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RESEARCH ARTICLE

Characterization and Evaluation of Faba Bean (*Vicia faba* L.) Germplasm Collected from Kashmir, India

Sheikh M. Sultan[1*], Susheel K. Raina[2], Suheel Ahmad[3] and Sheeraz S. Bhat[4]

Abstract

Faba bean (*Vicia faba*) is an ancient legume crop with high protein content of around 27%. In this study 39 local faba bean genotypes differing in seed shape, size and color were collected from different areas of Kashmir valley and evaluated during three successive *rabi* growing seasons of 2019–20, 2020–21 and 2021–22. Data were recorded on ten agro-morphological traits *viz*., plant height, number of branches/plant, days to 50% flowering, days to 80% maturity, pod length, pod width, number of seeds/pod, pod yield/plant, seed yield/plant and 100-seed weight. Average plant height ranged from 55.8 to 91.3 cm, pod length 5.2 to 9.7 cm, pod width 1.1 to 1.8 cm, seed yield/plant 18.748 to 42.050 g and 100-seed weight 41.118 to 89.966 g. Pod yield/plant evaluated during one year of 2021–22 only ranged from 43.633 to 199.930 g with a mean value of 99.981 g. The results have indicated significant variability in most of these traits. Flattened, medium-sized, beige seeds were more common traits in these faba bean genotypes. Lower mean plant height, number of branches/plant, pod length and seed yield/plant were recorded in 2021–22 than the other two experimental years due to lower rainfall and higher mean temperatures during the active vegetative, flowering and pod filling stages. Principal component and cluster analysis revealed three distinct clusters mainly on the basis of greater agro-morphological similarity. Interestingly, 8 genotypes with the highest individual 100-seed weight were clustered in a separate group with an average 100-seed weight of 83.997 g. Besides, this cluster recorded highest average plant height, pod length, pod width and seed yield/plant as well; all these traits showed significant positive correlations with each other. Therefore, these traits should be considered when selecting faba bean genotypes to improve the region's crop performance.

Keywords: Agro-morphological traits, Cluster analysis, Genetic diversity, Principal components, *Vicia faba*.

[1,2]ICAR-NBPGR, Regional Station, Srinagar, Jammu & Kashmir, India

[3,4]ICAR-IGFRI, Regional Station, Srinagar, Jammu & Kashmir, India

***Author for correspondence:**

mohmmad.sheikh@icar.gov.in

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Introduction

Faba bean (*Vicia faba* L.) also fava bean, broad bean, field bean or horse bean is a multipurpose ancient legume crop belonging to the family *Faba*ceae have a high protein content and biomass and is used as human food and animal feed (Musallam *et al*., 2004). Mature seeds of faba bean are rich in proteins (26.1%), carbohydrates (58.3%), and dietary fiber (25.0%) (USDA, 2021), the protein content ranging from 22.7 to 34.7% (Martineau-Côté *et al*., 2022). Faba beans also contain a variety of bioactive compounds such as phenolics and flavonoids with antioxidant activity (Valente *et al*., 2018). However, faba beans also contain anti-nutritional factors such as lectins, saponins, trypsin inhibitors, phytic acids, condensed tannins, etc., that are believed to undermine its biological value (Revilla, 2015). Consuming faba beans may cause a condition known as 'favism', which is a severe form of hemolytic anemia (Mínguez & Rubiales, 2021), the highest incidence of this disease has been reported in the Mediterranean region. Faba beans, a fresh vegetable, represent a traditional food in several Mediterranean countries and are consumed in large quantities in countries such as China, Turkey, Egypt, Ethiopia, and Central America. In fact, it is a common breakfast food in the Middle East, Mediterranean region, China, and Ethiopia (Dhull *et al.*, 2021). Faba beans also play an important role in crop rotations, effective nitrogen fixation and soil improvement (Ye *et al.*, 2003) and are considered among the most efficient legumes in terms of nitrogen fixation (Phillips, 1980). Due to its very efficient nitrogen fixation capability, it is used as a green manure globally (Duc *et al.*, 2015), providing about 90% of the plant's nitrogen needs (Hauggaard-Nielsen *et al.*, 2009), probably the highest value among grain legumes. About half of the crop nitrogen content is left in the field for the next crop (Watson *et al.*, 2017).

Faba bean is believed to have been domesticated some 10,000 years BC in the near east, where archeological findings of domestic (Cubero, 1974) and wild specimens were discovered (Caracuta *et al.*, 2016). Ancient faba bean remains have been found in northwest Syria and Turkey (Tanno and Willcox, 2006). Faba bean cultivation spread to Anatolia and then Europe via the Mediterranean coast and to other countries, including India and China via Mesopotamia (Cubero, 2011). Today, the faba bean is considered the fourth most important cool season food legume after chickpeas, lentils, and peas as is grown on 2.57 million ha area with a total production of 5.4 million tons in 2019 (FAOSTAT, 2021) and cultivated worldwide (Mínguez & Rubiales, 2021). China is the leading producer of *faba* beans, followed by Ethiopia; these two countries represent about 50% of the total global production. Mediterranean countries, Ethiopia, Egypt, Afganistan, India, Northern Europe and Northern Africa are other major producers of *faba* bean (Rahate *et al.*, 2020). *Faba* bean gained specific adaptations to different environments and uses during its dispersal. These adaptations are reflected in plant architecture and seed size, weight, and shape (Alghamdi *et al.*, 2012). Accordingly, *faba* bean is separated into four groups based on seed size: major (large flattened or broad bean with 100–200 g/100 seed weight), equine (horse bean with 60–100 g/100 seed weight), minor (tic bean with ellipsoidal seed having 40–60 g/100 seed weight), and *paucijuga* (regarded as primitive one with 31–40 g/100 seed weight) (Cubero 1974, Serradilla *et al.*, 1993). The largest seeded type (major) is generally found in south Mediterranean countries and China. The medium-sized type (equina) emerged in the Middle East, North Africa, and Australia, whereas small-seeded types (minor and *paucijuga*) are prevalent in Ethiopia and northern Europe (Duc, 1997). Some workers have classified *paucijuga* as a sub-species. *V. faba* var. *paucijuga* has dehiscent pods as do the other groups but to a much lesser extent, it is self-fertile with short stature and is closest to wild type in traits (Ladizinsky, 1998), occurring in the Afghan-north Indian subcontinent region. Short stem, small leaves and seeds (100 seed weight less than 25 g) are primitive characteristics. The small seed/pod features dominate over the larger, more recent seed types (Cubero and Nadal, 2005). Owing to its numerous uses, great nutritional quality and ability to grow over a broad range of climatic and soil conditions, faba bean is appropriate for sustainable agriculture in many marginal areas (Nadal *et al.*, 2003), and the crop has gained greater global attention in recent years. Its production is poised for rapid growth because of demand for plant-based protein products.

Faba bean is a minor crop in India, grown in the states of Bihar, Uttar Pradesh, Rajasthan, Madhya Pradesh, West Bengal, Assam, Manipur and Nagaland (Singh *et al.* 2012) mainly as a *rabi* crop in plain areas and during rainy *kharif* season in hilly and mountainous regions (Singh and Bhatt, 2012). In Kashmir, it is cultivated in several areas on a limited scale, mainly as *rabi* crop for household consumption as a fresh vegetable and occasionally as a pulse. Locally known as 'Baghla', which is similar to 'Bakla', the Turkish and Persian name of the crop, faba bean is considered as a rustic crop able to withstand environmental and ecological vagaries. It is surprising, however, that not much work has been done on local faba bean genetic resources and their cultivation in Kashmir as there is scanty information available in literature in this regard. The present study was therefore undertaken to evaluate the field performance of 39 faba bean genotypes we collected from different areas of Kashmir by using nine agro-morphological traits. The study of genetic variation in morphological and agronomic traits among these local faba bean genotypes is imperative for their efficient utilization and for their effective conservation.

Materials and Methods

Plant materials and field conditions

Thirty nine (39) genotypes of faba bean (*V. faba*) collected by us during the year 2019 from farmers in different areas of Kashmir, especially Budgam, Shopian and Pulwama districts at an altitudinal range of 1591–1881 masl (Table 1) were studied for their field performance. The experiments were conducted over three successive *rabi* growing seasons of 2019–20, 2020–21 and 2021–22 under rainfed conditions at the experimental farm of ICAR-NBPGR Regional Station Srinagar, Jammu and Kashmir (33°59′ N latitude, 74°47′ E longitude, 1639 m above sea level). The experimental site is on dry Karewa land with a pH of 6.23 and an average normal monthly rainfall of 52 mm (Table 2). These genotypes were sown during the third week of November each year with two check varieties HFB-1 and Vikrant in a randomized block design with three replications. In each replication, the genotypes were sown in two rows of 2 m length spaced at 45 cm and the individual plants in a row spaced at 15 cm. Recommended agronomic practices and protective measures were followed to grow a healthy crop. The experiments were supplied with granulated NPKS in the 40:20:20:20 kg/ha ratio at the time of land preparation. Weeding was done by hand whenever necessary.

Table 1: Geographical coordinates of collection sites of 39 faba bean (*Vicia faba*) genotypes collected from different areas of Kashmir, India (those with IC numbers have been conserved in National Gene Bank, ICAR-NBPGR New Delhi)

S No.	*Collection No./ Accession No.*	*Place of collection*	*Latitude*	*Longitude*	*Altitude (m)*
1	SHEIKH/SR-899 *IC-0637960*	Buchroo, Budgam	33° 58′	74° 49′	1610
2	SHEIKH/SR-900 *IC-0637961*	Buchroo, Budgam	33° 58′	74° 49′	1610
3	SHEIKH/SR-901 *IC-0637962*	Manchuwa, Budgam	34° 00′	74° 48′	1600
4	SHEIKH/SR-902 *IC-0637963*	Dangerpora, Budgam	34° 07′	74° 46′	1600
5	SHEIKH/SR-903 *IC-0637964*	Bugam, Budgam	33° 45′	74° 47′	1642
6	SHEIKH/SR-903A	Bugam, Budgam	33° 45′	74° 47′	1642
7	SHEIKH/SR-903B	Bugam, Budgam	33° 45′	74° 47′	1642
8	SHEIKH/SR-903C	Bugam, Budgam	33° 45′	74° 47′	1642
9	SHEIKH/SR-904	Bugam, Budgam	33° 45′	74° 47′	1642
10	SHEIKH/SR-905 *IC-0637965*	Hayatpora, Budgam	33° 58′	74° 44′	1630
11	SHEIKH/SR-906 *IC-0637966*	Nowbugh, Budgam	33° 56′	74° 48′	1634
12	SHEIKH/SR-906A	Nowbugh, Budgam	33° 56′	74° 48′	1634
13	SHEIKH/SR-907 *IC-0637967*	Nowpora, Budgam	34° 09′	74° 54′	1620
14	SHEIKH/SR-908 *IC-0637968*	Pehroo, Budgam	34° 00′	74° 46′	1591
15	SHEIKH/SR-909 *IC-0637969*	Wadipora, Budgam	33° 57′	74° 47′	1637
16	SHEIKH/SR-910 *IC-0637970*	Gowharpora, Budgam	33° 59′	74° 47′	1650
17	SHEIKH/SR-910A	Gowharpora, Budgam	33° 59′	74° 47′	1650
18	SHEIKH/SR-911	Nohmu, Pulwama	34° 02′	74° 48′	1620
19	SHEIKH/SR/SA/SS-912 *IC-0637971*	Trenz, Shopian	33° 46′	74° 55′	1860
20	SHEIKH/SR/SA/SS-913 *IC-0637972*	Haripora, Shopian	33° 45′	74° 54′	1800
21	SHEIKH/SR/SA/SS-913A	Haripora, Shopian	33° 45′	74° 54′	1800
22	SHEIKH/SR/SA/SS-914 *IC-0637973*	Aawneera, Shopian	33° 48′	74° 58′	1867
23	SHEIKH/SR-915 *IC-0637974*	Newa, Pulwama	33° 54′	74° 53′	1623
24	SHEIKH/SR-915A	Newa, Pulwama	33° 54′	74° 53′	1623
25	SHEIKH/SR/SA/SS-916 *IC-0637975*	Chitragam, Shopian	33° 46′	74° 58′	1696
26	SHEIKH/SR/SA/SS-917	Chitragam, Shopian	33° 46′	74° 58′	1696
27	SHEIKH/SR/SA/SS-918 *IC-0637976*	Zanipora, Shopian	33° 54′	74° 48′	1770
28	SHEIKH/SR/SA/SS-918A	Zanipora, Shopian	33° 54′	74° 48′	1770
29	SHEIKH/SR-919 *IC-0637977*	Kakapora, Pulwama	33° 56′	74° 55′	1608
30	SHEIKH/SR-920 *IC-0637978*	Gangoo, Pulwama	33° 52′	74° 53′	1655

31	SHEIKH/SR/SA/SS-921 *IC-0637979*	Kundalan, Shopian	33° 46′	74° 55′	1881
32	SHEIKH/SR/SA/SS-922	Naidgam, Shopian	33° 47′	74° 57′	1878
33	SHEIKH/SR/SA/SS-922A	Naidgam, Shopian	33° 47′	74° 57′	1878
34	SHEIKH/SR/SA/SS-922B	Naidgam, Shopian	33° 47′	74° 57′	1878
35	SHEIKH/SR/SA/SS-923 *IC-0637980*	Naidgam, Shopian	33° 47′	74° 57′	1878
36	SHEIKH/SR/SA/SS-923A	Naidgam, Shopian	33° 47′	74° 57′	1878
37	SHEIKH/SR-924	Mattan, Anantnag	33° 45′	75° 12′	1686
38	SHEIKH/SR-925	Mattan, Anantnag	33° 45′	75° 12′	1686
39	SHEIKH/SR-926	Mattan, Anantnag	33° 45′	75° 12′	1686

Table 2: Average monthly minimum and maximum temperatures and total rainfall during three experimental years of 2019-20, 2020-2021 and 2021-2022

Parameter	*Year*	*Nov.*	*Dec.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*
Maximum temperature (°C)	2019-20	15.0	8.6	5.9	12.5	15.1	21.3	25.2	29.3	31.8
	2020-21	14.6	9.2	5.7	12.9	15.3	19.0	24.5	29.4	30.0
	2021-22	14.9	10.5	7.3	10.8	20.8	24.6	26.2	27.7	25.2
Minimum temperature (°C)	2019-20	1.9	-2.0	-2.0	-0.3	4.7	7.5	10.3	14.4	17.4
	2020-21	1.4	-2.0	-4.6	0.9	5.5	7.3	11.7	15.6	19.5
	2021-22	0.6	-2.0	-6.0	4.0	6.7	9.9	13.1	14.9	20.6
Total rainfall (mm)	2019-20	39	55	48	70	121	82	68	47	07
	2020-21	31	57	103.7	25.1	110.2	126.7	47.5	19.6	52.6
	2021-22	3.0	17.5	105	79	32	32.8	27.2	108	122

Recorded traits

At maturity, five guarded plants in each replication were used to measure the agro-morphological traits *viz*., plant height (cm), number of branches/plant, days to 50% flowering, days to 80% maturity, pod length (cm), pod width (cm), number of seeds/pod, pod yield/plant (g) and seed yield/plant (g). 100-seed weight (g) was also recorded in triplicate. Pod yield/plant was evaluated during the final year of the study *i.e*., 2021–22 only. To determine pod yield/plant, two harvests were carried out simultaneously for all the genotypes during the second fortnight of May 2022.

Statistical Analysis

Basic statistics of different quantitative traits was worked out on pooled data of all the traits studied excepting pod yield/plant, which was evaluated only during one year of 2021–22. Least significance difference (LSD) was worked out at p = 0.05 level of probability. Pearson's correlation determined correlations between different traits. The data were then analyzed by cluster and principal component analysis. Principal components analysis (PCA) was carried out on the correlation matrix, calculating the mean data of the genotypes. The genotypes in each resultant cluster were also analyzed for basic statistics. Statistical tests were carried out by the Statistical Package for Social Sciences (version 21) and OpenStat software.

Results and Discussion

A total of 39 *Vicia faba* bean genotypes (*V. faba*) were collected by us during an exploration and germplasm collection programme in 2019 from the farmers in different areas of Kashmir (Table 1). Most of these have been conserved in National Gene Bank at ICAR-NBPGR New Delhi. In Kashmir, *faba* bean is cultivated as a minor *rabi* crop mostly for household consumption. It is used as a vegetable either in the form of green pods or immature seeds, sometimes, its dried seeds are used as a pulse. Generally, these farmers maintain a mixture of seeds of different size, shape and color, most commonly being medium-sized beans of beige color. Seed shape varies from more or less rounded, angular to flattened, the latter being observed as dominant.

The average combined values of 9 out of 10 agro-morphological traits for the 39 *faba* bean genotypes evaluated during three successive years of 2019–20, 2020–21 and 2021–22 are given in Table 3. Pod yield/plant was only evaluated during the single year of 2021–22. The results revealed a wide range of differences, as evidenced by the characteristic ranges that especially include plant height (55.8–91.3 cm), number of branches per plant (1.2–3.3), pod length (5.2–9.7 cm), pod yield/plant (43.633–199.930 g), seed yield per plant (18.700–42.000 g) and 100-seed weight

Table 3: Mean performance of 39 local *faba* bean (*Vicia faba*) genotypes evaluated under rainfed conditions of Kashmir, India combined over three *rabi* seasons of 2019-20, 2020-2021 and 2021-2022

S No.	Genotype	PH (cm)	DTF	DTM	NB	PL (cm)	PW (cm)	SP	SY (g)	SW (g)	*PY (g)
1	SHEIKH/SR-899	61.6	142.5	195.2	1.5	5.8	1.5	2.4	32.246	51.936	89.217
2	SHEIKH/SR-900	72.3	141.5	198.0	2.1	6.9	1.5	3.2	33.776	60.103	49.217
3	SHEIKH/SR-901	74.2	142.7	194.7	2.2	7.9	1.8	3.2	38.696	88.684	85.017
4	SHEIKH/SR-902	74.5	139.5	198.5	2.5	8.5	1.5	3.1	36.835	84.497	80.500
5	SHEIKH/SR-903	73.9	141.5	196.5	2.0	8.3	1.6	2.9	25.716	70.091	95.933
6	SHEIKH/SR-903A	57.3	142.0	194.0	1.6	7.0	1.1	2.9	27.639	60.350	161.730
7	SHEIKH/SR-903B	56.1	140.5	194.0	2.0	5.7	1.2	2.8	33.400	67.318	119.950
8	SHEIKH/SR-903C	55.8	141.2	196.5	1.5	5.2	1.1	2.7	18.748	54.950	82.650
9	SHEIKH/SR-904	68.4	141.5	196.5	2.5	7.8	1.5	2.9	26.301	69.730	153.630
10	SHEIKH/SR-905	66.9	142.7	196.0	2.0	7.2	1.5	2.7	36.553	71.282	198.930
11	SHEIKH/SR-906	73.6	143.5	194.2	3.1	7.3	1.4	2.9	32.559	51.048	97.433
12	SHEIKH/SR-906A	65.4	145.0	197.2	2.7	5.9	1.3	3.4	29.224	50.082	199.930
13	SHEIKH/SR-907	67.9	143.2	194.0	2.6	7.6	1.5	3.1	30.404	64.958	108.630
14	SHEIKH/SR-908	71.6	141.5	193.0	2.3	7.5	1.4	2.7	29.952	59.665	58.100
15	SHEIKH/SR-909	75.8	144.5	195.7	2.0	6.7	1.4	2.8	25.669	66.846	67.400
16	SHEIKH/SR-910	72.7	144.5	195.2	3.0	6.6	1.4	3.1	32.874	51.832	108.180
17	SHEIKH/SR-910A	75.0	142.0	199.0	2.8	6.8	1.2	2.8	25.000	45.90	99.683
18	SHEIKH/SR-911	78.2	145.5	196.0	2.7	5.9	1.2	3.1	35.238	48.661	97.200
19	SHEIKH/SR/SA/SS-912	91.3	144.0	196.0	3.3	9.2	1.7	2.8	39.604	67.784	121.700
20	SHEIKH/SR/SA/SS-913	83.1	142.0	200.0	2.8	9.7	1.8	3.1	36.500	81.333	82.000
21	SHEIKH/SR/SA/SS-913A	65.7	142.0	197.5	2.3	7.7	1.7	3.2	34.552	52.850	85.300
22	SHEIKH/SR/SA/SS-914	84.7	142.0	199.0	2.4	8.5	1.6	2.5	40.254	72.248	80.133
23	SHEIKH/SR-915	74.2	144.0	195.5	1.9	7.9	1.6	3.0	42.050	82.587	109.130
24	SHEIKH/SR-915A	72.8	144.0	197.2	2.4	7.2	1.2	3.1	19.137	56.900	91.850
25	SHEIKH/SR/SA/SS-916	72.7	143.2	197.7	2.7	6.9	1.4	3.1	33.063	45.343	78.350
26	SHEIKH/SR/SA/SS-917	69.9	142.5	198.5	1.2	8.2	1.7	3.3	37.386	79.563	80.800
27	SHEIKH/SR/SA/SS-918	70.8	143.0	199.0	2.6	7.3	1.8	2.7	34.859	70.408	110.250
28	SHEIKH/SR/SA/SS-918A	82.7	141.0	199.0	2.4	8.9	1.5	2.2	35.220	79.200	90.350
29	SHEIKH/SR-919	70.4	146.0	196.5	2.5	7.3	1.4	3.1	30.940	49.535	59.600
30	SHEIKH/SR-920	76.9	141.5	197.5	2.2	8.9	1.7	2.8	41.725	89.966	89.433
31	SHEIKH/SR/SA/SS-921	74.9	143.2	196.2	2.4	7.9	1.5	3.2	28.915	65.182	91.000
32	SHEIKH/SR/SA/SS-922	73.5	143.5	196.2	3.3	6.5	1.4	3.1	27.997	52.149	87.233
33	SHEIKH/SR/SA/SS-922A	60.6	145.5	199.0	2.1	5.2	1.1	2.7	27.600	42.950	105.870
34	SHEIKH/SR/SA/SS-922B	62.2	143.0	196.0	2.3	5.8	1.1	3.2	22.876	41.118	43.633
35	SHEIKH/SR/SA/SS-923	68.1	147.5	194.5	2.7	6.8	1.4	3.2	26.787	49.505	107.370
36	SHEIKH/SR/SA/SS-923A	69.7	143.5	197.5	3.1	6.2	1.3	3.4	24.988	62.844	119.430
37	SHEIKH/SR-924	63.2	144.5	195.5	2.2	8.1	1.8	2.9	21.278	86.146	102.470
38	SHEIKH/SR-925	65.1	142.5	198.0	2.8	6.4	1.4	2.9	41.724	42.401	106.470
39	SHEIKH/SR-926	69.1	142.5	196.5	2.3	6.1	1.1	3.4	26.220	41.866	103.570
Mean		70.8	142.5	196.0	2.4	7.2	1.4	2.9	31.397	62.302	99.981
Minimum		55.8	139.0	193.0	1.2	5.2	1.1	2.2	18.748	41.118	43.633
Maximum		91.3	147.0	200.0	3.3	9.7	1.8	3.4	42.050	89.966	199.930
CV (%)		10.7	1.1	0.9	20.2	15.4	14.9	9.2	19.800	23.0	33.1
LSD at 0.05		8.6	4.3	4.3	1.3	1.9	0.4	0.6	11.885	27.605	75.4
Mean values for check varieties											
HFB-1		55.4	141.8	196.5	2.3	5.1	1.1	3.0	17.585	26.526	69.700
Vikrant		52.5	142.1	196.8	1.8	4.3	1.2	2.7	20.018	26.713	68.133

PH = Plant height, DTF = Days to 50% flowering, DTM = Days to 80% maturity, NB = Number of branches/plant, PL = Pod length, PW = Pod width, SP = Seeds/pod, SY = Seed yield/plant, SW = 100 - Seed weight and PY = Pod yield/plant

*Single year data of 2021- 2022

(41.100–89.966 g). Significant differences have been recorded among various genotypes in these traits. The results suggest the presence of a wide range of genetic variability among these genotypes and highlight the genetic refinement that could be possible with the use of such a genetic pool for breeding. This conclusion agrees with those of Elshafei *et al.* (2019) and Ton *et al.* (2021), who reported a significant variance in various agronomic characteristics, especially of plant height, number of branches per plant, seed yield per plant and 100-seed weight in *Vicia faba* beans in their respective studies. The seed coat color of greenish, brown, purple, beige, chocolate or black was observed in freshly harvested plants. The seeds also varied in shape and size (Figure 1). Flattened, medium-sized, beige seeds were more common traits in these *Vicia faba* bean genotypes. As indicated in Table 3, the 100-seed weight ranged widely from 41.118–89.966 g (CV 23%), implying sufficient variability in this trait.

All the 39 faba bean genotypes studied exhibited indeterminate or semi-determinate growth habit. The apical vegetative growth continued even after the plants entered the reproductive phase and flowering ensued and flowers appeared on short or long peduncles laterally (Figure 1).

Figure 1: Representative faba bean (*V. faba*) inflorescences of 39 local genotypes with flowers showing anthocyanin coloration and striations. Note also variability in seed shape, size and color in these genotypes

The terminal vegetative growth stopped as soil moisture became limiting. The flower color of white with black spot on wing petal was observed in all the genotypes studied. In some genotypes, standard petal showed some purplish or reddish anthocyanin coloration. Streaks of medium color intensity were observed on standard petal in nearly all the genotypes studied. However, white flowers known to be a pleiotropic effect of an allele for very low tannins in the seed testa were not observed in any of these 39 genotypes.

A perusal of the data recorded in Table 4 suggests that the mean plant height, number of branches/plant, pod length and seed yield/plant in the third year of evaluation *viz.*, 2021-22 were lower as compared to other two years of 2019–20 and 2020–21. This may be due to lower rainfall and higher mean temperatures during the active vegetative,

Table 4: The means and range of variation of 39 local faba bean (*Vicia faba*) genotypes evaluated under rainfed conditions of Kashmir, India during three years of 2019-20, 2020-2021 and 2021-2022

Trait	*Year*	*Mean*	*Range*	*Best check value*
Plant height (cm)	2019-20	82.8	61.8–92.2	67.4 (HFB-1)
	2020-21	73.7	58.5–92.2	54.1 (HFB-1)
	2021-22	57.0	45.0–69.0	44.7 (HFB-1)
Days to 50% flowering	2019-20	139.5	139–142	140 (Vikrant)
	2020-21	142.2	137–145	140.7 (HFB-1)
	2021-22	144	140–151	142 (Vikrant)
Days to 80% maturity	2019-20	198.5	195–199	193 (HFB-1)
	2020-21	198.2	196–200	197 (HFB-1)
	2021-22	195	188–199	196 (HFB-1)
No. of branches/ plant	2019-20	2.2	1.1–3.6	2.7 (HFB-1)
	2020-21	2.6	1.0–4.3	2.2 (HFB-1)
	2021-22	2.0	1.0–3.1	2.5 (HFB-1)
Pod length (cm)	2019-20	8.1	5.7–10.5	4.6 (HFB-1)
	2020-21	7.9	5.7–10.8	6.1 (Vikrant)
	2021-22	5.9	3.7–8.8	5.4 (HFB-1)
Pod width (cm)	2019-20	1.7	1.4–2.1	1.4 (Vikrant)
	2020-21	1.3	0.9–1.8	1.1 (HFB-1)
	2021-22	1.2	1.0–2.0	1.0 (HFB-1)
No. of seeds/pod	2019-20	2.9	2.3–3.8	3.1 (HFB-1)
	2020-21	2.9	2.2–3.8	3.3 (HFB-1)
	2021-22	3.0	2.4–4.0	2.6 (HFB-1)
Seed yield/plant (g)	2019-20	43.158	15.675–66.525	24.500 (Vikrant)
	2020-21	30.441	21.025–41.604	26.354 (Vikrant)
	2021-22	16.731	9.467–29.700	10.400 (HFB-1)
100-seed weight (g)	2019-20	69.474	41.854 - 111.253	31.927 (Vikrant)
	2020-21	60.777	39.2 00- 88.400	33.667 (Vikrant)
	2021-22	61.273	38.400 - 105.600	24.106 (Vikrant)
Pod yield/ plant (g)	2021-22	99.981	43.633 - 199.930	69.700 (HFB-1)

flowering and pod-filling period of March–May during 2021–22 than the other two years (Table 2). Under plain conditions faba bean can grow up to 30–35°C. However, in hilly areas, the temperature seems to be on lower side. Generally, the freezing winter in Kashmir arrests the growth of *rabi* crops and as soon as the temperature rises gradually from March onwards, the crops begin to grow rapidly. During these post-winter months, adequate rainfall is crucial for raising a good crop, especially in dryland areas. According to Flores *et al.* (2012), faba bean is a winter crop that grows better under cool and moist conditions, whereas hot and dry weather is unfavorable and could lead to decrease in the seed yield and quality. It has also been reported that the production response in faba beans is closely linked to the availability of water during the production phases and that heat stress during floral development reduced the seed yield (Giordano *et al.*, 1994, Abdelmula and Abuanja, 2007, Bishop *et al.*, 2016, Ton *et al.*, 2021).

Highly significant correlations were observed between pod length and plant height, pod width and pod length, seed yield and pod width, 100-seed weight with both pod length and pod width (Table 5). Similar correlations have been reported in some earlier studies on faba beans (Kumar *et al.*, 2017, Sharma *et al.*, 2017, Ton *et al.*, 2021).

To understand sources of variance among faba bean genotypes, principal component analysis (PCA) was carried out which grouped the 9 studied agro-morphological traits into the first three axes, describing more than 70%

Table 5: Pearson's correlation matrix for various agro-morphological traits of 39 local faba bean (*V. faba*) genotypes evaluated under rainfed conditions of Kashmir, India during three years of 2019-20, 2020-2021 and 2021-2022

	PH	*DTF*	*DTM*	*NB*	*PL*	*PW*	*SP*	*SY*	*SW*
PH	-								
DTF	0.015	-							
DTM	0.321 *	- 0.197	-						
NB	0.482 **	0.293	0.093						
PL	0.690 ***	-0.279	0.229	0.111	-				
PW	0.470 **	-0.127	0.183	0.032	0.774 ***	-			
SP	-0.082	0.294	-0.057	0.229	-0.127	-0.090	-		
SY	0.451 **	-0.189	0.191	0.072	0.465 **	0.548 ***	-0.152	-	
SW	0.346 *	-0.375 *	0.093	-0.249	0.738 ***	0.717 ***	-0.188	0.394 *	-

* $p < .05$, ** $p < .01$, *** $p < .001$

PH = Plant height, DTF = Days to 50% flowering, DTM = Days to 80% maturity, NB = Number of branches/plant, PL = Pod length, PW = Pod width, SP = Seeds/pod, SY = Seed yield/plant and SW = 100 - Seed weight

Table 6: Eigen values and percentage of total variance for PCA in 39 local faba bean (V. *faba*) genotypes evaluated under rainfed conditions of Kashmir, India during three years of 2019-20, 2020-2021 and 2021-2022

Trait	*PC1*	*PC2*	*PC3*	*PC4*	*PC5*	*PC6*	*PC7*	*PC8*	*PC9*
Eigen value	3.498	1.759	1.061	0.835	0.638	0.602	0.314	0.185	0.108
Relative variance (%)	38.86	19.54	11.79	9.28	7.08	6.69	3.49	2.07	1.20
Cumulative variance (%)	38.86	58.4	70.19	79.47	86.55	93.24	96.73	98.8	100

Table 7: Vector loadings (varimax) for yield contributing traits in 39 local faba bean (*V. faba*) genotypes evaluated under rainfed conditions of Kashmir, India combined over three rabi seasons of 2019-20, 2020-2021 and 2021-2022

Trait	*Vec 1*	*Vec 2*	*Vec 3*	*Vec 4*	*Vec 5*	*Vec 6*	*Vec 7*	*Vec 8*	*Vec 9*
Plant height (cm)	0.381	0.392	-0.153	-0.190	-0.200	0.023	-0.599	-0.076	-0.484
Days to 50% flowering	-0.193	0.465	0.338	-0.203	0.302	0.664	-0.081	0.132	0.183
Days to 80% maturity	0.190	0.097	-0.718	0.478	0.179	0.389	0.098	0.101	0.074
No. of branches/plant	0.041	0.646	-0.153	-0.192	-0.267	-0.325	0.500	0.283	0.110
Pod length (cm)	0.488	0.051	0.127	0.048	-0.299	0.051	-0.128	-0.356	0.709
Pod width (cm)	0.455	0.020	0.290	0.074	0.124	0.199	0.563	-0.385	-0.425
No. of seeds/pod	-0.131	0.367	0.365	0.774	0.067	-0.276	-0.171	-0.027	-0.050
Seed yield/plant (g)	0.365	0.044	-0.017	-0.173	0.788	-0.406	-0.100	0.108	0.159
100-Seed weight (g)	0.427	-0.250	0.296	0.135	-0.181	0.128	-0.012	0.772	-0.038

Table 8: Mean and standard deviation for three clusters based on nine quantitative characters of 39 local faba bean (*V. faba*) genotypes evaluated under rainfed conditions of Kashmir, India combined over three *rabi* seasons of 2019-20, 2020-2021 and 2021-2022

Trait	*Cluster 1 (16 Genotypes)*	*Cluster 2 (15 Genotypes)*	*Cluster 3 (8 Genotypes)*
Plant height (cm)	70.6 ± 9.4	68.9 ± 5.4	74.8 ± 6.5
Days to 50% flowering	142.5 ± 1.2	143.9 ± 1.7	142.2 ± 1.6
Days to 80% maturity	196.2 ± 1.8	196.6 ± 1.5	197.4 ± 1.9
Number of branches/plant	2.3 ± 0.5	2.6 ± 0.4	2.2 ± 0.5
Pod length (cm)	7.3 ± 1.0	6.5 ± 0.7	8.5 ± 0.6
Pod width (cm)	1.4 ± 0.2	1.3 ± 0.2	1.7 ± 0.1
No. of seeds/pod	2.9 ± 0.2	3.0 ± 0.3	2.9 ± 0.3
Seed yield/plant (g)	29.745 ± 6.409	30.593 ± 4.789	36.211 ± 6.508
100 - Seed weight (g)	65.041 ± 5.363	47.811 ± 4.161	83.997 ± 4.039

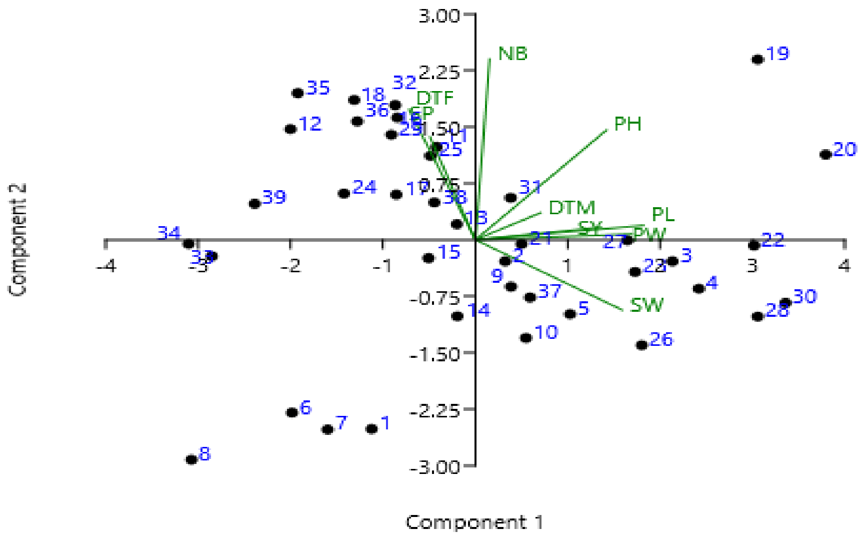

Figure 2: The first (X-axis) and second (Y-axis) principal component projection of 39 faba bean genotypes used in the present study. The dispersal of the 39 genotypes in the four quadrants of the biplot suggest appreciable genetic variability

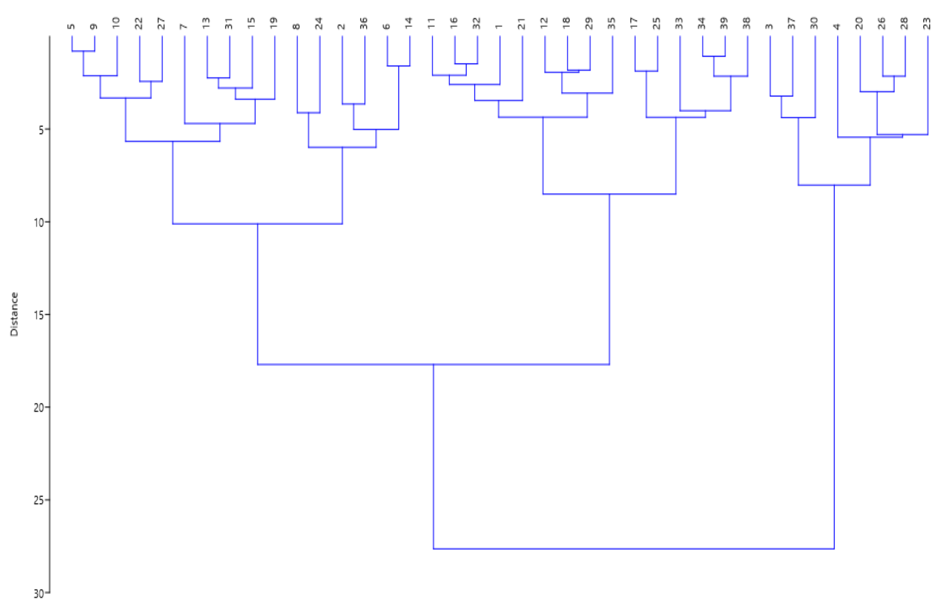

Figure 3: Unweighted pair group method with arithmetic average (UPGMA) cluster for the 39 faba bean genotypes based on 9 agronomic variables

of the total variations (Tables 6 and 7). The first principle component (PC1) demonstrated 38.86% of the total variation and was positively associated with pod length, pod width and 100-seed weight traits. Major effective traits in PC2 accounting for 19.54% variance were days to 50% flowering and no. of branches/plant, while PC3 demonstrated 11.79% variance and associated negatively with trait days to 80% maturity. The first PC thus, was more related to yield contributing traits while PC2 and PC3 solely to vegetative growth. Traits loading more on these first three principal components with Eigen values greater than 1 and contributing around 70% of the variance were used to cluster 39 faba bean genotypes into closely related groups. The critical examination of the dendrogram generated from an unweighted pair group method analysis (UPGMA) after the cluster analysis and PCA, revealed three clusters (Figures 2 and 3). The mean value ± SD of all the traits studied of these three clusters are presented in Table 8. Sixteen (16) genotypes representing 41% of the total genotypes grouped in cluster 1 with medium 100-seed weight. Cluster 2 with fifteen (15) genotypes has lower 100-seed weight and plant height. On the other hand cluster 3 with eight (8) genotypes recorded highest plant height, pod length, pod width, seed yield/plant and 100-seed weight. Average 100-seed weight of 65.041, 47.811 and 83.997 g was recorded for clusters 1, 2 and 3, respectively. Interestingly cluster 2 with lowest 100-seed weight also exhibited lowest average plant height of 68.9 cm, while cluster 3 with highest 100-seed weight recorded highest plant height as well. Average pod length and pod width was also lower in cluster 2. Short stem and smaller seeds are believed to be primitive characteristics and that small seed/pod features are said to be dominant over larger, more recent seed types (Cubero and Nadal, 2005). Broadly speaking our study has thus revealed the occurrence of three size classes of faba beans in Kashmir as three clusters differed appreciably in 100-seed weight. Thus, three distinct clusters were observed mainly on the basis of greater morphological similarity than place of collection in the present study as a result of the multivariate analysis. These findings corroborate earlier similar studies on faba beans (Duc *et al*., 2010, Chaeib *et al*., 2011, Laureles *et al*., 2019). According to Duc *et al.* (2010), the response of genotypes is differential since the adaptation to the environment and its interaction with it is determinant in a desirable phenotypic expression. Interestingly, all the 8 genotypes in cluster 3 are topmost in 100-seed weight among 39 genotypes studied. The average plant height, pod length and pod width besides 100-seed weight in this cluster are higher than the other two clusters, and these traits show strong positive correlations. Thus, while revealing good amount of variability in local faba bean collections, the present study provides an opportunity to select adapted genotypes with good yield potential traits.

Conclusion

The results of the current study showed high genetic diversity in faba bean genotypes collected from different areas of Kashmir. Significant variability has been recorded in traits of plant height, number of branches/plant, pod length, pod width, number of seeds/pod, seed yield/plant and 100-seed weight. Principal component and cluster analysis have revealed three distinct clusters, mainly on the basis of greater agro-morphological similarity. Genotypes with the highest average plant height, pod length, pod width, seed yield/plant and 100-seed weight were clustered in a separate group; all these traits showed significant positive correlations. Pod yield/plant evaluated during single year of 2021–22 also showed significant variation among the genotypes. These traits, therefore, should be given due consideration while performing selection for improving the performance of faba bean crop in the region. From the present study, it is also concluded that since the production response in faba beans is closely linked to the availability of water during the production phases, adequate rainfall during the months of active growth *i.e.*, March-May in dryland areas of Kashmir is very crucial for raising a good faba bean crop. Thus, assured irrigation can enhance the overall performance of faba bean crop.

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