*Indian Journal of Ecology (2023) 50(5): 1443-1451*
*DOI: https://doi.org/10.55362/IJE/2023/4076*

**Manuscript Number: 4076**
**NAAS Rating: 5.79**

# Morphological and Genetic Variability in French Bean

**Tarra Supriya, Subhrajyoti Chatterjee* and K. Vimala Charishma[1]**

*Department of Horticulture, M S Swaminathan School of Agriculture (MSSSoA), Centurion University of Technology and Management (CUTM), Paralakhemundi-761 211, India*
*[1]St. Joseph's College for Women, Gnanapuram, Visakhapatnam-530 004, India*
**E-mail: subhrarahul@gmail.com*

***Abstract*:** In the present study, 12 morphological and 13 quantitative characters of French bean were recorded from 16 varieties to assess the genetic variability for growth, yield and quality traits. The overall mean value of Shannon-Weaver diversity index was 0.96 which confirmed the existence of diversity among the genotypes. The genotypes 'Arka Sharath', 'NFL-35' and 'Harsha' were most promising in respect to green pod yield per plant and tolerance to bean anthracnose disease. High phenotypic and genotypic co-efficient of variation were recorded for 10 pod weight, 100 seed weight, protein content of green pod, total sugar content of green pod, PDI of bean anthracnose and pod yield per plant. High heritability coupled with high genetic advance as per cent of mean was observed for pod diameter, number of pods per plant, 10 pod weight, 100 seed weight, number of seeds per pod, protein content, total sugar content of green pod, PDI of bean anthracnose and pod yield per plant indicated that these traits are predominantly governed by additive gene, so early generation selection would be rewarding for improving these traits. Pod diameter, pod length, number of pods per plant and 10 pod weight should be considered as the most important selection indices for enhancing green pod yield in French bean.

***Keywords:*** French bean, Genetic variability, Shannon-Weaver diversity index, Selection indices

French bean (*Phaseolus vulgaris*), commonly known as common bean, snap bean or kidney bean is a widely grown self-pollinated leguminous crop (Kalauni and Dhakal 2020). The genus *Phaseolus* is large, including approximately 80 cultivated and wild species, but *Phaseolus vulgari*s is the most widely cultivated species (Porch et al 2013). The crop is consumed worldwide principally for its green pods, dry (mature) beans and shell beans (seeds at physiological maturity). It is a major source of dietary protein that complements carbohydrate rich sources such as rice, maize, and cassava (Mohammed 2013). It is also a rich source of dietary fibers, minerals, and certain vitamins (Gepts et al 2008). This vegetable not only plays an important role in human nutrition but also improve soil fertility and fits well in crop rotations because of short growing period (Mishra et al 2010). The maximum genetic diversity of wild and cultivated beans is distributed throughout the Americas from northern Mexico through Central America and the Andes to northwest Argentina (Singh et al 1991a). Mexico has been established as the centre of origin, diversification and domestication of the common bean based on ethnobotanical, archaeological, morphological, genetic, biochemical and isoenzyme evidence (Papa et al 2003, Asfaw et al 2009, Bitocchi et al 2012). Domesticated beans are commonly separated into Andean and Mesoamerican gene pools (Singh et al 1991b). This crop is adapted to a wide variety of climatic conditions, being grown from 52° North latitude to 32° South latitude in the humid tropics, semi-arid tropics and even cold climate regions (Panchbhaiya et al 2017).

A wide variety of nutritional compounds with multiple positive effects for human health are contained in bean seeds like high contents of protein, fibre, polyphenols, flavonoids, carotenoids, saponins, oligosaccharides, condensed tannins, lectins, trypsin inhibitors and phytic acid. Polyphenols, anthocyanins and flavonoids among other phytochemical compounds, are particularly related with antioxidant biological activities and preventive effects against chronic degenerative diseases like cancer, obesity and diabetes, cardiovascular diseases as well as other conditions related to the triglycerides, cholesterol and metabolic syndromes (Chavez-Servia et al 2016). At present, the productivity of French bean is quite low (9.84 t/ha) in India (Department of Agriculture and Farmers Welfare, 2021). The probable causes of lower productivity may be unavailability of high yielding and various biotic and abiotic stress resistant varieties. Therefore, much emphasis needs to be given for the development of high yielding and stress resistant varieties and hybrids to increase the productivity comparable to other leading producing countries in the world. Evaluation of the potentialities of the existing genotypes is very necessary because the promise for further crop improvement depends on the genetic diversity of the initial parental materials (Mondal et al 2020). The phenotypic expression of plant character is mainly controlled by genetic makeup of the plant

and the environment, in which it is grown and their interaction between the genotype and environment. Further, variance in any quantitative trait depends on additive (heritable) and non-additive (non-heritable) variance, which include dominance and epistatis (non-allelic interaction). Therefore, it becomes essential to partition the observed phenotypic variability into genotypic (partly heritable) and environmental (non-heritable) components with suitable parameters, such as phenotypic and genotypic co- efficient of variation and heritability in broad sense. Furthermore, genetic advance may be used to predict the efficiency of selection (Jhanavi et al 2018). A measure of heritability and genetic advance gives an idea about the expected gain in the next generation. Green pod yield in French bean is a complex character like other legume vegetables and many morphological and physiological characters constitute it so that high yield can be achieved by selection of those characters that are having high heritability coupled with genetic advance. Assessing direct or indirect effects of each component traits towards green pod yield through path analysis would help in identifying reliable characters contributing to yield (Lyngdoh et al 2017).

## MATERIAL AND METHODS

Field experiment was conducted during *rabi* season of 2021-22 at Horticulture Research Farm (HRF) of M S Swaminathan School of Agriculture (MSSSOA), Centurion University of Technology and Management, Paralakhemundi, Gajapati, Odisha. Genotypes of French bean were collected from different places of India constituted the plant materials for this study. The experiment was conducted in randomized complete block design (RCBD) with 16 treatments and 3 replications. The crop was grown in individual plots of 3.6 m × 2.4 m with a spacing of 45 cm × 30 cm from row to row and plant to plant respectively. Standard cultural practices and protective measures recommended in the 'Manual on Agricultural Production Technlogy' (Directorate of Agriculture and Food Production, 2008) were followed to ensure a healthy crop stand.

**Observations:** The observations on both qualitative and quantitative characters were recorded from 10 randomly selected plants of each plot in each replication.

**Qualitative parameters:** Qualitative characters like plant growth habit, stem pigmentation, leaf colour, leaflet shape, flower wing colour, pod colour, orientation of pods, pod beak shape, pod shape, pod curvature, pod pubescence and seed colour were recorded.

**Quantitative parameters:** 13 quantitative traits were recorded. Total soluble protein and sugar content of green pod were estimated as per Lowry et al (1951) and by Anthrone method (Dubois et al 1956) respectively.

**Bean anthracnose disease severity:** The severity of bean anthracnose [C.O: *Colletotrichum lindemuthianum* (Sacc. and Mang.)] was recorded from each plant of a genotype in each plot starting from seedling to pod maturity stages. Assessment on the reaction of the genotypes to bean anthracnose was recorded with the disease parameter Percent Disease Index (PDI) following the disease rating scale *i.e.* 0-9 (Mayee and Dattar 1986) in Table 1.

Percent Disease Index (PDI) was calculated from the numerical ratings (McKinney 1923).

**Statistical analyses:** Statistical analyses were done with Windostat (ver.8.0, Indostat Services, Hyderabad, India. The frequency distributions were used to calculate the Shannon-Weaver diversity index (H) for each character (Hennink and Zeven 1991). The index is as follows:

$$H = -\sum_{i=1}^{S} Pi \ln Pi$$

Where,

H= Shannon-Weaver diversity index, S= the number of genera, Pi= ni/N as the proportion of type I (ni= the total number of individuals of microbe in total i type, N= the total number of all the individuals in total n).

The genotype and phenotypic co-efficient of variations were calculated as per Burton (1952). Heritability in broad sense (H) was estimated by the method proposed by Hanson et al (1956). The expected genetic advance (GA) was

**Table 1.** Disease rating scale (0-9) of bean anthracnose

| Symptom severity grade | Symptom | Reaction |
|---|---|---|
| 0 | No symptoms on leaf/pods | Highly resistant (HR) |
| 1 | Small, round brown spots covering 1% or less of leaf/pod area | Resistant (R) |
| 3 | Brown, sunken spots covering 1-10 % of leaf/pod area | Moderately resistant (MR) |
| 5 | Brown spots enlarging to form circular spots covering 11-25% of leaf/pod area | Moderately susceptible (MS) |
| 7 | Circular brown, sunken spots, covering 26–50% of leaf/pod area | Susceptible (S) |
| 9 | Circular to irregular, brown sunken spots covering 50% or more of the leaf/pod area | Highly susceptible (HS) |

Percent Disease Index (PDI) was calculated from the numerical ratings (McKinney 1923).

calculated as per Lush (1949) and Johnson et al (1955). Direct and indirect effects of component traits on green pod yield per plant were calculated through path coefficient analysis (Dewey and Lu 1959).

## RESULTS AND DISCUSSION

**Morphological characterization of genotypes:** 12 morphological/ qualitative characters recorded in 16 bush type genotypes of French bean as per descriptors of NBPGR (Table 2). Frequency distribution patterns, percent of proportion and Shannon-Weaver Diversity Index (H) were estimated from the same 12 characters (Table 3). All the genotypes (100 %) showed bush type of plant growth habit. Genotypes of the present study revealed great variation for the traits stem pigmentation, leaf colour and pod colour where those were grouped into 9 categories according to the Royal Horticultural Society Colour Chart (RHCC). 56.20 % genotypes had round shaped leaflet while 43.70 % genotypes exhibited ovate shaped leaflet. This type of grouping was also reported by Kanwar et al (2019). Flower wing colour of the genotypes varied from 87.50 % genotypes with white colour to only 12.50 % genotypes with deep pink to purple flower wing. Kalauni et al (2019) also reported white and violet-purple colour flower wing of six genotypes of French bean. 13 out of 16 genotypes (81.20 %) showed prostrate pod orientation whereas 3 genotypes had upright orientation. All the genotypes were grouped into 3 categories *viz*., short, medium and long regarding the trait pod beak shape. Out of these genotypes, 5 each was having short (31.20 %) and long pod beak (31.20 %) whereas rest 6 had medium pod beak. Pod shape of different French bean genotypes were grouped into 2 categories *i.e*., straight and

**Table 2.** Morphological characterization of 16 French bean genotypes

| Genotypes | Plant growth characters | | | | | Pod characters | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PGH | SP | LS | LC | FWC | PC | OP | PBS | PS | PCU | PP | SC |
| Malgudi | Bush type | 137 (B) | Round (1.44) | 137 (B) | White | 137 (B) | Prostrate | Long | Slightly curved | Slightly curved | No hairs | White |
| Akshara | Bush type | 138 (A) | Round (1.46) | 138 (A) | White | 139 (D) | Prostrate | Long | Straight | Straight | Sparse | Creamish |
| Falguni | Bush type | N137 (B) | Ovate (1.56) | N137 (B) | White | 138 (C) | Prostrate | Short | Straight | Straight | No hairs | White |
| Anupama | Bush type | 146 (A) | Round (1.43) | 146 (A) | White | 139 (D) | Prostrate | Medium | Slightly curved | Slightly curved | No hairs | Dark brown |
| Anup | Bush type | 137 (A) | Ovate (1.57) | 137 (A) | White | 137 (B) | Upright | Medium | Slightly curved | Slightly curved | Sparse | Dark brown |
| Arka Komal | Bush type | N137 (A) | Round (1.49) | N137 (A) | Deep pink to purple | 139 (C) | Prostrate | Medium | Straight | Straight | Sparse | Light brown |
| Serengeti | Bush type | 138 (A) | Ovate (1.57) | 138 (A) | White | 138 (B) | Upright | Long | Slightly curved | Slightly curved | No hairs | Creamish |
| NFL-35 (Suman) | Bush type | 146 (A) | Round (1.45) | 146 (A) | Deep pink to purple | 139 (C) | Prostrate | Medium | Straight | Straight | Sparse | Light brown |
| Rani | Bush type | 138 (A) | Round (1.46) | 138 (A) | White | 139 (D) | Prostrate | Short | Straight | Straight | No hairs | White |
| Bean Roshni | Bush type | 146 (D) | Ovate (1.64) | 146 (D) | White | 137 (C) | Upright | Short | Straight | Straight | No hairs | White |
| Rupali | Bush type | 146 (A) | Ovate (1.51) | 146 (A) | White | 137 (B) | Prostrate | Short | Straight | Straight | No hairs | Creamish |
| Fiesta | Bush type | 138 (A) | Ovate (1.67) | 138 (A) | White | 139 (D) | Prostrate | Long | Straight | Straight | No hairs | White |
| Aishwarya | Bush type | 137 (A) | Round (1.42) | 137 (A) | White | 139 (C) | Prostrate | Long | Slightly curved | Slightly curved | No hairs | White |
| Arka Arjun | Bush type | 146 (C) | Ovate (1.52) | 146 (C) | White | 146 (B) | Prostrate | Short | Straight | Straight | No hairs | White |
| Arka Sharath | Bush type | 146 (B) | Round (1.43) | 146 (B) | White | 138 (D) | Prostrate | Medium | Straight | Straight | No hairs | White |
| Harsha | Bush type | 146 (A) | Round (1.40) | 146 (A) | White | 146 (A) | Prostrate | Medium | Slightly curved | Slightly curved | No hairs | White |

Where, PGH = Plant growth habit, SP = Stem pigmentation, LS = Leaflet shape, LC = Leaf colour, FWC = Flower wing colour, PC= Pod colour, OP= Orientation of pods, PBS = Pod beak shape, PS = Pod shape, PCU = Pod curvature, PP = Pod pubescence and SC = Seed colour

**Table 3.** Frequency distribution, proportion and Shannon-weaver diversity index (H') of qualitative traits of 16 French bean genotypes

| Characters | Morphological description | Frequency distribution | | H'-index |
|---|---|---|---|---|
| | | No. of genotypes in the group | Percent (%) | |
| Plant growth habit | Bush type | 16 | 0 | 0 |
| Stem pigmentation | 137 (A) | 2 | 12.50 | 1.98 |
| | 137 (B) | 1 | 6.20 | |
| | 138 (A) | 4 | 25.00 | |
| | N 137 (A) | 1 | 6.20 | |
| | N 137 (B) | 1 | 6.20 | |
| | 146 (A) | 4 | 25.00 | |
| | 146 (B) | 1 | 6.20 | |
| | 146 (C) | 1 | 6.20 | |
| | 146 (D) | 1 | 6.20 | |
| Leaflet shape | Round | 9 | 56.20 | 0.68 |
| | Ovate | 7 | 43.70 | |
| Leaf colour | 137 (A) | 2 | 12.50 | 1.98 |
| | 137 (B) | 1 | 6.20 | |
| | 138 (A) | 4 | 25.00 | |
| | N 137 (A) | 1 | 6.20 | |
| | N 137 (B) | 1 | 6.20 | |
| | 146 (A) | 4 | 25.00 | |
| | 146 (B) | 1 | 6.20 | |
| | 146 (C) | 1 | 6.20 | |
| | 146 (D) | 1 | 6.20 | |
| Flower wing colour | White | 14 | 87.50 | 0.37 |
| | Deep pink to purple | 2 | 12.50 | |
| Pod colour | 137 (B) | 3 | 18.70 | |
| | 137 (C) | 1 | 6.20 | |
| | 138 (B) | 1 | 6.20 | 2.00 |
| | 138 (C) | 1 | 6.20 | |
| | 138 (D) | 1 | 6.20 | |
| | 139 (C) | 3 | 18.70 | |
| | 139 (D) | 4 | 25.00 | |
| | 146 (A) | 1 | 6.20 | |
| | 146 (B) | 1 | 6.20 | |
| Orientation of pods | Prostrate | 13 | 81.20 | 0.48 |
| | Upright | 3 | 18.70 | |
| Pod beak shape | Short | 5 | 31.20 | 1.09 |
| | Medium | 6 | 37.50 | |
| | Long | 5 | 31.20 | |
| Pod shape | Straight | 10 | 62.50 | 0.66 |
| | Slightly curved | 6 | 37.50 | |
| Pod curvature | Straight | 10 | 62.50 | 0.66 |
| | Slightly curved | 6 | 37.50 | |
| Pod pubescence | No hairs (glabrous) | 12 | 75.00 | 0.56 |
| | Sparse hair | 4 | 25.00 | |
| Seed Colour | White | 9 | 56.20 | 1.15 |
| | Creamish white | 3 | 18.70 | |
| | Light brown | 2 | 12.50 | |
| | Deep brown | 2 | 12.50 | |
| Overall mean of H' | | | | 0.96 |

slightly curved in the present study. 10 genotypes were categorized under straight (62.50 %) whereas 6 were grouped under slightly curved category. Kalauni et al (2019) and Kanwar et al (2019) earlier found significant variation in pod shape among common bean genotypes. Most of the varieties showed pods with 2 curvature pattern *viz*., slightly curved (62.50 %) and straight (37.50 %). Pod pubescence of genotypes varied from no hairs on the pods (75 %) to sparse hairs (25 %). All the genotypes fell in 4 colour groups regarding the trait seed colour *viz*., white (56.20 %), creamish white (18.70 %), light brown (12.50 %) and deep brown (12.50 %). Pandey et al (2011) and Kalauni et al (2019) also found significant variation in seed colour among common bean genotypes.

Biodiversity in any crop species can be summarized with two of its components *i.e.* allelic evenness and allelic richness. The richness indicates the number of genotype present in a designated area whereas evenness stands for the relative abundance of each genotype (Mondal et al 2020). The value of Shannon-Weaver diversity index (H) value varied from 0.00 for plant growth habit to 2.00 for pod colour. High Shanon-Weaver diversity index with an overall mean of 96 % was obtained, confirming the existence of diversity among the genotypes. The predominant traits that showed wider variations among the genotypes were pod colour, stem pigmentation, leaf colour, seed colour and pod beak shape. The Shannon-Wiener index values can range from 0 to 4.6. A value near 0 indicated that every species in the sample is the same and a value near 4.6 indicated the numbers of individual are evenly distributed between the French bean genotypes. A low H indicates unbalance frequency class and lack of diversity for the traits studied. A higher H' value indicates presence of variability or diversity for the trait (Hennink and Zeven 1991). Values below overall mean indicate unbalance frequency class and lack of diversity for the traits. Chatterjee (2022) also observed highly divergent qualitative traits among indigenous bush and pole type French bean germplasm collections in India.

**Mean performance of genotypes:** Genotypes showed highly significant variations for all the thirteen quantitative characters under study (Table 4). Wide variation in plant height was observed among French bean genotypes ranging from 34.36 cm in 'Rupali' to 46.97 cm in 'NFL-35' with a mean of 40.11 cm. Early flowering leads to early production of pods which can fetch higher market price. Days to first flowering also varied widely between 30.66 days in 'Arka Sharath' to

**Table 4.** Mean performance of sixteen French bean genotypes

| Genotype | Plant height (cm) | Days to first flowering | Days to 50% flowering | Pod length (cm) | Pod diameter (cm) | Number of pods per plant | 10 pod weight (g) | 100 seed weight (g) | Number of seeds per pod | Protein content (%) | Total sugar (%) | PDI of bean anthracnose | Pod yield per plant |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Malgudi | 42.813 | 31.333 | 34.667 | 13.940 | 0.867 | 19.800 | 72.793 | 17.107 | 6.500 | 2.057 | 3.820 | 12.340 | 87.193 |
| Akshara | 40.180 | 33.667 | 37.333 | 13.267 | 0.693 | 17.000 | 54.620 | 20.197 | 6.300 | 3.737 | 5.430 | 17.083 | 77.787 |
| Falguni | 40.940 | 33.667 | 37.000 | 13.323 | 0.707 | 17.400 | 56.100 | 15.490 | 6.767 | 3.320 | 5.283 | 16.717 | 78.813 |
| Anupama | 41.487 | 32.667 | 36.333 | 13.440 | 0.773 | 18.000 | 59.093 | 24.057 | 6.133 | 2.887 | 5.027 | 14.877 | 79.387 |
| Anup | 38.653 | 34.667 | 38.333 | 13.150 | 0.640 | 14.133 | 47.107 | 22.530 | 5.467 | 4.993 | 6.330 | 18.453 | 72.760 |
| Arka Komal | 41.987 | 31.667 | 36.333 | 13.500 | 0.803 | 18.333 | 63.933 | 35.033 | 4.267 | 2.267 | 4.747 | 13.760 | 81.167 |
| Serengeti | 37.367 | 37.333 | 40.667 | 12.383 | 0.607 | 12.600 | 41.133 | 20.830 | 6.167 | 5.317 | 6.803 | 19.757 | 68.140 |
| NFL-35 (Suman) | 46.973 | 31.000 | 34.333 | 14.173 | 0.977 | 20.387 | 74.933 | 20.387 | 5.367 | 1.633 | 3.760 | 12.040 | 92.240 |
| Rani | 37.260 | 38.000 | 41.000 | 12.320 | 0.587 | 12.400 | 41.027 | 16.257 | 6.033 | 5.503 | 7.327 | 21.840 | 68.047 |
| Bean Roshni | 39.953 | 34.333 | 38.000 | 13.190 | 0.683 | 15.867 | 47.133 | 15.490 | 6.267 | 4.150 | 6.020 | 17.800 | 74.543 |
| Rupali | 34.360 | 39.333 | 41.333 | 11.840 | 0.577 | 12.200 | 39.513 | 15.337 | 5.333 | 5.600 | 7.630 | 25.397 | 66.050 |
| Fiesta | 40.073 | 34.333 | 37.667 | 13.207 | 0.683 | 16.067 | 47.833 | 16.810 | 6.033 | 4.057 | 5.783 | 17.780 | 76.727 |
| Aishwarya | 37.620 | 36.333 | 39.333 | 12.527 | 0.630 | 13.867 | 44.053 | 20.000 | 6.667 | 5.117 | 6.703 | 18.643 | 70.307 |
| Arka Arjun | 42.480 | 31.333 | 36.000 | 13.770 | 0.830 | 18.933 | 67.167 | 20.080 | 5.967 | 2.123 | 3.967 | 12.780 | 83.580 |
| Arka Sharath | 44.127 | 30.667 | 33.667 | 14.260 | 0.987 | 21.600 | 79.420 | 20.083 | 5.967 | 1.447 | 3.390 | 11.860 | 95.293 |
| Harsha | 35.520 | 40.000 | 43.000 | 11.503 | 0.547 | 11.800 | 38.680 | 20.113 | 5.433 | 5.610 | 7.680 | 26.750 | 61.387 |
| Mean | 40.112 | 34.396 | 37.813 | 13.112 | 0.724 | 16.274 | 54.659 | 19.988 | 5.917 | 3.739 | 5.606 | 17.367 | 77.089 |
| CD (p=0.05) | NA | 2.054 | 2.44 | 0.931 | 0.061 | 4.113 | 9.145 | 0.519 | 0.267 | 0.244 | 0.267 | 0.325 | NA |
| C.V. (%) | 12.70 | 3.581 | 3.87 | 4.25 | 5.010 | 15.155 | 10.034 | 1.558 | 2.709 | 3.907 | 2.857 | 1.123 | 18.363 |

40.00 days in 'Harsha' with a mean of 34.39 days. Similar trend was found for the trait days to 50 % flowering. The minimum days taken to 50 % flowering was recorded in 'Arka Sharath' (33.66 days) whereas 'Harsha' (43.00 days) was found to take maximum days for 50 % flowering. Kumar et al (2014) and Lyngdoh et al (2017) also observed similar range regarding the flowering traits. Combination of both pod length and pod diameter determines pod shape. Pod length varied widely between 11.50 cm in 'Harsha' and 14.26 cm in 'Arka Sharath'. Similarly, minimum pod diameter was observed in 'Harsha' (0.54 cm) and the maximum was observed in 'Arka Sharath' (0.98 cm). Kanwar et al (2017) at Himachal Pradesh and Razvi et al (2017) at Jammu and Kashmir also found similar range among genotypes regarding pod length and diameter. Higher number of pods per plant leads to more pod yield per plant. Number of pods varied widely among genotypes ranging from 11.80 to 21.60. The maximum number of pods was produced by 'Arka Sharath' (21.60) followed by 'NFL-35' (20.38) whereas the lowest was recorded in 'Harsha' (11.80). 10 pod weight varied between 38.68 g in 'Harsha' and 79.42 g in 'Arka Sharath', the mean being 54.65 g. Jhanavi et al (2018) reported similar range regarding these traits among the genotypes from a study conducted at College of Horticulture, Bagalkot, Karnataka.

In case of the trait 100 seed weight, 'Rupali' exhibited minimum value (15.33 g) whereas 'Arka Komal' showed maximum value (35.03 g). Number of seeds per pod ranged from 4.26 to 6.76 with a mean value of 5.91. The minimum and maximum value regarding this trait was exhibited by the genotypes 'Arka Komal' (4.26) and 'Falguni' (6.76 g) respectively. Prakash and Ram (2014) and Razvi et al (2017) reported similar ranges regarding these two traits among the genotypes they studied. Regarding the trait protein content of green pod, minimum and maximum value was observed in 'Arka Sharath' (1.44 %) and 'Harsha' (5.61 %) respectively with a mean value of 3.73 %. The mean value of the trait total sugar content of green pod was 5.60 %, the minimum being 'Arka Sharath' (3.39 %) and the maximum in 'Harsha' (7.68 %). The range of total sugar content of green pod in the present study is in line with the findings of Prakash and Ram (2014).

**Genetic variability and heritability:** The genotypes exhibited highly significant differences for all the characters under study (Table 5) which clearly supports the justification of studying genetic variability of different characters employing these genotypes. Coefficient of variation was widely different ranging from minimum of 1.12 to maximum of 18.36 (Table 4). In the present investigation, the phenotypic coefficient of variations was slightly higher than the corresponding genotypic coefficient of variations for all the characters studied (Table 6) which indicated that the apparent variation was not only due to genotypes but also due to the influence of environment in the expression of the traits. However, the influence of environment for the expression of characters was not very high suggesting appreciable genotypic worth for all the characters. Such inference could also be drawn from the magnitude of low to moderate coefficient of variation for the characters. Hence, the characters could be improved following different phenotypic selections like directional, disruptive and stabilized selections (Mondal et al 2020).

Phenotypic coefficients of variation (PCV) and genotypic coefficients of variation (GCV) were categorized as low (0-10%), moderate (10-20%) and high (>20%) (Sivasubramanian and Madhavamenon 1973). Accordingly, very high PCV and GCV values were recorded for protein content of green pod (PCV 40.69; GCV 40.50) which indicated the highest magnitude of variability for this character. High magnitude of GCV and PCV, respectively were recorded for 10 pod weight, PDI of bean anthracnose, total sugar content of green pods, 100 seed weight and pod yield per plant. Moderate PCV and GCV were registered for the trait pod diameter. Whereas, the trait number of pods per plant had high PCV value and moderate GCV value. Similar findings were previously reported by earlier researchers like Kumar et al (2014), Verma et al (2014), Topwal and Gaur (2016), Lyngdoh et al (2017), Jhanavi et al (2018), Ramandeep et al (2018) and Yumkhaibam et al (2019). High

**Table 5.** ANOVA for thirteen quantitative characters of French bean

| Source of variation | Mean sum of square | | |
|---|---|---|---|
| | Replication | Treatments | Error |
| DF | 2 | 15 | 30 |
| Plant height (cm) | 593.37 | 481.20** | 778.89 |
| Days to first flowering | 3.16 | 410.81** | 45.50 |
| Days to 50% flowering | 0.87 | 323.97** | 64.45 |
| Pod length (cm) | 0.92 | 28.83** | 9.34 |
| Pod diameter (cm) | 0.001 | 0.83** | 0.03 |
| Number of pods per plant | 30.02 | 448.52** | 182.49 |
| 10 pod weight (g) | 118.22 | 8230.35** | 902.35 |
| 100 seed weight (g) | 0.42 | 1034.23** | 2.90 |
| Number of seeds per pod | 0.002 | 17.51** | 0.77 |
| Protein content of green pod (%) | 0.10 | 103.51** | 0.63 |
| Total sugar content of green pod (%) | 0.009 | 90.38** | 0.76 |
| PDI of bean anthracnose (%) | 0.67 | 918.39** | 1.14 |
| Pod yield per plant (g) | 99.91 | 3996.51** | 6011.62 |

** Significant at 0.01 level of probability

to moderate magnitude of GCV and PCV generally indicated ample scope for improvement through selection. The present findings clearly indicated the worth of the traits namely protein content of green pod, 10 pod weight, PDI of bean anthracnose, total sugar content of green pods, 100 seed weight, pod yield per plant, pod diameter and number of pods per plant for the study of genetic variability in French bean.

Genotypic coefficients of variation do not estimate the variations that are heritable hence, estimation of heritability is absolutely necessary (Falconer 1960). Heritability is classified as low (below 30 %), medium (30-60 %) and high (above 60 %) (Johnson et al 1955). Among the characters studied, high heritability estimate was recorded for days to first flowering (85.04 %), days to 50 % flowering, pod length, pod diameter, number of pods per plant, 10 pod weight, 100 seed weight, number of seeds per pod, protein content of green pod, total sugar content of green pod, PDI of bean anthracnose and pod yield per plant. The trait plant height only showed low heritability (Table 6). High heritability indicates less environmental influence in the observed variation (Songsri et al 2008) which suggested that selection based on phenotypic expression could be relied upon as

**Table 6.** Mean, range and estimates of genetic parameters of sixteen French bean genotypes

| Character | Mean | Range | GCV*(%) | PCV*(%) | GCV:PCV | h² in broad sense (%) | Genetic advance as % of mean |
|---|---|---|---|---|---|---|---|
| Plant height (cm) | 40.112 | 34.360-46.973 | 3.559 | 13.192 | 26.984 | 7.280 | 1.978 |
| Days to first flowering | 34.396 | 30.666-40.000 | 8.537 | 9.258 | 92.219 | 85.041 | 16.219 |
| Days to 50% flowering | 37.813 | 33.666-43.000 | 3.876 | 6.733 | 57.566 | 75.117 | 12.022 |
| Pod length (cm) | 13.112 | 11.503-14.260 | 5.589 | 7.025 | 79.558 | 63.303 | 9.159 |
| Pod diameter (cm) | 0.724 | 0.546-0.986 | 18.616 | 19.279 | 96.563 | 93.254 | 37.03 |
| Number of pods per plant | 16.274 | 11.800-21.600 | 17.313 | 23.009 | 75.245 | 60.623 | 26.837 |
| 10 pod weight (g) | 54.659 | 38.680-79.420 | 24.054 | 26.063 | 92.292 | 85.187 | 45.733 |
| 100 seed weight (g) | 19.988 | 15.336-35.033 | 23.968 | 24.019 | 99.789 | 99.580 | 49.271 |
| Number of seeds per pod | 5.917 | 4.266-6.766 | 10.427 | 10.773 | 96.788 | 93.682 | 20.790 |
| Protein content of green pod (%) | 3.739 | 1.446-5.610 | 40.506 | 40.694 | 99.538 | 99.080 | 83.058 |
| Total sugar content of green pod (%) | 5.606 | 3.390-7.680 | 25.225 | 25.387 | 99.364 | 98.733 | 51.634 |
| PDI of bean anthracnose (%) | 17.367 | 11.860-26.750 | 26.004 | 26.028 | 99.906 | 99.812 | 53.518 |
| Pod yield per plant (g) | 77.089 | 61.386-95.293 | 20.086 | 21.345 | 94.10 | 71.423 | 34.432 |

GCV = Genotypic coefficient of variation; PCV = Phenotypic coefficient of variation

**Table 7.** Phenotypic path analysis for thirteen characters of sixteen French bean genotypes

| Character | PH | DFF | D50F | PL | PD | NPPP | 10PW | 100SW | NSPP | PC | TS | PDIA | Correlation with FYPP at phenotypic level |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PH | -0.049 | 0.048 | 0.405 | -0.139 | 0.356 | -0.185 | 0.228 | 0.008 | 0.001 | 0.141 | -0.458 | -0.004 | 0.353* |
| DFF | 0.025 | -0.097 | -0.716 | 0.293 | -0.562 | 0.331 | -0.345 | -0.017 | 0.001 | -0.213 | 0.727 | 0.007 | -0.568** |
| D50F | 0.024 | -0.084 | -0.832 | 0.314 | -0.562 | 0.327 | -0.334 | -0.011 | -0.009 | -0.205 | 0.696 | 0.006 | -0.669** |
| PL | -0.020 | 0.081 | 0.747 | 0.538 | -0.350 | -0.284 | 0.316 | 0.010 | 0.016 | 0.187 | -0.663 | -0.006 | 0.571** |
| PD | -0.027 | 0.083 | 0.708 | -0.285 | 0.660 | -0.336 | 0.379 | 0.013 | -0.011 | 0.223 | -0.744 | -0.006 | 0.657** |
| NPPP | -0.021 | 0.076 | 0.637 | -0.233 | -0.426 | 0.520 | 0.316 | 0.011 | 0.004 | 0.198 | -0.642 | -0.006 | 0.432** |
| 10PW | -0.027 | 0.081 | 0.670 | -0.267 | 0.603 | -0.325 | 0.415 | 0.014 | -0.010 | 0.219 | -0.728 | -0.006 | 0.641** |
| 100SW | -0.007 | 0.029 | 0.162 | -0.062 | 0.152 | -0.082 | 0.105 | 0.056 | -0.121 | 0.073 | -0.193 | -0.002 | 0.110 |
| NSPP | 0.000 | -0.001 | 0.039 | -0.031 | -0.040 | -0.010 | -0.023 | -0.037 | 0.182 | -0.019 | -0.018 | -0.001 | 0.043 |
| PC | 0.029 | -0.087 | -0.716 | 0.275 | -0.619 | 0.355 | -0.383 | -0.017 | 0.014 | -0.238 | 0.776 | 0.006 | -0.604** |
| TS | 0.028 | -0.089 | -0.730 | 0.293 | -0.619 | 0.345 | -0.381 | -0.014 | 0.793 | -0.233 | -0.004 | 0.007 | -0.603** |
| PDIA | 0.028 | -0.091 | -0.733 | 0.297 | -0.584 | 0.337 | -0.357 | 0.007 | -0.014 | -0.219 | 0.755 | -0.018 | -0.590** |

Residual effect = 0.0443, Direct effect = Bold diagonals.
Where, PH =Plant height; DFF= Days to first flowering; D50F= Days to 50% flowering; PL=Pod length (cm); PD=Pod diameter (cm); NPPP =Number of pods per plant; 10 PD= 10 Pod Weight(g); 100 SW= 100 seed weight (g); NSPP= Number of seeds per pod; PC= Protein content of green pod (%); TS= Total Sugar content of green pod (%); PDIA= PDI of anthracnose (%); PYPP= Pod yield per plant (g)

there was major role of genetic constitution in the expression of these characters. At the same time, heritability value alone cannot provide information on amount of genetic progress that would result from selection of best individuals. High heritability coupled with high genetic advance as per cent of mean was observed for pod diameter, number of pods per plant, 10 pod weight, 100 seed weight, number of seeds per pod, protein content of green pod, total sugar content of green pod, PDI of bean anthracnose and pod yield per plant.

**Selection indices:** Among the yield component traits, pod diameter (0.660) showed high positive direct effects on pod yield per plant followed by pod length, number of pods per plant and 10 pod weight (Table 7). High and positive direct effect on green pod yield per plant through pod diameter, pod length, number of pods per plant and 10 pod weight was earlier reported by earlier researchers namely Ghimire and Mondal (2019), Noopur et al (2018), Verma and Naidu (2018), Kalauni and Dhakal (2020) and Elias et al (2021). Other traits like number of seeds per pod and 100 seed weight expressed low positive direct effects on pod yield per plant. The indirect effects via other characters were negligible. Hence, direct selection through pod diameter, pod length, number of pods per plant and 10 pod weight could be beneficial for yield improvement of French bean. Some other characters like plant height, days to first flowering, days to 50 % flowering, protein content of green pod, total sugar content of green pod and PDI of bean anthracnose showed direct negative effects on pod yield per plant. Residual effect of the path analysis was very low (0.044) suggesting the inclusion of maximum pod yield determining characters (66 %) in the present study.

## CONCLUSION

The present study illustrated significant variation among genotypes for both qualitative and quantitative traits. The overall mean of Shannon-Wiener diversity index (H) value of 0.96 amply suggest the existence of diversity among the genotypes under study. Pod diameter, number of pods per plant, 10 pod weight, 100 seed weight, number of seeds per pod, protein content of green pod, total sugar content of green pod, PDI of bean anthracnose and pod yield per plant exhibited high heritability in conjunction with high genetic advance which suggests that the characters concerned are conditioned by additive gene action and therefore, these characters would be more reliable for effective selection. The maximum positive direct effects were exerted by pod diameter, pod length, number of pods per plant and 10 pod weight on green pod yield per plant. The genotypes 'Arka Sharath', 'NFL-35' and 'Harsha' were found most promising in respect to green pod yield per plant and tolerance to bean anthracnose disease. The information generated through this study will help the breeders to develop high yielding and disease resistant varieties of French bean in future.

## ACKNOWLEDGEMENT

The authors want to duly acknowledge the Department of Horticulture, MSSSOA, CUTM for providing all the support during the period of the research work.

## REFERENCES

Asfaw A, Blair MW and Almekinders C 2009. Genetic diversity and population structure of common bean (*Phaseolus vulgaris* L.) landraces from the East African highlands. *Theoretical and Applied Genetics* **120**(1): 1-12.

Bitocchi E, Nanni L, Bellucci E, Rossi M, Giardini A, Zeuli P S, Logozzo G, Stougaard J, McClean P, Attene G and Papa R 2012. Mesoamerican origin of the common beans (*Phaseolus vulgaris* L.) is revealed by sequence data. *Proceedings of the National Academy of Sciences of the United States of America* **109**(14): 788-796.

Burton GW 1952. Quantitative Inheritance in Grasses, pp. 277-283. Proceedings of 6th *International Grassland Congress (Vol. 1)*, August 17-23, 1952, Pennsylvania State College, USA.

Chatterjee S 2022. *Yield components, nodulation and gene action in French bean (Phaseolus vulgaris* L.). Ph.D. Dissertation, Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India.

Chavez-Servia JL, Heredia-Garcia E, Mayek-Perez N, Aquino-Bolanos EN, Hernandez-Delgado S, Carrillo-Rodriguez JC, Gill-Langarica HR and Vera-Guzman AM 2016. Diversity of Common Bean (*Phaseolus vulgaris* L.) Landraces and the Nutritional Value of their Grains, pp. 1-33. In: Goyal AK (eds). *Grain Legumes*. IntechOpen Limited, London, United Kingdom.

Department of Agriculture and Farmers Welfare 2021. 2021-22 (First Advance Estimates). Published by Ministry of Agriculture and Farmers Welfare, Government of India.

Dewey DR and Lu KH 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agronomy Journal* **51**(9): 515-518.

Directorate of Agriculture and Food Production 2008. *Manual on Agricultural Production Technology*, pp. 69-70. Published by 'Directorate of Agriculture & Food Production, Bhubaneswar, Odisha' with technical support from Odisha University of Agriculture and Technology, Bhubaneswar.

Dubois M, Gilles KA, Hamilton JK, Rebers PA and Smith F 1956. Colorimetric method for determination of sugars and related substances. *Analytical Chemistry* **28**(3): 350-356.

Elias M, Tesso B and Bekele A 2021. Variability and association of characters among common bean (*Phaseolus vulgaris* L.) genotypes in Southern Ethiopia. *Research & Reviews: Journal of Botany* **10**(2): 21-27.

Falconer DS 1960. *Introduction to Quantitative Genetics*, Oliver and Boyd Limited, Edinburgh and London, UK, p 365.

Gepts P, Aragão FJL, De Barros E, Blair MW, Brondani R, Broughton W, Galasso I, Hernandez G, Kami J, Lariguet P, McClean P, Melotto M, Miklas P, Pauls P, Pedrosa-Harand A, Porch T, Sanchez F, Sparvoli F and Yu K 2008 Genomics of *Phaseolus* Beans, a Major Source of Dietary Protein and Micronutrients in the Tropics, pp 113-40. In: Moore PH and Ming R (eds). *Genomics of Tropical Crop Plants*. Springer, Germany.

Ghimire NH and Mandal HN 2019. Genetic variability, heritability and genetic advance of common bean (*Phaseolus vulgaris* L.) genotypes at mountain environment of Nepal. *International Journal of Advanced Research in Biological Sciences* **6**(10): 46-56.

Hanson CH, Robinson HF and Comstock RE 1956. Biometrical

studies of yield in segregating populations of Korean Lesedezo. *Agronomy Journal* **48**(6): 268-272.

Hennink S and Zeven AC 1991. The interpretation of Nei and Shannon-Weaver within population variation indices. *Euphytica* **51**: 235-240.

Jhanavi DR, Patil HB, Justin P, Revanappa HPH, Mulla SWR and Sarvamangala C 2018. Genetic variability, heritability and genetic advance studies in French bean (*Phaseolus vulgaris* L.) genotypes. *Indian Journal of Agricultural Research* **52**(2): 162-166.

Johnson HW, Robinson HF and Comstock RE 1955. Genotypic and phenotypic correlation in soyabean and their implication in selection. *Agronomy Journal* **47**(10): 477-483.

Kalauni S and Dhakal D 2020. Correlation and path coefficient analysis of seed yield and yield components of French bean (*Phaseolus vulgaris* L.) genotypes in sub-tropical region. *Turkish Journal of Agriculture - Food Science and Technology* **8**(9): 1928-1934.

Kalauni S, Pant S, Luitel B P and Bhandari B. 2019. Evaluation of pole-type French bean (*Phaseolus vulgaris* L.) genotypes for agro-morphological variability and yield in the mid-hills of Nepal. *International Journal of Horticulture* **9**(3): 15-23.

Kanwar R, Mehta DK and Sharma R 2017. Studies on variability, correlation and path coefficient analysis in French bean. *Journal of Hill Agriculture* **8**(2): 138-143.

Kanwar R, Mehta DK, Sharma R and Dogra RK 2020. Studies on genetic diversity of French bean (*Phaseolus vulgaris* L.) landraces of Himachal Pradesh based on morphological traits and molecular markers. *Legume Research* **43**(4): 470-479.

Kumar PA, Reddy RVSK, Pandravada SR, Rani Ch VD and Chaitanya V 2014. Genetic divergence studies in indigenous French bean (*Phaseolus vulgaris* L.) germplasm. *Plant Archives* **14**(1): 189-192.

Lowry OH, Rosbrough NJ, Farr AL and Randall RJ 1951. Total protein estimation by Lowry's method. *The Journal of Biological Chemistry* **193**(1): 265-275.

Lush JL 1949. Heritability of quantitative characters in farm animals, pp. 356-375. Proceedings of 8th *Congress of Genetics and Heredity* (*Hereditas*, Supplymentary Volume).

Lyngdoh YA, Thapa U, Singh ASJ and Tomar BS 2017. Studies on genetic variability and character association for yield and yield related traits in French bean (*Phaseolus vulgaris* L.). *Legume Research* **41**(6): 810-815.

Mayee CD and Dattar VV 1986. *Phytopathometry* (Technical Bulletin), p. 85. Marathwada Agriculture University, Parbhani, Maharashtra.

McKinney HH 1923. Influence of soil temperature and moisture on infection of wheat seedling by *Helminthosporium sativum*. *Journal of Agricultural Reearch* **26**(5): 195-217.

Mishra S, Sharma MK, Singh M and Yadav SK 2010. Genetic diversity of French bean (bush type) genotypes in north-west Himalayas. *Indian Journal of Plant Genetic Resources* **23**(3): 285-287.

Mohammed A 2013. An overview of distribution, biology and the management of common bean anthracnose. *Journal of Plant Pathology and Microbiology* **4**(8): 1-6.

Mondal R, Banerjee S, Maurya PK, Bhattacharjee T, Dutta S, Dutta T, Lalramhlimi B, Mukherjee D, Acharya B, Islam SKM, Saha S, Chattopadhyay A and Hazra P 2020. Morphological and genetic variations among advance breeding lines and varieties of brinjal grown in Eastern Gangetic plains of India. *International Journal of Current Microbiology and Applied Sciences* **9**(4): 2008-2028.

Noopur K, Jawaharlal M, Praneetha S, Kashyap P and Somasundaram E 2009. Genetic variability and character association studies in French bean (*Phaseolus vulgaris*) in Nilgiri hills of Tamil Nadu. *Indian Journal of Agricultural Sciences* **89**(12): 2009- 2013.

Panchbhaiya A, Singh DK, Verma P, Jatav V and Maurya AK 2017. Genetic analysis of French bean (*Phaseolus vulgaris* L.) germplasm through principal component analysis and $D^2$ cluster analysis. *Journal of Pharmacognosy and Phytochemistry* **6**(3): 537-542.

Pandey YR, Gautam DM, Thapa RB, Sharma MD and Paudyal KP 2011. Variability of French bean in the western mid hills of Nepal. *Agriculture and Natural Resources* **45**(5): 780-792.

Papa R and Gepts P 2003. Asymmetry of gene flow and differential geographical structure of molecular diversity in wild and domesticated common bean (*Phaseolus vulgaris* L.) from Mesoamerica. *Theoretical and Applied Genetics* **106**(2): 239-250.

Porch TG, Beaver JS, Debouck DG, Jackson SA, Kelly JD and Dempewolf H 2013. Use of wild relatives and closely related species to adapt common bean to climate change. *Agronomy* **3**(2): 433-461.

Prakash J and Ram RB 2014. Genetic variability, correlation and path analysis for seed yield and yield related traits in French bean (*Phaseolus vulgaris* L.) under Lucknow conditions. *International Journal of Innovative Science, Engineering and Technology* **1**(6): 41-50.

Ramandeep, Dhillon TS, Dhall RK and Gill BS 2018. Genetic variability of yield and yield attributing traits in French bean (*Phaseolus vulgaris* L.). *Agricultural Research Journal* **55**(2): 219-223.

Razvi SM, Khan MN, Bhat MA, Ahmed M, Ganaie SA, Sheikh FA, Najeeb S and Parry FA 2018. Morphological variability and phylogenetic analysis in common bean (*Phaseolus vulgaris* L.). *Legume Research* **41**(2): 208-212.

Singh SP, Gutierrez JA, Molina A, Urrea C and Gepts P 1991a. Genetic diversity in cultivated common bean: II. Marker-based analysis of morphological and agronomic traits. *Crop Science* **31**: 23-29.

Singh SP, Gepts P and Debouck DG 1991b. Races of common bean (*Phaseolus vulgaris*, Fabaceae). *Economic Botany* **45**(3): 379-396.

Songsri P, Joglloy S, Kesmala T, Vorasoot N, Akkasaeng CPA and Holbrook C 2008. Heritability of drought resistant traits and correlation of drought resistance and agronomic traits in peanut. *Crop Science* **48**: 2245-2253.

Topwal M and Gaur G 2016. Studies on genetic variability in different genotypes of French bean (*Phaseolus vulgaris* L.). *International Journal of Life Sciences Scientific Research* **2**(3): 219-221.

Verma AK and Naidu AK 2018. Per se performance of parents and hybrids of cowpea (*Vigna unguiculata* L.). *Indian Journal of Ecology* **45**(1): 152-157.

Verma VK, Jha AK, Pandey A, Kumar A, Choudhury P and Swer TL 2014. Genetic divergence, path coefficient and cluster analysis of French bean (*Phaseolus vulgaris* L.) genotypes. *Indian Journal of Agricultural Sciences* **84**(8): 925-930.

Yumkhaibam T, Deo C, Ramjan M, Chanu NB and Semba S 2019. Estimation of genetic variability, heritability and genetic advance for yield and its component traits of garden pea (*Pisum sativum* L.) in North East India. *Journal of Pharmacognosy and Phytochemistry* **8**(3): 4034-4039.

*Received 31 March, 2023; Accepted 02 September, 2023*