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Morphological characterization and genetic diversity of Fenugreek (*Trigonella foenum-graecum* L.) accessions in Oman

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Abstract

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Fenugreek (*Trigonella foenum-graecum* L.) is one of the important legume crops grown in the Sultanate of Oman. The objective of this study was to characterize morphological differences and yield related traits among 20 Omani fenugreek accessions. A field experiment was carried out in a randomized complete block design for two winter seasons. Significant differences were observed among Omani fenugreek accessions in plant height (mean = 26.8± 14.9 cm), number of branches (3.4 ± 2.7), number of leaves (42.1± 33.0), leaf area (2.3 ± 0.96 cm²), number of pods (32.1 ± 21.4), pod length (9.1 ± 1.2 cm), weight of pods (17.3 ± 0.0 g),1000 seed weight (11.2 g),and number of seeds (134.2 ± 101.7). The heritability index of number of seeds (0.94), leaf area (0.90) and number of leaves (0.81) showed the highest values, while it was lowest for number of pods (0.44) and 1000 seed weight (0.54). A higher genetic advance was observed in number of seeds (100.39) while the lowest genetic advance was observed in pod length (0.51).The principle component analysis (PCA) yielded 77% of the total variation in two seasons. PCA 1 and PCA 2 contributed 65% of the total variation (45% and 20%, respectively) followed by PCA 3 (12%) and PCA1 was found to be the most important in the separation of the accessions. Accession 160 showed distinguished variation in the dendrogram for all the studied parameters.

Keywords: Fenugreek; genetic diversity; principal component analysis; cluster analysis

Introduction

Fenugreek (*Trigonella foenum-graecum* L.) is the important minor legume species grown in Oman, which is being planted on small areas throughout the country. However, due to severe fresh water shortage, legume plantation is limited to the places having springs, wades or a flag system of irrigation. The natural features of climate and land favor large legume genotypes to be grown in many areas of Oman. Fenugreek grows faster and produces flowers and seeds in a short span of time, which shows its adaptation to Omani climate. The herbaceous leaves and seeds are used for human consumption, while whole green plant is used as forage. It is also grown for green manuring to enhance the organic matter within the soils of dry areas.

Genetic erosion is considered a worldwide threat to the extinction of plant species. It has been reported that worldwide agriculture has lost three quarters of the genetic diversity in

major food crops and this erosion is continuing at an annual rate of 1–2% (Mazhar, 1997). There are very few cultivars known or well defined while explicit information on fenugreek's genetic diversity, intraspecific variability and association of these species with their wild relatives is largely lacking (FAO, 1994). As fenugreek is considered one of the minor crops, the genetic resources of these indigenous underutilized species face rapid destruction owing to erosion of traditional farming culture, change of traditional food habits and the introduction and adaptation of high yielding crops (Zahoor, 2007).In fact, the availability of fenugreek germplasm is low or almost scanty in gene banks (Hymowitz, 1990; Ellison et al., 2006). It is a matter of great concern that Omani fenugreek accessions (land races) are affected adversely either by the introduction of new cultivars, climate change impact or by the decrease of agricultural land. It is therefore required to characterize, document and develop strategies to preserve the valuable resources of indigenous fenugreek species from extinction.

Assessment of genetic divergence in fenugreek germplasm is important for long term crop improvement programme. Undoubtedly, the study of the genetic diversity of fenugreek genotypes is not only important for germplasm conservation but also in selecting the parents for breeding purposes. The biological variations in an organism are combined response of genotypic, phenotypic and environmental components. Of which the genotypic variation is of great importance from crop improvement point of view (Mazzucato et al., 2008) and consists of heritable (additive) and non-heritable (dominance and epistatic components). It therefore becomes essential to differentiate observed variability into heritable and non-heritable portion in term of phenotypic and genotypic coefficient of the variation, heritability and genetic advance (Saleem et al., 2013). Since no information is available concerning genetic diversity of fenugreek in Oman, it is not clear whether fenugreek consists of one or several genotypes. Similarly, little information is available about the relationship of fenugreek with each other and with exotic populations from different parts of the country. This establishes a barrier towards future breeding programs of indigenous cultivars. In addition, the recent introduction of new fenugreek cultivars may replace indigenous cultivars that have adapted to the local conditions. There is dire need to characterize, document and develop strategies to preserve and save the indigenous fenugreek valuable resources from extinction which took centuries to develop genetic diversity and brought it into present shape. Therefore present study was designed to categorize different fenugreek accessions from diverse regions of Oman into separate clusters or groups on the basis of genetic diversity among their morphological attributes using agglomerative hierarchical clustering and principal component analysis.

Materials and Methods

Plant Materials

Twenty fenugreek (*Trigonellafoenum-graecum* L.) accessions were collected from the Gene Bank of Agricultural Research Center, Ministry of Agriculture and Fisheries, Oman (Table 1). Fenugreek seeds were planted and morphologically evaluated at experimental area of Biodiversity International Passport at the Masarat Al Andhar, Royal Court Affairs (RCA) in Al Suwaiq District.

Germination Test

Germination of fenugreek accessions were recorded in triplicate (25±2°C) with 20 seeds per replication under controlled conditions. The seeds were incubated on Whatman filter paper in 9 cm plastic Petri-dishes, topped up with deionized. Germination was recorded after 9 days of sowing.

Field Experimental Setup

The experiment was conducted in two consecutive winter seasons following randomized complete block design (RCBD) with three replications. The distance between each block was kept 2m and accessions were separated by keeping 1m distance throughout. Each block contained twelve plants of each 20 accessions in each replicate. The distance between each plant was 50 cm. The fenugreek field was fertilized initially with the recommended dose of 100 kg/ha P_2O_5 and 50 kg K_2O/ha in the form of triple super phosphate and potassium sulphate, respectively (Akhtar & Nadaf, 2001). Plants were uniformly irrigated with light irrigation till their germination and later thrice a week till one week prior to harvest. Plants were monitored for pest and disease infestation and appropriate protective measures were taken whenever necessary as described by Akhtar & Nadaf (2001).

Characters studied

Plant protocol described by Bioversity International, was followed for detailed quantitative and qualitative studies throughout the experiment. The parameters studied were plant height (cm), number of branches per plant, number of leaves per branches, number of leaves per plant, leaf area (cm^2), number of pods per plant, number of pods per branch, weight of pods per plant (g), number of flowers per plant, pod length (cm), number of seeds per pod, weight of seeds per plant (g), growth habit, color of stem, leaf, flower and seeds and plant hairiness. Observations were recorded on10 selected plants leaving the border plants of each accession.

Table 1. Origion, year of collection of *Trigonella foenum-graecum* L. accessions

SN	Accession No.	Region	District	Village
1	312	Batinah North	Sohar	Al-Ghudafa
2	63	Batinah South	Rustaq	Haat
3	135	Batinah South	Rustaq	WadiBaniAouf
4	153	Batinah South	Rustaq	WadiBaniGhafer
5	160	Batinah South	Rustaq	Aldhahir
6	209	Batinah South	Rustaq	WadibaniGhafer
7	235	Buraimi	Buraimi	Al-Hail
8	240	Buraimi	Muhadha	Al-Khabeen
9	122	Dhahira	Yanqul	Al-Bouwerdah
10	97	Dhahira	Ibri	Asubal
11	2	Dakiliya	Nizwa	Tanuf
12	17	Dakiliya	Manah	Al-Blaad
13	31	Dakiliya	Adam	Al-Belad
14	35	Dakiliya	Bahla	Al-Khatwa
15	49	Dakiliya	Al-Hamra	Al-Qlaah
16	212	Dakiliya	Bidbid	Al-Buwareed
17	246	Sharqiya North	Al-Qabel	Bateen
18	260	Sharqiya North	Ibra	Al-Haimah
19	274	Sharqiya North	Mudhaibi	WadiEndam
20	304	Sharqiya North	WadiBaniKhaled	Halfah

Genetic Estimates (Heritable)

Phenotypic variances were obtained from the analysis of variance table according to Comstock & Robinson (1952). Heritability in broad sense (H^2 or h^2) was estimated as described Falconer (1989).The mean values used for genetic analyses to determine Phenotypic Coefficient of Variation (PCV) and Genotypic Coefficient of Variation (GCV) were determined according to Singh & Chaudhury (1985).The genetic advance (GA) was calculated according to the method suggested by Allard (1960) and Singh &Chaudhury (1985). Phenotypic and genotypic correlations were estimated as described by Miller et al. (1958) and Kashiani & Saleh (2010) from the corresponding variance and covariance components.

Statistical Analysis

Data was analyzed using the computer software system of PAST (PAST version 2.08 2011).

Results

Interaction of components

Results showed significant differences ($P < 0.05$) among all plant morphological traits, including plant height, number of branches, number of leaves, number of pods, weight of seeds, weight of pods, pod length, number of seeds and leaf area in both seasons (Table 2). However, the interactive effect between the accessions and the seasons and; replications and blocks was non-significant for both seasons. However, the results showed a non-significant ($P < 0.05$) interaction between the accessions and the season, replications and blocks for both seasons. The estimates of mean of different vegetative and reproductive traits are presented in Table 3. The mean plant height and number of branches were 26.85 cm and 3.5, respectively. Mean number of leaves and leaf area per plant was 42.18 and 2.3 while mean number of pods per plant, pod length and pod weight was 32.18, 9.15 and 17.37. Similarly, mean number of seeds and seed weight was 134.2 and 11.23, respectively.

Morphological traits comparison

In morphological trait studies, the highest plant height was recorded for accession 2 (34.9 cm) followed by accession 31 (30.3 cm) and 122 (30.2 cm) during both the seasons as presented in Table 4. However, accession 160 (22.3 cm) showed minimum plant height. Likewise, accessions 274 (4.95) produced highest number of branches followed by accession 246 (4.75) and 122 (4.3). However, less mean number of branches were observed in accessions153 (2.2), 63 (2.4) and 160 (2.4). On the other hand, accession 246 was superior in the mean number of leaves (59.0) followed by accession 122 (57.7) and accession 240 (56.2). Accessions 160 showed the lowest number of leaves (21.1).The results revealed that accession 235 has the highest mean number of

Table 2. Analysis of variance of nine morphological descriptors among Omani fenugreek accessions for both seasons

		df	Mean Square	F	Sig.
Plant Height	Accessions	19	519.750	2.372	0.001
	Accessions x Season	1180			
Number of Branches	Accessions	19	36.276	5.229	0.000
	Accessions x Season	1180	6.938		
Number of Leaves	Accessions	19	5497.616	5.378	0.000
	Accessions x Season	1180	1022.280		
Leaf Area	Accessions	19	8.264	10.283	0.000
	Accessions x Season	1180	0.804		
Number of Pods	Accessions	19	819.757	1.813	0.017
	Accessions x Season	1180	452.247		
Pod Length	Accessions	19	6.402	4.233	0.000
	Accessions x Season	1180	1.512		
Weight of Pods	Accessions	19	622.370	2.104	0.004
	Accessions x Season	1180	295.811		
Number of Seeds	Accessions	19	158086.767	19.799	0.000
	Accessions x Season	1180	7984.616		
Weight of Seeds	Accessions	19	304.065	2.183	0.002
	Accessions x Season	1180	139.257		

Table 3. Descriptive values of minimum, maximum, mean and standard deviation of Omani fenugreek accessions for nine morphological descriptors

	Minimum	Maximum	Mean	Std. Deviation
Plant Height (cm)	3.00	62.00	26.8522	14.96292
Number of Primary Branches	0.00	19.00	3.4908	2.72080
Number of Leaves per plant	5.00	199.00	42.1833	33.06356
Leaf Area per plant (cm^2)	0.68	7.28	2.3190	0.96014
Number of Pods per plant	2.00	130.00	32.1802	21.40259
Pod Length per plant (cm)	3.50	18.63	9.1527	1.26091
Weight of Pods per plant (g)	0.32	118.00	17.3772	17.34893
Number of Seeds per plant	1.80	793.00	134.2432	101.79988
Weight of Seeds per plant (g)	0.10	78.67	11.2377	11.91086

pods (38.6) as compared to other accessions and accession 209 produced the lowest mean number of pods (24.5). Leaf area measurement showed greater leaf area (3.05 cm^2) for accession 209. However, accession 35 produced the lowest mean leaf area 1.8 cm (Table 4).

Highest weight of seeds (16.3g) was recorded for accession 160 (Table 4). Accession 209 showed the lowest mean weight (7.7 g) of seeds. The highest pod weight (24.7 g) was for accession 160, followed by accession 49 (21.8 g) and accession 304 (19.5 g) while it was lowest (12.1 g) in accession 209. However, pod length was more (9.7 cm) for accession 209. In contrast, accession 63, showed the lowest mean pod length(8.4 cm).Accession 212 was superior to produce more number of seeds (299.5) and on the other hand, the accessions 160 (73.0) was not been able to produce more weight of seed.

Heritability estimates

The genotypic coefficient of variation was ranged from 3.11 for pod length to 37.25 for the number of seeds, while phenotypic coefficient of variation for pod length was ranged from 3.56 to 8.23 for the number of seeds. The number of seeds (0.94), leaf area (0.90) and number of leaves (0.81) showed the highest broad sense heritability (Table 5). In contrast, lowest heritability was recorded for number of pods (0.44) and the weight of seeds (0.54) (Table5).

Principle Component Analysis (PCA) of Quantitative Characters

Nine morphological parameters were evaluated statistically for all fenugreek accessions (Table 6). Out of 5 principal components (PCs), three viz. PC-1, PC-II and PC-III had Eigen values >1 and contributed for 77.33% of total

Table 4. Mean performance of Omani fenugreek accessions for nine morphological descriptors for both seasons

Accessions	Plant Height (cm)	Number of Branches	Number of Leaves	Leaf Area (cm^2)	Number of Pods	Pod Length (cm)	Weight of Pods (g)	Number of Seeds	Weight of Seeds (g)
2	34.9 [a]	3.9167	42.8667	3.0[ab]	28.5167	9.0790	12.6 [b]	110.8000	8.0 [b]
17	26.3667	3.1333	44.0667	2.1475	31.6333	9.1460	16.7335	118.3000	10.5207
31	30.3[ab]	4.3667	48.5000	2.1255	30.8500	9.3382	18.8877	168.4667	11.9097
35	24.6500	3.4500	36.8667	1.8 [f]	33.4333	9.1140	17.5637	127.3667	11.4793
49	25.9167	2.7333	34.7167	2.2177	37.4[ab]	9.0885	23.1[ab]	94.4333	15.2[ab]
63	26.5667	2.4 [de]	36.1500	2.4212	30.4000	8.4 [d]	17.6355	93.5667	11.3440
97	25.2167	3.2667	39.0500	2.1143	31.3167	9.4[abc]	17.8943	188.6 [b]	11.3682
122	30.2[ab]	4.3[abc]	57.7 [a]	2.4447	34.3333	9.1335	16.2550	186.0 [b]	10.1078
136	30.1333	3.3000	49.9167	2.8193	29.0333	9.7[ab]	17.6947	127.1333	11.4103
153	25.8333	2.2 [e]	28.9 [de]	1.9370	30.3333	9.1903	16.2538	119.1000	10.3958
160	22.3 [b]	2.4500	21.1 [e]	2.5208	38.2[ab]	8.8 [cd]	26.3 [a]	75.4 [f]	17.4 [a]
209	25.5833	3.9667	48.9833	3.05 [a]	24.5 [b]	9.7 [a]	12.1 [b]	95.9667	7.7 [b]
212	28.8667	4.0333	43.8667	1.9210	32.9667	9.2445	15.8977	299.5 [a]	10.1422
235	23.4 [b]	3.7167	41.2833	1.9[ef]	38.6 [a]	8.8405	18.9630	124.3667	12.4965
240	26.4250	3.5667	56.4[ab]	2.8488	34.8333	9.6282	18.1392	122.5333	11.9065
246	28.1500	4.7[ab]	59.4 [a]	2.3462	28.7500	8.9635	15.6412	110.0333	10.0703
274	26.3140	4.9 [a]	40.1000	1.9377	35.4333	9.3470	15.7262	186.8333	10.1147
260	24.4167	3.5500	33.1[cde]	2.1687	31.4500	8.9015	15.9245	89.3[ef]	10.2663
304	27.3167	2.8333	39.8167	2.1327	33.9500	8.7 [cd]	19.5[ab]	143.6000	13.5[ab]
312	23.9 [b]	2.8000	40.7167	2.3955	27.5[ab]	8.9390	14.3958	103.4333	9.1812

Table 5. Genetic parameters of nine morphological descriptors in Omani fenugreek accessions

	σ 2g	σ 2p	GCV (%)	PCV (%)	H 2	GA	GAM
Plant Height	5.01041	8.6625	8.335985	10.96079	0.578403	3.506866	13.05988
Number of Branches	0.48897	0.604605	20.03151	22.27443	0.80875	1.29544	37.10975
Number of Leaves	74.5889	91.62693	20.47371	22.69191	0.81405	16.05203	38.05305
Leaf Area	0.12434	0.137737	15.20558	16.0036	0.902756	0.690181	29.76154
Number of Pods	6.12517	13.66262	7.690765	11.48623	0.448316	3.413644	10.60789
Pod Length	0.081488	0.106695	3.118859	3.568791	0.763746	0.513911	5.614842
Weight of Pods	5.44265	10.37283	13.42534	18.53398	0.524703	3.481203	20.03315
Number of Seeds	2501.7	2634.779	37.25852	38.23666	0.949492	100.3993	74.78914
Weight of Seeds	2.74681	5.067757	14.74811	20.03226	0.542017	2.513552	22.36712

Abbreviation: (σ2g): Genotypic variance, (σ 2p): Phenotypic variances, (PCV): phenotypic Coefficient of Variation, (GCV): Genotypic Coefficient of Variation,(H 2)*:* Heritability, (GA); genetic advance, (GAM): genetic advance % of mean

cumulative variability among different fenugreek accessions (Table 7). PCA1 and PCA2 manifested 65% of the total variation (45% and 20%, respectively) followed 12% by the PCA3 (Table 7).The contribution of PC-I towards variability was highest (44.99%) followed by PC-II and PC-III which contributed 19.99% and 12.35% variability respectively.

The PC-I showed positive factor loadings for plant height, number of primary branches, number of leaves per plant, leaf area, pod length and seed number plant. PC-II indicated positive factor loading for plant height all the traits except leaf area. Traits which contributed positive factor loadings towards PC-III were plant height followed by number of primary branches per plant, number of leaves per plant, leaf area, and number of pods per plant, pod length per plant, pod weight per plant and seed weight per plant. It is evident that vegetative traits (plant, number of primary branches per plant and number of leaves per plant) were those with highest contribution to PC-I whereas number of seeds per plant and number of pods per plant was the chief contributors to PC-II. Therefore, PC-I could be referred as vegetative axis while PC-II as reproductive axis. Leaf area contributed maximum share in PC-III therefore, it could also be designated as vegetative axis.

Table 6. Principle component analysis loadings of nine quantitative traits based on Ward`s phenotypic distance of 20 fenugreek accessions obtained from six geographical regions in Oman

0	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5	Axis 6	Axis 7	Axis 8	Axis 9
122	1.830319	1.58802	0.742649	-0.81639	-0.16937	-0.2798	0.464832	-0.28877	-0.07766
136	1.398576	-0.49252	1.735335	0.980547	0.857524	-0.19369	-0.55136	-0.15931	0.029076
153	-0.62986	-1.20633	-1.5996	0.889095	1.056951	-0.05362	-0.32868	-0.48041	0.003399
160	-4.98872	-0.737	1.28367	0.119351	0.091588	0.688771	0.277822	0.757229	-0.02565
17	-0.09533	-0.16426	-0.35132	0.138883	-0.05494	-0.44471	-0.16963	-0.40514	-0.07457
2	3.039209	-1.42148	0.595473	-1.82474	1.150479	1.050631	0.238071	-0.21567	0.020052
209	3.309	-2.06333	0.336353	1.669579	-0.78907	0.318652	0.267521	0.286109	0.016184
212	1.159669	2.818995	-1.18427	0.155638	1.292615	-0.13061	0.797004	0.415126	0.053744
235	-2.07145	1.191922	-0.19688	-0.39683	-1.28197	-0.0078	0.187899	-0.33385	0.041851
240	0.562278	0.105915	2.043017	0.479509	-0.70293	-0.46506	0.746639	-0.28562	0.004735
246	1.963393	0.176804	0.164895	-1.09494	-1.29141	-0.58798	-0.70056	0.521556	0.046081
260	-0.16367	-1.21428	-1.60928	-0.37955	-0.80855	0.522285	-0.03861	-0.01216	-0.02755
274	0.659646	1.955905	-0.70954	0.284238	-0.91171	1.113344	-0.11099	-0.12421	-0.01703
304	-1.7336	0.240201	0.007741	-0.77549	0.543529	-0.46726	-0.17715	-0.09236	0.021555
31	1.125227	1.29187	0.435937	-0.0869	0.490622	0.002374	-1.08779	0.458076	-0.04614
312	0.276664	-1.74106	-1.22624	0.119668	-0.31417	-0.64029	0.419972	0.169704	-0.00156
35	-1.12575	0.364378	-0.79621	0.362775	-0.37558	0.097828	-0.36765	-0.25153	0.04627
49	-2.86462	0.198777	1.164322	0.17873	0.229696	0.186278	-0.24045	-0.45214	0.030967
63	-1.41731	-1.6877	-0.38636	-1.33542	0.396455	-0.54084	0.213681	0.207477	-0.0104
97	-0.23367	0.795181	-0.44968	1.33225	0.590244	-0.16851	0.159421	0.2859	-0.03336

Table 7. Principal component analysis CA results for Omani fenugreek accessions based on nine plant descriptors

Season 1	PCA 1	PCA 2	PCA 3	PCA 4	PCA 5
Plant height	0.32943	0.11029	0.27496	-0.48178	0.60455
Number of primary Branches	0.32792	0.40084	0.05977	-0.15677	-0.49156
Number of Leaves per plant	0.3703	0.20921	0.34773	-0.10482	-0.33383
Leaf Area	0.22254	-0.42391	0.58897	-0.02914	0.02772
Number of Pods per plant	-0.33691	0.42864	0.23122	-0.14712	-0.22795
Pod length per plant	0.28973	0.11641	0.25025	0.82906	0.09549
Weight of Pods per plant	-0.43042	0.16411	0.38227	0.06085	0.12643
Number of Seeds per plant	0.15665	0.59862	-0.20749	0.12199	0.44191
Weight of Seeds per plant	-0.43595	0.14535	0.38439	0.06256	0.09126
% variance	44.994	19.993	12.357	8.625	7.096
Eigen value	4.0494	1.7994	1.1122	0.7763	0.6386

All PCA's were scattered in all four quadrants (Figure 1). PCA1 was the most important in the separation of the accessions as it contributes 45% of the total variation. All the accessions were grouped into one main group except for accession 160 which was far away from the main group.

Cluster analysis

A dendrogram of studied fenugreek accessions was drawn using Ward's phenotypic diversity according to nine quantitative morphological descriptors (Figure 2). The dendrogram showed two main clusters of accessions, group A and B. Group (A) was the largest group and it was divided into two sub clusters, A1 and A2.Accession 160 with minimum number of leaves and maximum weight of seeds was included alone in sub cluster A1. Cluster A2 divided into two sub clusters, A2.1 and A2.2. Cluster B was also into two main sub clusters; B1 and B2.

The geographical location of the collected fenugreek accessions were examined through principle components analysis (Figure 3). Four quadrants performed by PCA showed the arrangement of Omani fenugreek accessions four different PCA's (Figure 3). The spread of the accessions in the

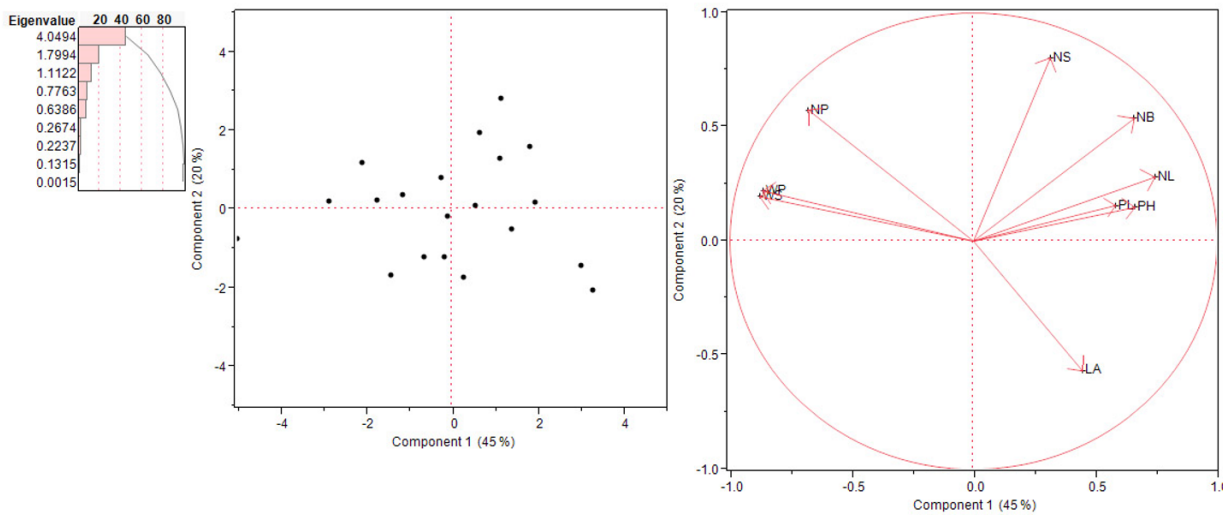

Fig. 1. Eigen value scatter diagram based on nine plant descriptors of Omani fenugreek accessions

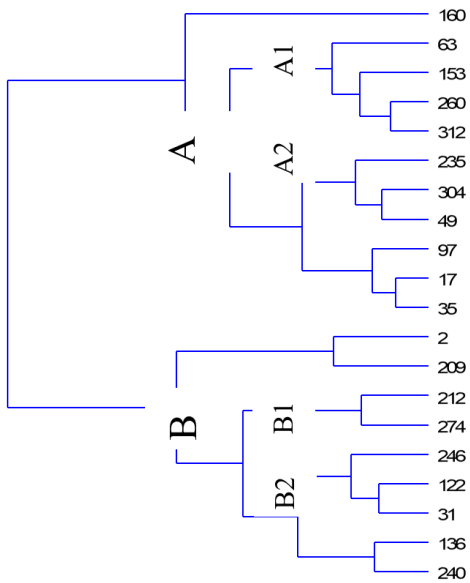

Fig. 2. A Dendrogram analysis of nine quantitative traits based on Ward's phenotypic distance of 20 fenugreek accessions under study

dendrogram indicated that the morphological descriptors were widely different within Omani fenugreek accessions. Principal component analysis (dendrogram) showed that two accessions viz., 17 and 97 were nearby to the center and were more related to each other. In contrast, accession 160 was far away in the dendrogram indicating the phenotypic diversity of this line. The relationship between geographical distances and phenotypic distances is presented in Figure 4.

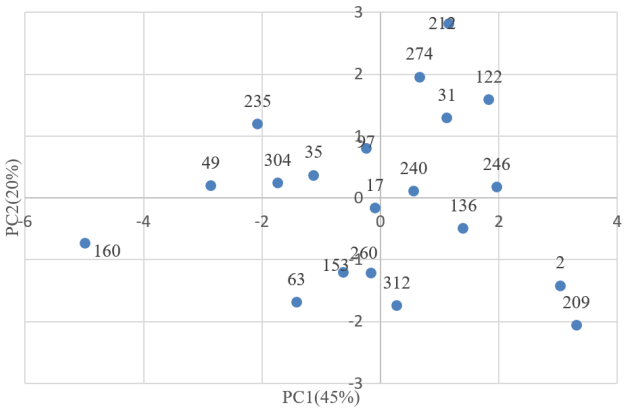

Fig. 3. Principle component analysis scatter diagram illustrating the arrangement of different Omani fenugreek accessions

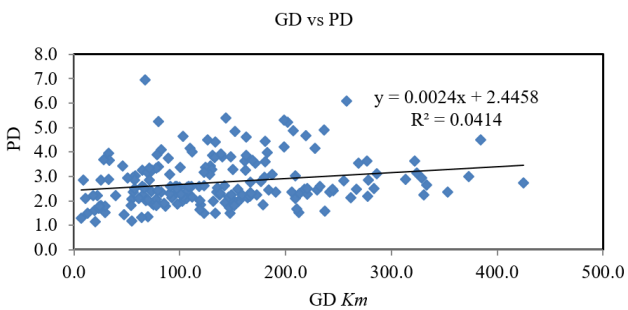

Fig. 4. A scatter diagram between Geographical distance and phenotypic distance of fenugreek accessions under study

Discussion

The results showed non-significant effect of the season and environment on the fenugreek plants, replication order in the field and block arrangement.

In Oman, fenugreek is cultivated mainly for food, fodder and medicinal purposes. This study on morphological characterization showed significant differences in plant height, primary branches, days to 50% flowering, pods/plant, grains/pod, days to maturity, 1000-seed weight and seed yield/plant in an experiment over two years. Such differences were also reported for fenugreek accessions in few other countries (Sharma & Sastry, 2008; Soori & Nejad, 2012; Gangopadhyay et al., 2009; Jain et al., 2005). Our findings suggest the existence of desirable diversity among these accessions.

Sharma & Sastry (2008) found that the mean plant height in fenugreek genotypes was 49.8 cm and produced 4.33 g seed yield. Mean plant height found in this study was less as compared to previous results, but the mean seed yield was more than double in current experiment. The occurrence of significant differences between accessions in agronomic components gave a good indication of variability among the accessions. Sarada et al. (2008) documented that genotypic coefficient of variation is more useful than phenotypic coefficient of variation for the estimates of variability as it depicts more on heritable portion of variability. Similar genetic variability for various agronomic traits was reported by Shokat et al. (2015).

Furthermore, the differences between GCV and PCV indicated that the environment does not have any impact on different traits studied in present investigation. The measures of GCV and PCV for all the traits ranged from 3.1 to 37.2 and from 3.5 to 38.2, which revealed that the traits are less influenced by the environment. These results are in agreement with Singh & Pramila (2009), Gangopadhyay et al. (2009), Sharma & Sastry (2008) and Singh & Pramila (2009).

Heritable variation is a major mechanism for stable genetic improvement (Singh, 2000) and the overall variability relies on heritable and non-heritable traits (Al-Tabbal, 2012). The results presented here support the highest heritability variation in the number of seeds that are an agreement with Singh & Pramila (2009) that 1000 grain weight has high heritability in fenugreek. In addition, Gangopadhyay et al. (2009) found that pods/plant; 1000-seed weight and seed yield/plant have high heritability. In contrast, Sarada et al. (2008) reported high heritability estimates for plant height, pods per plant and seeds per pod.

Heritability is also considered as a useful tool in following up the selection process for the best accession. Burton (1952) stated that the genotypic coefficient of variation along with heritability estimates provide reliable estimates of genetic advance for phenotypic selection. It was interesting to note that the accessions from Al Dakhilia and Al Batinah regions scored the high heritability. Johnson et al. (1955) and Swarup and Chaugale (1962) documented that the heritability index cannot be judged on the basis of genetic richness. The study reported that high heritability is not always an indication of high genetic gain. However, Singh and Pramila (2009) reported that high heritability for the character was controlled by additive genes, which might be useful to plant breeder for making effective selection. Coupling of the heritability and genetic advance is a useful way of sieving and collecting the high genetic gain accessions or cultivars (Panse, 1957; Shokat et al., 2015). Sarada et al. (2008) stated that high heritability and high genetic advance are crucial for the improvement of any character and an important factor for predicting the resultant effect for selecting the best individuals (Al-Tabbal, 2012, Shokat et al., 2015). Number of seeds is considered an important component of seed yield and most importantly in final plant production. Our results demonstrated high values in both heritability or genetic advance, as more genetic gain was observed in case of number of seeds (Table 5). This is in agreement with Sharma &Sastry (2008), who found that high genetic advance forseed yield.

Present results revealed that Omani fenugreek accessions were distributed according to variation in their morphological descriptors. These results are in line with the findings of Soori & Nejad (2012) that high percentage of the variation of seed yield is because of more variations in the number of seeds per plant, number of seeds per pod and 1000 seed weight. The most interesting results came up through the dendrogram and the map, which showed that the accessions viz.160, 63 and 153 were distributed in one cluster (cluster A), which means that they are related to each other and may have the same origin. Accessions 17 and 240 were nearby to the center according to their morphological performance. These distributions of the different accessions between the regions were due to several factors like the trade between the far or closer districts, the movement of the people from one area to another and the distribution of the recommended fenugreek seeds through the ministry of agriculture extension workers.

Conclusion

Results of this study showed that the tested accessions had significant divergence in morphology. The unique differences in the level of phenotypic characteristics evaluated for these accessions can be used as a useful material for producing hybrid varieties. Two accessions 246 and 122 can

be used to produce more green matter and accession 212 for high seed yield. There is an ample scope to improve existing varieties by crossing with these accessions. However, use of molecular techniques is further advised to know the genetic basis of these fenugreek accessions.

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