**GENETIC VARIABILITY AND CORRELATION STUDIES IN IN FRENCH BEAN (*PHASEOLUS VULGARIS* L.) UNDER LUCKNOW CONDITIONS**

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**ABSTRACT**

Genotypic variability, heritability and genetic advance expressed as percentage of mean for yield and its component were studies in twenty five genotypes of french bean collected from different sources and maintained in the Department of Applied Plant Science (Horticulture) under the School for Bio-sciences & Biotechnology, Babasaheb Bhimrao Ambedkar University Vidya-Vihar, Rae Bareli, Road, Lucknow (U.P.) India, were evaluated for various quantitative and quality traits. The material showed wide range of variability for green pod yield per plant (91.50-248.09q/ha), green pod yield per plant (54.91-148.87g), plant height (34.47-128.21cm), germination percent (68.87-100) and protein (17.09-30.38). The genotypic and phenotypic variances were high for 100-seed weight (43.11-43.22g) and plant height (40.92-41.71g). heritability was high for 100-seed weight (99.50%) and plant height (96.50%) whereas it was lowest for green pod breath (26.80cm), high heritability combined with high genetic advance expressed as percentage of mean for 100-seed weight (88.59%), plant height (82.72%) and green pod yield q/ha (54.01%). The characters like 100-seed weight, plant height, green pod yield/plot, green pod yield/plant and green pod yield (q/ha), showed high genotypic coefficient variation and phenotypic coefficient variation with genetic advance, indicating there by that selections based on phenotypic performance could be effective for improvement of these characters.

**Key word:** French bean,genetic variability, correlation, path analysis, heritability, agronomic characters

**INTRODUCTION**

French bean, (*Phaseolus vulgaris* L. 2n=2x=22) belongs to family Leguminosae is a nutritious vegetable consumed as tender pods, shelled beans and dry beans. It has many synonyms like snap bean, kidney bean, haricot bean and also called “Raj mash” in Hindi. French bean originated from Central America and Peruvian Andes in South America. It spreaded to Europe during 16th and 17th centuries and reached England by 1594. It was introduced to India during 17th century form Europe. The statistics with respect to this crop is very deficient owing to the small area of production and short duration. However, as per as the FAO estimates, it is grown in the world in an area of 0.83 m ha with annual production of 5.64 m t with productivity of 6.76 t per ha. In India, it is mainly grown in Himachal Pradesh, UKO, J&K, Punjab, Haryana, Uttar Pradesh, Bihar, Gujarat, Madhya Pradesh, Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu. Annually, french bean is grown in an area of 0.15 m ha with annual production of 0.42 m t and productivity of 2.8 t per ha FAO STAT (2). Considering the nutritive value, 100 g of green pod contains (1.7 g) protein, (0.1 g fat), (4.5 g) carbohydrate, (1.8 g) fiber and is also rich in minerals and vitamins. It also posses medicinal properties which is useful in controlling diabetes and certain cardiac problems and it is a good natural cure for bladder burn. It has both carminative and reparative properties against constipation and diarrhoea respectively Duke (8). Beans, the “meat of the poor”, contribute essential protein to the undernourished people living in the hills. Being a short duration crop French bean can be grown under different cropping patterns of hills and plains of India. An important part of the tropical African production is exported to Europe: nearly 40,000 tones, the most important exporters being Senegal, Burkina Faso, Kenya and Zimbabwe. french bean is the third most important agricultural export product of Kenya, after only tea and pineapple. Pole type French bean is an important legume vegetable in Meghalaya of North Eastern Hill region has high agro economic and dietary values as compared to other legume vegetables Shah *et al* (20). The exploitation of variability is a pre-requisite for the effective screening of superior genotypes in all crops including French bean. The progress in breeding for the yield and its contributing characters of any crop is polygenic ally controlled, environmentally influenced and determined by the magnitude and nature of their genetic variability. Hence, it is essential to partition the overall variability into its heritable and non-heritable components with the help of genetic parameters like genetic coefficient of variation, heritability and genetic advance. Knowledge of correlations among different characters and further, partitioning those direct and indirect effects are a rational approach to understand the nature and extent of such relationship. Therefore, study of genetic variability, characters association and path coefficient are pre-requisite for improvement of any crop. Therefore, genetic analysis involving inheritance system of seed yield and related traits may provide useful information on various genetic features leading to crop improvement. Hence, the present study was conducted to find out the information on nature and magnitude of gene action for yield and yield related traits. Therefore, a systematic breeding approach for crop improvement of French bean is highly required. Knowledge of genetic variability, heritability and genetic advance of important economic traits and their genotypic and phenotypic correlation coefficient among themselves, play an important role in farming the breeding programme of any crop .The success of breeding programme depends on the genetic variability present in the population. Therefore partitioning of the phenotypic variation into genetic and environmental variation is necessary. the extent of transmission of a quantitative character from parent to the offspring depends upon the heritability of the particular character .The heritability value alone does not have much significance as it fails to account for the magnitude of absolute variability. It’s, therefore, necessary to utilize heritability along with genetic advance, while advocating for selection.

**MATERIALS AND METHODS**

The present investigation was carried out at the Horticultural Research Farm of the Department of Applied Plant Science (Horticulture), Babasaheb Bhimrao Ambedkar Central University, Vidya Vihar, Rae Bareli Road Lucknow (U. P.) India, during *Rabi* season of October, 2012 to April, 2013, in well levelled field having proper drainage. Geographically, Lucknow is situated at an elevation of 111m above the mean sea level in the subtropical tract of central U.P. at 26056’ North latitude and 80052’ East longitude. The place experiences winter and very hot summer with average rainfall. Agro climatically, the location represent Central Zone of the state of Uttar Pradesh, India, and is characterised by sub-tropical climate. The experimental material comprising of twenty five genotypes of French bean was collected from different sources and maintained in the Horticultural Research Farm. All recommended package of practices were followed to raise good crop. Experimental field was laid out in randomized block design with 25 genotypes/lines and replicated thrice. Each block was further subdivided into 25 unit plots. The twenty five genotypes were allotted to the 25 unit plots of each block. The plots were raised by 15cm from the ground level to avoid water-logging, if occurred. The unit plot size was 1.80mX1.00m, and the row-row and plant –plant spacing were 30cm and 20cm, respectively. The plot to plot (1.00m) and block to block (1.80m) distances were 30cm and 1.0m, respectively. All necessary cultural operations were done as and when required during the growing period. Data was recorded on 5 randomly selected plants per entry per replication for various horticultural characters namely, germination (%), plant height (cm), primary branches/ plant, secondary branches/ plant, number of leaves /Plant, size of leaves (length and width cm), days to first flowering, days to 50 percent flowering, flower colour, number of pods/ plant, number of grains/ pod, green pod length (cm), green pod width (cm), green pod breadth (cm), single green pod weight (g), green pod yield per plant (g), green pod yield per plot (kg), green pod yield (q/ ha),100- seed weight (g), moisture(%), total sugars(%)andprotein(%). The data were analysed for estimation of genotypic and phenotypic coefficient of variation following Burton (6). Heritability in broad sense and genetic advance were calculated according to the methods of Allard (1960).simple correlation coefficient among the characters at phenotypic and genotypic levels were analysed following Hayes *et al* (9), Singh and Chaudhary (1985). Path analysis at genotypic level was done following Deway and Lu (7). Heritability (h2) in the broad sense (in per cent) was computed by the formula given by Johnson *et al* (10).

**RESULT AND DISCUSSION**

The analysis of variance revealed significant differences for the characters under study indicating wide variation among the genotypes. The range mean and other genetic parameters estimated are present a large variation in vegetative growth, yield and quality performance was noticed among the 25 genotypes of french bean (Table 1& 2). Genotypes vary highest mean performance range (91.50-248.09) of green pod yield (q/ha) and the lowest mean performance range (0.48-0.95) of Green pod width. The tallest genotype ET-3409, while the shortest one was VL, Bauni Bean-1. The number of pods /plant was the highest in ET-3409 (29.87) followed by EC-400409 (28.71) and lowest in LD-2-1 (10.11). The highest number of seeds/pod was obtained from EC400401 (5.72) while LD-2-1 (3.58) the least. The highest 100-seeds weight (55.28g/100-seeds weight) were produced by EC-400407, while the lowest (12.46g/100-seeds weight) by ET-8415. Based on the number of pods /plant , green pods yield per plant , green pod yield/plot, number of seeds/pods, 100-seeds weight, green pods yield (q/ha), the 25 genotypes were grouped as i) high yielder ( 3 genotypes viz., ET-3409, EC-4004007 and EC-400401) which ET-3409 produced for 4 characters number of pods /plant , green pods yield per plant , green pod yield/plot and green pod yield (q/ha), ii) medium yielder (7genotypes viz; BSSR-2,EC-400445, ET-8415, IL-25537, EC-400407, LD-2-1, PLB-438, ) iii) low yielder ( 9 genotypes viz; LD-2-1, EC-400400, HURG-15, EC-400445, IC-14351, VL, Bauni Bean-1, VL, Bean-2, ET-8415 and IL-25537). Siddhartha *et al* (18).

The analysis of variance revealed significant differences for the characters under study indicating wide variation among the genotypes. The range, mean and other genetic parameters estimated are presented in (Table 3). A wide range of variability was observed for green pod yield (91.50-248.99 q/ha), green pod yield /plant (54.91-148.87 g), plant height (34.47-128.21cm), germination percent (68.87-100) and protein (17.09-30.38). The characters showing wide range of variability have sample scope of selections for the desirable types phenotypic coefficient of variation ranged from (8.50%) for days to 50% flowering to (43.22%) for 100-seeds weight. High phenotypic coefficient variation was observed for 100-seeds weight (43.22%), plant height (41.21%), green pod yield/plot (28.89%) and green pod yield/plant (28.33%). Genotypic coefficient of variation ranged from 5.54% for green pod breath to 43.11% for 100-seeds weight high genotypic coefficient of variation was observed for 100-seeds weight (43.11%) and plant height (40.92%). The magnitude of phenotypic coefficient of variation was in general higher than corresponding genotypic coefficient of variation indicating the influence of environmental factors in their expression. Johanson *et al* (10) also reported similar result while studying seven inbreed lines of diverse origin and their 21 hybrids of French bean. This shows more preponderance of environmental factors of yield contributing characters in French bean. High heritability (broad sense) was observed for 100-seeds weight (99.50%), plant height(96.50%), number of pods /plant (94.70%), green pod yield q/ha (92.70%), green pod yield/plant (92.30%) and green pod yield/plot (86.80), indicating the least influence of environment in their expression, thus suggesting that selection for these traits/ characters based on phenotypic appearance would be reliable. High genetic advance as percentage of mean was observed for 100-seeds weight (88.59%), plant height (82.72%) and green pod yield q/ha (54.01). High genetic advance coupled with high heritability could be resulted are in accorandance with the findings of Liang and Waltre (12).

The estimates of genotypic correlation coefficients in general were higher in magnitude than phenotypic correlation coefficients (Table 4&6), indicating the more preponderance of heritable components. Germination percentage was positively and significantly correlated (genotypic and phenotypic) with secondary branches/plant (0.546; 0.317), number of pods/plant (0.405; 0.359) and green pod width (0.603; 0.517), green pod yield (q/ha) were positively and significantly correlated with germination percentage (genotypes). Plant height was positively and significantly correlated (genotypic and phenotypic) with number of leaves /plant (0.810; 0.733), secondary branches/plant (0.473; 0.430), number of pods /plant (0.656; 0.634), green pod yield /plant (0.537; 0.503), green pod yield /plot (0.540; 0.499) and green pod yield q/ha (0.538; 0.504), green pod yield q/ha were positively and significantly correlated with plant height (genotypic). Secondary branches/plant were positively and significantly correlated with (genotypic and phenotypic) with number of pods/plant (0.849; 0.730), green pod length (0.424; 0.342), green pod yield /plant (0.789; 0.687), green pod yield /plot (0.798; 0.664) and 100-seed weight (0.604; 0.548), green pod yield q/ha were positively and significantly correlated with secondary branches/plant (genotypic). Numbers of pods /plant were positively and significantly correlated with (genotypic and phenotypic) with green pod length (0.619; 0.542), green pod width (0.393; 0.333), single green pod weight (0.394; 0.318), green pod yield/plant (0.668; 0.627), green pod yield /plot (0.681; 0.603) and 100-seed weight (0.398; 0.386), green pod yield q/ha were positively and significantly correlated with number of pods/plant (genotypic). Days to first flowering was positively and significantly correlated with (genotypic and phenotypic) with days to 50% flowering (0.990; 0.879), green pod yield q/ha were positively and significantly correlated with days to first flowering (genotypic). Shah *et al* (20), observed between pod yield and pod length. Singh *et al* (22), Sinde and Dumare (21), Rai *et al* (15) and Atilla Dursum (3), observed between pod yield, plant height, pod length, pod width, pod weight and number of seeds/pod at both genotypic and phenotypic level. Days to 50% flowering with green pod width (-0.512; -0.404), and green pod breath (-0.551; -0.361) and number of seeds /pod (-0.624; -0.306) were negatively and significantly correlated. Germination percentage with days to 50% flowering (-0.721; -0.522) were negatively and significantly correlated was reported by Saha *et al* (17), Kumar Swamy (11) also reported Days to 50% flowering to be negatively associated with green pod width and green pod breath.

The characters showing significantly correlation were subjected to estimation of direct and indirect effects (Table 5&7). Data depleted that germination percentage (0.125; 0.005), plant height (0.031; 0.039), secondary branches/plant (0.574; 0.033) and green pod yield /plant (0.635; 0.874). Expected high positively direct and indirect effects green pod yield (q/ha). The direct and indirect effects of remaining characters were poor in magnitude. Green pod yield/plant (0.635; 0.874) showed high direct and indirect effects on green pod yield (q/ha) via secondary branches/plant. these findings in agreement with Baswana *et al* (4) and Biju *et al* (5) in Indian bean , Rai *et al* (16) in French bean and Patil *et al* (14) in cow pea. From the present studies it can be concluded that characters like 100-seed weight, plant height, green pod yield /plot, green pod yield/plant and green pod yield (q/ha). Showing higher values of genotypic coefficient of variation, heritability (broad- sense) and genetic advance can be improved by selections. Further correlation and path analysis revealed that number of leaves/plant , leaf width, secondary branches /plant, green pod length, and green pod yield/plant are good indicator green pod yield (q/ha) in French bean and are effective selection parameters for development of productive genotypes in French bean.

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**Table 1: mean performance of vegetative growth contributing characters in 25 french bean genotypes.**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Characters**  **Genotypes** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** |
| LD-2-1  EC-400400  IL-25537  HURG-15  EC-400445  NO.3127  IC-14351  EC-400401  ET-8415  PLB-438  EC-400407  BSRR-2  EC-400414  ET-8435  ET-8490  IPR-98-3-1  EC-400409  ET-3409  BLF-101  PDR-14  IL-25337  BD-19162  GPR-203  VL Bauni Bean-1  VL,BEAN-2  F-value | 84.04  84.00  93.83  99.76  99.09  83.17  96.23  84.53  85.87  94.22  93.14  90.95  82.53  86.57  98.00  93.15  90.47  100.00  86.24  83.54  87.12  86.14  81.54  70.44  68.87  \*\* | 43.20  36.87  34.47  38.43  48.91  41.85  52.58  39.86  36.15  47.22  46.01  50.82  48.59  40.17  39.67  44.73  83.20  128.21  78.84  60.91  46.87  38.43  37.87  37.55  37.25  \*\* | 44.77  47.95  51.58  44.79  58.85  45.28  56.53  64.88  56.80  60.85  48.45  59.30  46.86  45.52  46.51  44.90  53.41  86.54  66.85  63.15  50.84  41.51  47.14  46.79  45.51  \*\* | 7.62  9.11  10.35  11.12  12.02  13.12  11.77  10.42  12.15  12.72  10.19  12.62  11.13  12.22  11.55  9.62  9.61  11.00  11.17  10.51  11.10  9.36  9.71  7.73  7.24  \* | 7.21  9.39  10.39  10.60  9.05  12.49  9.62  10.74  11.93  8.95  13.10  11.44  10.31  9.27  10.13  10.48  10.78  10.93  10.42  8.54  10.10  11.44  8.13  4.99  6.31  \* | 2.45  2.75  2.64  3.91  4.30  3.69  3.94  3.61  4.10  4.42  3.07  3.97  4.24  4.41  3.77  4.51  3.98  5.10  3.67  4.33  3.68  3.94  3.97  3.91  3.42  \* | 4.24  5.21  5.55  7.08  5.00  7.15  7.42  7.10  7.32  6.89  9.09  8.22  8.78  7.87  9.55  7.52  8.18  9.57  7.99  8.42  8.98  8.05  5.31  5.09  5.19  \* | 33.33  33.67  34.67  32.33  35.00  39.00  40.00  36.00  39.00  31.00  30.33  39.67  39.67  29.67  33.33  34.00  40.00  38.33  33.33  40.33  36.00  38.00  42.67  41.33  43.33  \*\* | 40.00  40.00  40.00  38.00  40.00  44.67  42.33  40.33  42.67  36.67  37.33  41.67  43.33  35.33  37.00  39.33  43.00  41.33  37.67  42.00  40.33  42.00  46.00  45.67  47.67  \*\* | 10.11  11.81  16.35  16.09  19.10  22.43  23.41  24.21  22.03  21.54  24.21  19.87  21.48  20.41  24.84  22.43  28.71  29.87  24.76  25.48  22.71  18.32  17.56  15.57  15.56  \*\* | 8.32  9.30  11.31  9.02  12.24  13.66  12.02  12.38  13.86  11.43  12.69  11.65  13.32  9.22  11.21  12.32  10.84  11.45  12.08  11.72  9.26  9.06  9.39  9.28  8.96  \* |
| **GM** | 88.13 | 49.54 | 53.01 | 10.60 | 9.87 | 3.83 | 7.23 | 36.56 | 40.97 | 20.75 | 11.03 |
| **Range** | 68.87-100.00 | 34.47-28.21 | 41.51-86.54 | 7.24-13.12 | 4.99-12.49 | 2.45-5.10 | 4.24-9.57 | 29.67-43.33 | 35.33-47.67 | 10.11-29.87 | 8.32-13.86 |
| **SEm±** | 3.82 | 3.260 | 3.499 | 0.8361 | 1.155 | 0.3398 | 0.5376 | 1.384 | 1.608 | 0.9168 | 0.6465 |
| **CD (p= .05)** | 7.67 | 6.55 | 7.03 | 1.67 | 2.32 | 0.681 | 1.079 | 2.77 | 3.216 | 1.841 | 1.298 |

**\* Significance at 5% level; \*\* significance at 1% level**

1 = Germination percentage 6= Primary branches /plant 11= Green pod length (cm)

2 = Plant height (cm) 7= Secondary branches/plant

3 = No. Of leaves/plant 8= Days to first flowering

4= Leaf length (cm) 9= Days to 50% flowering

5= Leaf width (cm) 10= No. Of pods /plant

**Table 2: mean performance of vegetative growth contributing characters in 25 french bean genotypes.**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Characters**  **Genotypes** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** |
| LD-2-1  EC-400400  IL-25537  HURG-15  EC-400445  NO.3127  IC-14351  EC-400401  ET-8415  PLB-438  EC-400407  BSRR-2  EC-400414  ET-8435  ET-8490  IPR-98-3-1  EC-400409  ET-3409  BLF-101  PDR-14  IL-25337  BD-19162  GPR-203  VL Bauni Bean-1  VL,BEAN-2  F-value | 0.58  0.57  0.64  0.76  0.78  0.72  0.64  0.95  0.66  0.87  0.73  0.90  0.50  0.57  0.73  0.68  0.61  0.71  0.69  0.70  0.63  0.59  0.54  0.48  0.49  \* | 0.94  0.91  0.93  1.00  1.01  0.90  0.87  0.87  0.82  0.96  1.01  1.04  1.00  1.00  0.99  0.92  0.90  0.96  1.05  0.87  0.96  1.04  0.87  0.83  0.95  \* | 5.54  5.35  5.72  6.88  6.02  6.15  7.01  5.99  6.50  7.93  6.52  7.07  5.22  6.41  6.42  6.40  6.43  5.72  6.91  6.41  5.79  6.18  6.16  4.55  5.83  \* | 54.91  79.87  62.00  67.05  61.76  83.52  66.13  80.53  72.55  93.14  90.44  92.53  106.91  119.91  142.85  125.43  108.37  148.87  107.96  100.57  104.56  102.22  101.57  66.12  64.57  \*\* | 1.65  2.40  1.86  2.01  1.85  2.51  1.98  2.42  2.18  2.79  2.71  2.78  3.20  3.60  4.28  3.76  3.25  4.47  3.24  3.02  3.14  3.07  3.05  1.98  1.94  \* | 3.58  4.53  5.21  4.59  5.08  4.38  5.20  5.72  4.67  4.84  4.85  4.95  4.82  5.19  5.66  4.89  4.55  4.33  4.70  4.84  5.02  4.61  4.15  4.66  4.11  \* | 16.27  20.66  13.00  26.49  23.85  49.43  19.52  19.65  12.46  21.73  55.28  47.05  35.29  36.77  12.46  54.44  34.07  32.48  35.46  28.41  38.49  39.14  45.19  19.09  20.48  \*\* | 91.50  133.09  103.29  111.73  102.96  139.16  110.16  133.86  120.89  155.20  150.64  154.18  177.65  199.81  237.88  208.68  180.59  248.09  179.90  167.57  174.24  170.33  169.24  110.19  107.61  \*\* | 11.10  11.36  11.10  12.71  10.69  10.17  10.39  10.60  10.79  10.87  10.90  10.52  12.90  11.24  12.66  10.85  9.92  10.33  11.06  10.73  12.06  11.50  11.22  9.52  9.47  \* | 5.07  6.89  7.77  7.33  7.40  7.06  6.50  8.92  6.05  5.96  6.38  7.38  7.00  7.14  7.62  6.45  7.11  7.62  7.69  7.13  6.63  7.39  7.76  6.74  5.21  \* | 18.71  19.03  17.09  18.58  18.09  20.79  19.95  23.77  22.78  26.61  26.58  29.53  30.38  28.56  26.83  24.18  19.28  23.12  24.50  27.88  30.38  19.06  19.77  20.34  22.04  \*\* | white  purple  white  white  white  purple  Purple  Purple  White  White  Purple  white  White  White  white  Purple  Purple  Purple  White  Purple  Purple  White  Purple  Pink  purple |
| **GM** | 0.66 | 0.94 | 6.20 | 92.16 | 2.76 | 4.76 | 32.19 | 153.52 | 10.98 | 6.96 | 23.11 |
| **Range** | 0.48-0.95 | 0.82-1.05 | 4.55-7.93 | 54.91-148.87 | 1.65-4.47 | 3.58-5.72 | 12.46-55.28 | 91.50-248.09 | 9.47-12.90 | 5.07-8.92 | 17.09-30.38 |
| **SEm±** | 4.346 | 7.075 | 0.3849 | 5.934 | 0.2371 | 0.4384 | 0.8124 | 9.563 | 0.5710 | 0.4574 | 0.9812 |
| **CD (p= .05)** | 8.73 | 14.22 | 0.771 | 11.92 | 0.476 | 0.880 | 1.632 | 19.21 | 1.971 | 0.9185 | 1.147 |

**\* Significance at 5% level; \*\* significance at 1% leve**

12 = Green pod width (cm) 17 = No. Of seeds /pod 22= Protein (%)

13 = Green pod breadth (cm) 18 =100-seed weight (g) 23= Flower colour

14 = Single green pod weight (g) 19= Green pod yield (q/ha)

15 = Green pod yield /plant (g) 20= Moisture (%)

16 = Green pod yield /plot (kg) 21= Total sugars (%)

**Ist Vegetative Growth And Yield And Yield Attributing Traits:**

**Table-3: Range, genetic variability, heritability in broad sense, genetic advance and genetic advance in percent of mean different characters in French bean**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S.No.** | Characters | Range | | General  Mean  SEm± | Genotypic  Variance | Phenotypic  Variance | Co-efficient of variation | | | Heritability in broad sense (%) | Genetic advance  (GA) | Genetic advance in % of mean |
| Min. | Max. | CV | PCV (%) | GCV (%) |
| 1  2  3  4  5  6  7  8  9  10  11  12  13  14  15  16  17  18  19  20  21  22 | X1  X2  X3  X4  X5  X6  X7  X8  X9  X10  X11  X12  X13  X14  X15  X16  X17  X18  X19  X20  X21  X22 | 68.87  34.47  41.51  7.24  4.99  2.45  4.24  29.67  35.33  10.11  8.32  0.48  0.82  4.55  54.91  1.65  3.58  12.46  91.50  9.47  5.07  17.09 | 100.00  128.21  86.54  13.12  12.49  5.10  9.57  43.33  47.67  29.87  13.86  0.95  1.05  7.93  148.87  4.47  5.72  55.28  248.09  12.90  8.92  30.38 | 88.13  49.54  53.01  10.60  9.87  3.83  7.23  36.56  40.97  20.75  11.03  0.66  0.94  6.20  92.16  2.76  4.76  32.19  153.52  10.98  6.96  23.11 | 8.62  40.92  18.42  13.92  16.73  14.62  20.91  10.37  7.02  22.91  14.44  17.62  5.54  10.25  27.21  26.92  7.36  43.11  27.23  7.16  11.07  17.97 | 10.12  41.71  20.11  16.94  22.04  18.20  22.81  11.36  8.50  23.54  16.12  19.34  10.70  12.76  28.33  28.89  13.46  43.22  28.27  9.58  13.68  18.71 | 5.31  8.05  8.08  9.65  14.34  10.84  9.10  4.63  4.80  5.41  7.17  7.96  9.14  7.60  7.88  10.50  11.26  3.09  7.62  6.36  8.03  5.17 | 10.12  41.71  20.11  16.94  22.04  18.20  22.81  11.36  8.50  23.54  16.12  19.34  10.70  12.76  28.33  28.89  13.46  43.22  28.27  9.58  13.68  18.71 | 8.62  40.92  18.42  13.92  16.73  14.62  20.91  10.37  7.02  22.91  14.44  17.62  5.54  10.25  27.21  26.92  7.36  43.11  27.23  7.16  11.07  17.97 | 72.50  96.50  83.80  67.50  57.60  64.50  84.10  83.30  68.00  94.70  80.20  83.00  26.80  64.5  92.30  86.80  29.9  99.50  92.7  55.90  65.50  92.30 | 13.32  40.98  18.42  2.50  2.58  0.93  2.86  7.13  4.88  9.53  2.94  0.22  0.06  1.05  49.62  1.43  0.40  28.52  82.92  1.21  1.29  8.22 | 15.11  82.72  34.74  23.58  26.13  24.28  39.55  19.50  11.91  45.92  26.65  33.33  6.38  16.93  53.84  51.81  8.40  88.59  54.01  11.02  18.53  35.56 |

1 = Germination percentage 2 = Plant height (cm) 3= No. Of leaves/plant 4 = Leaf length (cm) 5 = Leaf width (cm)

6 = Primary branches /plant 7= Secondary branches/plant 8= Days to first flowering 9 = Days to 50% flowering 10 = No. Of pods /plant

11 = Green pod length (cm) 12 = Green pod width (cm) 13= Green pod breadth (cm) 14 = Single green pod weight (g) 15 = Green pod yield /plant (g) 16 = Green pod yield /plot (kg) 17 = No. Of seeds /pod 18=100-seed weight (g) 19 = Green pod yield (q/ha) 20 = Moisture (%)

21= Total sugars (%) 22= Protein (%)

**Table-4: Estimates of genotypic and phenotypic correlation coefficients of different characters in French bean**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Characters | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** |
| **1**  **2**  **3**  **4**  **5**  **6**  **7**  **8**  **9**  **10**  **11**  **12**  **13**  **14**  **15**  **16**  **17**  **18** | G  P  G  P  G  P  G  P  G  P  G  P  G  P  G  P  G  P  G  P  G  P  G  P  G  P  G  P  G  P  G  P  G  P  G  p | 0.361\*  0.258  rg | 0.370\*  0.289  0.810\*\*  0.733\*\*  rg | 0.667\*\*  0.417\*  0.130  0.099  0.369\*  0.252  rg | 0.671\*\*  0.385\*  0.202  0.151  0.186  0.128  0.673\*\*  0.489\*\*  rg | 0.303\*  0.187  0.500\*\*  0.424\*  0.470\*  0.383\*  0.528\*\*  0.330  0.039  0.147  rg | 0.456\*  0.317\*  0.473\*  0.430\*  0.334\*  0.269  0.550\*\*  0.374\*  0.725\*\*  0.505\*\*  0.516\*\*  0.406\*  rg | 0.566\*\*  -0.425\*  0.120  0.105  0.074  0.064  -0.274  -0.220  -0.327\*  -0.203  0.240  0.126  -0.106  -0.132  rg | -0.721\*\*  -0.522\*\*  -0.039  -0.021  -0.140  -0.052  -0.440\*  -0.338\*  -0.436\*  -0.209  -0.010  0.043  -0.348\*  -0.281  0.990\*\*  0.879\*\*  rg | 0.405\*  0.359\*  0.656\*\*  0.634\*\*  0.607\*\*  0.546\*\*  0.515\*\*  0.423\*  0.571\*\*  0.427\*  0.651\*\*  0.523\*\*  0.849\*\*  0.730\*\*  0.068  0.052  -0.158  -0.122  rg | 0.321\*  0.226  0.185  0.174  0.416\*  0.301\*  0.666\*\*  0.491\*  0.663\*\*  0.502\*\*  0.298  0.269  0.424\*  0.342\*  0.018  0.074  -0.052  -0.020  0.619\*\*  0.542\*\*  rg | 0.603\*\*  0.517\*\*  0.135  0.117  0.524\*\*  0.418\*  0.680\*\*  0.452\*  0.553\*\*  0.397\*  0.211  0.132  0.304\*  0.238  -0.377\*  -0.328  -0.512\*\*  -0.404\*  0.393\*  0.333\*  0.489\*  0.363\*  rg | 0.451\*  0.204  0.179  0.108  -0.059  0.026  0.356\*  0.138  0.456\*  0.163  0.152  0.019  0.513\*\*  0.262  -0.568\*\*  -0.271\*  -0.551\*\*  -0.361\*  0.044  0.031  -0.106  0.038  0.210  0.054  rg | 0.579\*\*  0.424\*  0.083  0.073  0.239  0.167  0.731\*\*  0.414\*  0.487\*  0.291  0.312\*  0.239  0.358\*  0.295  -0.365\*  -0.230  -0.569\*\*  -0.289  0.394\*  0.318\*  0.275  0.258  0.667\*\*  0.511\*\*  0.246  0.154  rg | 0.291  0.279\*  0.537\*\*  0.503\*\*  0.295  0.249  0.260  0.229  0.362\*  0.234  0.620\*\*  0.477\*  0.789\*\*  0.678\*\*  -0.124  -0.109  -0.294  -0.269  0.668\*\*  0.627\*\*  0.144  0.101  0.066  0.070  0.404\*  0.240  0.170  0.109  rg | 0.303\*  0.259  0.540\*\*  0.499\*\*  0.298  0.245  0.258  0.232  0.349\*  0.254  0.625\*\*  0.472\*  0.798\*\*  0.664\*\*  -0.128  -0.103  -0.302  -0.257  0.681\*\*  0.603\*\*  0.144  0.101  0.067  0.069  0.405\*  0.238  0.184  0.089  1.021  0.963\*\*  rg | 0.519\*\*  0.270  -0.243  -0.087  0.231  0.056  0.683\*\*  0.326\*  0.582\*\*  0.065  0.290  0.094  0.568\*\*  0.283\*  -0.397\*  -0.200  -0.624\*\*  -0.306\*  0.559\*\*  0.278  0.537\*\*  0.251  0.681\*\*  0.298  0.177  0.043  0.411\*  0.072  0.274  0.168  0.240  0.203  rg | 0.224  0.199  0.081  0.078  -0.207  -0.195  0.256  0.219  0.485\*  0.374\*  0.245  0.197  0.604\*\*  0.548\*\*  -0.133  -0.120  -0.195  -0.159  0.398\*  0.386\*  0.182  0.163  0.133  0.122  0.556\*\*  0.272  0.223  0.183  0.685\*\*  0.655\*\*  0..690\*\*  0.645\*\*  0.200  0.111  rg | 0.294  0.273  0.538\*\*  0.504\*\*  0.297\*  0.245  0.270  0.214  0.371\*  0.221  0.631\*\*  0.462\*  0.790\*\*  0.677  -0.126  -0.105  -0.307  -0.247  0.668\*\*  -0.625\*\*  0.144  0.099  0.059  0.080  0.428\*  0.217  0.168  0.112  1.008\*\*  0.985\*\*  1.024\*\*  0.957  0.257  0.184  0.683\*  0.656\*\* |

\*and\*\* indicate significant of values at P=0.05and 0.01, respectively

1 = Germination percentage 2 = Plant height (cm) 3= No. Of leaves/plant 4 = Leaf length (cm) 5 = Leaf width (cm)

6 = Primary branches /plant 7= Secondary branches/plant 8= Days to first flowering 9 = Days to 50% flowering 10 = No. Of pods /plant

11 = Green pod length (cm) 12 = Green pod width (cm) 13= Green pod breadth (cm) 14 = Single green pod weight (g) 15 = Green pod yield /plant (g) 16 = Green pod yield /plot (kg) 17 = No. Of seeds /pod 18=100-seed weight (g) 19 = Green pod yield (q/ha)

**Table-5: Genotypic and phenotypic path coefficient effect of different characters in French bean**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Characters | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** |
| **1** G  P  **2** G  P  **3** G  P  **4** G  P  **5** G  P  **6** G  P  **7** G  P  **8** G  P  **9** G  P  **10** G  P  **11** G  P  **12** G  P  **13** G  P  **14**  G  P  **15** G  P  **16** G  P  **17** G  P  **18** G  P | **0.125**  **0.005**  0.045  0.002  0.046  0.002  0.083  0.002  0.084  0.002  0.038  0.001  0.057  0.002  -0.071  -0.002  -0.090  -0.003  0.051  0.002  0.040  0.001  0.075  0.003  0.056  0.001  0.072  0.002  0.036  0.002  0.038  0.001  0.065  0.001  0.028  0.001 | 0.011  0.011  **0.031**  **0.039**  0.025  0.028  0.004  0.004  0.006  0.006  0.015  0.016  0.015  0.017  0.004  0.004  -0.001  -0.001  0.020  0.024  0.006  0.007  0.004  0.005  0.006  0.004  0.003  0.003  0.017  0.019  0.017  0.019  -0.007  -0.003  0.002  0.003 | -0.042  -0.009  -0.092  -0.022  **-0.114**  **-0.030**  -0.042  -0.007  -0.021  -0.004  -0.054  -0.011  -0.038  -0.008  -0.008  -0.002  0.016  0.002  -0.069  -0.016  -0.048  -0.009  -0.060  -0.012  0.007  0.001  -0.027  -0.005  -0.034  -0.007  -0.034  -0.007  -0.026  -0.002  0.024  0.006 | -0.025  -0.001  -0.005  0.000  -0.014  -0.001  **-0.038**  -**0.003**  -0.025  -0.002  -0.020  -0.001  -0.021  -0.001  0.010  0.001  0.017  0.001  -0.019  -0.001  -0.025  -0.002  -0.026  -0.002  -0.013  0.000  -0.028  -0.001  -0.010  -0.001  -0.010  -0.001  -0.026  -0.001  -0.010  -0.001 | -0.213  -0.017  -0.064  -0.007  -0.059  -0.006  -0.214  -0.021  **-0.317**  **-0.043**  -0.012  -0.006  -0.230  -0.022  0.104  0.009  0.138  0.009  -0.181  -0.019  -0.210  -0.022  -0.176  -0.017  -0.145  -0.007  -0.155  -0.013  -0.115  -0.010  -0.111  -0.011  -0.185  -0.003  -0.154  -0.016 | -0.013  -0.005  -0.022  -0.012  -0.021  -0.011  -0.023  -0.009  -0.002  -0.004  **-0.044**  **-0.029**  -0.023  -0.012  -0.010  -0.004  0.000  -0.001  -0.028  -0.015  -0.013  -0.008  -0.009  -0.004  -0.007  -0.001  -0.014  -0.007  -0.027  -0.014  -0.027  -0.013  -0.013  -0.003  -0.011  -0.006 | 0.262  0.010  0.271  0.014  0.192  0.009  0.315  0.012  0.416  0.017  0.296  0.013  **0.574**  **0.033**  -0.061  -0.004  -0.199  -0.009  0.487  0.024  0.243  0.011  0.174  0.008  0.294  0.009  0.205  0.010  0.453  0.022  0.458  0.022  0.326  0.009  0.347  0.018 | 0.015  0.035  -0.003  -0.009  -0.002  -0.005  0.007  0.018  0.009  0.017  -0.006  -0.010  0.003  0.011  **-0.026**  **-0.082**  -0.026  -0.072  -0.002  -0.004  0.000  -0.006  0.010  0.027  0.015  0.022  0.010  0.019  0.003  0.009  0.003  0.008  0.010  0.016  0.003  0.010 | -0.003  -0.050  0.000  -0.002  0.000  -0.006  -0.002  -0.037  -0.002  -0.023  0.000  0.005  -0.001  -0.031  0.004  0.097  **0.004**  **0.110**  -0.001  -0.013  0.000  -0.002  -0.002  -0.044  -0.002  -0.040  -0.002  -0.032  -0.001  -0.030  -0.001  -0.028  -0.002  -0.034  -0.001  -0.018 | -0.143  -0.001  -0.233  -0.002  -0.215  -0.002  -0.182  -0.001  -0.203  -0.001  -0.231  -0.002  -0.301  -0.002  -0.024  0.000  0.056  0.000  **-0.355**  **-0.003**  -0.219  -0.002  -0.139  -0.001  -0.016  0.000  -0.140  -0.001  -0.237  -0.002  -0.242  -0.002  -0.198  -0.001  -0.141  -0.001 | 0.071  0.002  0.041  0.002  0.092  0.003  0.147  0.005  0.147  0.005  0.066  0.002  0.094  0.003  0.004  0.001  -0.012  0.000  0.137  0.005  **0.221**  **0.009**  0.108  0.003  -0.023  0.000  0.061  0.002  0.032  0.001  0.032  0.001  0.119  0.002  0.040  0.002 | 0.100  0.018  0.022  0.004  0.087  0.014  0.112  0.015  0.091  0.014  0.035  0.005  0.050  0.008  -0.062  -0.011  -0.085  -0.014  0.065  0.011  0.081  0.012  **0.165**  **0.034**  0.035  0.002  0.110  0.017  0.011  0.002  0.011  0.002  0.112  0.010  0.022  0.004 | -0.057  -0.003  -0.023  -0.002  0.008  0.000  -0.045  -0.002  -0.058  -0.003  -0.019  0.000  -0.065  -0.004  0.072  0.004  0.070  0.006  -0.006  -0.001  0.013  -0.001  -0.027  -0.001  **-0.127**  **-0.016**  -0.031  -0.003  -0.051  -0.004  -0.052  -0.004  -0.023  -0.001  -0.071  -0.004 | 0.001  0.005  0.000  0.001  0.000  0.002  0.001  0.005  0.001  0.003  0.000  0.003  0.001  0.003  -0.001  -0.003  -0.001  -0.003  0.001  0.004  0.000  0.003  0.001  0.006  0.000  0.002  **0.002**  **0.011**  0.000  0.001  0.000  0.001  0.001  0.001  0.000  0.002 | 0.185  0.244  0.341  0.439  0.187  0.218  0.165  0.200  0.230  0.205  0.394  0.417  0.501  0.592  -0.079  -0.096  -0.187  -0.235  0.424  0.548  0.091  0.088  0.042  0.061  0.256  0.210  0.108  0.096  **0.635**  **0.874**  0.648  0.841  0.174  0.147  0.435  0.572 | 0.111  0.031  0.198  0.060  0.109  0.030  0.094  0.028  0.128  0.031  0.229  0.057  0.292  0.080  -0.047  -0.012  -0.110  -0.031  0.294  0.073  0.053  0.012  0.024  0.008  0.148  0.029  0.067  0.011  0.373  0.116  **0.366**  **0.121**  0.088  0.024  0.252  0.078 | -0.076  0.005  0.036  -0.002  -0.034  0.001  -0.100  0.006  -0.085  0.001  -0.043  0.002  -0.083  0.005  0.058  -0.004  0.092  -0.006  -0.082  0.005  -0.079  0.005  -0.100  0.006  -0.026  0.001  -0.060  0.001  -0.040  0.003  -0.035  0.004  **-0.147**  **0.019**  0.029  0.002 | -0.012  0.001  -0.004  0.000  0.011  -0.001  -0.014  0.001  -0.026  0.002  -0.013  0.001  -0.033  0.003  0.007  -0.001  0.011  -0.001  -0.022  0.002  -0.010  0.001  -0.007  0.001  -0.030  0.001  -0.012  0.001  -0.037  0.003  -0.038  0.003  -0.011  0.001  **-0.055**  **0.005** | 0.294\*  0.273\*  0.538\*\*  0.504\*\*  0.297\*  0.245  0.270\*  0.214  0.371\*  0.221  0.631\*\*  0.462\*  0.790\*\*  0.677\*\*  -0.126  -0.105  -0.307\*  -0.247  0.668\*\*  -0.625\*\*  0.144  0.099  0.059  0.080  0.428\*  0.217  0.168  0.112  1.008\*\*  0.985\*\*  1.024\*\*  0.957\*\*  0.257  0.184  0.683\*\*  0.656\*\* |

\*and\*\* indicate significant of values at P=0.05and 0.01, respectively

**Residual value: (Genotypic - 0.0094 and phenotypic - 0.0242) Bold figures indicate direct effects.**

1 = Germination percentage 2 = Plant height (cm) 3= No. Of leaves/plant 4 = Leaf length (cm) 5 = Leaf width (cm)

6 = Primary branches /plant 7= Secondary branches/plant 8= Days to first flowering 9 = Days to 50% flowering 10 = No. Of pods /plant

11 = Green pod length (cm) 12 = Green pod width (cm) 13= Green pod breadth (cm) 14 = Single green pod weight (g) 15 = Green pod yield /plant (g) 16 = Green pod yield /plot (kg) 17 = No. Of seeds /pod 18=100-seed weight (g) 19 = Green pod yield (q/ha)

**2nd Set Quality Parameters**

**Table-6: Genotypic correlation coefficients of different characters in French bean**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Characters | **1** | **2** | **3** | **4** |
| **1** G  P  **2** G  P  **3** G  P | rg | 0.259  0.146  rg | 0.323\*  0.245  0.011  -0.019  rg | 0.311  0.208  0.348\*  0.299  0.539\*\*  0.515\*\* |

\*and\*\* indicate significant of values at P=0.05and 0.01, respectively

1= Moisture (%) 2= Total sugars (%) 3= Protein (%) 4= Green pod yield (q/ha)

**Table -7: Genotypic and phenotypic path coefficient effect of different quality characters in French bean**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Characters | **1** | **2** | **3** | **4** |
| **1** G  P  **2** G  P  **3** G  P | **0.060**  **0.039**  0.015  0.006  0.019  0.009 | 0.085  0.044  **0.327**  **0.303**  0.004  -0.006 | 0.167  0.125  0.006  -0.010  **0.516**  **0.511** | 0.311\*  0.208  0.348\*  0.299\*  0.539\*\*  0.515\*\* |

\*and\*\* indicate significant of values at P=0.05and 0.01, respectively

**Residual value: (Genotypic -0.5891 and phenotypic - 0.6380) Bold figures indicate direct effects.**

1= Moisture (%) 2= Total sugars (%) 3= Protein (%) 4= Green pod yield (q/ha)