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Research Article

Characterization of pinto and cranberry bean (*Phaseolus vulgaris* L.) landraces from western Himalayan Kashmir for yield and quality

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Abstract

The present study aimed to characterize pinto and cranberry bean landraces of Kashmir valley. A set of 30 genotypes including 16 pinto and 12 cranberry type bean landraces and two checks *viz*., Shalimar Rajmash-1 (SR-1) and Shalimar French Bean-1 (SFB-1) were evaluated for seven qualitative and 10 quantitative traits. There was a substantial variation among 30 accessions (28 landraces and 2 checks) evaluated for all the traits. Out of 28 landrace accessions, 13 were bushy type and 15 were pole type. Pods were predominantly green and seed colour was predominantly brown with characteristic mottling of varying colour shades. Out of 30 accessions, 16 were medium sized with oval seeds. There was substantial variability as depicted by a wide range for both morphological and seed quality traits pertaining to water absorption as well as protein content and phytic acid. The heat map revealed that seed yield had a significant correlation with the number of pods per plant (0.505), followed by seed length (0.455) and seeds per pod (0.414). Similarly, water absorption percentage was significantly correlated with hydration coefficient followed by seed wet weight and hydration capacity but was negatively correlated with hard shell percentage and coat proportion. Principal component analysis based on the seed yield and related traits concentrated the variability in the first three components for morphological traits and four components for seed quality traits explaining 67.23 % and 78.60 % variation, respectively. A number of desirable genotypes could be identified based on consistent performance for various maturity, yield and seed quality traits including high protein and low phytic acid content.

Keywords: Common bean, Western Himalayas, Pinto beans, Cranberry beans, Cooking quality, Seed protein, Phytic acid

INTRODUCTION

The Himalayan state of Jammu and Kashmir is known for its huge diversity of crops including the genus *Phaseolus*. In the state, two *Phaseolus* species are cultivated with *Phaseolus vulgaris* being the principal specie and *Phaseolus coccineus* (Scarlet runner bean) found sporadically in some areas. However, due to its longer maturity period, indeterminate growth habit and leathery pods scarlet bean is not preferred as much. Common bean (*Phaseolus vulgaris* L.) is mainly consumed as dry (mature) beans, shell beans (physiologically matured seeds) as well as green pods. Driven by its use, bean diversity is largely composed of the small and large seeded red beans, pinto and cranberry beans as well as vegetable type snap and shelled beans.

Historically, the genetic diversity in common beans in Kashmir was largely represented by local landraces of small seeded red beans that have adapted to lower yields under low input farming system and the modern varieties have found little favour and the traditional landraces have persisted through times. In Kashmir valley, substantial diversity in beans has been reported by various earlier workers (Sofi *et al.,* 2014, Iram Saba *et al.,* 2016, Choudhary *et al.,* 2017) for yield and quality traits. Across the world, farmers highly value their seeds, they are part of their cultural heritage and they like to grow and "*conserve*" local varieties as the way to keep traditions (Lhome, 2005). These landraces have evolved under natural and farmer-driven selection processes under diverse eco-geographies and have developed useful genes and alleles related to adaptability, fitness, resilience and quality. These are locally adapted and also possess co-adapted gene complexes with less linkage drag and as such can be easily mainstreamed in breeding programmes (Dwivedi *et al.,* 2016).

In addition to the small red seeded, there is huge diversity in mottled beans (pinto and cranberry). Pinto beans are invariably oval to cuboidal in shape with 100-seed weight of 25-35 g, while as cranberry beans are large seeded kidney shaped beans mostly with typical red or cran markings. Both types have a vast diversity of size, colour and seed coat marking pattern that ranges from small dots to stripes and speckles of different colour shades and intensities. Both these classes fetch a premium price in view of attractive seed colour and pattern, excellent cooking quality and better nutritional quality. Both these classes are important especially in the low input marginal farming system and not only act as a cheap source of protein but also an important livelihood source. In view of the agricultural importance of pinto and cranberry beans, the present study was conducted to assess the variability and trait association in pinto and cranberry landraces of Kashmir Himalayas for morphological, yield and seed quality traits.

MATERIALS AND METHODS

A set of 30 genotypes including 16 pinto and 12 cranberry type bean landraces collected from six districts of Jammu and Kashmir, and two checks *viz*., Shalimar Rajmash-1 (SR-1) and Shalimar French Bean-1 (SFB-1) released by SKUAST-Kashmir were used in the present study. The geographical location of collection sites of the accessions are given in **Fig. 1**. The landraces represented diverse market classes based on growth habit, seed colour, shape and size.

The present study was conducted during 2016-2020 at the research fields of various constituent research stations of SKUAST-Kashmir. The main evaluation for most of the traits was carried out at research fields and greenhouse facility of the Division of Genetics and Plant Breeding, Faculty of Agriculture Wadura, SKUAST-K, Sopore (34° 17′ North and 74° 33′ E at an altitude of 1594 MSL). The soil of the main experimental site at Wadura is a typical inceptisol with a clay loam texture. The pH was almost neutral (7.2), with organic carbon 0.65%, the electrical conductivity of 0.18 dS/m and CEC of 16 meq/kg. All the accessions were grown five row plots of four-meter length, with a spacing of 15 cm x 30 cm for bush and 15 x 70 cm for pole types. Recommended crop management practices as per SKUAST-K package of practices were followed to ensure a good crop.

The data were recorded for 17 traits that included seven qualitative traits of economic importance (growth habit, pod colour, pod markings, pod cross sectional shape, seed colour, seed shape and seed size) and 10 quantitative traits *viz*. days to flowering (DF), days to maturity (DM), plant height (PH), pod length (PL), pods per plant (PPP), seeds per pod (SPP), seed length (SL), seed breadth (SB), 100-seed weight (100SW) and seed yield per plant (SYPP), measured on different scales from randomly selected five plants of each genotype. Observations were recorded using minimal descriptors for common bean characterization and evaluation available from PPVFRA (Protection of Plant Varieties and Farmers Rights Authority, India). The observations on days to flowering, days to maturity and seed yield per plant were taken on a plot basis.

The biochemical parameters recorded were protein content and phytic acid. The protein content was estimated using the Near Infrared Reflectance Spectroscopy (CROP SCAN 2000G) facility available at Seed Technology Laboratory of SKUAST-K. It is a quick and non-destructive method for the estimation of protein content. Phytic acid content (mg/g) was estimated according to the modified Haug and Lantzsch (1983) method. The determination was based on the indirect spectrophotometric determination of phytic phosphorus in dry bean extracts. Phytic acid was precipitated by the addition of ferric ammonium sulphate. Part of iron forms insoluble ferric phytate and the remaining iron was determined spectrophotometrically at 519 nm. A calibration curve was prepared by a series of standard solutions of a sodium salt of phytic acid.

Ten seed quality traits that define water absorption parameters such as seed dry weight, seed wet weight, water absorption percentage (%), swelling coefficient (%), swelling capacity, hydration coefficient (%), hydration capacity and coat proportion (%), were calculated for each accession using ambient stored seed samples equilibrated to uniform moisture condition following standard methods of Bishnoi and Khetarpaul (1993) and Youssef (1978). Seed coat proportion was determined on 20 seeds per accession, as the ratio in weight between coat and cotyledon expressed in percentage, after removing the seed coat from the cotyledons, both after soaking and keeping them for 24h at 105°C. The bulk density of the bean seeds was calculated using the standard method of Shimelis and Rakshit (2005). 100 g of the sample seeds were transferred to a measuring cylinder, which had 100 ml of distilled water at 20° C. Seed volume (ml/100 g seeds) was obtained after subtracting 100 ml from the total volume (ml). The bulk density was then calculated and recorded in g/ml. Hard shell percentage was done as per the method of Correa *et al*. (2010). The samples were washed and immersed for 8 hours in distilled water and the seeds that did not absorb water were counted. These grains were visually verified for shell wrinkling and those without wrinkles were treated as hard shell. The result was expressed as hard-shell percentage (without water-holding capacity). The bulk density of the bean seeds was calculated using the standard method of Shimelis and Rakshit (2005). 100 g of the sample seeds were transferred to a measuring cylinder, which had 100 ml of distilled water at 20ºC. Seed volume (ml/100 g seeds) was obtained after subtracting 100 ml from the total volume (ml). The bulk density was then calculated and recorded in g/ml.

The quantitative traits were analyzed for various statistical parameters viz., mean, range, variance, correlation and principal component analysis (PCA). Before pooling the data, the homogeneity of variances was tested. PCA was done using JASP (CIMMYT)

RESULTS AND DISCUSSION

There was a substantial variation among 30 accessions (28 landraces and 2 checks) evaluated for all the traits. Out of 28 landraces accessions 13 were bushy type and 15 were pole type with varying degrees of twinning. Pods were predominantly green. Seed colour was predominantly brown (15) followed by dark red (6), white and pink (02 each) and light red, black and chocolate (01 each). In all these landraces, seeds had characteristic mottling of varying colour shades ranging from stripes (WBP-7, WBP-8 and WBP-13) to specks (in other landraces) (**Fig. 1** and **2)**. In terms of seed size, most of the accessions (20) were medium sized (25-40 g), while as eight had large seed size (>40 g). Out of 28 accessions, 13 had oval seeds, three were cuboidal and 12 were kidney shaped. Substantial variation has been reported in western Himalayan beans by Sofi *et al.* (2014a) and Rana *et al.* (2015) for various for qualitative traits based on growth habit, seed colour, shape, size and mottling pattern.

Morphological and Seed yield traits: Among quantitative traits data was recorded for days to flowering, days to maturity, plant height, the number of pods, pod length, seeds per pod, seed length, seed breadth, 100-seed weight and seed yield per plant. The mean data and descriptive statistics pertaining to morphological and seed yield parameters are given in **Tables 1 and 3,** respectively. Days to flowering had a mean value of

Fig. 1. Variation in seed colour, shape and mottling pattern in pinto beans

Fig. 2. Variation in seed colour, shape and mottling pattern in cranberry beans

46.54. Based on the five year mean data, genotypes WBP1 (35), WBP2 (38) and WBC2 (39) were early to flower (<40 days) whereas genotype WBP14 was late to flower (52 days). Genotypes WBP1, WBP2 were early to mature (68 days) whereas WBC4 (92) and WBP9 (90) were late to mature. In terms of plant height 13 genotypes were the short bush type with height as small as 32.33 cm (WBP1) and 15 were typical indeterminate types with height as high as 240 cm (WBC1). The number of pods had a mean value of 16.01 with genotypes such as WBP6 (40.12) and WBC4 (38.45) had very high pod number and WBC3 (4.67) and WBC2 (5.33) had very low pod number. Pod length had a mean value of 11.78 cm with the longest pods recorded in WBP12 (18.25 cm) and the smallest pod recorded in WBC9 (8.50 cm). Seeds per pod ranged from 3.34 (WBP2) to 6.23 (WBP12) with a mean value of 4.31. Seed length had a mean value of 1.43 cm with the longest seed recorded in WBC1 (1.88 cm) and the smallest seed length recorded in WBP13 (1.07 cm). Seed breadth was highest in WBP11 and WBP12 (0.96 cm) and smallest in WBC8 (0.62 cm). The mean value for 100 seed weight was 37.37 g with the largest 100-seed weight as large as 60.83 g (WBC1) and the lowest value for WBP1 (22.55 g). Seed yield also had a very broad range with genotypes WBC3 (5.67 g) as the low yielder and WBP12 (46.88 g) and WBP3 (45.33 g) being the highest yielder.

The western Himalayan region is a rich repository of bean genetic resources evolved over generations of farmer selection and substantial variability in Western Himalayan bean landraces has been reported in earlier studies across different qualitative traits (Rani Shama *et al.,* 2019, Sofi *et al.,* 2020, Jan *et al.,* 2021). Despite the fact that most of the accessions had similar seed characteristics as well as plant growth habits on account of similar ecology *viz*., intercropping, there was substantial variability for various qualitative traits such as pod shape and curvature, quantitative traits including those related to phenology and yield. This diversity has arisen on account of varied selection pressures and farmer preferences for seed colour and plant type. However, among, the lines studied a number of desirable genotypes could be identified based on consistent performance between 2016-2020 for various quantitative traits such as maturity (WBP1, WBP2, and WBP8). Similarly for yield components, WBP6 and WBC4 had high pod number; WBP5, WBP12 and WBC11 had higher pod length; WBP12, WBP14, WBP15 and WBC8 had high seed number, while as WBC1, WBC6 and WBC9 had large seeds. Seed yield also had a very broad range with genotypes WBP3, WBP4, WBP6, WBP12 and WBC1 being the highest yielder. In Kashmir valley, substantial diversity in beans has been reported by various earlier workers (Iram Saba *et al.,* 2016, Sofi *et al.,* 2020 and Jan *et al.,* 2021) for yield and quality traits, even though the spectrum of diversity may be comparatively lesser as the pinto and cranberry beans form a small subset of landrace diversity of beans in Western Himalayan Kashmir valley that comprises huge diversity in small seeded red beans,

Table 1. Mean performance for seed yield and its component traits in pinto and cranberry beans

Genotype	DF	DM	PH	NOP	PL	SPP	SL	SB	100SW	SYPP
WBP1	35	68	32.33	9.67	9.60	3.89	1.64	0.71	22.55	24.50
WBP2	38	68	46.00	6.33	10.80	3.34	1.28	0.72	35.27	9.12
WBP3	46	77	52.33	14.42	12.30	4.45	1.69	0.84	36.75	45.33
WBP4	50	87	49.33	15.64	13.20	5.12	1.81	0.88	34.33	31.09
WBP5	44	80	46.33	6.00	14.40	5.34	1.61	0.74	34.77	20.66
WBP6	51	83	154.00	40.12	10.15	3.88	1.14	0.75	32.43	40.28
WBP7	52	89	244.00	18.75	10.8	3.56	1.24	0.78	31.18	11.98
WBP8	35	68	42.00	10.33	13.00	3.95	1.29	0.71	39.68	16.22
WBP9	55	90	213.67	15.25	12.85	4.12	1.58	0.89	31.80	26.33
WBP10	44	83	51.67	11.00	13.00	4.44	1.18	0.64	29.06	14.21
WBP11	46	79	181.00	15.91	8.87	3.44	1.21	0.96	36.44	18.98
WBP12	51	86	213.33	21.83	18.25	6.23	1.69	0.96	35.65	46.88
WBP13	50	83	213.33	26.42	12.90	4.13	1.07	0.63	23.93	25.67
WBP14	52	85	193.00	16.95	9.90	5.12	1.25	0.66	33.49	22.45
WBP15	44	79	50.00	12.67	11.20	5.36	1.41	0.79	32.77	27.77
WBP16	45	79	205.00	20.11	9.20	4.26	1.31	0.84	35.90	26.14
WBC1	45	86	175.00	19.00	11.25	4.33	1.88	0.72	60.83	35.78
WBC2	39	78	47.00	5.33	11.60	4.66	1.38	0.78	43.45	11.85
WBC3	44	78	46.00	4.67	10.00	3.73	1.18	0.67	31.40	5.67
WBC4	51	92	88.33	38.45	10.10	3.98	1.21	0.68	43.45	29.57
WBC5	51	88	181.33	18.67	11.30	4.06	1.82	0.78	44.76	22.89
WBC6	45	78	37.67	10.00	10.00	3.93	1.46	0.88	58.33	18.98
WBC7	51	82	186.67	17.31	8.60	3.55	1.34	0.76	43.22	18.28
WBC8	44	78	53.67	13.00	13.80	5.33	1.21	0.62	29.60	15.86
WBC9	51	96	183.33	16.20	8.50	3.53	1.58	0.77	54.28	19.34
WBC10	54	89	63.33	10.13	13.33	4.33	1.48	0.69	35.57	15.20
WBC11	49	77	240.00	10.66	16.60	3.66	1.42	0.80	42.80	14.69
WBC12	51	87	211.67	15.26	8.20	4.40	1.24	0.85	43.16	24.19
SR1 (Check)	44	83	46.82	10.40	13.88	4.26	1.61	0.72	38.54	32.07
SFB 1 (Check)	39	79	42.04	29.66	15.94	5.01	1.57	0.63	25.75	27.21

DF= days to flowering; DM=days to maturity; PH= plant height (cm); PL= pod length (cm); NOP= pods per plant; SPP= seeds per pod; SL = seed length (cm); SB= seed breadth (cm); 100-SW= 100 seed weight (g); SYPP= seed yield per plant (g)

kidney beans as well as other market classes. Elsewhere, significant diversity in pinto and cranberry beans has been reported in Turkey (Balkaya and Ergun, 2008), Pakistan (Nawaz and Farhatullah, 2020), and Africa (Mukankusi *et al.,* 2019).

Seed quality parameters: There was substantial variability as depicted by a wide range for seed quality traits pertaining to water absorption as well as protein content and phytic acid (**Table 2 and 3**). Seed weight after soaking had a mean value of 79.26 g with range of 41.89 g (WBC4) to 163.01 g (WBC1). Water absorption percentage also had a broad range from 55.08 (WBC3) to 168.10 per cent (WBC1). A similar trend was recorded for hydration coefficient and hydration capacity. For swelling coefficient, mean value was 185.97 with a range of 112.35 (WBP5) to 263.10 (WBC3). Similarly, swelling capacity also had a broad range from 0.06 (WBP10) to 0.55 (WBP* and WBP9). Coat proportion had a mean value of 16.62 per cent with the lowest value recorded for WBP3 (10.48 %) and the highest value recorded for WBP12 (23.96%). Bulk density ranged from 0.82 (SFB-1) to 3.47 (WBC1). Similarly, the proportion of hard shells after soaking had a mean value of 12.87 per cent with a range of 5.02 per cent (WBP13) to 25.89 (WBC5). In terms of seed biochemical parameters, protein content

Table 2. Mean performance for seed quality traits in pinto and cranberry beans

Genotype	SDW	SWW	WA %	H CO	H CA	S CO	S CA	CP	BD	HS	PRO	PA
WBP1	22.55	57.62	156.41	256.41	0.35	164.81	0.13	13.11	1.19	6.35	20.44	0.57
WBP2	35.27	87.88	149.53	249.53	0.52	193.47	0.22	16.50	1.47	12.34	19.23	0.75
WBP3	66.75	128.99	93.25	193.25	0.62	135.07	0.15	10.48	1.51	20.35	18.43	0.59
WBP4	54.33	131.82	142.62	242.62	0.77	139.71	0.15	13.82	1.40	11.70	18.62	2.33
WBP5	44.77	97.80	118.91	218.91	0.53	112.35	0.05	15.55	1.13	8.26	19.80	0.38
WBP6	32.43	51.03	57.19	157.19	0.18	188.57	0.27	22.05	1.11	11.06	17.89	1.02
WBP7	31.18	65.20	109.17	209.17	0.34	150.08	0.15	15.95	1.04	14.31	17.94	2.20
WBP8	39.68	83.63	110.88	210.88	0.44	258.42	0.55	18.83	1.14	13.98	19.09	1.64
WBP9	61.80	141.75	129.44	229.44	0.80	178.75	0.55	11.94	0.88	13.75	19.23	2.66
WBP10	29.06	65.88	127.22	227.22	0.37	123.94	0.06	13.66	1.09	5.14	19.39	1.30
WBP11	46.44	102.06	119.89	219.89	0.55	177.96	0.35	13.04	1.04	15.04	18.56	2.36
WBP12	65.65	137.49	109.46	209.46	0.72	139.75	0.20	23.96	1.31	14.73	19.44	1.47
WBP13	23.93	53.86	124.99	224.99	0.30	226.79	0.25	16.22	1.21	5.02	18.05	2.25
WBP14	33.49	57.45	71.86	171.86	0.24	233.12	0.37	16.49	1.20	19.87	18.18	2.25
WBP15	42.77	90.72	112.08	212.08	0.48	176.80	0.30	13.92	1.08	15.89	22.15	3.15
WBP16	35.90	80.80	125.16	225.16	0.45	189.74	0.22	21.34	1.49	10.53	19.97	0.44
WBC1	60.83	163.01	168.10	268.10	1.02	177.65	0.13	11.98	3.47	12.67	19.03	3.90
WBC2	43.45	102.06	135.05	235.05	0.58	150.00	0.20	21.85	1.09	5.84	20.21	1.60
WBC3	31.40	48.73	55.58	155.58	0.17	263.10	0.43	11.18	1.19	10.38	18.29	2.13
WBC4	23.45	41.89	78.76	178.76	0.18	219.28	0.27	20.17	1.03	13.00	20.61	3.11
WBC5	44.76	85.05	90.02	190.02	0.40	137.99	0.11	16.44	1.47	25.89	19.60	4.24
WBC6	58.33	117.56	101.52	201.52	0.59	178.75	0.33	17.29	1.39	15.87	18.38	2.55
WBC7	43.22	81.89	89.77	189.77	0.38	210.93	0.42	20.22	1.14	11.04	18.51	2.54
WBC8	29.60	70.87	139.46	239.46	0.41	202.34	0.25	15.36	1.21	8.23	19.52	4.10
WBC9	54.28	104.72	92.91	192.91	0.50	178.68	0.23	19.60	1.83	20.35	18.60	2.70
WBC10	35.57	86.46	143.05	243.05	0.51	233.71	0.40	17.22	1.19	12.00	19.58	2.33
WBC11	42.80	67.89	58.48	158.48	0.25	127.60	0.13	22.23	0.91	18.10	17.36	2.75
WBC12	43.16	80.80	87.23	187.23	0.37	225.44	0.50	11.94	1.08	16.75	17.39	2.59
SR1 (Check)	42.22	92.13	118.28	218.28	0.49	183.09	0.33	20.54	1.07	11.74	19.97	4.16
SFB 1 (Check)	28.77	83.63	191.40	291.40	0.55	301.09	0.70	15.48	0.82	5.82	17.84	2.21

SDW= seed dry weight (g), SWW= seed wet weight (g), WA%= water absorption percentage, HCO= hydration coefficient, HCA= hydration capacity, SCO= swelling coefficient, SCA= swelling capacity, CP= coat proportion (%), BD= bulk density (g/m^3), HS= hard shell (%), PRO= protein content (%), PA= phytic acid (mg/g).

ranged from 17.36 (WBC11) to 22.15 per cent (WBP15). Similarly, the anti-nutritional factor namely phytic acid ranged from 0.38 mg/g (WBP5) to 4.24 mg/g (WBC5). The food value of common bean is largely confined to local consumer preferences and as such, traditional varieties and landraces offer great value to plant breeders as they possess better quality. Substantial variability has been reported in seed quality traits in local and exotic common bean in Kashmir by Iram Saba *et al.* (2016) and Sofi *et al.* (2020). In the present study, four accessions viz., WBP1, WBP15, WBC2 and WBC4 had protein content in excess of 20 per cent whereas, two accessions WBP5 and WBP16 had phytic acid below 0.5 mg/g. These lines can be used in breeding programmes for high protein and low phytic acid content.

The Pearson correlation coefficients for morphological and seed yield traits are presented as a heat map (**Fig. 3**). Seed yield had a significant correlation with the number of pods per plant (0.505), followed by seed length (0.455) and seeds per pod (0.414). Among other trait correlations, days to maturity were significantly correlated with days to flowering (0.835) and seeds per pod were significantly correlated with pod length (0.564).

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Table 3. Descriptive statistics for agro-morphological and seed quality traits in pinto and cranberry beans

Trait	Mean ± SE	Minimum	Maximum
Days to flowering	46.54 ± 0.99	35.00	55.00
Days to maturity	81.85 ± 1.23	68.00	96.00
Plant height (cm)	120.01 ± 14.76	32.33	280.00
Number of pods	16.01 ± 1.57	4.67	40.12
Pod length (cm)	11.78 ± 0.54	8.20	18.25
Seeds per pod	4.31 ± 0.12	3.34	6.23
Seed length (cm)	1.43 ± 0.04	1.07	1.91
Seed breadth (cm)	0.76 ± 0.02	0.62	0.96
100-seed weight (g)	37.37 ± 1.65	22.55	60.83
Seed yield per plant (g)	23.64 ± 1.92	5.67	46.88
Seed dry weight (g)	37.37 ± 1.65	22.55	60.83
Seed wet weight (g)	79.26 ± 5.49	48.85	163.09
Water absorption (%)	113.59 ± 5.99	55.58	191.40
Hydration coefficient	213.59 ± 5.99	155.58	291.40
Hydration capacity	0.47 ± 0.03	0.17	1.02
Swelling coefficient	185.97 ± 8.27	112.35	301.10
Swelling capacity	0.28 ± 0.03	0.05	0.70
Coat proportion (%)	16.62 ± 0.68	10.48	23.96
Bulk density (g/m^3)	1.28 ± 0.08	0.82	3.47
Hard shell (%)	12.87 ± 0.92	5.02	25.89
Protein content (%)	19.04 ± 0.19	17.36	22.15
Phytic acid (mg/g)	2.21 ± 0.20	0.38	4.24

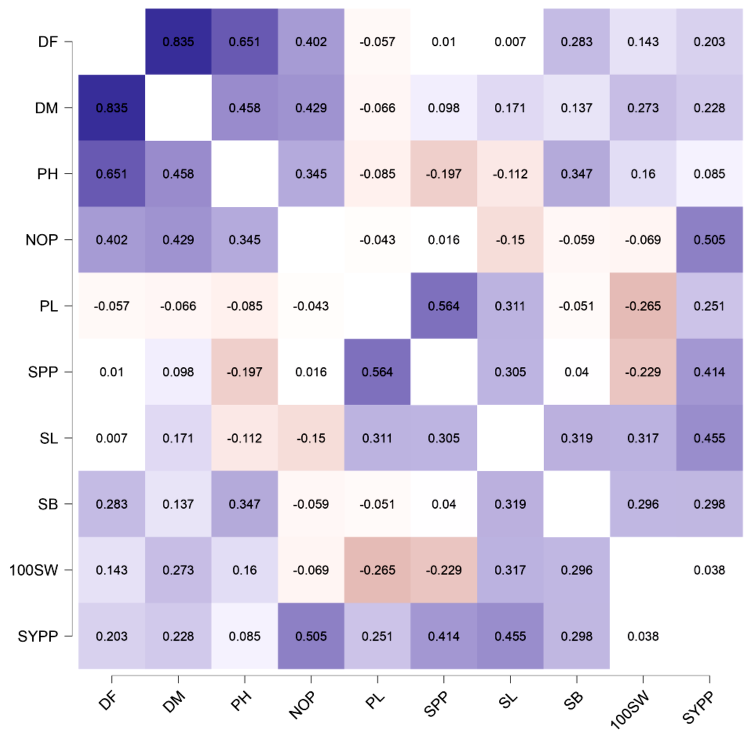

Fig. 3. Correlation heat map for morphological and yield traits in pinto and cranberry landraces

The Pearson correlation coefficients for seed quality traits are presented as a heat map (**Fig. 4**). Water absorption percentage was significantly correlated with hydration coefficient (1.00) followed by seed wet weight (0.697) and hydration capacity (0.608), but was negatively correlated with hard shell percentage (-0.520) and coat proportion (-0.254). Phytic acid was positively correlated with seed dry weight (0.377) followed by seed wet weight (0.328) and hard shell percentage (0.316).

Since the variation in quantitative characters is often influenced by variation in other characters either due to pleiotrophy or genetic linkage, the knowledge about trait associations between yield and its component traits is imperative to identify key characters for selection for grain yield as direct selection for a complex trait like yield, is invariably less rewarding (Sofi *et al.,* 2020). The results of the present study indicate that selection for pods per plant, seed length and seeds per pod may favor improvement in seed yield and should be given high priority during selection for grain yield in pinto beans. Similarly, for developing beans with desirable cooking quality, coat proportion and hard shell should be selected against. Similar results have also been reported in Indian common bean collection by Rana *et al.* (2015), Iram Saba *et al.* (2016) and Sofi *et al.* (2020).

Principal component analysis based on ten seed yields and related traits concentrated the variability in the first three principal components. The criterion used based on eigen value of > 1 forthe first three PC's explained 67.23 % (**Table 4**). Latent roots (Eigen values) for significant PCs ranged from 2.94 (PC1) to 1.58 (PC3). The first two PC's that were used for constructing the PCA biplot (**Fig. 5**) graph explained 51.40 % of total variation (PC1 accounted for 29.42 % of the total variation while PC2 accounted for 21.98% variation. The traits that mainly contributed to PC1 were days to flowering and days to maturity, plant height and the number of pods per plant while as in PC2 and major contributors were seeds per pod, seed length, seed breadth and 100-seed weight, while as seed yield per plant was a major contributor to PC3. Seed length and seed breadth were common to PC2 and PC3, whereas, pod length did not contribute to any PC. Thus PC1 can be designated as a component of maturity and PC2 and PC3 can be designated as components of productivity.

Principal component analysis based on 12 seed quality traits concentrated the variability in the first four principal components based on eigen value of unity or more. The first four PC's explained 78.60 % (**Table 5**). Latent roots (Eigen values) for significant PCs ranged from 3.55

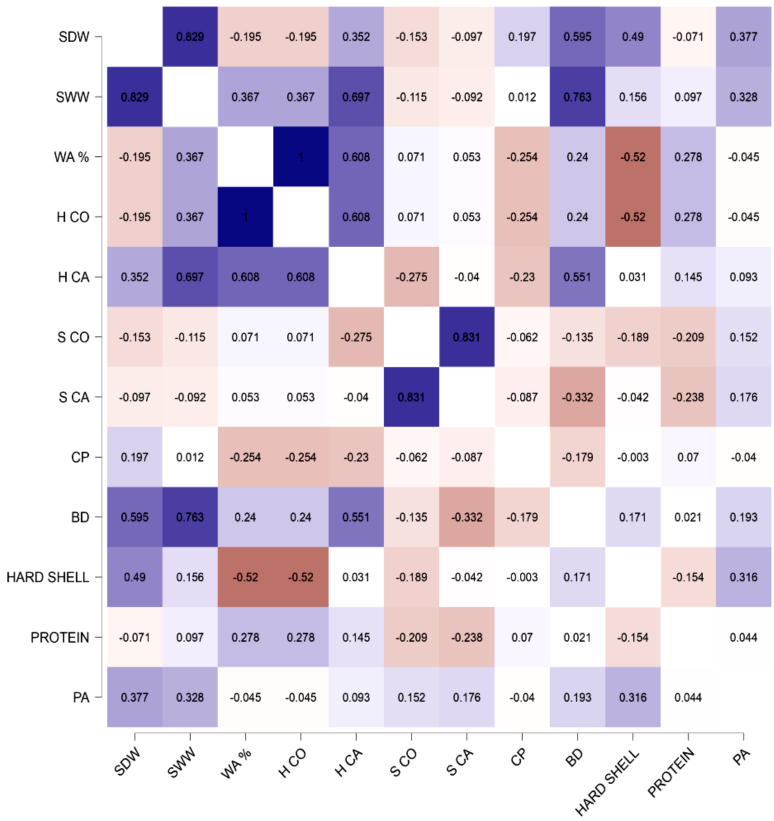

Fig. 4. Correlation heat map for seed quality traits in pinto and cranberry landraces

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Table 4. Eigen values and variation accounted by first four principal components yield and its component traits

Principal component	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
Eigen value	2.94	2.20	1.58	0.94	0.85	0.54	0.41	0.26	0.18	0.08
Percent variation accounted	29.42	21.98	15.83	9.43	8.47	5.38	4.15	2.65	1.84	0.86
Cumulative variation accounted	29.42	51.40	67.23	76.66	85.13	90.51	94.66	97.31	99.15	100.00

Table 5. Eigen values and variation accounted by first four principal components for quality traits

Principal component	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11	PC12
Eigen value	3.55	2.82	1.96	1.10	0.93	0.60	0.53	0.29	0.19	0.02	0.01	0.00
Percent variation accounted	29.58	23.48	16.33	9.21	7.79	4.97	4.44	2.44	1.58	0.15	0.003	0.00
Cumulative variation accounted	29.58	53.06	69.39	78.60	86.39	91.36	95.80	98.24	99.82	99.97	100.00	100.00

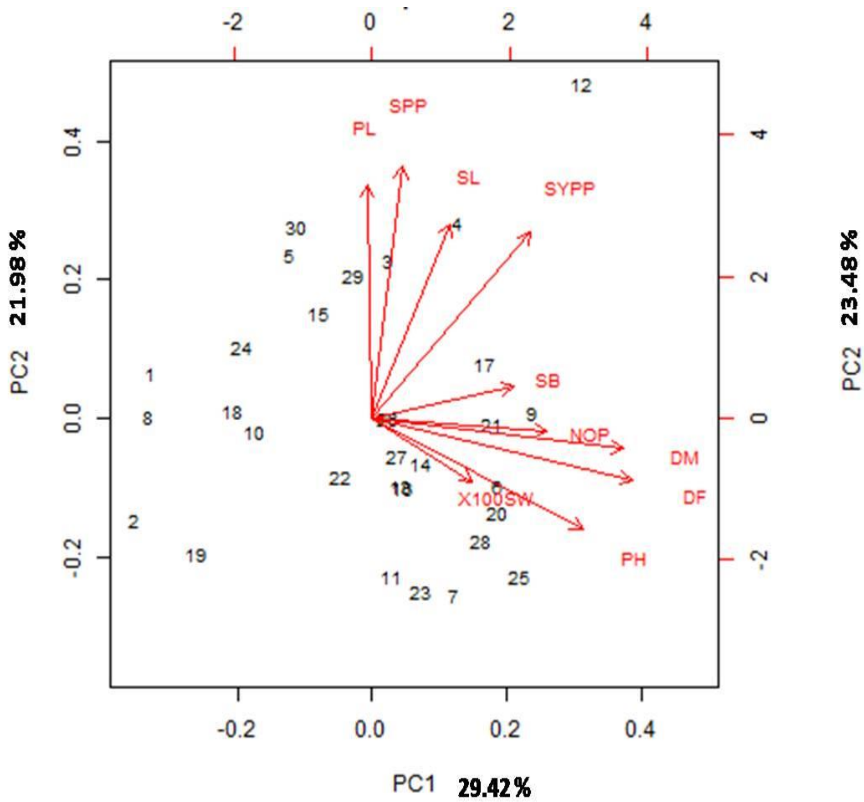

Fig. 5. GT biplot for seed yield and its component traits in pinto and cranberry beans

(PC1) to 1.10 (PC4). The first two PC's that were used for constructing PCA biplot (**Fig. 6**) graph explained 53.06 % of total variation (PC1 accounted for 29.58 % of the total variation while PC2 accounted for 23.48% variation). Seed dry weight, seed wet weight and bulk density is major contributors to PC1, while as water absorption percentage and hydration coefficient are major contributors to PC2. Similarly, swelling coefficient and swelling capacity are the main contributors to PC3 and coat proportion is the main contributor to PC4. Except for hard shell, all other traits contributed positively to respective PC's **(Table 6)**.

The genotype-trait biplot indicated various trait correlations based on the proximity and angle of two vectors (Yan and Rajcan, 2002). In a PCA biplot, close alignment of trait rays forming a small acute angle corresponds to a strong

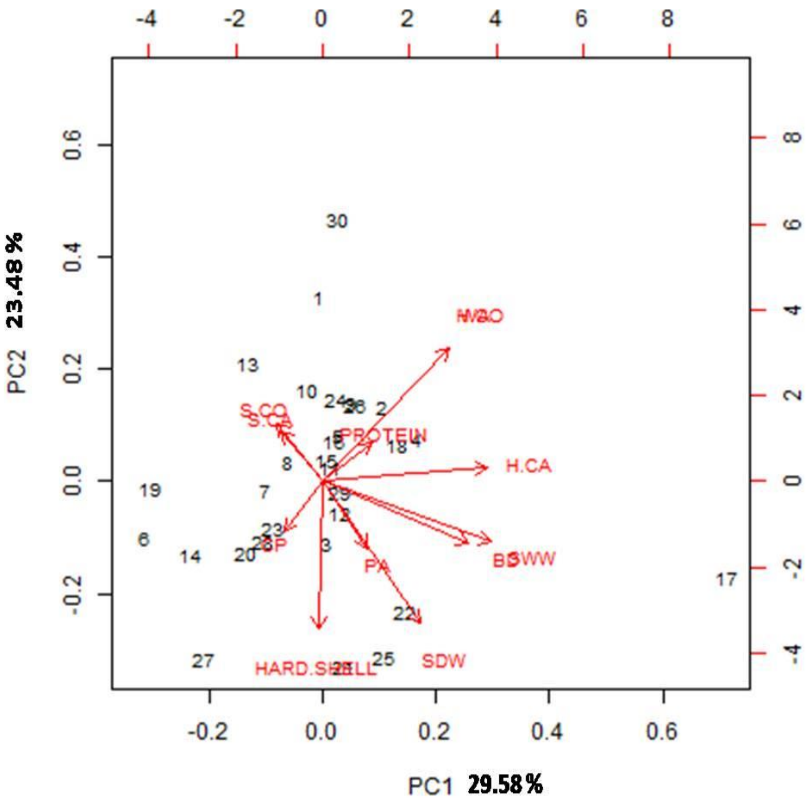

Fig. 6. GT biplot for seed quality traits in pinto and cranberry beans

positive correlation. In the present study, based on the factor loading graph, the number of pods per plant, seeds per pod and seed length are strongly positively correlated with seed yield per plant. Similarly, for seed quality traits water absorption which is an important determinant of cooking quality in beans is significantly influenced by hydration coefficient and hydration capacity but is negatively correlated with coat proportion and hard shell percentage. The nature and level of trait relationships may not be in complete conformity to correlation heat maps as the GT biplot is based on only two components that account for part of total variation, even though the broader contours of trait relations are more or less similar. However, the Genotype-trait graphs derived from the PCA biplot is advantageous over simple correlation data as it enables the comparison of accessions on the basis of the multiple measured variables and as such can be effectively used as independent selection criteria in multiple trait evaluation trials (Yan and Rajcan, 2002). Sofi *et al.* (2014b) evaluated a set of 300 common bean accessions and found for PC1 contained traits related to maturity while as PC2 contained traits related to productivity such as pods per plant, pod length as well as seed yield per plant. Rana *et al.* (2015) have also reported similar results in 4274 accessions preserved in Indian bean bank (NBPGR) with three PC's accounting for about 80 % of variation largely contributed by pods per plant, 100-seed weight, pod length and seed yield. Panchbhaiya *et al.* (2017) and Rani Shama *et al.* (2019) and Sofi *et al.* (2020) also reported similar results in beans.

Delayed cooking and hard to cook trait are important varietal attributes that have shaped up the adoption and persistence of landraces. Western Himalayan landraces are known for better cooking quality and organoleptic characters. In the present study, various water imbibition traits and cooking time scores of the collected landraces were evaluated. Water imbibition parameters *viz*., water absorption percentage, swelling coefficient, hydration coefficient and coat proportion are increasingly used as surrogates for cooking time. Cooking quality is a major varietal attribute in beans and determines the acceptability with end users. The issues related to energy requirements in bean value chain as well as implications of delayed cooking make it a more important focus in breeding programmes. Despite the fact that red seeded landraces are usually good in quality, but there was substantial variability in cooking time score that provides opportunity for selection. However, a major impediment in screening large germplasm sets is the difficulty associated with cooking. In the present study we used water imbibition parameters, coat proportion as well as alkali spreading test as effective surrogates for cooking quality.

Table 6. Component scores (Trait contributions to Principal components) for seed yield and its component traits (A) and seed quality traits (B)

A:Yield and component traits				B:Seed quality traits				
Traits	PC 1	PC 2	PC 3	Variable	PC 1	PC 2	PC 3	PC 4
DF	0.88	NS	NS	SDW	0.93	NS	NS	NS
DM	0.81	NS	NS	SWW	0.94	NS	NS	NS
PH	0.76	NS	NS	WA %	NS	0.97	NS	NS
NOP	0.74	NS	NS	H CO	NS	0.97	NS	NS
PL	NS	NS	NS	H CA	0.57	0.53	NS	NS
SPP	NS	0.84	NS	S CO	NS	NS	0.93	NS
100SW	NS	0.77	NS	S CA	NS	NS	0.94	NS
SL	NS	0.67	0.70	CP	NS	NS	NS	0.87
SB	NS	0.51	0.76	BD	0.73	NS	NS	NS
SYPP	NS	NS	0.69	HS	0.43	-0.69	NS	NS
-	-	-	-	PRO	NS	0.41	NS	0.52
-	-	-	-	PA	0.58	NS	NS	NS

A: DF= days to flowering; DM=days to maturity; PH= plant height; PL= pod length; NOP= pods per plant; SPP= seeds per pod; SL = seed length; SB= seed breadth; 100-SW= 100 seed weight; SYPP= seed yield per plant; **B:** SDW= seed dry weight, SWW= seed wet weight, WA%= water absorption percentage, HCO= hydration coefficient, HCA= hydration capacity, SCO= swelling coefficient, SCA= swelling capacity, CP= coat proportion, BD= bulk density, HS= hard shell PRO= protein content, PA= phytic acid

Iram Saba *et al.* (2016) have also reported substantial variability in cooking quality parameters, organoleptic traits as well as established utility of surrogate traits for cooking quality in bean germplasm of Kashmir.

Given the importance of Western Himalayan region in terms of crop biodiversity resources and sustainability imperatives, local crops that have cultural value need to be conserved through the promotion of large scale cultivation necessitates the development of improved varieties that can compete with cereals. The useful variations for the traits of economic importance and identified genotypes that can be used as trait sources in breeding programmes. Thus, phenotypic characterization, genetic and genomic studies can help harness the trait value of landraces and traditional varieties and help link gene banks and germplasm repositories with farmer's aspirations. Local biodiversity holds value in adaptive traits, organoleptic qualities and resilience to system bottlenecks. Red seeded varieties are the most prominent beans cultivated across whole Himalayan states and not only adds livelihood value to subsistence farming systems but also fetches better prices on account of its quality.

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