	46.26 **	43.59**	14.66	0.74	3.27	595.94 **
4	Environment+ (G X E)	33	196.51 **	0.87	48.34 **	43.47	28.93 **	1.62 *	3.65	1719.17 **
5	E (linear)	1	6249.78 **	8.16 **	207.50**	126.93	514.80 **	31.48 **	22.5	3885.73 **
6	GXE (linear)	10	6.20	0.52	132.70 **	49.65	24.42 *	0.49	2.18	700.42
7	Pooled deviation	22	7.87 **	0.69 *	2.77	36.87 **	8.89 **	0.79	3.47	494.27
8	Pooled error	80	3.37	0.39	31.21	6.06	2.72	0.71	1.96	89.06

Table 3: Stability parameters for growth components in Recombinant inbreed lines of French bean

Plant height at 60 DAS				Number of branches per plant at 60 DAS			Days to 50 percent flowering			Days to maturity		
Lines	Mean	Bi	S^2_{di}	Mean	Bi	S^2_{di}	Mean	Bi	S^2_{di}	Mean	Bi	S^2_{di}
2-2	59.07	0.92	8.30	5.79	0.06	-0.35	36.00	0.69	-0.51	101.60	0.64	0.95
4-6	48.95	0.97	6.29	4.72	-0.53	0.26	36.33	1.08	-0.50	103.20	1.06	-1.00
5-2	47.71	0.96	-0.85	5.52	1.49	-0.19	35.41	1.48	0.06	101.30	0.96	-1.58
5-3	52.30	0.90	3.27	6.52	1.73	1.19*	35.83	1.64	0.79	102.00	1.28	-1.59
6-1	55.65	1.00	0.10	6.82	0.08	-0.30	35.08	1.51	0.07	100.00	0.36	0.17
7-1	45.59	0.85	-1.37	5.56	0.65	1.60*	36.33	1.07	-0.79	103.80	3.37	13.82**
8-2	48.52	1.02	-1.19	6.83	2.02	-0.37	35.83	1.02	-0.69	102.50	2.13	1.25
9-2	50.40	0.99	-1.97	6.04	0.83	-0.02	35.08	0.45	1.04	102.50	1.03	-1.49
10-1	49.42	1.11	-2.20	6.45	1.74	0.18	35.16	0.73	0.35	102.20	0.35	0.80
Arka Suvida	54.21	0.97	9.22	7.38	1.68	1.40*	35.83	0.47	0.24	103.10	-0.46	7.25*
Ring Bean	54.54	1.24	14.79*	6.87	1.16	-0.02	35.58	0.80	-0.36	102.20	0.26	0.52
Mean	50.27			6.24			35.68			102		
S.Em±	1.62	0.12		0.48	0.96		0.51	0.52		1.10	1.30	

S^2_{di}* - Deviation of regression differed significantly from zero at p = 0.05

Table 4: Stability parameters for yield components in Recombinant inbreed lines French bean

	Pod length (cm)			Pod weight(g)			Number of pods per plant			Green pod yield per plant (g)		
Lines	**Mean**	**Bi**	S^2_{di}	**Mean**	**Bi**	S^2_{di}	**Mean**	**Bi**	S^2_{di}	**Mean**	**Bi**	S^2_{di}
2-2	11.65	-0.09	-41.47	4.70	3.15	14.00*	15.95	1.94*	-2.03	73.65	1.54	23.06*
4-6	12.97	0.33	-40.46	4.60	4.39	47.47**	17.69	1.03	26.08**	83.72	1.12	51.35*
5-2	13.85	8.97	-17.88	4.86	-1.50	11.52	16.81	1.24	-0.86	100.23	0.97	19.12*
5-3	12.23	0.30	-41.44	4.70	-2.50	14.23*	19.56	1.46	21.86**	85.23	0.90	162.50*
6-1	15.75	0.89	-6.50	5.67	-0.80	10.56	25.43	0.96	-0.42	124.23	0.75	6.42
7-1	11.96	0.56	-40.33	4.40	1.10	-0.34	19.5	1.85	5.41	86.52	1.33	41.23*
8-2	12.30	0.20	-40.95	4.30	-0.60	83.25**	18.10	-0.09	2.44	58.61	0.33	14.23
9-2	12.25	0.29	-39.88	5.10	2.91	64.23**	17.13	1.45	-0.58	78.95	1.14	32.56*
10-1	12.20	0.33	-40.59	4..22	0.46	38.59**	18.20	0.67	4.90	83.6	0.73	61.23*
Arka Suvida	12.49	-0.08	-41.10	5.29	1.63	57.56**	21.12	1.27	10.84**	99.56	1.75	32.56*
Ring Bean	13.53	-0.21	-41.41	5.09	1.92	-4.07	21.64	-0.15**	-2.19	117.86	0.87	-37.18
Mean	13.00			4.84			19.43			87.57		
S. Em±	0.96	0.38		3.50	1.78		1.72	0.43		12.83	1.37	

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