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RESEARCH ARTICLE

FABA BEAN (*VICIA FABA* L.) GERMPLASM COLLECTION AND IT'S DIVERSITY IN OMAN

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ABSTRACT

Faba bean (*Vicia faba* L.) is one of the popular pulse crops grown for traditional consumption, not only in Oman but also in Arabian Peninsula and other countries. In Oman, the farmers living in and around high altitude mountain areas mostly grow it. This paper highlights features of variation in seed color and diversity in seed traits found in collected accessions from the joint collecting missions between 2008 and 2011 involving the staff of College of Agriculture, Sultan Qaboos University and the Ministry of Agriculture and Fisheries from all the governorates of the Sultanate of Oman. 41 seed samples/accessions were collected from 38 sites. Of these, the highest number of accessions was collected from Batinah South governorate (28) represented mostly by the mountains of Rustaq, followed by the mountains of Interior/Al-Dakhliyah (8), and Dhahira and Buraimi (4). Only one accession was collected from mountains of the Eastern/ Al-Sharqiyah governorates. The seed accessions were found diverse with respect to all seed characters studied, i.e. seed length (cm) and width (cm) and 100-seed weight (g) besides seed color. The faba bean accessions were classified into 9 genetically diverse clusters based on the Principal Component Analysis, which indicated that the contribution of seed width and 100-seed weight to the total variation existing in indigenous germplasm collected from all the governorates of Oman. It was found from the critical analysis of seed colors that 38 accessions were homogenous (pure) with one color and three were heterogeneous with combinations of colors.

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INTRODUCTION

Faba bean (*Vicia faba* L) is a major legume crop in the world after dry beans, peas and chickpeas (Kumari and Van Leur, 2011). It is used as both food and fodder because of its high lysine-rich proteins, vitamins, minerals and carbohydrates(Crepton *et al.,* 2010). Faba bean has gained greater global attention in recent years because of its ability to grow over wide range of soil and climatic conditions for sustainable agriculture in several marginal areas (Nadal *et al.,* 2003 and Gasim *et al.,* 2015). The Sultanate of Oman is one of the arid countries in the Arabian Peninsula with 85473.10 ha of cultivated agricultural land of which fruits occupy 36.11% followed by perennial and annual fodder crops (39.40%), vegetables (19.72%) and field crops (4.77%)(MAF, 2017). Of the minimum field crop area, the area under faba bean (*Vicia faba* L.) is very insignificant and not documented. However, it forms an essential crop during winter between November and April among only with few interested farmers in the plains and mountainous areas of North Oman grown primarily for its edible seeds (beans). Faba bean has been divided into distinct groups based on seed size as small seeded (0.2 to 0.8 g per seed), medium and large seeded ones (1.0 to 2.6 g per seed) which have significance from marketing view point (Zeid *et al.,* 2001; Kaur *et al.,* 2014). A range of faba bean ecotypes are grown in Oman under varied ecological conditions for their food and fodder value besides interest in the crop among farming community. Of late, the local indigenous germplasm of various crop species like faba bean is slowly facing the serious problem of getting extinct. This is mostly attributed to gradual introduction of high yielding crops of commercial value and shift in land use patterns to either growing high profit yielding crops like vegetables under green houses, hydroponics, etc or to urbanization. The germplasm collections and their conservation would safeguard the rare accessions from their extinct. Worldwide more than 43,500 faba bean accessions are conserved in about 37 global collections of which ICARDA gene bank house the highest of more than 9000 accessions followed by the Chinese Academy of Agricultural Sciences (CAAS) in China, that conserve more

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than 5200 accessions(FAOSTAT, 2016; Duc *et al.,* 2010; Kaur *et al.,* 2014). Several crop germplasm collection missions were held in Oman since early 1990's primarily to conserve indigenous plant genetic resources for future food security of Oman (Guarino, 1990; Osman *et al.,* 2002; AlSaady *et al.,* 2014). In continuation of these efforts, a series of joint collection missions between the Sultan Qaboos University and the Ministry of Agriculture and Fisheries were carried out from different sites within different governorates of Oman from April 2008 to March 2011 to explore the vast indigenous genetic diversity available in legume crops of Oman. This paper presents the results of faba bean (*Vicia faba* L.) germplasm collecting mission besides the diversity existing in collected indigenous faba bean accessions in respect of few seed traits.

MATERIALS AND METHODS

Seven exploration trips were undertaken from April 2008 to March 2011 in different Governorates of Oman with the support of the staff of Agriculture Development Centers of the Ministry of Agriculture and Fisheries following standard method of collecting missions(IPGRI, 1995; Hay and Probert, 2011; AlSaady *et al.,* 2014) for the collection of seed samples of indigenous germplasm of alfalfa and food legumes like chickpea, faba bean, cowpea, lentil, field pea, mung bean and pigeon pea, and the medicinal legume fenugreek. The collections were made from individual farmers, farmers-fields and stores, and Agriculture Development Centers by recording the crop passport data and site descriptions including GPS data, electrical conductivity and pH of soil and water samples. The sites covered during the trips lied between coastal and interior plains from 12 m to 1,983 m altitude. In all, 156 collecting sites were visited. Indigenous faba bean accessions were collected from 38 sites (Table 1). Seed traits such as seed length and width (cm) and test weight (100 seed) were measured, and seed color and nature of seed samples (pure or mixture) were determined on visual basis. The principal component analysis (PCA) was carried out with the extraction of the components using correlated matrix from the crop collection data on quantitative seed traits using XLSTAT software (XLSTAT, 2017).

RESULTS

41 seed samples/accessions were collected, with the highest of 28 accessions from Batinah South coastal governorate represented mostly by mountainous areas of wilayat Rustaq, followed by Al-Dakhiliyah / Interior governorate (8), Dhahira and Buraimi governorates (4) and the least of only one accession from Sharqiya governorates. There were no accessions collected from either Dhofar (South Oman) governorate or from coastal areas of North and South Batinah governorates.

Variation in seed characters: Seed accessions were found diverse with respect to all but few quantitative seed characters studied like seed length (cm) and width (cm) and 100-seed weight (g) and qualitative trait like seed color (Table 2). Seed length was found varied from 1.180 cm

Table 1. The locations of collecting / farm sites from where indigenous faba bean seed samples were collected as accessions

Sl.No.	Site No	Governorate	Wilayat	Village/location	Latitude (N)	Longitude (E)	Altitude(m)
1	1	Interior	Nizwa	Tanouf	23° 02.00'	57° 43.45'	604
2	8	Interior	Nizwa	Jabel Akhdar	23° 04.35'	57° 39.62'	1927
3	10	Interior	Adam	Alsmeerat	22° 22.38'	57° 31.95'	278
4	20	Interior	Al Hamra	Ghamour	23° 05.02'	57° 16.45'	663
5	21b	Interior	Bahla	Bilad Sait	23° 01.88'	57° 15.93'	605
6	22	Interior	Al Hamra	Jabel Shams	23° 15.52'	57° 09.95'	1680
7	23	Batinah South	Rustaq	Haat	23° 11.34'	57° 24.52'	1978
8	24	Batinah South	Rustaq	Balad Sait	23° 11.16'	57° 23.51'	1983
9	26	Dhahira	Ibri	Bilad Al-Shahoom	23° 23.94'	56° 57.91'	793
10	28	Dhahira	Ibri	Bilad Al-Shahoom	23° 22.96'	57° 00.57'	947
11	29	Dhahira	Ibri	Bat	23° 15.22'	56° 45.23'	508
12	32	Interior	Bahla	Sint	23° 07.96'	57° 04.64'	952
13	38	Dhahira	Yanqul	Al-Bouwerdah	23° 41.89'	56° 30.33'	623
14	42	Batinah South	Rustaq	Amq	25° 15.96'	56° 33.52'	643
15	43	Batinah South	Rustaq	Amq	23° 17.45'	57° 19.72'	285
16	44	Batinah South	Rustaq	Al-Ayeer	23° 12.79'	57° 27.56'	723
17	46	Batinah South	Rustaq	Fasah	-	-	-
18	49	Batinah South	Rustaq	Stal	23° 12.67'	57° 33.32'	655
19	50	Batinah South	Rustaq	Al hodineeyah	23° 11.15'	57° 37.81'	769
20	51	Batinah South	Rustaq	Al Ghasahb	23° 24.97'	57° 25.92'	274
21	52	Batinah South	Rusaq	Almari	23° 27.89'	57° 02.19'	678
22	54	Batinah South	Rusaq	Dhabaa	23° 26.86'	57° 06.86'	626
23	55	Batinah South	Rusaq	AL Dahir	-	-	--
24	56	Batinah South	Rustaq	Atayeeb	23° 25.40'	57° 09.78'	557
25	57	Batinah South	Rustaq	Almahdooth	23° 30.52'	57° 11.42'	482
26	59	Batinah South	ADC, Rustaq	-	-	-	-
27	60	Batinah South	ADC, Rustaq	-	-	-	-
28	61	Batinah South	ADC, Rustaq	Nezooh	23° 28.92'	57° 17.21'	344
29	62	Batinah South	ADC, Rustaq	-	-	-	-
30	64	Batinah South	Wadi Al-Maawel	Alghubrah	23° 16.41'	57° 41.78'	536
31	65	Batihah South	ADC, Rustaq	-	-	-	-
32	67	Batinah South	ADC, Rustaq	-	-	-	-
33	68	Batinah South	ADC, Rustaq	-	-	-	-
34	69	Batinah South	Rustaq	Makham	23° 25.93'	57° 07.39'	602
35	70	Batinah South	Rustaq	Alkhoof	23° 08.29'	57° 08.29'	579
36	72	Batinah South	Rustaq	Mori wadi bani Ghafer	-	-	-
37	110	Sharqiya	Mudhaibi	Wadi Endam	22° 52.71'	58° 00.31'	576
38	137	Batinah North	Suwaiq	AL-Musaifiah	23° 36.61'	57° 08.16'	382

* The team could not visit these sites as the seed samples were supplied at Agriculture Development Centers of respective Wilayats (districts).

Table 2. Variation among seed characteristics of 41 indigenous faba bean genotypes/accessions collected

Sl.No.	Collection No.	Length (cm)	Width (cm)	100 seed weight (g)	Seed color	Color	Governorates
1	4	1.245	0.805	43.7	Homogeneous	Dark purple	Interior
2	21	1.420	0.995	53.2	Homogeneous	Dark purple	Interior
3	22	1.500	1.005	55.4	Homogeneous	Dark purple	Interior
4	27	1.180	0.795	33.2	Homogeneous	Dark purple	Interior
5	55	1.300	0.830	40.1	Homogeneous	Dark purple	Interior
6	59	1.220	0.830	46.9	Homogeneous	Dark purple	Interior
7	65	1.410	0.880	47.2	Homogeneous	Dark purple	Batinah South
8	70	1.255	0.870	42.9	Homogeneous	Light purple to dark purple	Batinah South
9	73	1.320	0.865	43.1	Heterogeneous	Dark purple, yellowish white (very few)	Batinah South
10	80	1.375	0.925	50.5	Homogeneous	Dark purple	Dhahira
11	86	1.285	0.825	42.2	Homogeneous	Dark purple	Dhahira
12	91	1.275	0.835	37.3	Homogeneous	Light purple to dark purple	Dhahira
13	102	1.430	0.800	36.0	Homogeneous	Dark purple	Interior
14	124	1.335	0.885	47.3	Homogeneous	Dark purple	Dhahira
15	129	1.335	0.845	47.8	Homogeneous	Dark purple	Batinah South
16	133	1.275	0.860	51.2	Homogeneous	Dark purple	Batinah South
17	136	1.270	0.785	38.6	Homogeneous	Dark purple	Batinah South
18	142	1.240	0.895	43.2	Homogeneous	Dark purple	Batinah South
19	145	1.360	0.835	43.2	Homogeneous	Dark purple	Batinah South
20	146	1.265	0.840	41.5	Homogeneous	Dark purple	Batinah South
21	150	1.320	0.855	47.9	Homogeneous	Dark purple	Batinah South
22	152	1.405	0.895	44.3	Homogeneous	Light purple to dark purple	Batinah South
23	156	1.245	0.850	41.4	Homogeneous	Dark purple	Batinah South
24	158	1.245	0.835	42.5	Homogeneous	Light purple to dark purple	Batinah South
25	163	1.225	0.785	37.0	Homogeneous	Dark purple	Batinah South
26	168	1.255	0.835	43.3	Homogeneous	Dark purple	Batinah South
27	177	1.415	0.930	51.3	Homogeneous	Dark purple	Batinah South
28	179	1.340	0.845	41.4	Heterogeneous	Dark purple, yellowish white (very few)	Batinah South
29	180	1.200	0.775	38.69	Homogeneous	Dark purple	Batinah South
30	187	1.395	0.880	43.94	Homogeneous	Dark purple	Batinah South
31	189	1.320	0.950	50.0	Homogeneous	Dark purple	Batinah South
32	192	1.415	0.870	48.2	Homogeneous	Dark purple	Batinah South
33	194	1.220	0.890	49.2	Homogeneous	Dark purple	Batinah South
34	196	1.325	0.890	47.9	Homogeneous	Dark purple	Batinah South
35	199	1.290	0.865	49.0	Homogeneous	Dark purple	Batinah South
36	200	1.270	0.850	41.5	Homogeneous	Dark purple	Batinah South
37	202	1.305	0.895	42.3	Heterogeneous	Dark purple, yellowish white (very few)	Batinah South
38	205	1.200	0.860	39.9	Homogeneous	Dark purple	Batinah South
39	210	1.370	0.860	47.8	Homogeneous	Dark purple	Interior
40	275	1.315	0.910	45.4	Homogeneous	Dark purple	Sharqiya
41	323	1.383	0.750	35.0	Homogeneous	Dark purple	Batinah South
Statistical Parameters							
Minimum		1.180	0.750	33.200			
Maximum		1.500	1.005	55.400			
Mean		1.313	0.862	44.218			
S.E.(+)		0.012	0.008	0.816			

(Collection No. 27 of Al-Sameerat, Adam, Interior) to 1.500 cm (Collection No. 22 of Al-Ain, Jabal Al-Akhdar, Interior); seed width ranged from 0.750 cm (Collection No. 323 of Al-Musaifia, Suwaiq, Batinah North) to 1.005 cm (Collection No. 22 of Al-Ain, Jabal Al-Akhdar, Interior) and 100-seed weight ranged from 33.200 g (Collection No. 27 of Al-Sameerat, Adam, Interior) to 55.400 g (Collection No. 22 of Al-Ain, Jabal Al-Akhdar, Interior). In respect of seed color, 38 accessions were homogenous (pure) and 3 were heterogeneous (mixture). Among the homogenous accessions, all were dark purple except Collection No. 70 from Balad Sait of Rustaq, Collection No. 91 from Bat of Ibri, Collection No. 152 from Al-Mari Wadi Bani Ghafer of Rustaq and Collection No. 158 from Al-Dahir of Rustaq, which had light to dark purple seeds. The three heterogenous accessions Collection No. 73 from Balad Sait, Collection No. 179 from Al-Mahdooth Hajer Bani Omer and Collection No. 202 from Al-Makham all from wilayat Rustaq had dark purple seeds with few yellowish white seeds (Table 2).

Variation in collection sites: Collection sites were found varied in their soil and position characteristics and altitude. Altitude ranged from 12 m at site No.133 of Al-Muntafa, Wilayat Saham of Batinah North to 1983 m at site No. 24 of Balad Sait, wilayat Rustaq of Batinah South. The sites ranged in soil texture viz. sands, sandy loam, sandy clay, sandy clay loam, clay and loam. Soils were hard, firm or loose, variable-loose to crust and friable. With regard to drainage, soils were imperfect, free or variable. Soil pH ranged from 2.1 (Site No.58, Al-Mahdooth Hajer Bani Omer, Rustaq, Batinah South) and Site No.65, Al-Qoora, Nakhal, Batinah South) to 9.9 (Site No. 87, Al-Hafeet, Buraimi). Soil EC varied from 0.02 (Site No.42, Al-Amq, Rustaq, Batinah South) to 22.7 (Site No. 51, Al-Ghasab, Rustaq, Batinah South). Soil color ranged from light brown to dark brown).

Principal Component Analysis

The data on three quantitative three seed traits were subjected to the Principal Component Analysis (PCA) to understand which combination seed traits contribute to obtaining high quality of the indigenous faba bean germplasm in terms of their significance and value in marketing. The scree plot of the PCA (Figure 1) indicated that the first two eigenvalues had major proportion of the variance in the dataset as evidenced by the first two PCAs extracted from the components contributing to 91.719 % with PC 1 having eigenvalue of 2.104 and PC 2, 0.648 (Table 3). The PC 1 was positively and equally influenced by seed width (0.894) and 100-seed weight (0.892).

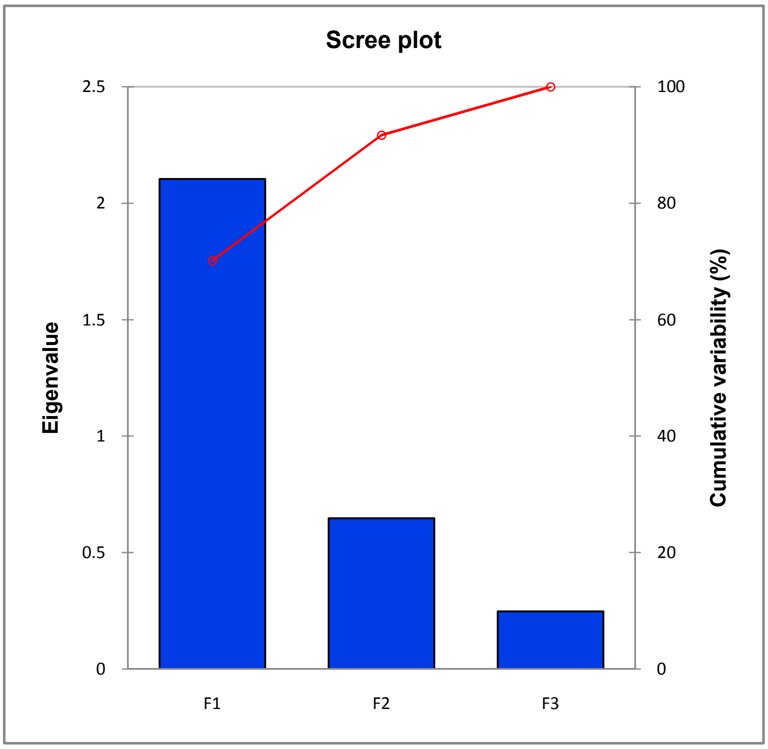

Figure 1. Scree plot showing eigenvalues in response to three principal components (F1 to F3) for three seed variables/ characters in 41 indigenous faba bean accessions

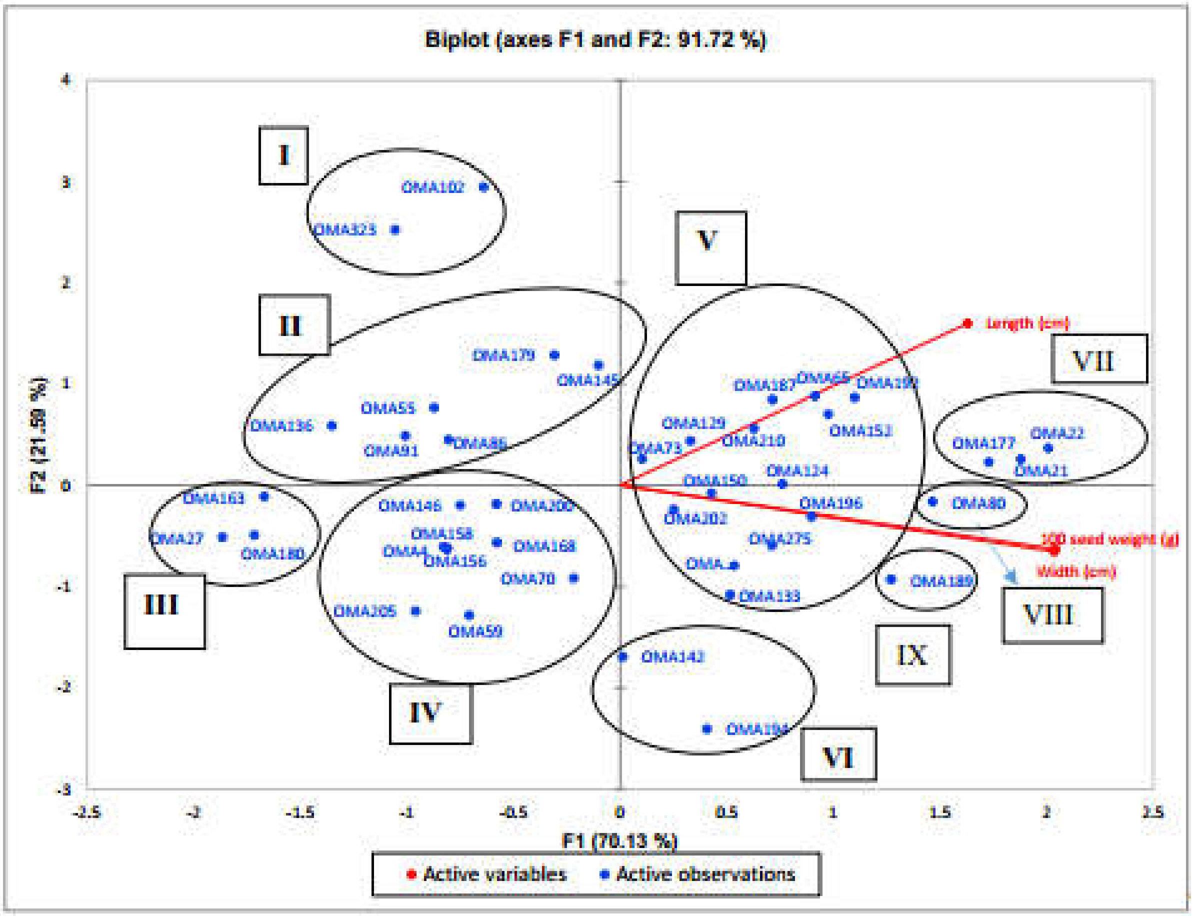

Figure 2. Principal component scores of PC1 (F1) and PC2 (F2) showing the overall variation/scattering among indigenous faba bean germplasm in terms of three quantitative seed traits

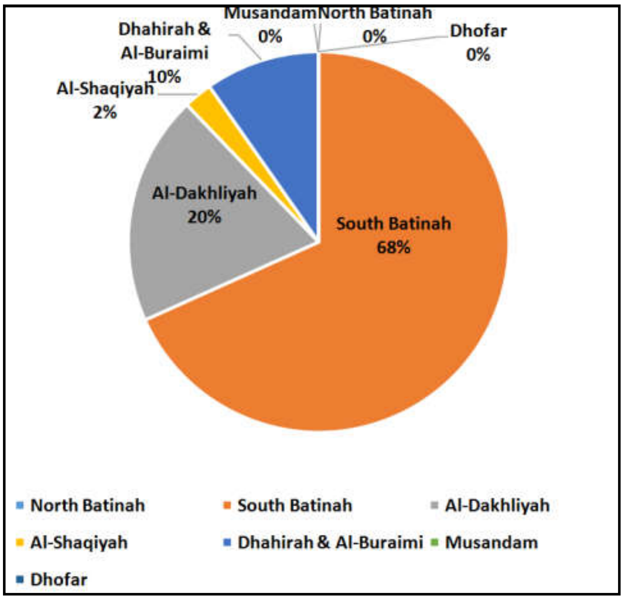

Figure 3. Percentages of indigenous accessions of faba bean collected from different governorates of Oman

Table 3. Eigen values and percent variance of principal components to total variation in 41 indigenous faba bean accessions

Principal Components (PC' s)	Eigen value	% Variance	Cumulative variance
PC 1	2.104	70.131	70.131
PC 2	0.648	21.588	91.719
PC 3	0.248	8.281	100.000

Table 4. The principal component values of three seed size characters in 41 faba bean accessions

Variables/Characters	PC 1	PC 2	PC 3
Seed length (cm)	0.714	0.701	-0.005
Seed width (cm)	0.894	-0.274	0.354
100 Seed-Weight (g)	0.892	-0.286	-0.351

Table 5. Correlation coefficients between seed size characters of 41 faba bean accessions

	Seed length (cm)	Seed width (cm)	100 Seed-Weight (g)
Seed length (cm)	1	0.444*	0.438*
Seed width (cm)		1	0.752**
100 Seed-Weight (g)			1

Table 6 The percent contribution of variables (three seed size characters) to three principal component values in 41 faba bean accessions

Variables/Characters	PC 1	PC 2	PC 3
Seed length (cm)	24.198	75.794	0.009
Seed width (cm)	38.008	11.606	50.386
100 Seed-Weight (g)	37.794	12.600	49.605

However, the PC 2 was also influenced positively by seed length (0.701) but negatively by seed width (-0.274) and 100-seed weight with low values. PC 3 was also positively associated with seed width but with low value (0.354) (Table 4). Similarly, only positive and significant correlation values (r) were found between three seed characters studied viz. seed length vs seed width (0.444*), seed length vs 100-seed weight (0.438*) and seed width vs 100-seed weight (0.752**) (Table 5). In terms of percent contribution of seed traits to the PCs, both seed width and 100-seed weight together contributed to the extent of 75.822% to PC1 and to the extent of 99.991% to PC3. However, seed length alone contributed to the extent of 75.794 % to PC2 (Table 6). The spread of 41 indigenous faba bean accessions in biplot graph of the first two PCs as X and Y axes clearly indicated pattern of grouping in all the four quadrants of the graph and separated into 9 clusters where the accessions belonging to the same group are in close proximity to form clusters in whichever quadrants of the graph they had occupied due to their similarities (Figure 2). The number of accessions in clusters were found varied from single (Cluster VIII and Cluster IX) to the highest of 14 in Cluster V. The remaining 6 clusters had accessions ranging from 2 to 9. The accessions of the clusters were found either belonged exclusively to the same governorates like Al-Batinah South (Clusters VI) or to different governorates (Clusters I to V, VII).

DISCUSSION

An array of indigenous faba bean germplasm accessions was collected during the collecting missions from as many as four of seven governorates of the Sultanate of Oman, targeted (Figure 3). Most of these accessions were acquired from the farmers whose faba bean fields were at high altitude locations. South Batinah represented by the mountainous areas of wilayat Al-Rustaq contributed the highest number to the extent of 68.29 % of accessions, followed by Al-Dakhliyah (Interior) governorate (19.51%), Dhahirah and Buraimi governorates (9.76%). Interestingly, Al-Sharqiya, easten governorates contributed the least of 2.44%. Interestingly, the mountains of North Batinah and Musandam had no contribution to collections perhaps due to water shortage in the area during cropping season. However, southern Dhofar governorate has no tradition of faba bean cultivation (MAF, 2005). The results of critical analysis of seed color of faba bean germplasm accessions at the laboratory indicated least variation in seed coat color pattern but large variation seed size characters (Table 2). These variations observed in seed size among the collected samples of indigenous Omani accessions are in conformity with those observed in previous studies that dealt with either local small or large germplasm collections (Terzopoulos *et al.,* 2003; Kaur *et al.,* 2014; Gasim *et al.,* 2015; Rebaa *et al.,* 2017). In the present study, villages located closely with the collecting sites appeared to have interestingly similar patterns of seed coat color indicating the presence of large amount of homogeneity in the collected faba bean seed samples/ accessions whereas heterogenous seed samples were found in seed samples from three different sites. Thus, variation in seed coat color pattern is attributed to the involvement of hilum/testa colours which are governed by independent or epistatic major genes(Recciardi *et al.,*1985). In such cases, there is need for intensive purification of seed accessions into sub-homogenous groups with respect to seed color pattern (Ricciardi *et al.,* 1985; Ghasim *et al.,* 2015). The extensive exchange of faba bean landraces among the farmers in the highlands of wilayats of different governorates like South Batinah and Interior governorates were presumably resulted from selections over centuries and adaptation to local climatic and edaphic factors. Constant availability of indigenous landraces with the farmers indicates the existence of local conservation strategy for sustainable production. Genetic erosion of faba bean landraces was perhaps found in both North Batinah and Musandam governorates, as there were no collections. However, in case of Dhofar governorate the faba bean is not traditionally cultivated and hence, not found

(Table 2; Figure 3). In other governorates like Al-Dakhliyah (Interior), Al-Sharqiya North and South and Dhahirah and Buraimi very less number of samples were obtained as compared to the collections made in the past in Oman (Guaerino, 1990; AlSaady *et al.,* 2018 a & b).This could be because of use of modern high-yielding crops like vegetables, changes in land use pattern for cultivation like greenhouses, hydroponics etc., urbanization, drought periods besides the lack of interest among the farmers these days to grow un-economical crops like faba beans. The correlation analysis of seed characters showed their significant ($p<0.05$) and positive associations between each other. Selection of strongly associated character like 100-seed weight can be used to improve seed quality characters that influences yield and their value in marketing(Terzopoulos *et al.,* 2003; Gasim *et al.,* 2015; Gidey *et al.,* 2016).

The results of PCA analysis would be of significance in breeding programs in detecting the appropriate phenotypic characters which contribute higher genetic variations among different genotypes for selecting parents in crossing program to improve the characters of interest for productivity in quantity and quality (Zeid *et al.,* 2001 and 2003; Duc *et al.,* 2010; Kaur *et al.,* 2014). In the present study, the results of PCA clearly showed that the quantitative seed traits, studied, positively contributed to PCA1 indicating that this component reflected the potentiality of seed size in faba bean germplasm whereas only seed length contributed positively to PCA2. The existence of wider phenotypic variation among the indigenous faba bean germplasm was further explained by the biplot graph that indicated an overview of the similarities and dissimilarities among the faba bean accessions as well as of the interrelationships between the variables, investigated. The graph characteristically demarcated the faba bean accessions about their scattering pattern based on the first two dimensions/ components into 9 clusters in all the four quadrants, indicating the existence of wide genetic variation for the seed traits, studied. The accessions OMA 102 from Al-Dakhliya (Interior), OMA 189 from South Batinah/ Coast and OMA 80 from Al-Dhahirah governorates occupied extreme positions from the origin of the graph showing that they are genetically distinct accessions whereas other accessions were more concentrated around the origin on PCA2, which indicated their genetic similarity for the seed traits. In the present study, the accessions of certain clusters like cluster VI (South Batinah) belonged to the same governorate whereas the accessions of remaining clusters like I to V and VII were from different governorates. OMA 80 from Al-Dhahirah and OMA 189 from South Batinah were isolated as different clusters (VIII and IX). Considering such a cluster pattern among the faba bean accessions studied, it is suggested that the accessions of different clusters be used in crossing program for improvement of seed characters, as these accessions would be genetically divergent (Zaid *et al,* 2001 and 2003; Duck *et al.,* 2010; Kaur *et al.,* 2014; AlSaady *et al.,* 2018 a and b).

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