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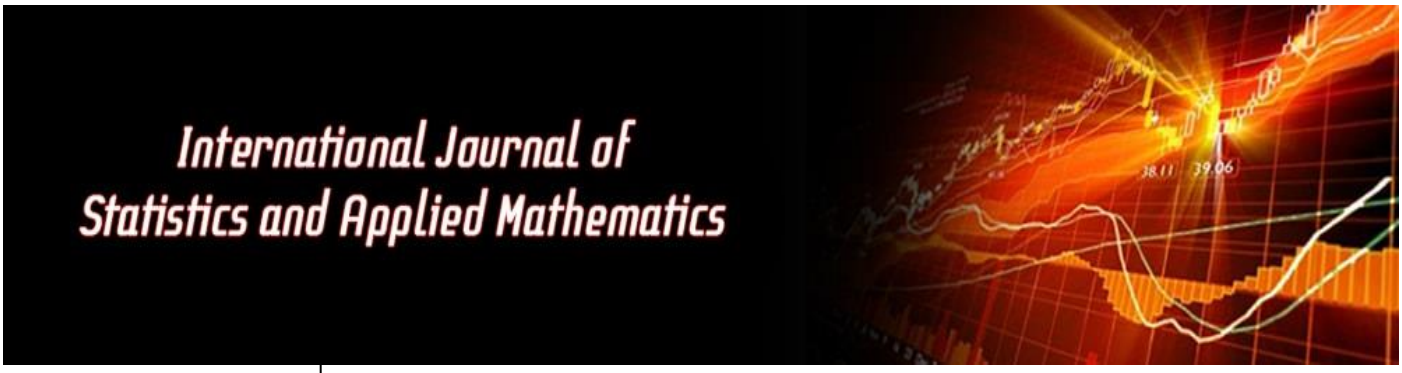

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DB Lad
Associate Professor of Botany, ZARS, Ganeshkhind, Pune, Maharashtra, India

AA Bhagat
Assistant Professor of Statistics, ZARS, Ganeshkhind, Pune, Maharashtra, India

BV Gondhali
Assistant Professor of Horticulture, ZARS, Ganeshkhind, Pune, Maharashtra, India

Anshul Chauhan
M.Sc. Student, College of Agriculture, Pune, Maharashtra, India

Corresponding Author:
DB Lad
Associate Professor of Botany, ZARS, Ganeshkhind, Pune, Maharashtra, India

Stability analysis in French bean (*Phaseolus vulgaris* L.) Genotypes during *rabi* season in Western Maharashtra

DB Lad, AA Bhagat, BV Gondhali and Anshul Chauhan

Abstract
The present investigation was carried out at College of Agriculture, Pune during *rabi*, season, 2021. Sixteen genotypes (14+2) of French bean were sown in Randomized Block Design (RBD) with three replications and in three different sowing dates *i.e.* E1 (15/10/2021), E2 (5/11/2021) and E3 (25/11/2021). Twelve quantitative traits *viz.*, days to 50 per cent flowering, days to maturity, plant height, plant spread, number of seeds per pod, pod length, 100-seed weight, harvest index and seed yield per plant were recorded based on the stability parameters using Eberhart and Russell model to estimate the stability for yield and its components.
The study revealed that environment E3 *i.e.*, sowing date 25th November was found most favorable for most of the characters under study. Both linear and non-linear component of G x E was found significant for the traits of days to maturity and seed yield per plant. On the basis of stability parameters the genotypes *viz.*, Phule Rajmah, Varun, GRB-903 and EC-21754 was found most promising and these genotypes can be recommended to be used as the best parents for generating the breeding material suited for development of new varieties with wider adaptability over different sowing dates to a particular environment.

Keywords: Stability, French bean, genotypes, variability environment

Introduction
French bean is one of the most popular and widely grown legume in India. The matured grains are edible and green immature pods are cooked and eaten as a vegetable. Immature pods are marketed fresh, frozen or canned, whole, cut or French cut. It is also an important pulse crop, with high yielding ability as compared to gram and pea. It is also known as Rajmash, kidney bean, common bean, snap bean, navy bean and haricot bean. Among French bean producing country's Brazil is the world's top producer followed by India, United States of America and Mexico. Globally French bean grown on 32.50 million ha. area with production of 19.86 m tonnes. In India beans are cultivated on an area of about 2.39 lakh ha. with production of 5.26 m tonnes. It is mostly grown in Maharashtra, Himachal Pradesh, Jammu and Kashmir, Gujrat, Uttar Pradesh, Madhya Pradesh, Odisha and other parts of India. The total area of French bean cultivation in Maharashtra is more than 1.0 lakh ha. In Maharashtra major French bean producing districts are Sangli, Kolhapur, Pune, and Satara and Marathwada region of Beed, Latur, Osmanabad and Jalana districts. Productivity of French bean under rain fed and irrigated conditions are 800 kg/ha and 1100 kg/ha respectively. In assessing and carrying out breeding programs, G X E interaction unquestionably plays a crucial role. In the expression of quantitative features, which are governed by polygenic systems and heavily impacted by environmental changes. A population is said to be "well buffered" if it can alter its genotypic or phenotypic status in response to environmental changes in a way that provides high and consistent economic benefits. Eberhart and Russell refined the regression analysis presented by (Finlay and Wilkinson, 1963) [5]. They included a further metric called deviation from regression (S^2di), which takes into account unpredictably irregular variations in how genotypes react to different environments. The regression technique, which divides the G X E interaction component of variability into its linear and non-linear elements for evaluating the stability of genotypes across various environments, is the most extensively used method in this regard.

In the present experiment, sixteen genotypes of French bean were studied through stability analysis. The material was sown on three different dates *viz.* 15/10/21, 05/11/21, 25/11/221and stability of genotypes assessed by (Eberhart and Russel, 1966) [4].

Materials and Methods

The present investigation was carried out at College of Agriculture, Pune during *rabi*, season, 2021. Sixteen genotypes (14+2) of French bean were sown in Randomized Block Design (RBD) with three replications and in three different sowing dates *i.e.,* E1(15/10/2021), E2 (5/11/2021) and E3 (25/11/2021). Each genotype was represented by 2 x 4m length with spacing of 15 x 30 cm. The standard package of practices was used to grow the crop with fertilizer dose of NPK in the ratio 60:80:00. The phenotypic stability of sixteen genotypes across the environments was worked out by linear model Eberhart and Russel, 1966) [4]. The estimated parameters were. mean of the trait (X), linear regression (bi) and mean square deviation from regression (S^2di), where X provides a measure of the performance of a variety as compared to other entries. The bi and S^2di values are the measure of the G x E interaction. If G x E interaction is non-significant or where this G x E interaction is either linear or predominantly linear as compared to its non-linear component, the prediction of stability of a genotype over environments becomes more reliable.

Results and Discussion

The results of analysis of variance for stability in the performance of different genotypes across the three environments are presented in Table 1. It revealed that the mean sum of squares due to genotypes significant for traits *viz.*, days to 50 per cent flowering, days to maturity, plant height, plant spread, number of seeds per pod, pod length, 100-seed weight, harvest index and seed yield per plant. The material selected were divergent and overcame significant genetic variation for all the traits and the mean sum of square due to environments were also significant for all the traits indicated that environment selected were random. The results of the analysis of variance for stability parameters are presented in (Table 2). It indicated that the presence of significant deviation from the environment for characters *viz.*, days to 50 per cent flowering, days to maturity, plant height, pod length and seed yield per plant, indicated considerable additive environment variance. Genotypic variance was significant for all the characters except (number of primary branches, number of secondary branches, number of seeds per pod and pod length), indicated that presence of genetic variability among the genotypes. Similar, results were given by Razvi and Khan (2011) [12] and Nigussie (2011) [7] in French bean. The genotypic variations assessed against the G x E interaction were significant for some of the traits, according to a pooled analysis of variance across three settings. When tested against the G x E interaction, a pooled analysis of variance over three different environments revealed that genotypes varied significantly for the character *viz.* days to maturity, plant height and seed yield per plant. This indicated that the material was variable and also environmental variation varied greatly for each character. These results were in conformity with findings of Ram and Dhar (1999) [10] and Harer *et al.* (2000) [5] in Rajma. Partitioning of G x E interaction showed that G x E (linear) effects were significant for the characters *viz.*, days to maturity, plant height, number of pods per plant and seed yield per plant when tested against pooled error and pooled deviation. Environment (linear) were also significant for the traits *viz*., days to 50 per cent flowering, days to maturity, plant height, number of secondary branches, number of pods per plant and seed yield per plant when test against pooled error and pooled deviation. Similar, results are in agreement with the findings of Park *et al.* (1987) [11] and (Panwar, 1995) [10], they reported that significant differences due to genotypes, environment and genotype x environment interaction in French bean and (Baisakh and Nayak, 1991) [2] reported significant differences for G, E and G x E interactions for grain yield in chickpea.

Table 1: Analysis of variance for stability of twelve characters in French bean

Sr. No.	Sources	Genotypes	Environment	G X E	E+ (G X E)	E (L)	G X E (L)	Pooled Deviation	Pooled Error
1	Degrees of freedom	6	15	32	2	30	1	15	15
1	Days to 50 per cent flowering	7.359++**##	26.468++**##	0.506	17.234++**##	536.301++**##	0.882	0.22	0.057
2	Days to maturity	16.765++**##	287.860++**##	2.649++**##	20.475++**##	575.720++**##	4.646++**##	0.611	0.067
3	Plant height (cm)	44.015++**##	26.468++**##	1.720+	26.468++**##	52.937++**##	4.646++**##	0.555	0.07
4	Plant spread (cm)	68.436++**##	0.211	0.012	0.024	0.421	0.012	0.011	0.025
5	No. of primary branches	0.213	0.204	0.005	0.017	0.408	0.007	0.002	0.08
6	No. of secondary branches	0.811	0.592	0.034	0.069	1.185+*#	0.026	0.039	0.011
7	No. of pods per plant	14.481++**##	1.718+	0.104	0.205	3.436++**##	0.179+*#	0.028	0.026
8	No. of seeds per pod	0.886	0.062	0.004	0.008	0.124	0.004	0.005	0.015
9	Pod length (cm)	0.739	1.76++**##	0.003	0.007	0.134	0.003	0.003	0.01
10	100 seed test weight (g)	33.819++**##	0.301	0.078	0.092	0.601	0.119	0.034	0.062
11	Harvest index (%)	189.600++**##	0.266	0.02	0.035	0.532	0.031	0.008	0.05
12	Seed yield per plant (g)	68.418++**##	3.834++**##	1.893++**##	0.608	7.669++**##	1.841++**##	0.136	0.051

+, ++ indicates significant at 5 and 1 per cent level of significance, respectively when tested against G × E.
*, ** indicates significant at 5 and 1per cent level of significance, respectively when tested against the pooled deviation (PD).
#, ## indicates significant at 5 and 1per cent level of significance, respectively when tested against pooled error (PE).

Stability analysis

Stability in performance is one of the most important properties of a genotype for acceptability for commercial cultivation. The breeder's aim is to develop cultivars that are stable across range of environments. An ideal genotype is defined as the one possessing high mean performance, with regression coefficient around unity (bi=1) and deviation from regression (S^2di) close to zero. The linear regression is regarded as the measure of linear response of a particular genotype to the changing environment. If the regression coefficient (bi) is greater than unity, the genotype is said to be highly sensitive to environmental fluctuations but adapted to all environments. If the regression coefficient (bi) is equal to unity, nit indicates average sensitivity to environmental changes and adaptable to all environments. If the regression coefficient (bi) is less than unity, it indicates less sensitivity to environmental fluctuations and if this is accomplished by a high mean value, then the genotype is said to be better adapted to poor conditions. The non-significant linear (bi) and non-linear (S^2di) estimates indicate average stability of genotype across different environments, whereas significant bi and non-significant S^2di values indicate stability to specific environments. However, the significance of S^2di estimate, irrespective of whether the corresponding bi estimate is significant or non- significant would suggest that that the behavior of genotype is unpredictable.

The average days to 50 per cent flowering ranges from 36.33 (Raj 20-8) to 41.77 (Kullu-2) with overall average of 39.02 across all three environments. The genotypes Phule Rajmah (37.66), GRB-912 (37.77) and Varun (37.88) were early to flower across the all three environments. Average stability exhibited by genotype Raj-20-8 (36.33), GRB-909 (38.55), GRB-912 (37.77), Phule Rajmah (37.66), EC-21754 (37.33), Shimla -3 (38) and Shimla-1 (37.55) had lower mean than population mean (earlier than mean) with non-significant regression coefficient close to unity (bi=0.977, 1.01, 1.05, 1.01, 1.18, 0.855 and 0.814 resp.) and non-significant deviation from regression indicating its suitability for all environments. The estimate of regression coefficient ranged between 0.651 to 1.343. The genotypes Varun (37.88) had recorded less mean value (earlier than mean) than population mean (39.148 days) with regression coefficient (1.018, 1.058, 1.343, 1.018, 1.18,) non-significantly greater than unity (bi>1) and non-significant deviation from regression indicating it's above average stability *i.e.*, suitable for rich environments. Lad and Bhagat (2021) [8] reported similar results.

Stability analysis of variance for this trait indicated that the genotypic and environmental variance were found significant, when tested against G × E, pooled deviation, pooled error. G × E interaction was found absent for this trait, indicating this character is not influenced by the environment. Similar, results were earlier given by Satish *et al.* (2017) [13] in Rajmash and Ravi *et al.* (2022) [11] in cluster bean.

The mean for days to maturity varied between 77 (GRB-909) and 84.66 (Kullu-2) with an average of 80.82 days over three environments. Genotypes GRB-912 (78.11), Varun (79.33), Phule Rajmah (80.66), Raj-20-8 (79.66), GRB-903 (79.66), EC-21754 (77.77), GRB-907 (79.11) were early maturing genotypes across the three environments. (Table 2). Average stability exhibited by genotypes GRB-912 (78.11), EC-21754 (77.77), Raj-20-8 (79.66), GRB-907 had high mean than population mean (80.81 days) (earlier than mean) with non-significant regression coefficient close to unity (bi=1.037, 1.163, 1.137, 1.124) and non-significant deviation from regression indicating its suitability for all environments. The estimate of regression coefficient ranged between 0.049 to 1.277. Genotype GRB-903 recorded higher mean value (earlier than mean) than population mean (80.82) with regression coefficient (0.049) non- significant and less than unity (bi<1) and deviation from regression is non-significant indicating its above average stability *i.e.*, suitable for stress or poor environments. None of the genotypes showed higher mean than population mean with bi>1 and non- significant deviation from regression. The genotypes GRB-909, Phule Rajmah, GR-1, HPR-35, Shimla-1, GRB-907 had significant deviation from regression (0.758, 0.756, 0.882, 0.53, 3.49, 1.174 respectively) indicating the unpredictable nature of genotypes for days to maturity.

Third date of sowing (E3) was highly favorable with high environmental index for trait days to maturity in the desired direction. Stability analysis of variance for this trait indicated that the genotypic and environmental variance was found significant when tested against G × E, pooled deviation and pooled error. Both linear and non-linear component of G × E interaction was found significant when tested against pooled deviation. Hence, it could be possible to predict the performance of genotype and selection would be reliable. This proves the earlier results of Rizvi and Khan (2011) [12] and Nigussie (2011) [7] in Rajmash.

The mean plant height varied from 42.92 (GRB-912) to 55.32 (Kullu-2) with the population mean of 48.13. The genotypes Phule Rajmah (54.67) have higher mean than the population mean with non-significant regression coefficient (bi=0.889) close to unity and non-significant deviation from regression, indicating average stability. The genotypes Kullu-2 (55.32), Varun (52.11) and Raj-20-8 (48.84) have high mean values than the population with non-significant regression coefficient (bi=0.028,0.418) less than unity (bi<1) and non-significant deviation from regression, indicating above average performance. None of the genotypes have high mean and non-significant regression coefficient greater than unity (bi>1) and non-significant deviation from regression. The genotypes GRB-910 (46.57), GRB-903 (46.61), EC-21754 (43.28), Raj-20-4 (47.45) and Shimla-1 (48.11) have lower mean than population mean with non-significant regression coefficient (bi=2.32, 1.64, 1.81, 0.99, 1.16, 2.52 respectively) and significant deviation regression (0.82, 1.05, 1.89, 0.66, 0.582 respectively), indicating unpredictable genotypes over all the environments for the character plant height. Both linear and non-linear component of G × E interaction was found significant when tested against pooled deviation, indicating differences between environments and their considerable influence on this trait. Similar, results were reported by Kelly *et al.* (1987) [6] in French bean.

The average plant spread ranged from 9.82 cm (GRB-910) to 26.07 cm (GRB-903) with the population mean of 19.05cm. The genotypes GRB-912 (21.10cm), GR-1 (24.35cm), Kullu-2 (19.29cm) and EC-21754 (19.67cm) have higher mean than the population mean and non-significant regression coefficient (bi = 1.007,0.974,0.854,0.876) close to unity and non-significant deviation from regression, indicates average stability *i.e.*, suitable for all the environment. Estimated regression coefficient ranges from 0.036 to 2.545. The genotypes Varun (22.45cm), GRB-903 (26.07cm), Raj-20-4 (19.41cm) exhibited high mean and non-significant regression coefficient (bi=0.38, 0.123, 0.30) less than unity with non-significant deviation regression indication stability for poor environment. The genotypes GRB-909 (19.52cm), Raj-20-08 (19.58cm), GRB-911 (25.05cm) have high mean and non-significant regression coefficient (bi=1.37, 1.89. 1.39) greater

than unity with non-significant deviation from regression. These genotypes indicated stability for rich environment *i.e.*, below average stability. Third date of sowing (E3) was found to be highly favorable with high environmental index for the trait. Genotype x environment interaction was found to be absent for this trait, indicating this trait is not influenced by the environment. Similar, results were reported by Ravi *et al.* (2022) [13] in Cluster bean.

The mean number of primary branches per plant ranged from 3.6 (HPR-35, Shimla-1) to 4.17 (Phule Rajmah) with population mean of 3.85. The genotype Raj-20-4 (3.93), EC-21754 (4.11) and GRB-907 (4.15) gave high mean and non-significant regression coefficient (bi=1.17,0.868, 0.89 respectively) close to unity and non- significant deviation from regression, indicated average stability for all the environment. The genotypes GRB-910 (4.04), GRB-909 (3.93), Varun (3.97), Phule Rajmah (4.17) exhibited high mean and non-significant regression coefficient (bi=1.79, 1.42, 1.2, 1.2) greater than unity and non-significant deviation from regression, indicated stability in rich environment *i.e.*, below average stability. The genotypes GRB-903 (3.93), GRB-911 (4.00), exhibited high mean and non-significant regression coefficient (bi=0.58,0.33) less than unity with non-significant deviation regression, indicated stability for poor environment *i.e.*, above average stability. The genotype GR-1 (3.68) exhibited low mean and significant regression coefficient (bi = 2.07*) and non-significant deviation from regression indicated unpredictable genotype over all the environment for the character of number of primary branches per plant. Third date of sowing (E3) was found to be highly favorable with high environmental index for the trait. Genotype x environment interaction was found to be absent for this trait thus, indicated this trait is not influenced by the environment. Similar, results were found by Satish *et al.* (2017) [13] in Rajmash and Senapati and Rao (1998) [15] in groundnut.

The average number of secondary branches per plant varied from 4.31 (Shimla-1) to 5.86 (Phule Rajmah and Varun) with population mean of 5.07. An estimates of regression coefficient ranged from 0.43 to 2.27. The genotypes Varun (5.86), Raj-20-8 (5.26) exhibited high mean and non-significant regression coefficient (bi=1.01, 0.91 respectively) close to unity and non-significant deviation from regression, thus indicated average stability for all the environment. The genotypes GRB-910 and GRB-909 (5.62), exhibited high mean and non-significant regression coefficient (bi=2.12, 1.77) greater than unity and non-significant deviation from regression, thus indicated stability in rich environment *i.e.*, below average stability. The genotypes EC-21754 (0.86) and GRB-911(5.13) exhibited high mean and non-significant regression coefficient (bi=0.57, 0.57) less than unity with non-significant deviation regression indicated stability for poor environment *i.e.*, above average stability. The genotype Phule Rajmah (5.86) exhibited high mean and non-significant regression coefficient (bi=1.11) and significant deviation from regression (0.45), indicated unpredictable genotypes over all the environment for the character of number of secondary branches per plant. Genotype x environment interaction was found to be absent for this trait, indicated this trait is not influenced by the environment. Similar, findings were reported by Razvi and Khan (2011) [14], Satish *et al.* (2017) [15] in Rajmash and (Senapati and Rao, 1998) [17] in groundnut. Environment (linear) was found significant for this character; similar results were found by Chaudhary and Haque (2010) [2] in chickpea.

The mean number of pods per plant ranged from 7.60 (Shimla -3) to 14.84 (Phule Rajmah) with the population mean of 11.58. An estimation of regression coefficient ranged from 0.25 to 1.83. The genotype GRB-910 (14.62) exhibited high mean and non-significant regression coefficient (bi=1.18) close to unity and non-significant deviation from regression indicated average stability for all the environment. The genotypes Phule Rajmah (14.84), GRB-903 (12.95), GRB-907 (13.4), Varun (12.62) and GRB-911 (13.28) exhibited high mean and non-significant regression coefficient (bi=1.49, 1.68, 1.55, 1.58, 1.77) greater than unity and non-significant deviation from regression, these genotypes indicated stability for rich environment *i.e.*, below average stability. The genotype EC-21754 (14.33) exhibited high mean and non-significant regression coefficient (bi=0.44) less than unity with non-significant deviation regression indicated stability for poor environment *i.e.*, above average stability. Third date of sowing (E3) was highly favorable with high environmental index for trait pods per plant in the desired direction. Stability analysis of variance for this trait indicated that the genotypic and environmental variances were found significant when tested against G × E, pooled deviation and pooled error. Linear component of G × E interaction was found significant when tested against pooled deviation. Similar, results were reported by Sheikh *et al.* (2020) [16] in French bean.

The number of seed per pod ranged from 3.42 (GR-1) to 5.26 (Phule Rajmah) with population mean 4.11. The genotypes GRB-907 (4.13) exhibited high mean and non-significant regression coefficient (bi=1.006) close to unity and non-significant deviation from regression, indicated average stability for all the environment. The genotypes GRB-910 (4.77), Varun (5.02), Phule Rajmah (5.26) and Raj-20-4 (4.24) exhibited high mean and non-significant regression coefficient (bi=1.43, 2.04, 1.83, 1.61) greater than unity and non-significant deviation from regression, indicated stability in rich environment *i.e.*, below average stability. The genotypes GRB-903 (4.37), HPR-35 (4.22) exhibited high mean and non-significant regression coefficient (bi=0.43, 0.21) less than unity with non-significant deviation regression indicated stability for poor environment *i.e.*, above average stability. Genotype x environment interaction was found to be absent for this trait thus, indicated that trait is not influenced by the environment. Similar, result was given by Sheikh *et al.* (2020) [16] in French bean

The mean Pod length varied from 7.63 (Shimla-1) to 9.31cm (Phule Rajmah) with population mean 8.20cm. An estimated regression coefficient varied from -0.16 to 2.04. The genotypes GRB-910 (8.4cm) and GRB-911(8.32cm) exhibited high mean and non-significant regression coefficient (bi=1.01, 0.83) close to unity and non-significant deviation from regression, indicated average stability for all the environment. The genotypes GRB-912 (8.36cm) and EC-21754 (8.32cm) exhibited high mean and non-significant regression coefficient (bi=1.23, 1.47) greater than unity and non-significant deviation from regression, thus indicated stability in rich environment *i.e.*, below average stability. The genotypes Varun (9.25cm), Phule Rajmah (9.31cm), GRB-903 (8.4cm) and GRB-907 (8.32cm) exhibited high mean and non-significant regression coefficient (bi=0.74, -016, 0.29, 0.75) less than unity with non-significant deviation regression indicated stability for poor environment *i.e.*, above average stability. Non-linear component of G x E interaction was found significant when tested against the pooled error and

pooled deviation for this trait. Similar results were disclosed by Santos *et al.* (1990) [14].

The 100-seed test weight varied from 25.47g (GRB-909) to 38.31g (GRB-912) with the population mean of 33.44g. An Estimates of regression coefficient ranges from -0.052 to 5.35. The genotypes GRB-910 (35.43g), HPR-35 (34.35g), Kullu-2 (34.21g) and Raj-20-8 (33.89g) have high mean and non-significant regression coefficient (bi=1.59, 1.71, 2.10, 4.62) greater than unity and non-significant deviation from regression, these genotypes indicated stability for rich environment *i.e.,* below average stability. The genotypes GRB-912 (38.31g), GRB-903 (34.25g), GR-1 (35.27g), EC-21754 (37.44g), GRB-911 (34.63g), Raj-20-4 (36.51g) exhibited high mean and non-significant regression coefficient (bi=0.74,0.05,0.61,0.26, -0.09, 0.56) less than unity with non-significant deviation regression indicated stability for poor environment *i.e.,* above average stability. None of the genotypes showed higher mean than population mean with regression coefficient (bi) close to unity and non-significant deviation from regression. Stability analysis of variance for this trait indicated that the genotypes were found significant when tested against G × E, pooled error, pooled error. Genotype x environment interaction was found to be absent for this trait thus, indicated this trait is not influenced by the environment.

The average of Harvest index ranged from 33.07% (Shimla - 3) to 65.38% (Phule Rajmah) with population mean of (50.38%). An estimated regression coefficient varied from 0.121 to 3.63. The genotypes GRB-912 (52.37%), Raj-20-4 (51.49%) have high mean and non-significant regression coefficient (bi=0.92, 0.88) close to unity and non-significant deviation from regression, indicated average stability for all the environment. The genotypes GRB-910 (59.00%), Phule Rajmah (65.38%) have high mean and non-significant regression coefficient (bi=1.98, 2.29) greater than unity and non-significant deviation from regression, indicated stability for rich environment *i.e.,* below average stability. The genotypes GRB-911 (54.11%), GRB-907 (52.08%) exhibited high mean and non-significant regression coefficient (bi=0.16, 0.12) less than unity with non-significant deviation regression indicated stability for poor environment *i.e.,* above average stability. Third date of sowing (E3) was highly favorable with high environmental index for trait harvest index in the desired direction. Stability analysis of variance for this trait indicated that the genotypic variance was found significant when tested against G × E, pooled error, pooled error. Genotype x environment interaction was found to be absent for this trait thus, indicated that traits not influenced by the environment. Similar results were obtained by Nigussie (2011) [7] in Rajmash.

The mean of seed yield per plant varied from 8.54g (Shimla - 3) to 24.80g (Phule Rajmah) with population mean 15.81g. An estimated regression coefficient ranged from 0.164 to 2.75. The genotypes Phule Rajmah (24.80g), Varun (19.06g) and GRB-903 (18.68g) exhibited high mean and non-significant regression coefficient (bi=0.1.19, 0.902, 1.07) close to unity and non-significant deviation from regression, indicated average stability of these genotypes for all the environment. The genotypes GRB-910 (23.83g), GRB-911 (18.81g) and GRB-907 (16.78g) exhibited high mean and non-significant regression coefficient (bi=2.75, 1.93, 2.5) greater than unity and non- significant deviation from regression, thus indicated that stability in rich environment *i.e.,* below average stability. The genotype EC-21754 (18.94g) exhibited high mean and non-significant regression coefficient (bi=0.38) less than unity with non-significant deviation regression indicated stability for poor environment *i.e.,* above average stability. The genotype GR-1 reported lower mean and non-significant regression coefficient (bi=0.22, - 2.28) and significant deviation from regression (1.163) indicated unpredictable genotypes over all the environment for the character of seed yield per plant. Third date of sowing (E3) was highly favorable with high environmental index for trait seed yield per plant the desired direction. Stability analysis of variance for this trait indicated that the genotypic and environmental variance was found significant when tested against G × E, pooled error. Both linear and non-linear components of G x E interactions were found significant when tested against the pooled error and pooled deviation. This result is in conformity with findings of Ram and Dhar (1999) [10], Harer *et al.* (2000) [5] and Anshul *et al.* (2023) [1] in Rajmash.

Table 2: Stability parameters for twelve difference quantitative characters in French bean *(Phaseolus vulgaris* L.*)* genotypes

Sr. No	Genotypes	Days to 50 per cent flowering			Days to maturity			Plant height (cm)			Plant spread (cm)			Primary branches per plant (No.)			Secondary branches per plant (No.)		
		$\bar{x}$	bi	S^2di	$\bar{x}$	bi	S^2di	$\bar{x}$	bi	S^2di	$\bar{x}$	bi	S^2di	$\bar{x}$	bi	S^2di	$\bar{x}$	bi	S^2di
1	GRB-910	40.22	0.895	0.233	83.44	0.677	-0.057	46.57	2.32	0.828***	9.82	0.036	-0.02	4.04	1.794	-0.007	5.53	2.126	0.036
2	GRB-909	38.55	1.018	-0.063	77.00	0.379	0.758**	43.46	1.396	-0.003	19.52	1.371	0.006	3.93	1.428	0.002	5.62	1.778	-0.011
3	GRB-912	37.77	1.058	0	78.11	1.037	-0.026	42.92	1.648	0.239	21.10	1.007	-0.026	3.68	1.486	-0.008	4.64	1.294	-0.008
4	VARUN	37.88	1.343	-0.06	79.33	0.719	-0.026	52.11	0.418	0.267	22.45	0.384	-0.026	3.97	1.206	-0.007	5.86	1.013	-0.007
5	P. Rajmah	37.66	1.018	0.057	80.66	1.332	0.756**	54.67	0.889	-0.068	21.44	2.545	-0.023	4.17	1.206	-0.007	5.86	1.114	0.457
6	RAJ 20-8	36.33	0.977	-0.088	79.66	1.137	0.264	48.84	0.413	0.21	19.58	1.896	-0.023	3.82	1.148	-0.003	5.26	0.911	-0.011
7	GRB-903	40.88	0.896	-0.027	79.66	0.049	0.07	46.61	1.815	1.059***	26.07	0.123	0.042	3.93	0.589	-0.008	4.93	1.013	-0.007
8	GR-1	40.77	1.14	0.176	81.66	1.254	0.882**	44.93	1.56	0.084	24.35	0.974	-0.026	3.68	2.074	-0.008	4.91	0.72	-0.011
9	HPR-35	39.88	0.937	0.342	82.22	1.17	0.53**	46.61	-1.265	-0.029	13.76	1.643	-0.022	3.6	0.338	-0.002	4.95	0.292	-0.006
10	EC 21754	37.33	1.18	0.103	77.77	1.163	0.187	43.28	0.996	1.897***	19.67	0.876	-0.026	4.11	0.868	-0.007	5.8	0.574	-0.009
11	GRB 911	39.88	1.059	-0.029	81.55	1.18	0.159	48.7	1.068	1.699***	25.05	1.399	-0.026	4.00	0.338	-0.002	5.13	0.574	-0.009
12	RAJ 20-4	40	0.651	-0.088	83.66	1.137	0.264	47.45	1.165	0.662**	19.41	0.303	0.015	3.93	1.177	-0.008	4.55	0.866	-0.011
13	KULLU 2	41.77	1.099	-0.078	84.66	1.137	0.264	55.32	0.028	0.012	19.29	0.854	-0.026	3.22	0.56	-0.004	4.55	0.529	-0.011
14	SHIMLA3	38	0.855	0.096	84.22	1.277	0.005	47.96	0.089*	-0.061	17.37	0.8	-0.026	3.48	0.309	-0.008	4.6	0.439	0.001
15	SHIMLA 1	37.55	0.814	-0.026	80.33	1.225	3.499**	48.11	2.525	0.582**	15.63	1.24	0.001	3.6	0.589	-0.008	4.31	0.484	-0.008
16	GRB-907	39.77	1.058	0	79.11	1.124	1.174**	52.45	0.857	0.409**	10.18	0.63	-0.025	4.15	0.897	-0.008	4.71	2.273	0.053
	Mean	39.02	1		80.82	1		48.13	1		19.05	1		3.85	1		5.07	1	

*, **= Significant at 5% and 1% level of significance, respectively

Sr. No	Genotypes	No. of pods per plant (No.)			Seeds per pod (No.)			Pod length (cm)			100- seed weight (g)			Harvest index (%)			Seed yield per plant (g.)		
		$\bar{x}$	bi	S^2di	$\bar{x}$	bi	S^2di	$\bar{x}$	bi	S^2di	$\bar{x}$	bi	S^2di	$\bar{x}$	bi	S^2di	$\bar{x}$	bi	S^2di
1	GRB-910	14.62	1.187	-0.022	4.77	1.437	-0.01	8.40	1.019	-0.01	35.43	1.596	-0.064	59	1.985	-0.033	23.83	2.754	0
2	GRB-909	10.26	1.376	0.004	4.08	1.221	-0.014	8.01	1.801	-0.01	25.47	0.183	-0.063	46.24	-0.164	-0.05	10.84	1.652	-0.039
3	GRB-912	10.84	1.837	-0.018	4.04	0.611	-0.014	8.36	1.234	-0.007	38.31	0.744	-0.045	52.37	0.923	-0.038	15.69	1.63	0.065
4	VARUN	12.62	1.58	-0.025	5.02	2.047	-0.008	9.25	0.749	-0.01	33.32	0.35	-0.06	48.16	3.637	-0.039	19.06	0.902	-0.05
5	P. RAJMAH	14.84	1.497	-0.023	5.26	1.831	-0.014	9.31	-0.164	-0.001	32.52	0.388	-0.062	65.38	2.29	-0.01	24.80	1.196	0.078
6	RAJ 20-8	10.17	0.764	-0.023	3.77	0.611	-0.014	7.8	0.888	0.003	33.89	-2.102	0.323	48.77	0.858	-0.042	12.75	0.911	0.039
7	GRB-903	12.95	1.686	0.007	4.37	0.432	-0.004	8.4	0.293	-0.009	34.25	0.052	-0.042	49.8	0.535	-0.05	18.68	1.077	0.07
8	GR-1	10.46	-0.521	0.103	3.42	1.4	-0.009	7.83	1.531	-0.01	35.27	0.616	-0.045	41.56	0.395	-0.051	13.06	0.224	1.163***
9	HPR-35	11.06	-1.286	0.082	4.22	0.217	-0.012	7.84	0.266	-0.01	34.35	1.716	-0.023	49.89	0.97	-0.041	15.75	-2.286	0.152
10	EC 21754	14.33	0.446	-0.006	3.57	1.795	-0.001	8.32	1.476	-0.006	37.44	0.268	-0.061	61.98	0.661	-0.051	18.94	0.387	-0.048
11	GRB 911	13.28	1.777	-0.025	4.08	0.575	0.004	8.32	0.832	-0.006	34.63	-0.09	-0.059	54.11	0.162	-0.05	18.81	1.936	-0.041
12	RAJ 20-4	9.44	0.476	-0.017	4.24	1.616	-0.014	7.86	0.722	-0.008	36.51	0.56	-0.063	51.49	0.881	-0.045	13.96	1.48	0.064
13	KULLU 2	10.93	0.25	-0.012	3.48	0.216	-0.012	7.78	1.047	-0.01	34.21	4.624	-0.064	51.18	0.436	-0.051	12.79	0.515	-0.049
14	SHIMLA 3	7.60	1.701	0.020	3.84	-0.393	-0.013	7.83	1.449	-0.001	28.26	5.354	-0.028	33.07	0.59	-0.051	8.54	0.951	0.011
15	SHIMLA 1	8.55	1.671	0.001	3.48	1.4	-0.009	7.63	2.043	-0.01	29.88	1.422	-0.064	40.94	1.547	-0.034	8.64	0.164	-0.051
16	GRB-907	13.40	1.557	-0.004	4.13	1.006	-0.013	8.32	0.75	-0.01	31.21	0.348	-0.056	52.08	0.121	-0.048	16.78	2.507	-0.002
	Mean	11.58	1		4.11	1		8.2	1		33.44	1		50.38	1		15.81	1	

Conclusion

The genotypes under study showed differential stability performance for all the twelve characters. The present investigation revealed that environment E3 *i.e.,* sowing date 25th November was found most favorable for most of the characters under study. Both linear and non-linear component of G x E was found significant for the traits of days to maturity and seed yield per plant. Linear component of G x E interaction was found significant for plant height and number of pods per plant. Linear components of environment (E) was found significant for the characters *viz.,* days to 50 per cent flowering, days to maturity, plant height, number of secondary branches per plant, number of pods per plant and seed yield per plant and E+ G X E was found significant for the characters *viz.,* days to 50 per cent flowering, days to maturity and plant height when tested against pooled error indicated environment and environment with genotype interactions contributed in expression of these characters. Based on the stability parameters genotypes *viz.,* Phule Rajmah, Varun, GRB-903 and EC-21754 was found promising in all the environment and these genotypes can be recommended to be used as the parents for generating the breeding material suited for development of new varieties with wider adaptability over different sowing dates to a particular environment.

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