DUS characterization and evaluation of untapped French bean (*Phaseolus vulgaris* L.) genotypes

ABSTRACT

Since time immemorial, French bean is being considered as an important legume for human diet having rich source of dietary proteins, minerals and vitamins. Germplasm characterization and evaluation is having great contribution in breeding and crop improvement. Substantial phenotypic and genetic characterization of untapped French bean germplasm are still needed to unlock its breeding potential. Purposefully, 27 diverse French bean genotypes comprising primitive, cultivars, commercial cultivars, farmers grown varieties were collected from different parts of India, characterized as per DUS and evaluated for associated morpho-phenological traits in randomized complete block design. The screened panel revealed highly significant differences among French bean genotypes for all the traits under study which witnessed the existence of sufficient variability in the French bean genotypes in which first two principal component analysis explained 20.03% and 13.32% of the total morphological variability. The genotypes were well scattered in PCA axis forming groups with various traits as per contribution towards the variability.

Key word: DUS, keel, primitive, PCA, standard petals

1. Introduction

The French bean is christened as common bean, snap bean, salad bean, kidney bean, haricot bean and string bean (Purseglove, 1968; Gepts and Debouck, 1991 and Wortmann, 2006). French bean is a member of the Fabaceae family with a chromosome number of 2n = 2x = 22. The crop is an annual species that primarily self-pollinating species. It prefers an optimum temperature for growth and development and commercially cultivated during rabi season in plains and during spring and summer in hills of India. It is cultivated for its tender, green pods which are either consumed fresh or processed into canned, frozen, or freeze-dried goods. As a food source, the crop offers essential vitamins like folic acid and thiamine (Petry *et al*., 2015) and proteins, fibers, vitamins and minerals (Broughton *et al*., 2003; Mora- Avilés *et al*., 2007) and additionally, the stems are useful for livestock feed, particularly during the dry period that follows the primary cropping season (Wondatir and Mekasha, 2014). It has natural anti-diabetic effects and is efficient in healing bladder burns and heart disorders. It helps in curing diarrhoea and constipation with both carminative and reparative properties (Duke, 1981). It is a protective and nourishing vegetable that provides 1.7% protein, 4.5% fat, 1.8% fibre, 0.5% mineral constituents and 0.1% carbohydrates (Thamburaj and Singh, 2001), flavonoids, antioxidants, and beneficial phytochemicals (FAO, 1999). Being a legume crop, it improves soil fertility by fixing nitrogen from the atmosphere. In world scenario, India is leading country in producing dry French bean seed followed by Brazil and Myanmar. However, China leads the world in green beans production preceded by Indonesia and Turkey (FAOSTAT, 2019).

French bean is native to Central America and South America (Vavilov, 1950). Its genesis is from wild species i.e., *Phaseolus aborigineus* L. which is regarded as progenitor (Smartt, 1976). Cultivated *P. vulgaris* are grouped into two types i.e., Bush types, determinate in growth habit and pole types, indeterminate in growth habit. Basically, the plant has tap root and lateral root system that are confined to top 15 cm of the soil surface. Conspicuous hair is present in plant and the density of the hairs and length on the stems vary depending on the cultivar. The hairs play an important role in resistance to disease and insects, particularly prevent the formation of fungal spores and lower the degree of secondary inoculum. The plant has trifoliate leaves which are arranged alternately on stem. Leaflet shapes vary among genotypes however leaflet with broad bases and acute tips are common leaf characteristics are observed. Depending on the cultivar, inflorescence is born as axillary or terminal racemes bears flowers of different colours i.e., white, purple, violet liliac, or pink. The flower is bisexual have a "keel" which has one to two turns and terminates in a coil. Depending on the cultivar, the pods vary in size, shape, and pigmentation in addition to having sparse hair. A diverse characteristic of seeds (colours, shapes, and sizes) are observed in French bean with an average weight test weight of 150-900 g which varies from one cultivar to another (Brink and Belay, 2006 and Wortmann, 2006).

An extensive crop improvement programme has been conducted in French bean witnessing development of a number of varieties which comprise diverse range of agronomic and morpho-physiological characteristics including diversity in growth habit, seeds size and colour (Purseglove, 1968 and Singh *et al*., 1991). Determinate growth, which is typically characterized by decreased branching, shorter and less number internodes, less twining, photo-insensitive, and, most importantly, an increased allocation of biomass to reproductive growth, is one of the traits that is most frequently chosen (Singh and Schwartz, 2010 and Kwak *et al*., 2012).

The DUS (Distinctness, Uniformity, and Stability) assessment mandated under the Plant Varieties and Farmers Right Act (PPV&FRA), 2001, is crucial for a valid varietal registration. A useful method for identifying and preventing duplication is DUS characterization of crop genotypes (Das and Kumar, 2012). The morphological characterization of genotypes facilitates in the development of a database that can be helpful for identification and assessment of the genetic variation present in the genotypes. In order to improve crops, germplasm evaluation is crucial. A significant source of genetic diversity is the farming community's production of French bean accessions in India and Odisha. A global initiative to preserve plant biodiversity involves collecting germplasm. Invaluable for breeding programmes is the diversity of local genetic resources. These tools can be applied to fundamental research on topics like gene expression, evolution, and crop plant improvement (Dudnik et al., 2001 and Mario et al., 2010).

High genetic diversity in French bean is available in in India and many local varieties and primitive cultivars have not been fully utilized in genetic improvement programme due to minimal database are available about these genotypes. Thus, this study was initiated with the objectives of collecting French bean germplasm followed by characterization for generating a strong database for utilization in future crop improvement programme.

2. Material and methods

The plant genetic materials for investigation comprised of 13 French bean genotypes collected from Guptakashi, Uttarakhand, 4 from Araku, Andhra Pradesh, one from Raikia, Kandhamal, two released varieties such as Arka Arjun and Arka Sukomal from IIHR, Bengaluru, Karnataka, 3 from Phulbani, Kandhamal, Odisha, 3 from Bhubaneswar, Odisha and one from Angul, Odisha (Table 1). Field evaluation and data collection of French bean genotypes was conducted at Central Horticulture Experiment Station (CHES-IIHR), Aiginia, Bhubaneswar, India of ICAR-Indian Institute of Horticulture Research, during rabi 2019-20. The site is located at 20.015^{0} N latitude, 85.053^{0} E longitude and 25.5 m above mean sea level. Seeds were sown on raised bed with 1m x 30cm spacing in RCBD (Randomized Complete Block Design) in three replications. Fertilizer applied at the rate 100:60:40 kg/ha NH_4: P_2O_5: K_2O and good agricultural practices were adopted for successful raising of the crop.

Table 1: List of genotypes considered for investigation

Sl. No.	Genotypes/ Variety	Type	Source of collection
1.	Arka Arjun	Commercial cultivar	IIHR, Bengaluru, Karnataka
2.	Arka Sukomal	Commercial cultivar	
3.	IIHR-B-PV-16	Primitive	Guptakashi, Uttarakhand
4.	IIHR-B-PV-4	Primitive	
5.	IIHR-B-PV-5	Primitive	
6.	IIHR-B-PV-9	Primitive	
7.	IIHR-B-PV-11	Primitive	
8.	IIHR-B-PV-12	Primitive	
9.	IIHR-B-PV-15	Primitive	
10.	IIHR-B-PV-17	Primitive	
11.	IIHR-B-PV-20	Primitive	
12.	IIHR-B-PV-21	Primitive	
13.	IIHR-B-PV-22	Primitive	
14.	IIHR-B-PV-24	Primitive	
15.	IIHR-B-PV-25	Primitive	
16.	IIHR-B-PV-26	Primitive	Araku Velly, Andhra Pradesh
17.	IIHR-B-PV-27	Primitive	
18.	IIHR-B-PV-29	Primitive	
19.	IIHR-B-PV-30	Primitive	
20.	IC 632961	Primitive	Raikia, Kandhamal, Odisha
21.	Ayoka	Commercial cultivar	Phulbani, Kandhamal, Odisha
22.	Phulbani local	Primitive	
23.	Baisnavi	Commercial cultivar	
24.	Anupam	Commercial cultivar	Bhubaneswar, Odisha
25.	Ranar	Commercial cultivar	
26.	Phalguni	Commercial cultivar	
27.	Angul local	Primitive	Angul, Odisha

2.1. Traits recording and scoring

The morpho-phenological trait for the genotypes were recorded as per international French bean descriptor of the International Board for Plant Genetic Resources (IBPGR, 1982), guidelines for the conduct of test for Distinctness, Uniformity, and Stability on French bean

(PPV & FR authority, GOI, 2007) and other descriptors were considered from literatures. In total 38 qualitative traits are observed (table 2). For qualitative traits particular scale is coded as per IBPGR descriptor for diversity analysis and elimination of repetition of data (table 3 and 4).

Table 2: List of morpho-phenological traits and assigned scale for different qualitative traits recorded in the study

Traits	Acronym	Description with scale
Growth habit	GH	Recorded for pole type and bush type; Determinate =1, indeterminate =2, semideterminate =3
Twinning habit	TH	Recorded as per twinning or climbing nature of plant; Viny= 1, non-viny=9
Stem pigmentation	SP	Observed at peak flowering stage; Absent= 0, present= +
Stem hairiness	SH	Presence or absence of space hair on stem; Absent= 0, present= +
Leaf colour	LC	Intensity of green colour at peak flowering stage; Pale green= 3, medium green= 5, dark green= 7
Leaf shape	LS	Shape of central leaflet at peak flowering stage; Ovate= 1, rhombohedric= 2, cordate= 3
Leaf pubescence	LP	Presence or absence of conspicuous hair on leaf surface; Hairy= +, smooth= 0
Leaflet size	LLS	Size of central leaflet at peak flowering stage; Small= 1, medium= 2, large= 3
Persistence of leaf	PL	Persistence of leaves when 90% of pods dry in plot; All leaf dropped= 3, intermediate= 5, all leaves peristent= 7
Flower colour	FC	Observed in freshly opened flowers; White= 1, yellow= 2, pink= 3, violet= 4
Standard petal pattern	SPP	Presence or absence of strips on outer surface of standard petal; Striped= 1, non-striped= 3
Colour of standard petal	CSP	Observed in freshly opened flower; White=1, light green= 2, lilac= 3, carmine red=8, purple= 9
Colour of wing	CW	Observed in freshly opened flower; White= 1, green= 2, lilac= 3, white with carmine stripes= 4
Flower bud size	FBS	Relative size of flowers in inflorescence; Small= 1, medium= 2, large= 3
Size of flower bracteolate	SBL	Size of bracteole at peak flowering stage; Small= 3, medium= 5, large= 7
Colour of pod	CP	Intensity of colour in full grown immature pod; Purple= 1, green with purple stripe= 3, green with red stripes=5, green= 7, pale green= 8
Pod shape	PS	Recorded in full grown immature pod; Flat= 1, round= 2
Pod curvature	PC	Recorded in full grown immature pod in relation to suture; Straight= 3, slightly curved= 5, curved= 7, recurving=9
Pod pigmentation	PP	Presence or absence of other pigments in pod surface; Absent=1, present=9
Position of pod	POP	Pod bearing habit in relation to portion of stem; Base= 1, center= 2, top= 3, combination= 4

Pod stringiness	PSN	Presence of string in pod cross-section; Stringless= 0, few strings= 3, moderately stringy=5, very stringy= 7
Pod pubescence	PPS	Hairy or smoothness pod recorded in full grown immature pod; Sparce= 1, intermediate= 2, glaborous= 3
Shape of pod distal part	SPDP	Shape of distal part of pod excluding beak; Acute= 3, acute to truncate= 5, truncate= 7
Pod beak position	PBP	Observed in full grown immature pod; Marginal= 1, non-marginal= 2
Pod beak orientation	PBO	Curving of beak to dorsal or ventral side of pod; Upward= 3, straight= 5, downward= 7
Pod cross-section	PCS	Shape of pod in cross-section along with seed; Very flat= 1, pear shaped= 2, round elliptic= 3, figure of eight= 4
Pod wall fiber	PWF	Recorded in fully matured dry pod ; Contracting= 3, leathery= 5, shattering= 7
Pod colour at physiological maturity	PCPM	Intensity of colour in fully matured dry pod Pink= 3, pale yellow= 4, copper brown= 5, brown= 6, brown with pigmentation= 7

3. Results

3.1. Characterization based on qualitative traits

It is very essential for finding duplications in germplasm collections, characterization of individuals, accessions, and cultivars as well as choosing parental genotypes in breeding programmes.

3.1.1. Plant growth traits

Plant growth traits is an important consideration for characterizing a set of genotypes as the traits has direct contribution towards plant architecture which influences the yield and its other components. The data on plant growth traits of studied twenty-seven genotypes are presented in Table 3 and Figure 1. Duran *et al*. (2005) adopted morphological descriptors such as leaf width, leaf length, leaf shape (cordate, ovate, rhombohedric, or hastate), growth habit, length of the fifth internode to characterize French bean landraces and cultivars from the Caribbean. Singh *et al*. (2014) characterized 18 French bean genotypes as DUS morphological descriptors for the protection of novel varieties under the PPV and FR Rules of 2001 and inferred that time of flowering, stem anthocyanin colouration, leaflet size (at terminal leaflet of first flowering mode), plant growth type, plant twining habit, plant habit, intensity of green colour of leaf, shape of central leaflet are important morphological markers. Kanwar *et al*. (2020) categorized 26 geographically diverse French bean genotypes for plant growth habit, stem pigmentation, hairiness on the stem, flower colour, hairiness on the flower, leaflet shape and reported significant differences among all the genotypes. Simon Yohannes *et al*. (2020) showed that the growth traits measured were significantly differed due to the existence of inherent genetic variations among the French bean genotypes.

Growth habit

The investigation revealed that the studied French genotypes show maximum variation on the basis of different plant growth parameters i.e., eight genotypes are observed with bushy plant frame with determinate growth habits, one is with semi erect with semi-determinate and others eighteen genotypes show erect plant frame with indeterminate growth habits (Figure 1). Voysest (2000) proposed classifications of French bean cultivars as per growth habit. Purseglove (1968) and Singh *et al*. (1991) reported a wide variability in growth habit in French bean. Garcia *et al*. (1997), Rosales-Serna *et al*. (2001) and Langarica *et al*. (2014) demonstrated that indeterminate growth habit with climbing ability and extend physiological maturity leads to more productive than plants with determinate growth habit. Rosales-Serna *et al*. (2001); Beebe et al. (2000); Langarica *et al*. (2014) found significant diversity for growth habit in French bean genotypes. Garcia *et al*. (1997) and Langarica *et al*. (2014) reported predominant presence of indeterminate, with non-climbing shoots in French bean genotypes. Albuquerque *et al*. (2011) and Tsutsumi *et al*. (2015) witnessed French bean exhibits wide agronomic traits variation, including cycle (early and late), growth habit (determinate and indeterminate), plant habit (erect, semi-erect, and prostrated). Rana *et al*. (2015) evaluated 4274 germplasm accession of French bean from 58 countries and observed that morphological traits such as early plant vigour and indeterminate growth habit are predominant among 27 morphological traits. Rana *et al*. (2015) noticed 43% accessions had indeterminate growth habit, 28% determinate and 29 % were intermediate type. Choudhary, Bawa *et al*. (2018); Choudhary, Hamid *et al*. (2018); Singh (2001) observed great diversity exists for plant type, growth habit in agro-ecological adaptation of landraces cultivated in a particular region. AlBallat and Al-Araby (2019) indicated a wide genetic variability for indeterminate growth habit traits among 27 accessions. Dhaliwal (2020) revealed plant growth type out of the 19 characters was found monomorphic and showed no variation amongst French bean genotypes which exhibited semi-determinate growth type. Jan *et al*. (2021) revealed spreading growth type, vinyl twining habit frequently noticed among genotypes for growth habit and growth type during screening of 109 French bean.

Figure 1: Frequency distribution of French bean genotypes for plant growth traits

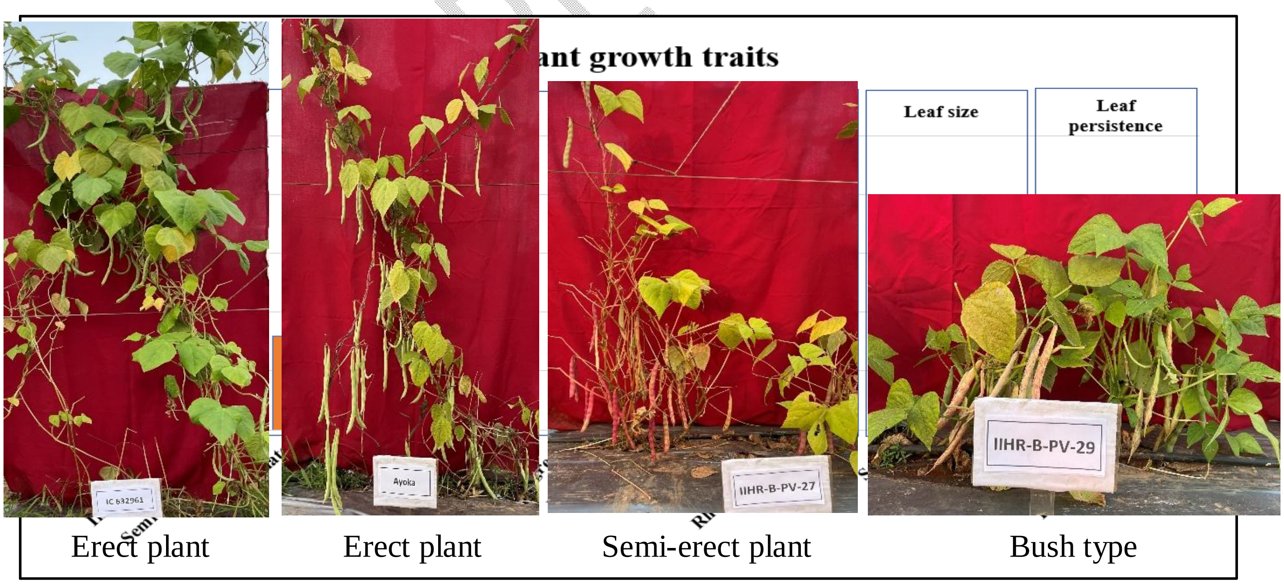

Figure 2: Different type of growth habit in studied French

Twinning habit

Regarding twinning habits of the plant which confer climbing ability of plants revealed nineteen genotypes are found to be viny and eight genotypes are non-viny in nature (Figure 1). Jan *et al*. (2021) revealed considerable variations noticed among French bean genotypes for twinning habit. Jan *et al*. (2021) and Sofi *et al*., (2014) observed predominance of indeterminate vinyl/climbing types in French bean.

Stem hairiness and pigmentation

As far as stem hairiness and pigmentation is concerned most of genotypes are reported with presence of conspicuous hair on stem and are non-pigmented whereas seven genotypes are having purple stem pigmentation (Figure 1). Prashanth (2003) grouped seven genotypes based on hairiness on the stem as glabrous and dense. Gupta *et al*., (2010) and Ramteke and Murlidharan (2012) reported that white-flowered genotypes exhibit no hypocotyl anthocyanin pigmentation, whereas the pigmentation is present in violet flowered genotypes. Kalauni *et al*. (2019) characterized and witnessed variability in French bean genotypes for stem pigmentation and hairiness. Dhaliwal (2020) inferred that presence of hypocotyl anthocyanin pigmentation is associated with violet flower colour.

Leaf traits

The French bean genotypes showed noticeable variation on leaf colour (light green and dark green), leaf shape (cordate, ovate, rhombobatic, Hestate), leaflet size (small, medium and large) and leaf persistence (persistent, intermediate and dropped) presented in Table 2 and Figure 1.

Leaf colour

The frequency table indicated that the studied French bean genotypes were varied as per green colour intensity i.e., light green and dark green which corroborates with findings of many scientists. Bonetti *et al.* (1995) evaluated 17 French bean cultivars based on leaf colour (very light green, light green, medium green, dark green, very dark green). Prakash and Singal (1997) used leaf colour to categories seven grain and six vegetable pea varieties. Surendra and Singhal (1997) classified seven grain and vegetable pea cultivars based on leaf colour (yellow green, blue green, green). Sultana (2001) observed green and purple vein colors among 107 genotypes and leaf color intensity varied from pale green to green to dark green in characterization of hyacinth bean. Jan *et al*. (2021) revealed dark green leaf color frequently noticed among genotypes during screening of 109 French bean.

Cordate Hastate Ovate Rhombobatic

Figure 3: Different leaf shape in studied French bean

Leaf shape and size

Leaflet shape is a certifying DUS characteristic for distinguishing genotypes. The data depicted that the French bean genotypes had varied leaf shape and size which helps in better characterization as it is a quite visible traits to naked to eye. Leaflet shape differs among the cultivars, but leaflets generally have broad bases and pointed tips (Singh *et al*., 1991). Duran *et al*. (2005) adopted morphological descriptor leaf shape (cordate, ovate, rhombohedric, or hastate) to characterize French bean landraces and cultivars from the Caribbean. Amirul Islam *et al*. (2006) evaluated 1105 French bean accessions for leaf shape. Bode *et al*. (2013) observed a great variability for leaf shape in French bean. Lenkala *et al*. (2015) grouped fifteen genotypes of Jack bean based on leaf density i.e., sparse, intermediate and dense. Rana *et al*., (2015) evaluated 4274 germplasm accession of French bean from 58 countries and observed that ovate leaf shape is predominant among 27 morphological traits. Kalauni *et al*. (2019) characterized and witnessed variability in French bean genotypes for leaf color and leaflet shape. Jan *et al*., (2021) reported two classes of leaf shape (Cordate and ovate) and 78.31% genotypes witnessed found cordate leaf shape predominantly. Jan *et al*., (2021) reported three classes of leaf size i.e., large, medium, and small in French bean with large leaf size predominantly.

3.1.2. Flowering traits

French bean genotypes witnessed considerable variation in term of flower colour, shape and size under study which offer quick and easy identification methods for characterization (table 4). The present investigation revealed that the flower colour of fifteen genotypes was white, four had pink flowers, four had violate flowers, one had purple flower, three had dual flower colour i.e., white & pink, white & yellow or yellow & pink (Figure 2). The studied genotypes are grouped into two categories i.e., eleven genotypes with striped standard petal and sixteen with non-striped petal in flower (table 4). The studied French genotypes showed different colour for standard petal noticeably, six with white colour standard petals, nine with light green, six with purple, two with white and lilac, one with carmine red and two with green standard petals (Figure 2). Similarly, sixteen genotypes are witnessed with white, seven with lilac and four with purple colour of wings. The French bean genotypes are varied as per size of flower i.e., twelve genotypes had large size flowers, ten genotypes had medium and five had small flower size. As far as size of bracteolate concerned, the genotypes also showed considerable variation whereas all genotypes are found to be glabrous in flower hairiness.

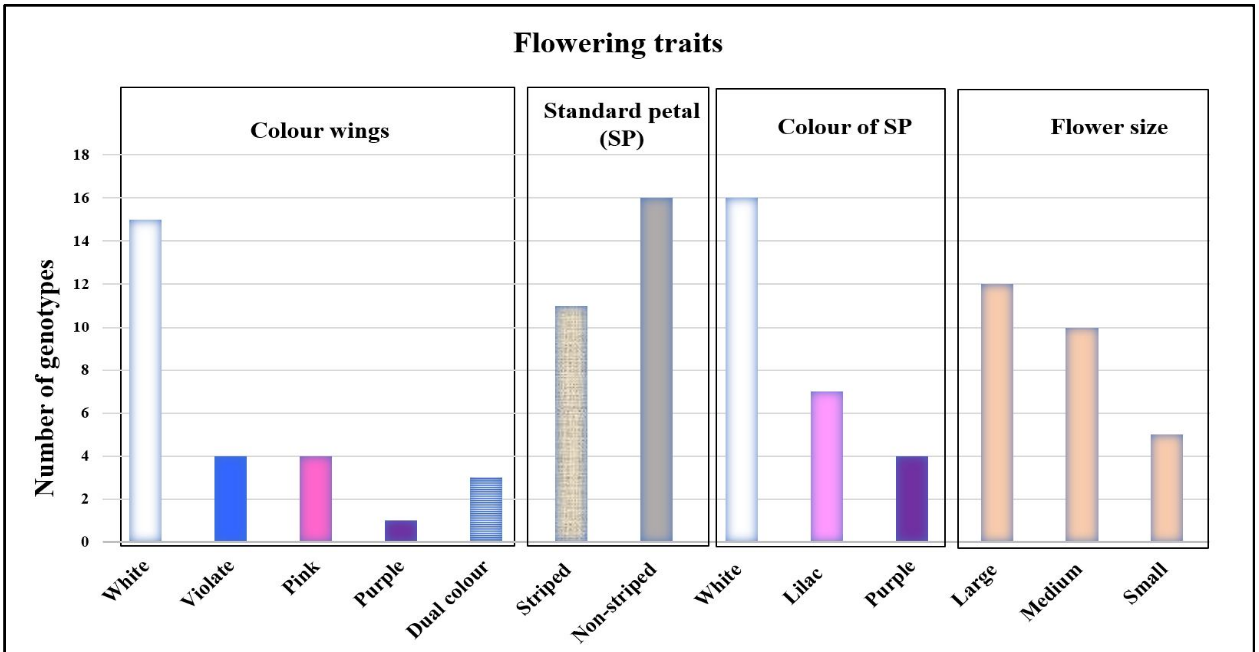

Figure 4: Frequency distribution of French bean genotypes for flowering traits

Gepts (2001) observed flower petal colour of blue to purple, pink to red and white in French bean genotypes. Papa and Gepts, (2003), Langarica *et al*. (2014) inferred that purple and pink flowers confer black seed coats. Duran *et al*. (2005) reported outer base of the standard of the corolla classified as striped or smooth to characterize French bean landraces and cultivars from the Caribbean. Amirul Islam *et al*. (2006) evaluated 1105 French bean accessions for primary colour of wings and primary colour of the standard petal traits. Bode *et al*. (2013) observed a great variability for 19 qualitative descriptors like colour of standard flower and colour of wings in French bean. Doriana *et al*. (2013) observed a great variability for colour of standard flower and colour of wings, in French bean. Okii *et al*. (2014) grouped 284 French bean accessions into three group viz., white, plain red to dark lilac and purple-colored flowers. Singh *et al*. (2014) inferred that colour of standard petal and outer surface of standard petal are important morphological markers. Rana *et al*. (2015) reported proportion of flower colour among 4274 French bean genotypes i.e., white (39%), pink (26%) and lilac (21%). Caproni *et al*. (2019) observed absence of seed coat pattern (87%), striped 'base of standard' (83%), purple flower (78%) and black seed (70%) in Mesoamerican group. Kalauni *et al*. (2019) characterized and witnessed variability in French bean genotypes for flower color. Dhaliwal (2020) revealed presence of hypocotyl anthocyanin pigmentation correlated with violet flower colour. Kanwar *et al*. (2020) categorized 26 geographically diverse French bean genotypes for flower colour and hairiness on the flower and reported significant differences among all the genotypes. Jan *et al*. (2021) studied standard of the flower in French bean genotypes and inferred that white flower color was most predominant (44.86%) with stripping on outer standard petal (23.85%) in comparison to pink, white, red, violet, and yellow colored flowers.

Figure 5: Different flower colour in studied French bean

3.1.3. Fruiting traits

Pod characteristics traits are vital NBPGR descriptor to screen French bean genotypes as

these observed with great diversity in term of pod colour, pod pubescence, pod curvature, pod shape, shape of pod curvature, pod pigmentation, pod position, pod orientation, beak shape, beak position, beak orientation, pod stringiness, pod cross-section, pod wall fiber, pod colour at phsiological maturity is presented in table 4.

Figure 6: Pod characteristics in studied French bean

Amirul Islam *et al*. (2006) evaluated 1105 French bean accessions for position of pod tip, form of pod and pod attributes traits. Massimo *et al*. (2013) found statistically significant differences in pod morphological traits and slightly curved pod are predominant. Doriana *et al.* (2013) observed a great variability for pod colour, pod cross-section, pod curvature, pod beak position, pod beak orientation in French bean. Singh *et al*. (2014) characterized 18 French bean genotypes and inferred that pod curvature, pod shape of cross section (through seed), pod shape (in relation to suture), pod shape of distal part (excluding beak), pod colour, pod stringiness, pod pigmentation on pod shell are important morphological markers. Rana *et al*., (2015) evaluated 4274 germplasm accession of French bean from 58 countries and observed that morphological traits such as green colour pod, glaborous pod surface, straight pod are predominant among 27 morphological traits. Kalauni *et al*. (2019) characterized and witnessed variability in French bean genotypes for pod color, pod shape, pod cross-section, pod beak position and pod appearance. Kanwar *et al*. (2020) categorized 26 geographically diverse French bean genotypes for pod colour at immature stage, orientation of pods, pod shape, pod pubescence and pod colour at physiological maturity and reported significant differences among all the genotypes. Jan *et al*. (2021) revealed green color of pods, acute to truncate pod shape, pigmentation on pods frequently noticed among 109 French bean genotypes.

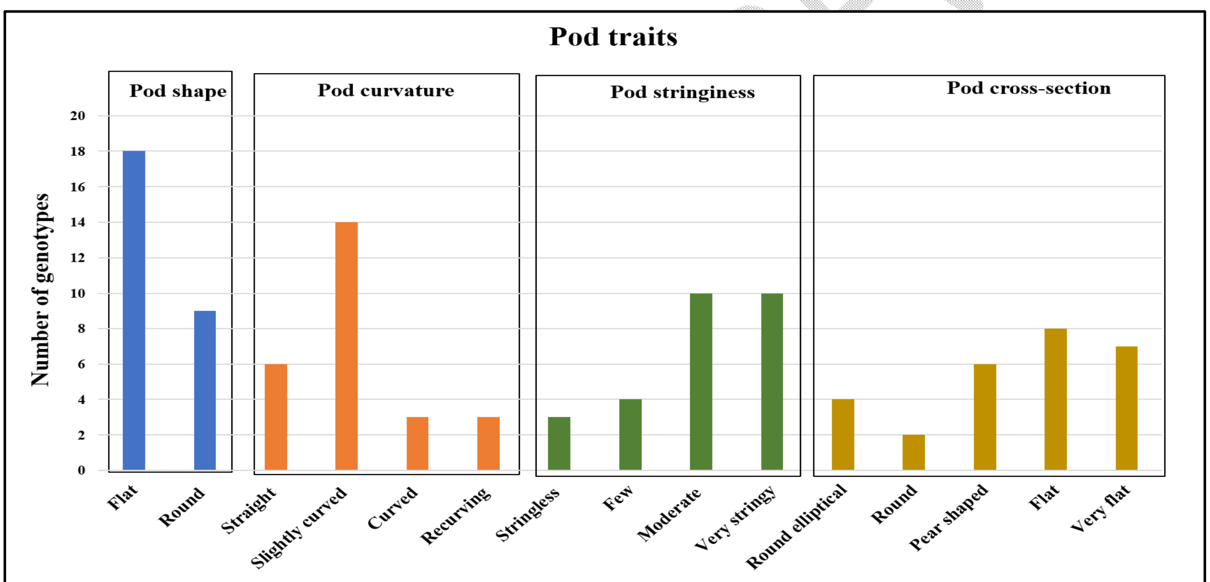

Figure 7: Frequency distribution of French bean genotypes for fruitng traits

Pod colour

Pod colour at immature stage is an important trait for classifying and grouping French bean genotypes under investigation (table 3). The data on pod colour revealed ten genotypes are observed with green pod, seven with light green pods, eight with green pods with red streaks and two with green with purple streaks. In most of genotypes, pigmentation was absent with green or light green pod colour. Okii *et al*. (2014) observed green, light green and green with red stripes in French bean pod. Rana *et al*., (2015) observed green pod colour as predominant pod colour in 87 % accessions in French bean. Jan *et al*. (2021) revealed green color of pods in French bean was predominant in 84.40% genotypes in compared to green, pale green, and violet pods. He also noticed pigmentation on pods was noticed only in 35.77% genotypes, but in rest of genotypes, it was absent.

Pod shape

Pod shape is major trait of French bean which influence consumer preference and taken into consideration for grouping of genotypes. The data on fruit shape is presented in table 3 which indicated that flat shape pod observed in eighteen genotypes and round shape pod in nine genotypes. Zaccardelli *et al*. (2013) observed great variability in characterizing French bean genotypes for pod shape. Rana *et al*., (2015) observed straight pod in 69 % French bean accessions. Kalauni *et al.* (2019) found two with very flat among six genotypes. Jan *et al*. (2021) witnessed concave pod shape was most common (in 93.75% genotypes) in comparison to convex, concave and straight pod shape in relation to suture.

Pod curvature

The present study on pod curvature witnessed six genotypes with straight pod, fourteen genotypes with slightly curved pod, three had curved pods and three had recurving pod curvature (table 3). Most of genotypes showed concave pod curvature than convex form (Arka Arjun). Muchui *et al*. (2008) observed predominantly straight pods and few slightly curved pods in French bean. Neupane *et al.* (2005) reported 43 accessions were slightly curved, 29 were straight and 7 accessions were curved among the eighty accessions of local and exotic French bean germplasm. Massimo *et al*. (2013) found slightly curved pod are predominant in French bean. Jan *et al*. (2021) found acute, truncate, and acute to truncate as shape of distal part of pods with maximum genotypes (63.30%) had acute to truncate shape.

Pod position

Pod position is an agronomical trait indicates the pod bearing habit of different genotypes. The data on pod position indicated that six genotypes bore pods in basal portion, nine bore pods in central portion and in twelve genotypes the pods found from base to top (table 3). All genotypes are found with prostrate bearing habit of pods.

Pod stringiness

Pod stringiness is a valuable pod characteristic from consumer acceptable point of view. Less stringy pod is of more edible value than stringy one which was considered for grouping different genotypes under study. The data on pod stringiness is presented in table 4. Jan *et al*. (2021) noticed dry pods of maximum genotypes (55.04%) possessed strings, whereas in rest, it was absent.

Pod pubescence

Pod pubescence indicates the presence of sparce hairs on pod surface which influence the fruit shelf life and consumer acceptance. The data on pod pubescence is presented in table 4 revealed twelve French genotypes were glabrous (without hair), eleven genotypes having intermediate hairs whereas four genotypes having sparce hair on pod surface. Kar *et al*. (2006) reported eight genotypes with smooth pod surface and seven genotypes with pubescent pod surface among 15 French bean genotypes. Rana *et al*., (2015) observed glabrous pod surface in 96 % French bean accessions.

Pod beak shape

The fruit trait has less agronomic importance though the studied French bean genotypes observed with different pod beak shape i.e., acute to truncate, truncate and acute is presented in table 4. Duran *et al*. (2005) adopted pod beak position to characterize French bean landraces and cultivars from the Caribbean.

Pod beak orientation

The observation on pod beak orientation is presented in table 4 showed variation among studied genotypes though the traits has least agronomic importance. Bode *et al*. (2013) observed a great variability for pod beak position, pod beak orientation, size of bracteole in French bean. Caproni *et al*. (2019) panel revealed 'marginal' Pod Beak Position (PBP), 'downward oriented' Pod Beak Orientation (PBO) within Mesoamerican group while the 'straight orientation' is the most abundant condition within the Andean group. Kalauni *et al.* (2019) found five with marginal, one with nonmarginal beak orientation among six genotypes.

Pod cross-section

The data on pod cross-section is presented in table 4 revealed that French genotypes show considerable variation in pod cross section shape i.e., round elliptical, round, pear shaped, flat and very flat which has importance in consumers' preference point of view. Kalauni *et al.* (2019) found four with round elliptic pod cross-section among six genotypes. Jan *et al*. (2021) reported cordate, elliptical, and ovate shape of cross section of pod in which cordate and elliptic shapes were most frequent.

Figure 8: Pod cross-section view in studied French bean

Pod wall fiber

The study reported that French bean genotypes with contracting and leathery pod wall are less prone to shattering loss of seeds where shattering type of pod wall become easily split and seeds comes out. The studied genotypes are grouped into contracting, leathery and shattering (table 4) which is crucial for crop improvement and seed production programme. Ashok *et al*. (2008) adopted constriction on pod to screen and group seven French bean germplasms. Caproni *et al*. (2019) panel revealed strongly contracting Pod Wall Fibre (PWF) within the Andean group of French beans.

Pod colour at physiological maturity

The data on pod colour at physiological maturity is presented in table 4 revealed that French bean genotypes witnessed different colour i.e., copper brown, brown, pale yellow, brown with pigmentation at full maturity stage of pod.

Principal component analysis

A statistical method for multivariate analysis called principal component analysis (PCA) is used to estimate and decompose complicated and large datasets. The pattern of variation in 27 French bean genotypes was also investigated using principal component analysis (PCA) on the basis of correlation between twenty nine traits under study and extracted clusters, to assess the variety of the genotypes and their link to the traits that have been observed. All examined yield and yield traits were subjected to PCA. There was a total of 26 principal components (PCs) were found, although only ten of them were deemed significant because of eigenvalues greater than 1 which together contribute 80.87% of the total variability of the traits. The remaining non-significant PCs (eigenvalue <1) weren't sufficient for investigation (Table 3). PCA biplot depicted PC1 and PC2 which revealed 33% of the total variance cumulatively for twenty nine morphological traits in the studied genotypes. The PC1 and PC2 explained 20.03% and 13.32% of the total variance (Figure 9). Depending on how differently they differ from one another in the traits, individuals were dispersed in various ordinates. The length of a vector in a biplot indicates, respectively, the primary component contribution of the traits and the quality of the depiction. The PCA biplot divided the traits into seven main groups based on homogeneity and dissimilarity. The group I included SH and SP, group II (GH, PWF, STV, PP, SCP, SV, SPDP), group III (PCPM, PSN, PDP, SS), group IV (FC, CSL, CW), group V (PS, LC, FBS, SBL), group VI (PBO, PC, CP, PCS, PS) and group VII (SS, PL, SPP, STC, PBP). The group I, II and III contributed significantly towards PC1 were strongly related with individuals of row clusters 1, 2 and 4 whereas, group III and IV contributed more towards PC2 related to clusters 1, 2,3 and 4 (Figure 10).

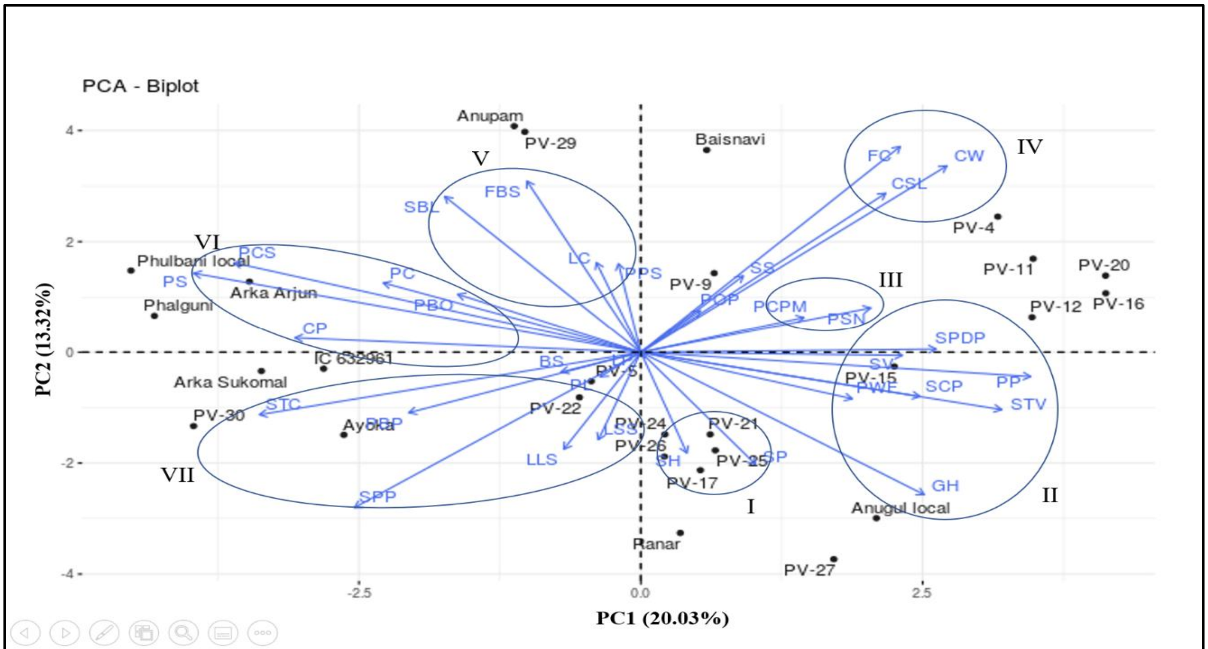

Figure 9. PCA-Biplot of twenty nine morphological traits for 27 French bean genotypes

The length of a vector in a biplot show, respectively, how well the qualities are represented and how much they contribute to the principal components. Groups I and IV; V and VII appear to be independent of one another for the qualities being researched based on the angles between the vectors derived from the middle point of biplots, which show positive (between I, II and III; V and VI) or negative (between I and V; IV and VII) interactions. Bigger circles indicate the centroid of the corresponding cluster (Figure 9).

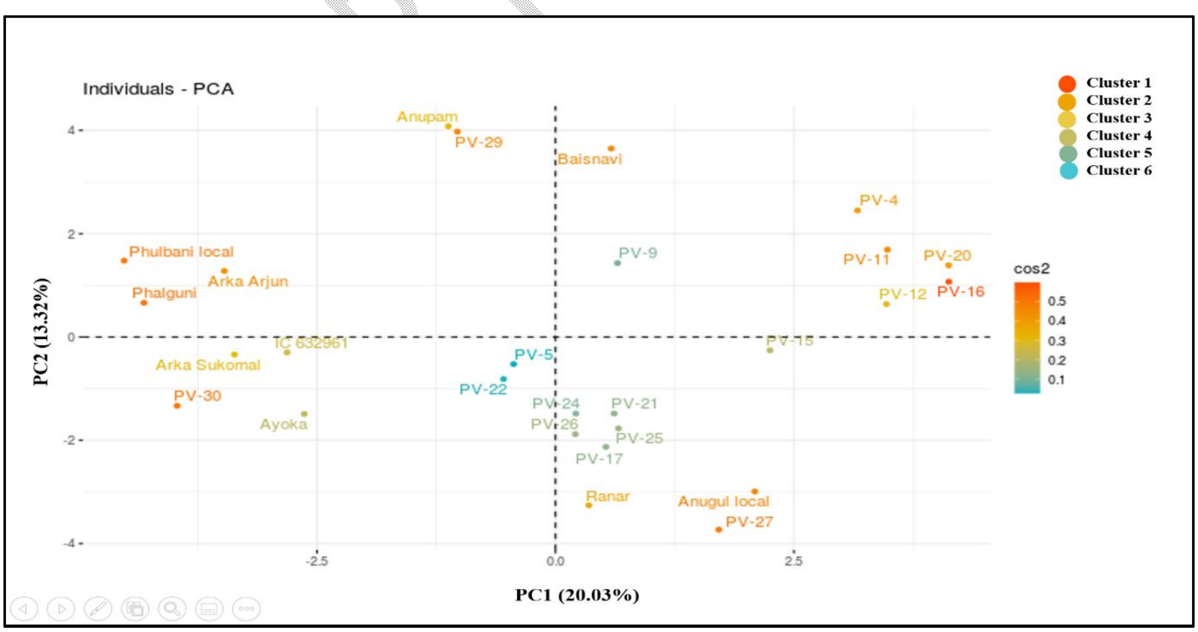

Figure 10: PCA showing clustering of 27 genotypes and traits contribution

Conclusion

To improve crops, germplasm characterization and evaluation is crucial. DUS characterization a useful method for identifying and preventing duplication in crop plants. The manuscripts described considerable variation for qualitative traits viz., growth, flowering and fruiting traits in twenty-seven French bean genotypes. The investigation depicted predominance of indeterminate growth habit (66.7%), viny twinning stem (70.4%), non-pigmented stem (74.1%), dark green leaves (51.9%), white color flowers (55.6%), non-striped standard petal (59.3%) with white colour, large size flower (44.4%), flat pod (66.7%), slightly curved pod shape (51.9%), very stringy pods (37%) with flat pod cross-section (29.6%) proved that there is wide genetic diversity exist in French bean genotypes. Some morphology traits like pod pubescence, pod beak shape and orientation, pod colour at physiological maturity having less importance for agronomic point view though witnessed remarkable variations due to broad genetic base among the genotypes. The detailed study on DUS characterization in French bean is one of major work has been conducted in Odisha for the very first time which generated a strong database and could be helpful for scientific personnel who are intended to contribute the crop breeding programme in future.

Table 3: Extracted Eigenvalues and correlation values for twenty nine morphological traits

Variables	Principles components							
	PC1	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**	**PC7**	**PC8**
Extracted Eigenvalues	6.61	4.397	2.689	2.381	2.144	2.062	2.027	1.712
Explained variance (%)	20.035	13.327	8.151	7.216	6.498	6.25	6.144	5.188
Cumulative variance (%)	20.035	33.363	41.514	48.73	55.227	61.477	67.621	72.809
Morphological traits								
GH	0.528	-0.539	-0.058	-0.131	0.284	0.123	0.269	-0.004
SP	0.214	-0.425	-0.047	-0.638	-0.039	0.285	-0.137	0.163
SH	0.086	-0.382	-0.39	0.201	-0.15	0.028	0.427	0.414
LC	-0.083	0.341	-0.309	-0.222	-0.572	0.289	0.319	0.155
LSS	-0.079	-0.331	0.591	-0.173	-0.215	0.026	0.185	0.436
LP	0	0	0	0	0	0	0	0
LLS	-0.144	-0.367	0.768	0.142	-0.052	-0.088	0.025	0.324
PL	-0.076	-0.093	0.487	-0.026	-0.575	0.087	0.172	0.167
FC	0.483	0.779	0.113	-0.184	0.012	-0.094	0.02	0.157
SPP	-0.533	-0.588	-0.113	0.345	-0.03	0.236	-0.188	-0.079
CSL	0.456	0.603	-0.082	-0.38	0.024	-0.173	0.075	0.252
CW	0.57	0.706	0.035	-0.049	0.136	-0.111	-0.046	-0.121

FBS	-0.212	0.649	-0.041	0.024	-0.045	-0.182	0.404	0.162
SBL	-0.365	0.59	0.112	0.503	-0.072	0.229	0.169	0.093
CP	-0.644	0.055	0.378	-0.124	0.083	-0.194	0.259	-0.301
PS	-0.832	0.3	0.076	-0.046	0.222	0.057	-0.224	0.161
PC	-0.48	0.264	0.112	0.094	0.592	0.27	0.093	0.04
PP	0.726	-0.092	-0.232	0.195	-0.073	0.168	-0.301	0.139
POP	0.111	0.159	-0.189	0.718	-0.095	-0.143	0.355	-0.233
PSN	0.428	0.169	0.475	0.194	-0.078	0.124	0.173	-0.298
PPS	-0.042	0.336	-0.042	-0.068	-0.227	-0.311	-0.443	0.223
SPDP	0.55	0.012	0.313	0.423	-0.031	0.328	-0.268	0.151
PBP	-0.432	-0.229	-0.408	0.024	-0.319	-0.497	0.024	0.023
PBO	-0.341	0.22	0.022	0.383	-0.231	-0.314	-0.357	0.148
PCS	-0.758	0.34	-0.011	-0.099	0.179	0.203	-0.149	0.06
PWF	0.394	-0.176	-0.085	0.448	0.045	-0.167	0.244	0.31
PCPM	0.304	0.132	-0.437	0.033	0.18	0.552	0.289	0.118

References

1. AlBallat IA, and Al-Araby AA. Correlation and path coefficient analysis for seed yield and some of its traits in common bean (*Phaseolus vulgaris* L.). *Egypt. J. Hortic.*, 2019; 46(1): 41–51. https//doi. org/10.21608/ejoh.2018.6481.1088
2. Amirul Islam FM, Basford KE, Redden RJ and Beebe S. Preliminary evaluation of the common bean core collection at CIAT. *Plant Genetic Resources Newsletter*, 2006; 145: 29-37
3. Ashok SS, Prashanth ND and Hosmani RM. RAPD markers and morphological characteristics form identification of French bean (*Phaseoous vulgaris* L.) cultivars. *Seed Res.*, 2008; 36(1): 81-83.
4. Rosales-Serna R, Marquez RO and Gallegos JAA. Phenology and yield of dry bean in the Mexican highlands and its response to photoperiod. *Agrociencia*, 2001; 35: 513-523.
5. Beebe S, Sckroch PM, Tohme J, Duque MC, Pedraza F and Nienhuis J. Structure of Genetic diversity among common beans landraces of Middle American Origin based on correspondence analysis of RAPD. Crop Sci. 2000; 40: 264-273. https://doi.org/10.2135/cropsci2000.401264x
6. Bode D, Elezi F and Gixhari B. Morphological characterization and interrelationships among descriptors in *Phaseolus vulgaris* accessions. *Agriculture and Forestry*, 2013; 59(2): 175-185.
7. Bonetti A, Miggiano A, Dinelli G and Lovato A. Identification of bean (*Phaseolus vulgaris* L.) cultivars grown in Italy by field and electrophoresis tests: a comparative study. *Seed Sci. Tech.*, 1995; 23: 69- 84.

8. Brink, M and Belay G. Plant Resources of Tropical Africa: Cereals and Pulses, PROTA Foundation, Wageningen, Netherlands; 2006.
9. Broughton, WJ, *et al*. "Beans (*Phaseolus* Spp.) – Model food legumes", *Plant and Soil*, 2003; 252(1): 55-128.
10. Caproni L, Raggi L, Ceccarelli S, Negri V and Carboni A. In-Depth Characterization of Common Bean Diversity Discloses Its Breeding Potential for Sustainable Agriculture. *Sustainability*, 2019; 11(19): 5443.
11. Choudhary N, Bawa V, Paliwal R, Singh B, Bhat MA, Mir JI and Mir RR. Gene/QTL discovery for anthracnose in common bean (Phaseolus vulgaris L.) from North-western Himalayas. Plos One, 2018; 13(2): e0191700.
12. Choudhary N, Hamid A, Singh B, Khandy I, Sofi PA, Bhat MA, and Mir RR. Insight into the origin of common bean (*Phaseolus vulgaris* L.) grown in the state of Jammu and Kashmir of North-Western Himalayas. Genetic Resources and Crop Evolution, 2018; 65: 963–977. https://doi.org/10.1007/s10722-017-0588-z
13. Das A, Kumar D. Genetic evaluation and characterization of jute (*Corchorus* spp. L) genotypes using DUS parameters. - SAARC Journal of Agriculture, 2012: 10: 147-153.
14. De Albuquerque AN, Barelli MAA, Neves LG, Arantes VR, Da Silva KLM. Avaliac¸ão de acessos de feijoeiro com uso de varia´veis multicatego´ ricas. Acta Scientiarum—Agronomy, 2011; 33: 627–632.
15. Dhaliwal I, Khosla G, Singh TP, Gill BS and Kaushik P. DUS Characterization of some Released Varieties and Advanced Breeding Lines of Soybean (Glycine max L.) under Punjab Agroclimatic Conditions. Int. J. Curr. Microbiol. App. Sci. 2020; 9(08): 2124-2135. doi: https://doi.org/10.20546/ijcmas.2020.908.242
16. Doriana B, Fetah E and Belul G. Morphological characterisation and interrelationships among descriptors in phaseolus vulgaris accessions. Agriculture & Forestry, 2013; 59: 175-185.
17. Dudnik NS, Thormann I and Hodgekin T. The extent of use of plant genetic resources In research- A literature survey. Crop Sci. 2001; 41: 6-10. https://doi.org/10.2135/cropsci2001.4116
18. Duran LA, Blair MW, Giraldo MC, Macchiavelli R, Prophete E, Nin JC and Beaver JS. Morphological and molecular characterization of common bean landraces and cultivars from the Caribbean. Crop Sci., 2005; 45: 1320-1328.
19. FAO. "Phaseolus bean: Post-harvest operations", INPhO Post-Harvest Compendium, Food and Agriculture Organization, Rome; 1999. www.fao.org/3/a-av015e.pdf.
20. Food and Agriculture Organisation of the United Nations. FAOSTAT Database. Available online: http://www.fao.org/faostat/en/#data/QC (accessed on 14 May 2019).
21. García EH, Peña-Valdivia CB, Aguirre JR and Muruaga JS. Morphological and agronomic traits of a wild population and an improved cultivar of common bean (Phaseolus vulgaris L.). Ann. Bot. 1997; 79: 207-213.
22. Gepts P and Debouck DG. "Origin, domestication, and evolution of the common bean (*Phaseolus vulgaris* L.)", in: van Schoonhoven A and Voysest O. (eds.), Common Bean: Research for Crop Improvement, CABI, Wallingford, United Kingdom; 1991.
23. Gepts P. Phaseolus vulgaris (Bean). ACADEMIC Press. 2001; 95: 616-851
24. Guidelines for the Conduct of Test for Uniformity and Stability On (Phaseolus vulgaris L.). Distinctiveness Kidney bean, Protection of Plant Varieties and Farmers' Rights Authority (PPV & FRA), Government of India; 2007.

25. Gupta A, Mahajan V, Khati P, Srivastava AK. Distinctness in Indian soybean (*Glycine max*) varieties using DUS characters. - Indian Journal of Agricultural Sciences. 2010; 80:1081-4.
26. Duke. Handbook of legumes of world economic importance. New York, USA/London, UK: Plenum Press, 1981; pp. 195-200.
27. Jan S, Rather IR, Sofi PA, Wani MA, Sheikh FA, Bhat MA and Mir RR. Characterization of common bean (*Phaseolus vulgaris* L.) germplasm for morphological and seed nutrient traits from Western Himalayas. *Legume Science*, 2021; 3:1-16.
28. Kalauni S, *et al*. Evaluation of Pole-type French Bean (*Phaseolus vulgaris* L.) Genotypes for Agro-Morphological Variability and Yield in the Mid-Hills of Nepal. *Acta Scientific Agriculture*, 2019; 3(12): 113-121.
29. Kanwar R, Mehta DK, Sharma R and Dogra RK. Studies on genetic diversity of French bean (*Phaseolus vulgaris* L.) landraces of Himachal Pradesh based on morphological traits and molecular markers. *Legume Research*. 2020; 43(4): 470-479.
30. Kwak M, *et al*. “Multiple origins of the determinate growth habit in domesticated common bean (Phaseolus vulgaris)”, Annals of Botany, 2012; 110 (8): 1573-1580, http://dx.doi.org/10.1093/aob/mcs207.
31. Langarica HRG, Serna RR, Delgado SH and Perez NM. Morphological and molecular characterization of common bean landraces cultivated in the semi-arid Mexican high plateau. *Bol. Soc. Argent. Bot*., 2014; 49(4): 525-540.
32. Lenkala P, *et al*. Morphological characterization of Jack bean an under exploited vegetable. *Annals of Plant and Soil Research*, 2015; 17(2): 183-186.
33. Mario PC, Becerra V, Tay J, Blair MW and Bascure G. Selection of a Representative core collection from the Chilean Common bean germplasm. Chil. *J. Agric. Res*., 2010; 70 (1): 3-15.
34. Massimo Z, Alfonso P, and Pasquale T. Characterization of bean (Phaseolus vulgaris L.) ecotype “Fagiolo Occhio Nero Di Oliveto Citra” using agronomic, biochemical and molecular approaches. Pakistan Journal of Biological Sciences, 2013; 16(18): 901-910
35. Mora-Avilés A, Lemus-Flores B, Miranda-López R, Hernández-López D, Pons-Hernández JL, Acosta-Gallegos JA and Guzmán-Maldonado SH. Effects of common bean enrichment on nutritional quality of tortillas produced from nixtamalized regular and quality protein maize flours. *Journal of the Science of Food and Agriculture*, 2007; 87: 880-886.
36. Muchui MN, *et al*. Post harvest evaluation of introduced French bean (*Phaseolus vulgaris* L.) varieties. *African Journal of Horticultural Science*, 2008; 1: 116-120.
37. Neupane RK, Shrestha R, Vaidya ML, Bhattarai EM and Daral R. Agromorphological diversity in common bean (*Phaseolus vulgaris* L.) landraces of Jumla, Nepal. *Proceeding of the Fourth International Food Legumes Research Conference (IFLRCIV)*, 2005; pp. 1-11.
38. Okii D, Tokamohabwa P, Odong T, Namayanja A, Mukabaranja J, Paparu P and Gepts P. Morphological diversity of tropical common beans germplasm. *Afr. Crop. Sci. J.*, 2014; 22(1): 59-67.
39. Papa R and Gepts P. Asymmetry of gene flow and differential geographical structure of molecular diversity in wild and domesticated common bean (*Phaseolus vulgaris* L.) from Mesoamerica. *Theor. Appl. Genet.*, 2003; 106: 239-250.

40. Petry N, Boy E, Wirth JP and Hurrell RF. Review: The potential of the common bean (*Phaseolus vulgaris*) as a vehicle for iron biofortification. *Nutrients*, 2015; 7: 1144–1173.
41. Prakash S and Singhal NC. Characterization of some Indian pea (*Pisum sativum* L.) cultivars. *Seed Research*, 1997; 25(1): 53-58.
42. Prashanth ND. Studies on spacing and phosphorus levels on seed yield and quality and varietal identification in French bean. *M.Sc. (Ag.) Thesis*, University of Agricultural Sciences, Dharwad, Karnataka, India; 2003.
43. Purseglove JW. Tropical Crops: Dicotyledons, Longmans, Longmans, London; 1968.
44. Ramteke R, Murlidharan P. Characterization of soybean (*Glycine max*) varieties as per DUS guidelines. - Indian Journal of Agricultural Sciences, 2012; 82:572-577.
45. Rana JC, Shatma TR, Tyagi RK, Chahota NK, Gautam PK, Sharma PN, Singh M and Ojha SN. Characterization of 4274 accessions of common bean (*Phaseolus vulgaris* L.) germplasm conserved in the Indian gene bank for phenological, morphological and agricultural traits. *Euphytica*, 2015; 205: 441-457
46. Simon Yohannes, Gobeze Loha, and Mesfin Kebede Gessese. Performance Evaluation of Common Bean (Phaseolus vulgaris L.) Genotypes for Yield and Related Traits at Areka, Southern Ethiopia. Hindawi; dvances in Agriculture. 2020;1-8
47. Singh B, Chaubey T, Upadhyay DK, Jha A and Pandey SD. Morphological description of French bean varieties based on DUS characters. *Indian Journal of Horticulture*, 2014; 71(3): 345-348.
48. Singh SP, Gutiérrez JA, Molina A, Urrea C, Gepts P. Genetic diversity in cultivated common bean: II. Marker-based analysis of morphological and agronomic traits. Crop Sci. 1991; 31: 23–29.
49. Singh SP. Broadening the genetic base of common bean cultivars: A review. Crop Science, 2001; 41, 1659–1675. https://doi.org/10.2135/cropsci2001.1659
50. Singh SP and Schwartz HF. "Breeding common bean for resistance to diseases: A review", Crop Science, 2010; 50 (6): 2199-2223, http://dx.doi.org/10.2135/cropsci2009.03.0163.
51. Smartt J. Evolution of American Phaseolus beans under domestication. In: Ucko PJ, Dimbleby GW, eds. The domestication and exploitation of plants and animals. London: Duckworth, 1969; 451–462.
52. Sofi PA, Zargar MY, Debouck D and Graner A. Evaluation of common bean (*Phaseolus vulgaris* L) germplasm under temperate conditions of Kashmir valley. *Journal of Phytology*, 2011; 3(8): 47-52.
53. Sultana N. Genetic variation of morphology and molecular markers and its application to breeding in Lablab bean. *Ph. D. Thesis*, Kyushu University, Fukuoka, Japan, 2001: 143.
54. Surendra P and Singhal NC. Characterization of some Indian pea (*Pisum sativum* L.) cultivars. *Seed Res.*, 1997; 25(1): 53-58.
55. Thamburaj T and Singh N. Textbook of vegetables, tubercrops and spices. Indian Council of Agriculture Research, New Delhi., 2016; pp. 201-206
56. Tsutsumi CY, Bulegon LG, Piano JT. Melhoramento Gene´ tico do Feijoeiro: Avanc¸os, Perspectivas eNovos Estudos, noAˆ mbito Nacional. Nativa. 2015; 3: 217–223. https://doi.org/10.14583/2318-7670.v03n03a12
57. Vavilov NI. The origin, variation and breeding of cultivated plants. *Chronicle Botany Italic*, 1950; 13: 1-364.

58. Voysest VO. Mejoramiento genético del frijol (Phaseolus vulgaris L.). Legado de variedades de América Latina 1930-1999. CIAT, PROFRIZA, COSUDE, Cali, 195 pp. Wallace, D.H. 1985. Physiological genetics of plant maturity, adaptation and yield. Plant Breeding Reviews, 2000; 3: 21-167.
59. Wondatir YM. Feed resources availability and livestock production in the central rift valley of Ethiopia, Int. J. Livest. Prod. 2014; 5 30–35.
60. Wortmann CS. Phaseolus vulgaris L. (common bean). In: Brink, M. & Belay, G. (Ed). Plant Resources of Tropical Africa 1. Cereals and Pulses. PROTA Foundation, Wageningen, Netherlands / Blackhuys Publishers, Leiden, Netherlands / CTA, Wageningen, Netherlands. 2006; p.146-151.

Table 4. Qualitative traits of different French bean genotypes

Sl. No.	Genotypes	GH	SP	SH	LC	LSS	LP	LLS	LP	FC	SPP	CSL	CW	FBS	SBL	PC	PS	PC	PP	POP
1.	IC 632961	2	0	+	7	3	+	3	5	1	3	1	1	3	5	7	2	9	1	2
2.	PV-26	2	+	+	7	3	+	2	5	1	1	2	1	2	3	7	1	3	1	1
3.	PV-16	2	0	+	7	1	+	2	5	3	1	9	3	2	3	5	1	5	9	4
4.	PV-4	2	0	+	7	2	+	2	5	4	1	2	4	3	7	3	1	5	9	4
5.	PV-5	2	0	+	5	2	+	2	5	1, 3	3	1, 3	3	3	5	8	1	5	1	4
6.	PV-9	2	+	+	7	2	+	1	5	3	1	9	3	3	3	7	1	5	1	1
7.	PV-11	2	0	+	5	1	+	1	3	3	1	8	4	3	5	5	1	5	9	4
8.	PV-12	2	0	+	5	3	+	2	3	3	1	9	4	3	3	5	1	3	9	1
9.	PV-15	2	0	+	5	1	+	1	3	1	3	1, 3	3	2	5	5	1	5	9	4
10.	Arka Sukomal	2	0	+	5	3	+	3	5	1	3	2	1	3	7	7	2	9	1	2
11.	PV-17	2	0	+	5	2	+	3	5	2, 3	1	1	1	2	3	7	1	5	1	4
12.	PV-20	2	+	+	7	1	+	1	5	4	1	9	3	2	3	3	1	5	9	1
13.	PV-21	2	0	+	7	1	+	1	5	1	3	1	1	1	3	5	1	5	9	4
14.	PV-22	2	0	+	7	1	+	1	5	1	3	1	1	2	5	7	1	3	1	4
15.	PV-24	2	0	+	5	2	+	3	5	1	3	1	1	2	5	8	1	7	1	4
16.	PV-27	3	+	+	5	3	+	3	5	1	3	2	1	1	3	8	1	3	1	2
17.	Ayoka	2	+	+	5	1	+	1	3	1	3	2	1	1	3	7	2	9	1	2
18.	Ranar	2	+	+	7	3	+	3	5	1	3	2	1	2	3	5	1	3	9	1
19.	Anugul local	2	+	+	5	3	+	3	5	1	3	1	1	1	3	5	1	3	9	2
20.	PV-25	1	0	+	5	3	+	3	5	1	3	2	1	1	5	5	1	3	9	2
21.	Arka Arjun	1	0	+	7	2	+	3	5	1	3	2	1	3	7	8	2	7	1	2
22.	PV-29	1	0	+	7	3	+	3	5	4	1	9	3	3	7	8	2	5	1	4
23.	PV-30	1	0	+	5	2	+	3	5	1	3	2	1	2	3	7	2	5	1	2
24.	Anupam	1	0	0	5	1	+	2	5	4	1	3	4	2	5	8	2	7	1	1
25.	Phulbani local	1	0	+	7	1	+	1	3	1	3	2	1	3	7	7	2	5	1	2
26.	Phalguni	1	0	+	7	2	+	1	5	1, 2	3	2	1	3	5	7	2	5	1	4
27.	Baisnavi	1	0	+	7	2	+	1	5	4	1	9	3	3	7	8	1	5	1	4

Table 5. Qualitative traits of different French bean genotypes

Sl. No.	Genotypes	PSN	PPS	SPDP	PBP	PBO	PCS	PWF	PCPM	STC	SS	STV	SCP	BS	SV
1.	IC 632961	7	1	5	1	3	3	3	5	2	3	1	0	7	1
2.	PV-26	5	2	5	1	3	1	3	5	3	2	1	0	7	3
3.	PV-16	7	3	7	1	3	1	5	7	2	3	9	5	7	3
4.	PV-4	7	2	7	1	5	1	7	7	2	5	1	0	7	3
5.	PV-5	7	2	5	1	5	1	5	4	3	2	1	0	7	3
6.	PV-9	5	3	3	1	5	2	5	6	1	2	1	0	7	2
7.	PV-11	5	1	7	1	5	1	5	6	2	3	9	2	7	3
8.	PV-12	3	3	5	1	3	1	3	5	2	3	9	7	7	3
9.	PV-15	5	3	7	1	5	1	5	6	2	3	9	1	5	3
10.	Arka Sukomal	0	3	5	1	3	2	5	6	7	4	1	0	7	1
11.	PV-17	7	1	3	2	5	1	7	4	3	3	9	7	7	1
12.	PV-20	5	3	7	1	5	1	5	5	2	5	9	3	3	2
13.	PV-21	3	2	5	1	5	1	5	6	2	3	1	0	7	2
14.	PV-22	5	2	3	2	3	1	3	6	2	3	1	0	3	3
15.	PV-24	7	3	7	1	5	1	5	4	3	3	9	3	7	3
16.	PV-25	5	2	7	1	5	1	5	6	2	4	9	5	7	2
17.	Arka Arjun	3	1	3	1	3	3	3	6	7	4	1	0	7	2
18.	PV-27	3	2	5	2	3	1	5	5	3	2	1	0	7	3
19.	PV-29	7	2	7	1	5	2	5	6	2	4	9	0	5	3
20.	PV-30	7	2	7	1	5	1	5	4	3	4	1	0	7	3
21.	Anupam	5	2	7	1	7	4	3	6	4	3	1	0	7	3
22.	Ranar	7	3	5	1	7	2	3	4	1	4	1	0	5	2
23.	Phulbani local	0	3	3	2	7	2	5	4	7	3	1	0	7	2
24.	Ayoka	7	3	5	1	5	3	3	4	1	4	1	0	7	3
25.	Phalguni	5	3	3	2	7	4	5	6	7	3	1	0	7	1
26.	Baisnavi	0	3	5	2	7	3	3	4	7	3	1	0	5	2
27.	Angul local	5	2	5	1	3	2	5	7	1	4	1	0	7	2