Characterization for Qualitative Traits in Segregating Population of Faba Bean (*Vicia faba* L.)

Abstract

Eight crosses of faba bean were characterized for the four qualitative characters such as stem colour, leaf colour, flower colour and pod colour. The present investigation revealed the wide variation for morphological characters among the eight F_3 populations of faba bean. Qualitative characters were recorded on the basis of descriptors published by International Plant Genetic Resources (IPGRI). Wide range of variability was observed for morphological characters like flower colour (white) under all the crosses followed by pod colour (light green) and leaf colour (light green) in all the crosses and pod colour (green) in Bak-16 × Bak-20 whereas only seven crosses had diverse flower colour *viz.* violet, dark brown, light brown, mix and pink and only three crosses had diverse pod colour *viz.* green in cross combination Bak-1 × Bak-20 and dark green in cross combinations Bak-2 × Bak-11 and Bak-12 × Bak-5. However, previous work on the characterization of faba bean for qualitative traits has been limited. Thus, the present study suggested that these traits maybe useful for further plant breeding programmes.

Keywords: *characterization, Vicia faba, faba bean, segregation, population, qualitative, traits*

Introduction :

Faba bean (*Vicia faba* L., 2n=2x=12), is an annual legume of the family Leguminosae also referred to as broad bean or field bean. It is one of the oldest crops grown by man and is used as a source of high protein in human diet, as fodder and forage crop for animals, and for available nitrogen in the biosphere (Singh and Bhatt, 2012). Faba bean (*Vicia faba* L.) is the fourth most important legume crop in the world after dried beans, dry peas, and chickpea due to its extensive cultivation and distribution in temperate and subtropical regions (Singh and Bhatt, 2013). Faba bean, like other beans, are a good source of calories, protein, carbohydrates, and other nutrients. Faba bean is an excellent source of levadopa (L-dopa), a precursor of dopamine that has the potential to be used as a treatment for Parkinson's disease (Oplinger, 1982; Vered *et al*., 1997). Despite its potential, the total area of faba bean cultivation in many countries continues to decrease over the past century (Singh *et al*., 2013 and Singh and Bhatt 2012). The area under faba bean cultivation in India is so small that it is still classified as minor, unutilized, underutilized and underexploited crops.

Yield enhancement is a significant breeding objective in faba bean, despite the fact that the selection of superior genotypes based solely on the yield is ineffective due to the quantitative inheritance and low heritability of yield (Bond, 1976). Since grain yield is a complex trait that is highly influenced by genetic and environmental factors, direct selection for yield per se is not very effective (Lawes *et al*., 1983). Effective selection in a plant breeding programme depends on the genetic variability and association of grain yield-related traits with genetic variability. Knowledge of the genetic diversity of conserved germplasm collections of a crop is crucial for establishing, managing, and assuring the long-term success of crop improvement programmes. In India, landraces of faba beans have not been evaluated genetically. Characterization of genetic resources has always been one of the most popular techniques used by the scientific community to investigate novel variations that can be used to develop improved cultivars with higher yield, superior quality, and resistance to biotic and abiotic stress (Martins *et al*., 2006 and Nadeem *et al*., 2018). Characterization of the genetic variation in the available germplasm is essential for further improvement of crop yield and to impart resistance to biotic and abiotic stresses (Terzopoulos and Bebeli, 2008). Using phenotypic data in cultivar identification, the genetic diversity of numerous plants has been previously measured (Ceccarelli *et al*., 1987; Polignano *et al*., 2008; Salem *et al*., 2008). It is vital to characterize for domestication and collection of the elite and promising genotypes of the faba bean with high yielding potentialities for vegetables and pulses purposes. However, it was seen that limited work has been done for the characterization of faba bean on the basis of qualitative traits. Keeping in view the above points and the importance of characterization for crop improvement, germplasm collection, conservation and breeding works of faba bean, this research work has conducted. Thus, the objective of the current study was to analyze the morphological variations on the basis of qualitative traits and identify divergent, and superior segregants among eight segregating populations of faba bean (*Vicia faba* L.).

Materials and Methods

The present investigation was conducted at Bhola Paswan Shastri Agricultural College, Purnea, Bihar, India during *Rabi* season 2022-2023 without replication. Each plot consisted of four rows of 1.8 m length with inter and intra row spacing of 45 cm and 15 cm, respectively. The eight F_3 populations *viz.*,Bak-1 × Bak-5, Bak-1 × Bak-11, Bak-1 × Bak-20, Bak-1 × Bak-5, Bak-2 × Bak-11, Bak-2 × Bak-20, Bak-12 × Bak-5, Bak-16 × Bak-20 and one national check (Vikrant) were taken from the Department of Plant Breeding and Genetics, BPSAC, Purnea, non-state plan project (SNP/CI/Rabi/2018-6) crop improvement. All the agronomic package of practices was done in the field during the research. The data were recorded from all eighty selected plants on the basis of single plant at reproductive phase for the four qualitative traits. The vegetative characters *viz*. stem colour, leaf colour, flower colour and pod colour were also characterized based on morphological characters with the help of faba bean descriptors published by International Plant Genetic Resources (IPGRI), Rome and International Center for Agricultural Research in Dry land Area (ICARDA), Aleppo, Syria, 1985. All qualitative traits were categorized in different groups based on the frequency distribution of germplasm in the excel software.

Results

Wide range of variability was observed among characterized segregating populations for all the qualitative traits. The observed leaf colour included light green and green. Stem colours were light green and dark green. While three types *viz.* light green, green and dark green pod colours were observed. White, dark brown, light brown, purple, mix and pink were flower colors present in the studied crosses and in cross-combination Bak-1 × Bak-5, maximum variability were observed for the trait flower colour (white) 91.25% followed by stem colour (light green) 85% and pod colour (light green) 85% and only two diverse progenies were observed for the trait *i.e.* flower colours violet (plant no. 37) 1.25% and dark brown (plant no. 14) 1.25%. Similarly in cross-combination Bak-1 × Bak-11 maximum variability was observed for the trait flower colour (white) 96.25% followed by pod colour (light green) 86.25% and only three diverse progenies were observed for the trait *i.e.* flower colours dark brown (plant no. 42, 63) 2.50% and light brown (plant no. 50) 1.25% whereas in cross-combination Bak-1 × Bak-20 maximum variability was seen for the trait pod colour (light green) 97.50% followed by stem colour (light green) 95% and only two diverse progenies were observed for the trait *i.e.* pod colour green (plant no. 16, 36) 2.50%. In cross-combination Bak-2 × Bak-5 the highest variability was observed for the trait flower colour (white) 90 % followed by leaf colour (light green) 87.50 % and only four diverse progenies were observed for the trait *i.e.* flower colours light brown (plant no. 20, 42) 2.50 % and mix (plant no. 56, 65) 2.50 % while in cross-combination Bak-2 × Bak-11 four qualitative traits showed a wide range of variation and maximum variability was observed for the trait pod colour (light green) 97.50 % followed by leaf colour (light green) 87.50 % and flower colour (white) 87.50 %.

Table 1: Frequency (%) distribution of four qualitative characters of F_3 progeny of faba bean

S.No.	Crosses	Characters	Descriptor score adopted	No. of progeny	Frequency (%)
1.	**Bak-1 × Bak-5**	Leaf colour	(0) Light Green	63	78.75
			(0) Green	17	21.25
		Stem colour	(1) Light Green	68	85
			(2) Dark Green	12	15
		Flower colour	(1) White	73	91.25
			(2) Violet	1 (P. No. 37)	1.25
			(3) Dark Brown	1 (P. No. 14)	1.25
			(4) Light Brown	2 (P. No. 72,77)	2.50
			(5) Pink	0	0
			(6) Mix	3	3.75
		Pod colour	(0) Light Green	68	85
			(0) Green	12	15
			(0) Dark Green	0	0
2.	**Bak-1 × Bak-11**	Leaf colour	(0) Light Green	56	70
			(0) Green	24	30
		Stem colour	(1) Light Green	55	68.75
			(2) Dark Green	25	31.25
		Flower colour	(1) White	77	96.25
			(2) Violet	0	0
			(3) Dark Brown	2 (P. No. 42, 63)	2.50
			(4) Light Brown	1 (P. No. 50)	1.25
			(5) Pink	0	0
			(6) Mix	0	0
		Pod colour	(0) Light Green	69	86.25
			(0) Green	11	13.75
			(0) Dark Green	0	0
3.	**Bak-1 × Bak-20**	Leaf colour	(0) Light Green	66	82.50
			(0) Green	14	17.50
		Stem colour	(1) Light Green	76	95
			(2) Dark Green	4	5
		Flower colour	(1) White	74	92.50
			(2) Violet	0	0
			(3) Dark Brown	3	3.75
			(4) Light Brown	3	3.75
			(5) Pink	0	0
			(6) Mix	0	0
		Pod colour	(0) Light Green	78	97.50
			(0) Green	2 (P. No. 16, 36)	2.50
			(0) Dark Green	0	0
4.	**Bak-2 × Bak-5**	Leaf colour	(0) Light Green	70	87.50
			(0) Green	10	12.50
		Stem colour	(1) Light Green	67	83.75
			(2) Dark Green	13	16.25
		Flower colour	(1) White	72	90
			(2) Violet	4	5
			(3) Dark Brown	0	0
			(4) Light Brown	2 (P. No. 20, 42)	2.50
			(5) Pink	0	0
			(6) Mix	2 (P. No. 56, 65)	2.50

			(0) Light Green	66	82.50
		Pod colour	(0) Green	14	17.50
			(0) Dark Green	0	0
5.	**Bak-2 × Bak-11**	Leaf colour	(0) Light Green	70	87.50
			(0) Green	10	12.50
		Stem colour	(1) Light Green	76	95
			(2) Dark Green	4	5
		Flower colour	(1) White	70	87.50
			(2) Violet	3	3.75
			(3) Dark Brown	3	3.75
			(4) Light Brown	1 (P. No. 9)	1.25
			(5) Pink	1 (P. No. 55)	1.25
			(6) Mix	2 (P. No. 42, 80)	2.50
		Pod colour	(0) Light Green	78	97.50
			(0) Green	1 (P. No. 40)	1.25
			(0) Dark Green	1 (P. No. 17)	1.25
6.	**Bak-2 × Bak-20**	Leaf colour	(0) Light Green	74	92.50
			(0) Green	6	7.50
		Stem colour	(1) Light Green	75	93.75
			(2) Dark Green	5	6.25
		Flower colour	(1) White	72	90
			(2) Violet	1 (P. No. 40)	1.25
			(3) Dark Brown	2 (P. No. 79, 80)	2.50
			(4) Light Brown	5	6.25
			(5) Pink	0	0
			(6) Mix	0	0
		Pod colour	(0) Light Green	63	78.75
			(0) Green	13	16.25
			(0) Dark Green	4	5
7.	**Bak-12 × Bak-5**	Leaf colour	(0) Light Green	75	93.75
			(0) Green	5	6.25
		Stem colour	(1) Light Green	69	86.25
			(2) Dark Green	11	13.75
		Flower colour	(1) White	77	96.25
			(2) Violet	0	0
			(3) Dark Brown	1 (P. No. 20)	1.25
			(4) Light Brown	2 (P. No. 43, 75)	2.50
			(5) Pink	0	0
			(6) Mix	0	0
		Pod colour	(0) Light Green	27	33.75
			(0) Green	51	63.75
			(0) Dark Green	2 (P. No. 74, 79)	2.50
8.	**Bak-16 × Bak-20**	Leaf colour	(0) Light Green	65	81.25
			(0) Green	15	18.75
		Stem colour	(1) Light Green	66	82.50
			(2) Dark Green	14	17.50
		Flower colour	(1) White	72	90
			(2) Violet	5	6.25
			(3) Dark Brown	2 (P. No. 5,63)	2.50
			(4) Light Brown	0	0
			(5) Pink	1 (P. No. 55)	1.25
			(6) Mix	0	0
		Pod colour	(0) Light Green	6	7.5
			(0) Green	69	86.25
			(0) Dark Green	5	6.25

Two different progenies were observed for the trait *i.e.*, pod colours green (plant no. 40) 1.25 % and dark green (plant no. 17) 1.25 % along with four diverse progenies were observed for flower colour trait, light brown (plant no. 9) 1.25 %, pink (plant no. 55) 1.25 % and mix (plant no. 42, 80) 2.50 %. A range of variability was observed in cross-combination Bak-2 × Bak-20 for four qualitative traits, with the trait of stem colour (light green) exhibiting the highest level of variability at 93.75 % and it was followed by leaf colour (light green) 92.50 %. In contrast, the trait of flower colour showed limited diversity, with only three distinct progenies observed. Specifically violet colour was observed (plant no. 40) accounting for 1.25 % of the observed variability, while dark brown flower colour was observed in (plant no. 79, 80) accounting for 2.50 % of the observed variability. In the cross-combination Bak-12 × Bak-5 only five diverse progenies were observed for the traits *i.e.* flower colours dark brown (plant no. 20) 1.25 %, light brown (plant no. 43, 75) 2.50 % and pod colour dark green (plant no. 74, 79)2.50 % whereas wide range of variability was observed for four qualitative traits and the maximum variability was observed for the trait flower colour (white) 96.25 % followed by leaf colour (light green) 93.75 % and in cross combination Bak-16 × Bak-20 wide range of variability were observed for and maximum variability were observed for the trait flower colour (white) showed greatest variation 90 % among the four qualitative traits studied, followed by pod colour (green) 86.25 % and only two diverse flower colours dark brown (plant no. 5, 63) 2.50 % and pink (plant no. 55) 1.25 % were found among the three progenies. From the study it was found that the most dominant flower colour was white.

In all the eight crosses, flower colour were found to have diverse type in seven crosses (violet, plant no. 37, dark brown, plant no. 14 and light brown, plant no. 72, 77) in cross Bak-1 × Bak-5 whereas flower colour (dark brown, plant no. 42, 63 and light brown, plant no. 50) were observed in cross Bak-1 × Bak-11. Diverse flower colours were observed (light brown, plant no. 20, 42 and mix, plant no. 56, 65) in cross Bak-2 × Bak-5 and four diverse progenies with flower colour (light brown, plant no. 9, pink, plant no. 55 and mix, plant no. 42, 80) were observed in Bak-2 × Bak-11 whereas (violet, plant no. 40 and dark brown, plant no. 79, 80) flower colour had exhibited under cross Bak-2 × Bak-20. Similarly three diverse progenies for the trait flower colour (dark brown, plant no. 20 and light brown, plant no. 43, 75) were observed in cross Bak-12 × Bak-5 whereas dark brown flower colour (plant no. 5, 63 and pink, plant no. 55) were observed in cross Bak-16 × Bak-20 followed by pod colour in only three crosses *viz.,* Bak-1 × Bak-20 (green, plant no. 16, 36), Bak-2 × Bak-11 (green, plant no. 40 and dark green, plant no. 17) and Bak-12 × Bak-5 (dark green, plant no. 74, 79). Similarly pod colour (light green); stem colour (light green) and leaf colour (light green) was found to be predominant among all the crosses except Bak-16 × Bak-20, where maximum variability was observed for pod colour (green).

Discussion

The crosses that were being studied showed a wide range of phenotypic variations, which are significant when it comes to breeding programmes. Given that these seemingly straightforward physical features are correlated in one way or another with a wide range of economically relevant qualities, their relevance cannot be understated. One important example of this kind of variation may be seen in the hues of flowers that may be related to antioxidant properties. Notably, some of the plants had mixed, pink, light brown, and dark brown flower colours. Furthermore, understanding the gene activities responsible for various economically significant features directs the proper breeding techniques to capitalize on genetic breakthroughs as well as the strategic selection of parent plants (Sharma & Sharma, 2013). Evaluating variation in genes within a species offers several benefits. These include the creation of conservation programmes, astute breeding initiative integration, and a more in-depth of agricultural evolution. The most sophisticated stage in characterizing and classifying germplasm is morphological characterization, which has been effective for many different plant species. Characterization based on elemental phenotypic features is a well-established approach of strategic relevance in the field of genotype identification.

Analysis of qualitative traits revealed green color dominance in leaf, pods and stem colour traits. It has also been previously noted that green genotypes predominate over genotypes of other colours in country beans (Islam *et al*., 2014; Sultana, 2001). Six flowers colour types were identified indicating the presence of more variability among the crosses (Islam *et al*., 2014). The most variable pod colour among the evaluated plants was green and dark green. Plants with pigmentation and colourful flowers are essential for pollinators to enable cross-pollination. The flower colour is a prominent visual trait that is often used as a marker gene in genetic studies and breeding programmes in faba bean. Plants with colorful flowers are vital attributes for pollinators to facilitate cross-pollination. The hue of the flower can be affected by environmental factors including temperature, light intensity, pH, and even insect pressure (Oh *et al*., 2014). Maternal affects, genotype-specific gene interactions with colour, and environmental factors that can promote anthocyanin upregulation, all have an impact on the intensity, hue, and pattern of faba bean flower colour. Epistatic genetic correlations between colours and within particular populations were also seen in the flower hue of faba beans. Flower trait is associated with the relationship between the flower colour and tannin content (an anti-nutritional component present in faba beans) and the screening and selection of floral characters is crucial. According to Martin *et al*., (1991), white flowers have the lowest tannin concentration when compared to other coloured flowers. Additionally, as a pleiotropic effect of this gene, Duc *et al.*, (1999) described a zero-tannin cultivar named Gloria that possessed a pure white blossom and recessive monogenetic segregation.

Therefore, selecting the white-flowered faba bean is the simplest approach to generate a faba bean devoid of tannins. However, because faba beans are a largely cross-pollinated crop with an average 35% outcrossing rate, the significance of floral characteristics—particularly petal pigmentation—is to draw bees as pollinators (Bond and Poulsen, 1983). Due to this largely outcrossing characteristic, pollination by wild bees is necessary for the ideal seed establishment, and it has been observed that a pollinator shortage can reduce grain output by as much as 64% (Nayak *et al*., 2015). Furthermore, foliage is protected from UV rays, diseases, and insects by a variety of defense-related molecules known as pigmentation chemicals (Freeman and Beattie, 2008). According to Goyal (1965), it was found that a green stem was dominant among the pigmented stems. Additionally, Yasar *et al*., (2014) investigated the inheritance of stem colour in chickpea and discovered that a single recessive gene is in charge of stem colour in this plant. One of the most important factors in assessing a crop's marketability and customer choice is the colour of the pods. It is a crucial phenotypic attribute that is impacted by both environmental and genetic variables. Multiple genes that are involved in the pigmentation of anthocyanins, flavonoids, and carotenoids interact to define the overall colour of pods (Smith *et al*., 2020). The quality and intensity of light can either promote or inhibit the expression of genes that produce pigment (Brown and Green, 2019). According to Williams *et al*., (2018), darker pods could be more heat-tolerant and appropriate for areas with high temperatures. In pulse crops, leaf colour is a measurable characteristic with important agronomic consequences. Numerous variables, including as the presence of disease, environmental stress, and nutritional availability, might be connected to variations in leaf colour (Husaini and Al-Khayri, 2016). According to Ghosh and Mahapatra (2014), darker green leaves are a sign of greater chlorophyll content and are often linked to increased biomass and better yield performance. Therefore, the characterization of germplasm is justified by research of qualitative plant morphological features. The domain of faba bean morphological traits has been marked by substantial variability, as demonstrated by earlier research by Rana *et al*., (2015); Loko *et al*., (2018); Attia *et al*., (2019); Kumar *et al*., (2020);

Patel *et al*., (2020) and Yuce *et al*., (2023). Characterization of eight F_3 populations of faba bean had been done based on its morphological traits such as stem colour, leaf colour, flower colour and pod colour which will be helpful in effective utilization of germplasm for further improvement for crop yield.

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