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Genetic Variability and Qualitative Traits in Pole-Type French Bean (*Phaseolus vulgaris* L.) Genotypes

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Abstract— *Thirty-two pole-type French bean genotypes were evaluated in a randomized block design with two replications during Rabi 2022–23 at the Regional Agricultural Research Station, Vijayapura, University of Agricultural Sciences, Dharwad, Karnataka, India. High genotypic and phenotypic coefficients of variation (GCV and PCV >20%) were recorded for protein content and reducing sugar content in pods, indicating substantial genetic variability with minimal environmental influence and good scope for improvement through direct selection. Moderate GCV and PCV (10–20%) for non-reducing sugar content in pods suggested the involvement of both additive and non-additive gene effects, reflecting adequate variability and the usefulness of phenotypic selection. High heritability (>60%) coupled with high genetic advance as per cent of mean (>20%) was observed for protein, reducing sugar, and non-reducing sugar contents in pods, indicating predominance of additive gene action. Therefore, direct selection would be effective for improving these traits. Evaluation of qualitative pod traits revealed significant variation for pod colour, shape, curvature, stringlessness, beak position, and beak orientation among genotypes. Genotypes IC-632961 and IIHR-01 were identified as superior based on round, stringless pods with attractive medium green colour, making them desirable for both consumer preference and commercial cultivation*.

Keywords— ***GAM, Heritability, GCV, PCV, Reducing sugar, Protein, Pole type French bean.***

I. INTRODUCTION

French bean (*Phaseolus vulgaris* L.) is one of the most common and widely grown vegetable crops in India with a chromosome number of 2n=22. According to Vavilov (1950), the origin of French bean is Southern Mexico and Central America, while the Peruvian-Ecuadorian-Bolivian area is considered to be a secondary centre of origin. It was originated from wild species *Phaseolus aborigineus* (L.) and domesticated in Mexico, Peru, and Colombia about 8000 years ago. This crop has extensive geographical distribution in the world.

French bean is known by several names related to its purpose of usage as vegetable viz., string bean, snap bean, salad bean, haricot bean, and green bean. However, the terms bean, dry bean, kidney bean, and navy bean are designated to pulses (George, 1985). Furthermore, string bean, dwarf bean, and pole bean pertain to distinct growth patterns. In different languages, it has diverse identities viz., rajmash in Hindi and tingala avare in Kannada. French bean varieties are categorized based on their growth habits i.e., bush type with compact segments, semi-pole type with more extended segment, and pole type with viny growth longer than semi-pole type (Prabhakar et al., 2016).

It is cultivated all over the world and has a wide geographical distribution. French bean is mainly used for immature green pods. Rajmash or dried pods are utilized as a pulse and provide a good source of proteins for humans (Abate, 2006). Immature pods are eaten fresh and can be easily preserved by freezing, canning, or dehydrating. Dried beans are eaten as boiled, baked, fried, or ground into flour. It is highly nutritious as 100 g of green pods contain 1.7 g protein, 4.5 g carbohydrates, 221 IU vitamin A, 11 mg vitamin C, and 50 mg calcium (Gopalakrishnan, 2007). French bean can be used to some extent against diabetes and cardiac problems and is a wonderful natural cure for bladder burn. It has both carminative and reparative qualities in the treatment of constipation and diarrhea (Duke, 1981).

It is a cool season vegetable, extensively grown in temperate and subtropical areas, as well as in many parts of tropical regions with a temperature around 16 to 24 °C. Among prominent food legumes globally, French bean ranks third after soybean (*Glycine max* L.) and peanut (*Arachis hypogea* L.). Furthermore, it stands second position in terms of beans vegetables (Singh, 1999). The present study was undertaken to evaluate genetic variability and qualitative traits in pole-type French bean genotypes to identify superior lines for breeding programs.

II. MATERIALS AND METHODS

2.1 Experimental Site and Design:

The experiment was conducted at the Regional Agricultural Research Station (RARS), Vijayapura during *Rabi* 2022-23. Thirty-two genotypes of pole-type French bean were grown in a randomized block design with two replications. Ridges and furrows were opened at 120 cm and seeds of different genotypes were sown by dibbling on one side of the ridge at 30 cm. Plots were irrigated immediately after the completion of sowing. Where seeds did not germinate, gaps were filled by re-sowing within a week. All other activities were carried out as per the recommended package of practices (RPP) given by University of Horticultural Sciences (UHS), Bagalkot (Anon., 2022) to grow the crop. Observations were recorded visually on five randomly selected plants from each genotype.

2.2 Quality Parameters:

2.2.1 Pod Colour:

The colour of harvested pods for vegetable purpose was observed in each genotype under natural daylight and grouped into green/dark green/light green.

2.2.2 Pod Shape:

The shape of pod was observed at edible stage for all the genotypes and was grouped into round or elliptic shapes.

2.2.3 Pod Curvature:

The pod curvature was observed and recorded at edible stage for all the genotypes and was grouped into straight or curved or slightly curved.

2.2.4 Pod Stringlessness:

The pod stringlessness was observed by breakup of the pod at edible maturity stage for all the genotypes and grouped into stringed or stringless.

2.2.5 Pod Beak Position:

The pod beak position was observed visually at edible maturity stage for all the genotypes and grouped into marginal or non-marginal.

2.2.6 Pod Beak Orientation:

The pod beak orientation was observed visually at edible maturity stage for all the genotypes and grouped into straight or upward or downward.

2.2.7 Protein Content in Pods (g/100 g):

Protein content in pods from each genotype was estimated by following Lowry's method. A sample of harvested green pods at marketable maturity was shade dried and ground to fine powder. A sample of 0.5 g was taken and ground with five ml of phosphate buffer solution with the help of pestle and mortar. The powdered sample was centrifuged and supernatant was used. The standards of 0.2 ml, 0.4 ml, 0.6 ml and up to 3 ml were pipetted out from working solution of bovine serum albumin (BSA). The volume of each tube was made up to three ml. A blank with 3 ml of distilled water was also maintained. Exactly 0.1 ml of sample was taken into a test tube and made into 3 ml by adding distilled water. Five ml of alkaline copper reagent was added to each test tube and incubated for ten minutes at room temperature. 0.5 ml of folin-ciocalteau reagent

(FCR) was added to each test tube and kept for 30 minutes in dark condition and spectrophotometer readings were observed at 660 nm. The protein content in pods was calculated with the help of standard graph and expressed in g per 100 g of green pods (Lowry et al., 1951).

2.2.8 Reducing Sugar in Pods (%):

The reducing sugar in pods was estimated by using 3,5-dinitrosalicylic acid (DNS) method. A sample of harvested green pods at marketable maturity was shade dried and ground to fine powder. A sample of 100 mg was taken and ground in boiling 80% ethyl alcohol thoroughly in a mortar with pestle for 5-10 minutes to extract the sugars. The sample extract was centrifuged for 10 minutes and supernatant was collected and evaporated on boiling water bath. Ten ml of water was added to the supernatant to dissolve the sugars. The standards of 0.2 ml, 0.4 ml, 0.6 ml and up to 3 ml were pipetted out from working solution of glucose. One ml of alcohol-free extract was taken into test tubes and volume was made up to 3 ml with water in all test tubes. Three ml of DNS reagent was added to a blank and heated for 5 minutes in boiling water bath. After the colour development, one ml of sodium potassium tartarate solution was added and mixed thoroughly. The test tubes were cooled under running tap water and absorbance was measured at 510 nm using reagent and blank was adjusted to zero absorbance. The amount of reducing sugar in the sample was calculated using a standard graph prepared from working standard glucose solution in the same manner (Thimmaiah, 1999)..

$$\text{Reducing sugars in the sample (\%)} = \frac{\text{Sugar value from graph (µg)} \times \text{Total volume of alcohol free extract (10 ml)}}{\text{Aliquot of alcohol free extract used (ml)} \times \text{Weight of sample (100 mg)}} \times \frac{1}{1000} \quad (1)$$

2.2.9 Non-Reducing Sugar in Pods (%):

The non-reducing sugar in pods was estimated by using 3,5-dinitrosalicylic acid (DNS) method. A sample of harvested green pods at marketable maturity was shade dried and ground to fine powder. A sample of 100 mg was taken and ground in boiling 80% ethyl alcohol thoroughly in a mortar with pestle for 5-10 minutes to extract the sugars. The sample extract was centrifuged for 10 minutes and supernatant was collected and evaporated on boiling water bath. Ten ml of water was added to the supernatant to dissolve the sugars. One ml of extract was pipetted out and 1 ml of 1N H_2SO_4 was added to hydrolyze the mixture by heating at 49°C for 30 minutes (the acid hydrolysis is effective in splitting the sucrose-type linkages). After the test tubes were cooled, 1 or 2 drops of methyl red indicator was added and the contents were neutralized by adding 1N NaOH drop wise from a pipette. The standards of 0.2 ml, 0.4 ml, 0.6 ml and up to 3 ml were pipetted out from working solution of glucose. Three ml of DNS reagent was added and heated for 5 minutes in boiling water bath. After the colour development, one ml of sodium potassium tartarate solution was added and mixed thoroughly. The test tubes were cooled under running tap water and absorbance was measured at 510 nm using reagent and blank was adjusted to zero absorbance. The amount of non-reducing sugar in the sample was calculated using a standard graph prepared from working standard glucose solution in the same manner (Thimmaiah, 1999).

$$\text{Non-reducing sugars in the sample (\%)} = \frac{\text{Sugar value from graph (µg)} \times \text{Total volume of extract (10 ml)}}{\text{Aliquot sample (1 ml)} \times \text{Weight of sample (100 mg)}} \times \frac{1}{1000} \quad (2)$$

2.3 Statistical Analysis:

Genotypic and phenotypic coefficients of variation were calculated according to the method suggested by Burton and de Vane (1953). Heritability in broad sense and genetic advance as per cent of mean were estimated using the formula given by Johnson et al. (1955). The range, mean, and standard error were computed for each trait.

III. RESULTS AND DISCUSSION

3.1 Quality Parameters:

High PCV and GCV (Table 1) were observed for protein and reducing sugar content in pods, indicating the existence of a broad genetic base, which would be amenable for further selection. Similar results were also obtained by Singh et al. (2020).

Moderate PCV and GCV (Table 1) were observed for non-reducing sugar in pods, indicating the presence of moderate to good amount of variability for these traits in the genetic stock, which would be amenable for further selection. These results are in agreement with Tanuja et al. (2021) and Prakash and Ram (2014).

High heritability (>60%) along with high GAM (>20%) was recorded for protein, reducing sugar, and non-reducing sugar content in pods (Table 1). Therefore, the additive component is predominant and hence, direct selection would be more effective in improving these traits. Similar results were also noticed by Singh et al. (2020), Razvi et al. (2018), and Lad et al.

(2017). Jhanavi et al. (2018) and Prakash and Ram (2014) in their experiments reported similar findings for protein content in pods, and Singh et al. (2020) for reducing sugar and non-reducing sugar content in pods.

TABLE 1
ESTIMATES OF RANGE, MEAN, COMPONENTS OF VARIANCE, HERITABILITY AND GENETIC ADVANCE FOR QUALITY TRAITS IN POLE-TYPE FRENCH BEAN GENOTYPES

Sl. No.	Characters	Range	Mean ± S.Em	Components of variance					Genetic advance	
				PV (σ^2p)	GV (σ^2g)	PCV (%)	GCV (%)	h^2 (%)	GA	GAM (%)
	Quality parameters									
1	Protein content in pods (g/100 g)	0.96 - 2.27	1.66 ± 0.05	0.14	0.13	22.89	22.45	96.17	0.75	45.36
2	Reducing sugar in pods (%)	2.36 - 5.75	4.02 ± 0.18	0.88	0.81	23.31	22.38	92.14	1.78	44.25
3	Non-reducing sugar in pods (%)	0.95 - 1.93	1.24 ± 0.06	0.04	0.03	16.15	14.13	76.58	0.31	25.48

GV = Genotypic variance; PV = Phenotypic variance; GCV = Genotypic coefficient of variation; PCV = Phenotypic coefficient of variation; h² = Heritability (broad sense); GA = Genetic advance; GAM = Genetic advance as per cent over mean

3.2 Pod Colour:

The dark green pods (Table 2) were observed in genotypes IC-636225, IC-636226, IC-582514, IC-326977, and IC-026624. The genotypes IC-636224, IC-636241, IC-641919, IC-280818, IC-341797, IC-341807, IC-430379, EC-398555, IC-326978, IIHR-02, IC-313320, Super King, and US-2 were included in the light green pods group. Medium green pods were noticed in genotypes IC-636245, IC-313309, IC-632961, IC-582511, IC-538077, IC-328398, IIHR-01, Marlida, Arka Sukomol, and Lakshmi. The genotypes IC-636240 and IC-538039 were grouped under medium green with purple stripes. IC-341922 (medium green with red stripe) and IC-538073 (dark green with purple stripe) had different fruit colour patterns.

3.3 Pod Shape:

Elliptic shaped pods (Table 2) were noticed in genotypes IC-636224, IC-636225, IC-636226, IC-636241, IC-636245, IC-641919, IC-280818, IC-341797, IC-341807, IC-341922, IC-636240, IC-430379, IC-313309, EC-398555, IC-582514, IC-538073, IC-538039, IC-328398, IC-326978, IC-326977, IC-026624, IC-313320, IC-582511, IIHR-02, and IC-538077. The genotypes IC-632961, IIHR-01, Arka Sukomol, Lakshmi, Marlida, Super King, and US-2 were grouped under round shaped pods.

3.4 Pod Curvature:

Slightly curved pods (Table 2) were observed in genotypes IC-636226, IC-636241, IC-636245, IC-280818, IC-341797, IC-341807, IC-636240, IC-430379, IC-313309, EC-398555, IC-582514, IC-538073, IC-538039, IC-328398, IC-326978, IC-326977, IC-026624, IC-313320, IC-582511, IC-538077, IIHR-01, IIHR-02, Arka Sukomol, Marlida, and US-2. Straight pods were observed in genotypes IC-636224, IC-636225, IC-641919, IC-341922, and Lakshmi. The genotypes IC-636225, IC-632961, and Super King had curved pods.

3.5 Pod Stringlessness:

Stringed pods (Table 2) were observed in genotypes IC-636224, IC-636225, IC-636226, IC-636241, IC-636245, IC-641919, IC-280818, IC-341797, IC-341807, IC-341922, IC-636240, IC-430379, IC-313309, EC-398555, IC-582514, IC-538073, IC-538039, IC-328398, IC-326978, IC-326977, IC-026624, IC-313320, IC-538077, Arka Sukomol, and Lakshmi. Stringless pods were noticed in genotypes IC-632961, IC-582511, IIHR-01, IIHR-02, Marlida, Super King, and US-2.

3.6 Pod Beak Position:

Marginal pod beak position (Table 2) was observed in genotypes IC-636225, IC-636226, IC-636245, IC-641919, IC-280818, IC-341797, IC-341807, IC-636240, IC-430379, IC-313309, EC-398555, IC-582514, IC-538073, IC-538039, IC-328398, IC-326977, IC-026624, IC-313320, IC-538077, Arka Sukomol, Lakshmi, IC-632961, IC-582511, IIHR-01, IIHR-02, Marlida, Super King, and US-2. Non-marginal pod beak position was observed in genotypes IC-636224, IC-341922, IC-636241, and IC-326978.

3.7 Pod Beak Orientation:

Straight pod beak orientation was observed in genotypes (Table 2) IC-636225, IC-636226, IC-636241, IC-641919, IC-280818, IC-636240, IC-582514, IC-538073, IC-538039, IC-328398, Super King, and US-2. Upward pod beak orientation was observed in genotypes IC-636224, IC-636245, IC-341797, IC-341807, IC-326977, IC-313320, IC-582511, IC-538077, Arka Sukomol, Lakshmi, and Marlida. Downward pod beak orientation was observed in genotypes IC-430379, IC-313309, EC-398555, IC-026624, IC-632961, IIHR-01, and IIHR-02.

TABLE 2
QUALITATIVE TRAITS OF POLE-TYPE FRENCH BEAN GENOTYPES

Sl. No.	Genotypes	Pod colour	Pod shape	Pod curvature	Pod stringness	Pod beak position	Pod beak orientation
1	IC-636224	Light green	Elliptic	Straight	Stringed	Non-marginal	Upward
2	IC-636225	Dark green	Elliptic	Curved	Stringed	Marginal	Straight
3	IC-636226	Dark green	Elliptic	Slightly curved	Stringed	Marginal	Straight
4	IC-636241	Light green	Elliptic	Slightly curved	Stringed	Non-marginal	Straight
5	IC-636245	Medium green	Elliptic	Slightly curved	Stringed	Marginal	Upward
6	IC-641919	Light green	Elliptic	Straight	Stringed	Marginal	Straight
7	IC-280818	Light green	Elliptic	Slightly curved	Stringed	Marginal	Straight
8	IC-341797	Light green	Elliptic	Slightly curved	Stringed	Marginal	Upward
9	IC-341807	Light green	Elliptic	Slightly curved	Stringed	Marginal	Upward
10	IC-341922	Medium green with red stripe	Elliptic	Straight	Stringed	Non-marginal	Straight
11	IC-636240	Medium green with purple stripe	Elliptic	Slightly curved	Stringed	Marginal	Straight
12	IC-430379	Light green	Elliptic	Slightly curved	Stringed	Marginal	Downward
13	IC-313309	Medium green	Elliptic	Slightly curved	Stringed	Marginal	Downward
14	EC-398555	Light green	Elliptic	Slightly curved	Stringed	Marginal	Downward
15	IC-582514	Dark green	Elliptic	Slightly curved	Stringed	Marginal	Straight
16	IC-538073	Dark green with purple stripe	Elliptic	Slightly curved	Stringed	Marginal	Straight
17	IC-538039	Medium green with purple stripe	Elliptic	Slightly curved	Stringed	Marginal	Straight
18	IC-328398	Light green	Elliptic	Slightly curved	Stringed	Marginal	Straight

Sl. No.	Genotypes	Pod colour	Pod shape	Pod curvature	Pod stringness	Pod beak position	Pod beak orientation
19	IC-326978	Light green	Elliptic	Slightly curved	Stringed	Non-marginal	Straight
20	IC-326977	Medium green	Elliptic	Slightly curved	Stringed	Marginal	Upward
21	IC-026624	Dark green	Elliptic	Slightly curved	Stringed	Marginal	Downward
22	IC-632961	Medium green	Round	Curved	Stringless	Marginal	Downward
23	IC-313320	Light green	Elliptic	Slightly curved	Stringed	Marginal	Upward
24	IC-582511	Medium green	Elliptic	Slightly curved	Stringless	Marginal	Upward
25	IC-538077	Medium green	Elliptic	Slightly curved	Stringed	Marginal	Upward
26	IIHR-01	Medium green	Round	Slightly curved	Stringless	Marginal	Downward
27	IIHR-02	Light green	Elliptic	Slightly curved	Stringless	Marginal	Downward
28	Arka Sukomol	Medium green	Round	Slightly curved	Stringed	Marginal	Upward
29	Lakshmi	Medium green	Round	Straight	Stringed	Marginal	Upward
30	Marlida	Medium green	Round	Slightly curved	Stringless	Marginal	Upward
31	Super King	Light green	Round	Curved	Stringless	Marginal	Straight
32	US-2	Light green	Round	Slightly curved	Stringless	Marginal	Straight

Note: Pod colour categories include dark green, light green, medium green, medium green with purple stripe, dark green with purple stripe, and medium green with red stripe. Pod shape: elliptic or round. Pod curvature: straight, slightly curved, or curved. Pod stringness: stringed or stringless. Pod beak position: marginal or non-marginal. Pod beak orientation: straight, upward, or downward.

IV. CONCLUSION

From the present study, the maximum protein content in pods was recorded in genotype EC-398555 (2.11 g per 100 g) followed by IC-538073 (2.07 g per 100 g) and IC-313320 (2.05 g per 100 g). These genotypes demonstrated superior nutritional potential compared to the others, indicating their suitability for improving dietary protein content through selection and breeding programs. Based on pod characteristics such as shape, stringlessness, and colour, the genotypes IC-632961 and IIHR-01 were identified as superior. These genotypes produced round, stringless pods with an attractive medium green colour, making them more desirable in comparison to the other genotypes studied. Their favourable pod traits suggest potential value for both consumer preference and commercial cultivation. The high heritability coupled with high genetic advance for protein and sugar contents indicates that additive gene action predominates, making direct selection effective for improving these nutritional traits.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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