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# Performance of french bean genotypes (*Phaseolus vulgaris* L.) for seed yield and related traits under mid hill conditions of North Western Himalayas

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**ABSTRACT**

*To breed new and better cultivars, the breeder requires a comprehensive knowledge on variability existing in the germplasms. The investigation was conducted using thirty three genotypes (including two standard checks 'Contender' and 'Arka Komal') of bush type french beans (Phaseolus vulgaris* L.*) to evaluate the genotypes for seed yield and related traits. The experiments were laid out in Randomized Complete Block Design with three replications for two seasons (summer-rainy season, 2008 and 2009).Quality analyses of these genotypes were also done for ascorbic acid, protein, total sugar and total soluble solids for one year. Based on crop characters genotype DPDFB-2(M) was the most superior line for seed yield among all the genotypes followed by MFB-2, DPDFB-1(M), MFB-3 and HAFB-1 which was attributed due to high 100 seed weight. Quality analysis showed that ascorbic acid content was highest in genotype JFB-97-1. Similarly, linesDPDFB-1 for protein, IVFB-2 for total sugar and KPV-2 for total soluble solids content were found to be superior.*

***Key words*:** Morphological characters, *Phaseolus vulgaris,* quality traits, seed yield

French beans (*Phaseolus vulgaris* L.) belongs to the family *Fabaceae* is an annual, diploid (2n=2x=22) species which is considered to be derived from its wild ancestors distributed from northern Mexico to north western Argentina (Galvan *et al.*, 2003). It is a dual purpose crop grown as pulse and also consumed as immature tender fruits. In the recent years, tremendous efforts have been made by the breeders for its genetic improvement. 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. Hence, it would be necessary to chalk out breeding strategy where appropriate genotype are selected which besides having higher yield possess desirable attributes based on the market preference. However, the improvement potential of any crop is proportional to magnitude of genetic variability in the germplasm (Singh *et al.*, 2009). A wide range of variability for various traits is available in *Phaseolus* spp. In relation to breeding programs, Falconer (1981) emphasized that when the genotypes are evaluated in more than one environment, with the objective of quantifying the diversity found in the interaction, evaluation of genotypes could bring forth more clarifying results on the behaviour of genotypes, with a subsequent influence on the performance of these in future breeding programs (Teixeira *et al.*, 2004). Therefore, the evaluation of French bean germplasms is the first step to identify the potential genotype for use in breeding programme. Keeping in view the importance of this crop, the objective of this study was to evaluate thirty three genotypes of French bean group, using various morpho-agronomic traits based on their mean performance.

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## MATERIALS AND METHODS

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The investigation was carried out at the Experimental Farm of Department of Vegetable Science and Floriculture, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur (1, 290.8 m mean sea level, with latitude $32^0$ 6' N, longitude $76^0$ 3' E) for two consecutive years, during the summer-rainy seasons of 2008 and 2009. The experimental material comprised of thirty three genotypes of bush type french beans including 'Arka Komal' and 'Contender' as standard checks, laid out in Randomized Complete Block Design with three replications in plots of size 2.7m long for two seasons (summer-rainy season, 2008 and 2009). These genotypes were sown at inter and intra-row spacing of 45 cm and 5 cm, respectively. Observations were recorded on ten competitive plants taken at random from each entry replication wise. The crop was well managed for optimum growth and yield. The fertilizers were applied at the time of sowing @ 50kg N: 90kg $P_2O_5$ and 60 kg $K_2O$ $ha^{-1}$. Weeds were controlled with pendimethalin @ 1 kg a.i. $ha^{-1}$ as pre-emergence application followed by two manual weedings at 40 and 60 days after sowing. Irrigation was applied at 15 days interval depending upon the requirement. Data were recorded for days to flowering, days to maturity, pods per plant, pod length, seeds per pod, plant height, 100-seed weight and seed yield per plant and for four quality parameters *viz.*, ascorbic acid of fresh pod basis), protein, total sugar and total soluble solids. However, the quality study was done only for one year. In addition, morphological characterization for pod shape and fibre was also recorded visually.

Analysis of variance was performed for individual season and error variance was tested for homogeneity (Gomez and Gomez, 1983). The ascorbic acid and Crude protein contents were estimated by titration method as described by A.O.A.C. (1990). Total sugar was estimated by following the method of Sadasivasam and Manickam (1996). The total soluble solids were estimated with the help of ERMA hand refractrometer.

**RESULTS AND DISCUSSION**

The French bean genotypes were significantly different for almost all the characters except seeds per pod for both the years and pooled over the years. Significant genotypic × environmental interactions were also observed for almost all characters except for few exceptions that of pod length and seeds peer pod (Table 1). The F-test of homogeneity over years showed significant differences for majority of the traits except days to maturity, 100 seeds weight and seed yield per plant which suggests that interpretation of the results on the basis of pooled over years would not provide clear picture. Hence, the results of the individual years along with pooled over years have been discussed.

**Table 1: Analysis of variance for different characters in french bean (pooled)**

| Characters | Mean sum of squares | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Replication | | Genotypes | | Error | | G | E | G×E | Error | F-Test |
| | I | II | I | II | I | II | Pooled over years | | | | |
| Df | 2 | | 32 | | 64 | | 32 | 1 | 32 | 128 | |
| Days to flowering | 0.58 | 5.18 | 16.73* | 6.84* | 2.22 | 1.4 | 16.65* | 8.91* | 6.91* | 1.81* | 2.51* |
| Days to maturity | 0.07 | 0.07 | 20.54* | 20.54* | 1.01 | 1.01 | 15.69* | 861.5* | 9.33* | 1.03 | 1.04 |
| Pods plant$^{-1}$ | 5.48 | 1.23 | 52.51* | 98.01* | 2.24 | 4.65 | 112.21* | 0.703 | 38.31* | 3.45* | 4.33* |
| Pod length | 1.44 | 1.44 | 8.54* | 8.54* | 0.41 | 0.41 | 16.89* | 0.39 | 1.40 | 0.72 | 6.30* |
| Seeds pod$^{-1}$ | 0.05 | 0.05 | 0.85* | 0.84* | 0.11 | 0.11 | 1.30 | 0.633 | 0.23 | 0.14 | 2.90* |
| Plant height | 176.50 | 2.00 | 30.74* | 25.68* | 3.93 | 5.95 | 40.12* | 145.19* | 16.30* | 4.94* | 2.29* |
| 100-seed weight | 24.17 | 24.17 | 283.51* | 283.52* | 7.29 | 7.29 | 389.31* | 57.89* | 35.26* | 7.04* | 1.16 |
| Seed yield plant$^{-1}$ | 24.87 | 24.87 | 228.40* | 228.4* | 15.08 | 15.08 | 399.87* | 477.71* | 126.65* | 17.47* | 1.73 |

*Note: *Significant at P ≤ 0.05; where G and E depicts genotypes and environment*

The variation in the mean performance of thirty three genotypes for different pairs of characters during 2008, 2009 and pooled over years showed that performance of majority of genotypes varied widely indicating thereby role of environment in that particular season in determining the performance of particular genotype for different traits.

The study revealed that 'Arka Suvidha' and 'MFB-5' were similar in performance for earliness to flowering as that of standard check 'Contender' and 'Arka Komal' during 2008, 2009 and also pooled over years (Table 2). Earliness for seed maturity is of paramount importance in bush beans as seed maturity in spring-summer and autumn sown crop coincides with rainy season and low temperature in winter, respectively. This ultimately affects the seed quality and seed yield. Accordingly, line MFB-1 was early in seed maturity over both the standard checks for the year 2008, while, for 2009 and pooled over the years it was at par with standard check 'Contender' and superior over 'Arka Komal'. Most of the other genotypes namely, 'DPDFB-1(M)', 'DPDFB-2(M)', 'DWDFB-1','HAFB-3', 'HAFB-4', 'IVFB-1', 'IVFB-2', 'IVFB-3', 'JFB-97-1''MFB-4', 'VLB-2003' and 'VLFB-130' were at par over both the standard checks for 2008 and pooled data over the years for days to seed maturity. Further, it was observed that 'DPDFB-1' provides green pods for longer duration as it took maximum days to seed maturity in both the years as well as pooled over the years. Similar trend was also reported for 'Falguni'. The genotype 'IVFB-1' in general produced longest pods on maturity in both the years of study. Total numbers of pods were highest in 'Aparna'. Plant height in bush bean is desirable upto the extent that it does not add to the cost of staking. However, not a single genotype was found to be stable for plant height in this study which might indicate the role of environment in expression of this trait (Table 3). Cultivars like 'MFB-5','MFB-1','Surya', 'Falguni', 'Chandini' and 'DPDFB-1' were found to have significantly more number of seeds per pod over both the standard checks 'Arka Suvidha' and 'Contender'. However, the above mentioned genotypes recorded low 100 seeds weight except 'MFB-5' and 'MFB-1' indicating small seed size. The main aim of a breeder is to isolate lines expressing higher yield. In this regard, a wide variation in seed yield per plant was recorded in the present genetic materials. 'DPDFB-1(M)' was the most superior line for seed yield among all the genotypes followed by 'MFB-2', 'DWDFB-1' and 'DPDFB-2(M)'. The genotypes differed markedly in producing seed yield per plant contributed through variation in yield components. The data obtained from this study could be useful for common bean (*Phaseolus vulgaris* L.) breeders in order to increase seed yield. Quality analysis showed (Table 4) that ascorbic acid content was highest in genotype 'JFB-97-1'. The lines 'DPDFB-1' for protein, 'IVFB-2' for

total sugar and 'KPV-2' for total soluble solids content were found to be superior.

**Table 2: Mean performance of different genotypes for seed yield per plant and related traits**

| Genotypes | Days to 50% flowering | | | Days to seed maturity | | | Pod length (cm) | | | Pods plant$^{-1}$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | Pool | I | II | Pool | I | II | Pool | I | II | Pool |
| Arka Suvidha | 39.3 | 40.7 | 40.0 | 87.0 | 78.3 | 82.7 | 14.4 | 13.6 | 14.0 | 12.0 | 19.7 | 15.9 |
| Arka Anoop | 43.0 | 43.7 | 43.3 | 86.3 | 80.0 | 83.2 | 13.5 | 13.4 | 13.5 | 13.0 | 8.9 | 11.0 |
| DPDFB-1 | 43.7 | 41.0 | 42.3 | 88.0 | 81.0 | 84.5 | 11.6 | 9.7 | 10.8 | 23.1 | 22.4 | 22.8 |
| DPDFB-1(M) | 41.0 | 44.3 | 44.2 | 81.7 | 80.0 | 80.7 | 15.4 | 16.1 | 16.1 | 18.6 | 17.2 | 17.3 |
| DPDFB-2(M) | 40.3 | 41.3 | 41.2 | 82.0 | 79.0 | 80.3 | 13.6 | 14.9 | 15.2 | 13.8 | 12.6 | 15.6 |
| DWDFB-I | 44.0 | 43.3 | 41.8 | 81.3 | 80.0 | 81.0 | 16.1 | 14.6 | 14.1 | 17.4 | 10.0 | 11.9 |
| DWDFB-53 | 44.3 | 42.7 | 43.5 | 86.3 | 79.7 | 83.0 | 13.2 | 14.2 | 13.7 | 18.9 | 24.8 | 21.8 |
| DWDFB-57 | 46.0 | 47.7 | 45.8 | 87.0 | 80.3 | 83.7 | 15.7 | 14.8 | 15.2 | 15.4 | 11.0 | 13.2 |
| HAFB-1 | 43.3 | 41.7 | 42.5 | 81.0 | 77.7 | 79.3 | 14.1 | 14.2 | 14.2 | 18.5 | 24.8 | 21.7 |
| HAFB-2 | 41.0 | 42.3 | 41.7 | 81.0 | 79.3 | 80.2 | 11.7 | 13.0 | 12.3 | 8.2 | 14.6 | 11.5 |
| HAFB-3 | 44.0 | 43.0 | 43.5 | 81.7 | 79.0 | 80.3 | 12.5 | 13.3 | 12.9 | 15.3 | 11.6 | 13.5 |
| HAFB-4 | 43.3 | 44.3 | 43.8 | 82.0 | 80.3 | 81.2 | 13.3 | 12.7 | 13.0 | 10.9 | 13.8 | 12.4 |
| IVRFB-1 | 47.7 | 45.7 | 46.7 | 86.3 | 78.3 | 82.3 | 16.3 | 15.0 | 15.7 | 14.6 | 9.0 | 11.8 |
| IVFB-1 | 41.3 | 43.3 | 42.3 | 81.7 | 78.7 | 80.2 | 16.0 | 16.1 | 16.1 | 11.8 | 15.8 | 13.8 |
| IVFB-2 | 42.7 | 42.0 | 42.3 | 81.7 | 79.3 | 80.5 | 14.7 | 16.0 | 15.3 | 13.1 | 24.6 | 18.9 |
| IVFB-3 | 44.3 | 41.7 | 43.0 | 81.7 | 79.7 | 80.7 | 16.2 | 15.6 | 15.9 | 13.6 | 16.8 | 15.2 |
| JFB-97-1 | 44.0 | 41.0 | 42.5 | 82.0 | 79.0 | 80.5 | 13.9 | 13.7 | 13.8 | 15.7 | 4.4 | 10.1 |
| KPV-2 | 39.0 | 41.0 | 40.0 | 81.0 | 80.3 | 80.7 | 11.9 | 11.4 | 11.6 | 7.2 | 11.0 | 9.1 |
| MFB-1 | 44.7 | 40.7 | 42.7 | 81.0 | 76.0 | 78.5 | 12.8 | 14.2 | 13.5 | 12.4 | 8.7 | 10.6 |
| MFB-2 | 40.0 | 44.3 | 42.2 | 81.0 | 79.3 | 80.2 | 15.3 | 15.1 | 15.2 | 20.7 | 21.3 | 21.0 |
| MFB-3 | 40.3 | 41.7 | 41.0 | 81.0 | 79.7 | 80.3 | 13.4 | 15.0 | 14.2 | 14.9 | 20.0 | 17.5 |
| MFB-4 | 41.3 | 42.7 | 42.0 | 81.3 | 79.7 | 80.5 | 14.8 | 14.7 | 14.8 | 14.2 | 11.3 | 12.8 |
| MFB-5 | 39.7 | 40.7 | 40.2 | 81.7 | 80.7 | 81.2 | 15.1 | 15.3 | 15.2 | 13.1 | 9.9 | 11.5 |
| VLB-8 | 40.3 | 43.7 | 42.0 | 87.7 | 78.3 | 83.0 | 11.8 | 12.9 | 12.4 | 14.2 | 13.7 | 13.9 |
| VLB-9 | 41.7 | 42.3 | 42.0 | 86.0 | 80.7 | 83.3 | 13.3 | 15.0 | 14.1 | 12.3 | 12.2 | 12.3 |
| VLB-2003 | 41.3 | 41.0 | 41.2 | 81.7 | 78.0 | 79.8 | 13.7 | 13.8 | 13.8 | 14.2 | 14.9 | 14.6 |
| VLFB-130 | 38.7 | 41.3 | 40.0 | 83.7 | 78.3 | 81.0 | 15.2 | 15.0 | 15.1 | 11.7 | 11.8 | 11.7 |
| Aparna | 45.3 | 43.0 | 44.2 | 86.7 | 80.0 | 83.3 | 10.9 | 11.4 | 11.1 | 24.4 | 29.0 | 26.7 |
| Chandini | 42.0 | 43.0 | 42.5 | 87.7 | 80.3 | 84.0 | 10.8 | 10.4 | 10.6 | 21.3 | 13.8 | 17.6 |
| Falguni | 46.0 | 45.3 | 45.7 | 86.3 | 81.7 | 84.0 | 13.1 | 12.0 | 12.6 | 16.4 | 16.9 | 16.6 |
| Surya | 41.3 | 44.3 | 42.8 | 86.7 | 80.7 | 83.7 | 11.1 | 9.1 | 10.1 | 23.1 | 15.0 | 19.1 |
| Arka Komal | 39.0 | 41.0 | 40.0 | 81.7 | 78.7 | 80.2 | 16.4 | 15.4 | 15.9 | 10.5 | 9.6 | 10.1 |
| Contender | 39.0 | 43.3 | 41.2 | 82.7 | 76.7 | 79.7 | 14.6 | 14.4 | 14.5 | 11.1 | 10.3 | 10.7 |
| **CV (%)** | **3.5** | **2.8** | **3.96** | **1.2** | **1.3** | **2.0** | **4.6** | **7.4** | **6.7** | **10.0** | **14.5** | **21.6** |
| **LSD(0.05)** | **2.4** | **1.9** | **1.91** | **1.6** | **1.7** | **1.9** | **1.0** | **1.7** | **1.1** | **2.4** | **3.5** | **3.68** |

On the basis of morphological characters (Table 5), it was observed that Arka Suvidha, 'DPDFB-1', 'HAFB-1', 'HAFB-3', 'HAFB-4', 'IVFB-1', 'JFB-97-1', 'KPV-2', 'MFB-1', 'MFB-2', 'Aparna', 'Chandini', 'Falguni', 'Surya' and 'Arka Komal' produced straight pods. On the other hand, genotypes 'Arka Anoop', 'DPDFB-1(M)', 'DPDFB-2(M)', 'DWDFB-I', 'DWDFB-53', 'DWDFB-57', 'HAFB-2', 'IVRFB-1', 'IVFB-2', 'IVFB-3', 'MFB-3', 'MFB-4', 'MFB-5', 'VLB-8', 'VLB-9', 'VLB-2003' and 'VLFB-130' had shown slightly curved pods, whereas the pods of standard check Contender was more curved.

Morphological characterization with respect to pod shape and pod quality is also of great significance. Most of the genotypes were found to be stringless and 'DWDFB-57', 'JFB-97-1', 'KPV-2' with stringly pods and 'DWDFB-I', 'IVFB-1', 'MFB-2', 'MFB-5' while 'Arka Komal' with semi-stringly pods (Table 5). On the basis of above study it may concluded that sufficient genetic variability existed in the materials under study, which could be exploited through selection. Apart from the higher yield, the genotypes 'DPDFB-1', 'Surya' and 'Chandini' were identified as stringless cultivars along with thin and green coloured pods.

**Table 3: Mean performance of genotypes for seed yield per plant and related traits**

| Genotypes | Plant height(cm) | | | Seeds pod$^{-1}$ | | | 100-seed weight (g) | | | Seed yield plant$^{-1}$ (g) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | Pool | I | II | Pool | I | II | Pool | I | II | Pool |
| Arka Suvidha | 38.3 | 37.3 | 37.8 | 5.4 | 5.7 | 5.6 | 45.0 | 37.0 | 41.0 | 21.7 | 36.8 | 29.22 |
| Arka Anoop | 38.6 | 33.5 | 36.0 | 5.9 | 5.8 | 5.8 | 26.4 | 24.0 | 25.7 | 13.1 | 13.7 | 13.40 |
| DPDFB-1 | 34.7 | 38.4 | 36.6 | 6.1 | 6.4 | 6.2 | 26.1 | 23.7 | 24.9 | 16.8 | 28.0 | 22.42 |
| DPDFB-1(M) | 36.9 | 37.1 | 37.6 | 5.4 | 5.6 | 5.8 | 55.4 | 41.7 | 40.9 | 48.4 | 38.4 | 35.92 |
| DPDFB-2(M) | 36.5 | 36.8 | 36.8 | 5.6 | 6.3 | 5.9 | 50.4 | 42.5 | 49.0 | 30.8 | 28.7 | 38.57 |
| DWDFB-I | 38.1 | 34.0 | 35.3 | 5.9 | 5.8 | 5.7 | 40.1 | 43.4 | 46.9 | 33.5 | 22.3 | 26.55 |
| DWDFB-53 | 37.7 | 40.2 | 39.0 | 4.6 | 5.7 | 5.2 | 38.9 | 36.2 | 37.5 | 26.1 | 39.8 | 32.95 |
| DWDFB-57 | 39.7 | 34.6 | 37.2 | 5.2 | 5.4 | 5.3 | 27.3 | 34.2 | 30.8 | 14.6 | 19.3 | 16.97 |
| HAFB-1 | 30.3 | 33.2 | 31.7 | 5.7 | 5.5 | 5.6 | 32.7 | 31.7 | 32.2 | 27.4 | 39.7 | 33.52 |
| HAFB-2 | 35.6 | 34.8 | 35.2 | 5.4 | 5.3 | 5.4 | 20.2 | 34.0 | 27.1 | 9.0 | 26.0 | 17.52 |
| HAFB-3 | 33.8 | 31.0 | 32.4 | 5.3 | 5.5 | 5.4 | 26.1 | 27.8 | 26.9 | 15.3 | 13.5 | 14.38 |
| HAFB-4 | 38.3 | 35.1 | 36.7 | 5.7 | 6.0 | 5.8 | 27.0 | 33.4 | 30.2 | 11.8 | 18.5 | 15.12 |
| IVRFB-1 | 36.2 | 35.8 | 36.0 | 5.7 | 5.6 | 5.6 | 24.9 | 26.9 | 25.9 | 14.7 | 23.7 | 19.17 |
| IVFB-1 | 31.8 | 32.5 | 32.2 | 5.3 | 5.7 | 5.5 | 36.8 | 34.3 | 35.5 | 17.2 | 2.7 | 21.90 |
| IVFB-2 | 37.9 | 37.6 | 37.8 | 5.4 | 5.7 | 5.5 | 34.0 | 32.5 | 33.3 | 18.0 | 36.6 | 27.35 |
| IVFB-3 | 38.9 | 35.9 | 37.4 | 5.5 | 5.7 | 5.6 | 35.3 | 33.7 | 34.5 | 20.0 | 28.7 | 24.33 |
| JFB-97-1 | 39.9 | 31.9 | 35.9 | 4.0 | 4.1 | 4.0 | 42.5 | 39.1 | 40.8 | 20.8 | 4.3 | 12.58 |
| KPV-2 | 31.5 | 27.2 | 29.4 | 5.2 | 4.9 | 5.0 | 30.2 | 32.5 | 31.4 | 11.4 | 17.0 | 14.67 |
| MFB-1 | 42.5 | 32.6 | 37.6 | 6.0 | 6.0 | 6.0 | 32.9 | 35.5 | 34.2 | 21.2 | 21.0 | 21.12 |
| MFB-2 | 37.6 | 35.5 | 36.6 | 5.2 | 5.5 | 5.4 | 40.1 | 34.2 | 37.2 | 39.4 | 37.0 | 38.23 |
| MFB-3 | 39.5 | 39.6 | 39.6 | 6.4 | 5.7 | 6.0 | 35.7 | 34.9 | 35.3 | 27.6 | 41.0 | 34.32 |
| MFB-4 | 38.1 | 30.7 | 34.4 | 5.4 | 5.2 | 5.3 | 39.4 | 35.8 | 37.6 | 23.5 | 18.0 | 20.75 |
| MFB-5 | 31.2 | 31.1 | 31.1 | 6.5 | 6.1 | 6.3 | 37.4 | 34.1 | 35.7 | 25.0 | 15.0 | 20.00 |
| VLB-8 | 36.2 | 37.5 | 36.8 | 5.2 | 5.5 | 5.4 | 38.6 | 32.2 | 35.4 | 22.0 | 22.0 | 22.00 |
| VLB-9 | 33.5 | 35.6 | 34.6 | 5.2 | 5.6 | 5.4 | 40.2 | 36.5 | 38.4 | 10.6 | 17.3 | 18.47 |
| VLB-2003 | 32.1 | 32.5 | 32.3 | 4.6 | 5.1 | 4.9 | 36.1 | 33.4 | 34.7 | 11.7 | 23.3 | 17.53 |
| VLFB-130 | 36.8 | 35.1 | 36.0 | 5.6 | 5.9 | 5.8 | 34.5 | 34.3 | 34.4 | 16.6 | 21.0 | 18.83 |
| Aparna | 39.8 | 35.6 | 37.7 | 5.7 | 6.1 | 5.9 | 26.8 | 25.5 | 26.2 | 30.4 | 37.7 | 34.05 |
| Chandini | 39.7 | 35.2 | 37.5 | 6.1 | 6.1 | 6.1 | 14.6 | 15.2 | 14.9 | 13.0 | 8.1 | 10.57 |
| Falguni | 38.7 | 35.5 | 37.1 | 6.2 | 5.7 | 6.0 | 15.2 | 18.1 | 16.7 | 19.5 | 15.0 | 12.77 |
| Surya | 35.3 | 32.8 | 34.1 | 6.4 | 6.4 | 6.4 | 14.1 | 17.2 | 15.6 | 15.7 | 12.9 | 14.27 |
| Arka Komal | 32.5 | 36.9 | 34.7 | 5.5 | 6.1 | 5.8 | 36.1 | 33.5 | 35.1 | 16.3 | 16.7 | 16.53 |
| Contender | 30.4 | 28.9 | 29.7 | 5.3 | 4.7 | 5.0 | 45.6 | 41.6 | 43.6 | 20.0 | 18.0 | 18.98 |
| **CV (%)** | **5.8** | **7.0** | **22.9** | **5.9** | **7.3** | **7.1** | **8.0** | **8.0** | **10.7** | **18.8** | **18.7** | **28.17** |
| **LSD(0.05)** | **3.2** | **4.3** | **7.6** | **0.5** | **0.7** | **0.5** | **4.4** | **4.2** | **4.05** | **6.3** | **7.3** | **7.2** |

**Table 4: Mean performance of different genotypes for quality characters**

| Genotypes | Ascorbic acid (mg $g^{-100}$ ) | Protein (%) | Total sugar (%) | Total soluble solids (°brix) |
|---|---|---|---|---|
| Arka-Suvidha | 12.10 | 22.54 | 11.79 | 6.13 |
| Arka Anoop | 10.41 | 21.61 | 8.89 | 7.50 |
| DPDFB-1 | 12.50 | 26.09 | 10.12 | 6.73 |
| DPDFB-1(M) | 11.31 | 20.44 | 9.95 | 6.16 |
| DPDFB-2(M) | 10.90 | 23.65 | 12.93 | 8.10 |
| DWDFB-I | 10.50 | 25.68 | 11.56 | 6.20 |
| DWDFB-53 | 12.61 | 20.65 | 9.56 | 8.37 |
| DWDFB-57 | 11.13 | 22.31 | 12.36 | 9.23 |
| HAFB-1 | 8.80 | 23.35 | 12.74 | 6.60 |
| HAFB-2 | 10.63 | 22.71 | 8.94 | 6.80 |
| HAFB-3 | 12.46 | 21.05 | 9.09 | 7.10 |
| HAFB-4 | 12.43 | 19.97 | 12.35 | 8.73 |
| IVRBF-1 | 11.17 | 23.36 | 8.56 | 9.00 |
| IVFB-1 | 12.41 | 22.55 | 11.39 | 6.10 |
| IVFB-2 | 13.24 | 21.96 | 13.26 | 9.13 |
| IVFB-3 | 12.40 | 22.36 | 11.17 | 6.17 |
| JFB-97-1 | 15.77 | 18.92 | 12.66 | 8.73 |
| KPV-2 | 12.27 | 23.77 | 12,37 | 11.33 |
| MFB-1 | 10.25 | 19.64 | 12.29 | 8.07 |
| MFB-2 | 11.45 | 23.95 | 9.31 | 7.97 |
| MFB-3 | 11.87 | 21.84 | 10.70 | 8.80 |
| MFB-4 | 11.50 | 22.37 | 9.24 | 7.10 |
| MFB-5 | 11.81 | 23.18 | `12.70 | 8.93 |
| VLB-8 | 6.25 | 23.01 | 10.67 | 7.10 |
| VLB-9 | 10.50 | 22.37 | 10.67 | 7.27 |
| VLB-2003 | 10.90 | 24.70 | 10.92 | 8.03 |
| VLFB-130 | 11.84 | 23.24 | 7.44 | 7.20 |
| Aparna | 6.25 | 22.43 | 12.23 | 7.20 |
| Chandini | 10.92 | 22.60 | 8.67 | 7.13 |
| Falguni | 7.51 | 21.96 | 10.41 | 9.43 |
| Surya | 12.50 | 22.12 | 8.75 | 8.20 |
| Arka Komal | 10.16 | 22.10 | 11.88 | 6.20 |
| Contender | 10.37 | 22.77 | 11.29 | 10.30 |
| **CV (%)** | **10.59** | **7.32** | **13.86** | **5.47** |
| **LSD(0.05)** | **1.92** | **2.66** | **2.46** | **0.70** |

**Table 5: Morphological characterizations of french bean cultivars based upon pod shape and tenderness**

| Pod shape and pod tenderness | Genotypes included in the group |
|---|---|
| Straight and Stringless | Arka Suvidha , DPDFB-1, HAFB-1, HAFB-3, HAFB-4, MFB-1, Aparna, Chandini, Falguni and Surya |
| Straight and Semi Stringy | IVFB-1, MFB-2 and Arka Komal |
| Straight and Stringy | JFB-97-1 and KPV-2 |
| Slightly curved and Stringless | Arka Anoop, DPDFB-1(M), DPDFB-2(M), DWDFB-53, HAFB-2, IVRFB-1, IVFB-2, IVFB-3, MFB-3, MFB-4, VLB-8, VLB-9, VLB-2003 and VLFB-130 |
| Slightly curved and Semi Stringy | DWDFB-I , MFB-5 |
| Slightly curved and Stringy | DWDFB-57 |
| Curved and Stringless | Contender |

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