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Germplasm Collection and Seed Diversity of Cowpea (*Vigna unguiculata* (L.) Walp.)

Nadiya A. Al-Saady[1,*], Saleem K. Nadaf[2], Ali H. Al-Lawati[3] and Saleh A. Al-Hinai[4],

[1*]Oman Animal & Plant Genetics Resources Center, The Research Council, PO Box 1422, PC 130, Al-Athiba, Sultanate of Oman
Formerly, Sultan Qaboos University, Oman

[2]Oman Animal & Plant Genetics Resources Center, The Research Council, PO Box 1422, PC 130, Al-Athiba, Sultanate of Oman
Formerly, Ministry of Agriculture & Fisheries, Oman

[3]Oman Animal & Plant Genetics Resources Center, The Research Council, PO Box 1422, PC 130, Al-Athiba, Sultanate of Oman
Formerly, Ministry of Agriculture & Fisheries, Oman

[4]Directorate General of Agriculture & Livestock Research, Ministry of Agriculture
PO Box 50 PC 121, Al-Seeb, Sultanate of Oman

[*]*Corresponding author's email: nadiya [AT] oapgrc.gov.om*

ABSTRACT---- ***Cowpea (Vigna unguiculata L.) is a legume crop cultivated in whole of Arabian Peninsula countries including Oman as a dual crop for both food and fodder during summer. Both consumers and farmers prefer large size seeds. This paper presents the results of collecting missions of indigenous cowpea germplasm and analysis of seed diversity of collected accessions. The collecting mission led to the accumulation of seed samples of 64 accessions with large number from the governorates of Sharqiya (North Eastern) (19), followed by Dhofar (Southern) (17), Al-Dakhiliyah (Interior) (10), South Batinah (South Coast) (9), North Batinah (North coast) (5) and Dhahira & Buraimi (4). The accessions were diverse in respect to all the seed traits studied, i.e. seed length (cm) and width (cm), 100-seed weight (g) and seed color. The accessions were grouped into 14 genetically diverse clusters based on the Principal Component Analysis, which revealed the contribution of seed length and 100-seed weight to the total variation existing in indigenous germplasm collected from all the governorates of Oman. The results of critical examination of seed color pattern of these samples indicated the presence of as many as 31 groups of which the largest group had 16 accessions followed by a group with 4 accessions, 2 groups with 3 accessions each and 9 groups with 2 accessions. There were 19 accessions numbering 193, 197, 251, 269, 276, 280, 293, 297, 301, 303, 325, 327, 328, 331, 332, 333, 339, 343 and 347 which formed groups of their own due to a unique combination of seed coat colors.***

Keywords--- Landraces, accession, seed characters, diversity, cowpea, *Vigna unguiculata* (L.) Walp.

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1. INTRODUCTION

The Sultanate of Oman is one of the largest countries in the Arabian Peninsula with 85473.10 ha of agricultural land under cultivation [1]. Fruits represent 36.11% followed by fodder crops (39.40%), vegetables (19.72%) and field crops (4.77%). Of the field crops, cowpea (*Vigna unguiculata* (L.) Walp.) is regarded as an important crop among the farmers who grow it for both food and green fodder [2]. The characteristic location of Oman makes its northern part represent Asian countries and its southern part, the African continent in both climate and culture.

Cowpea is a grain legume crop cultivated in the tropic and subtropical areas of the world perhaps because of its drought tolerance. Cowpea is one of the important legume crops in Africa [3-4], American countries [5] and Asia [6]. The cowpea is known for its ability to fix atmospheric nitrogen which allows it to grow on, and improve, poor soils and has high protein content. It is grown throughout Oman in both plains and mountains as summer crop between April and June. Its exact area, productivity and yield figures are not documented. The seeds can be eaten fresh along with the pods and leaves as a vegetable whereas dried seeds are cooked. The plant is used as a green or dry forage.

In cowpeas seed size is considered as an important trait as it directly influences productivity [7] along with seed colors, which determine grain quality for marketing. The seed sizes in cowpea range from less than 10 g to even more than 30g per 100 seeds [8-9]. Commercially, the consumers prefer cowpea seeds of medium to large (15 to 25 g) in the market

[10]. Genetic diversity in the crop species is the key for improvement and development of effective conservation strategies [11-13]. The available genetic diversity in the indigenous germplasm is very useful for selecting diverse parents in breeding programs. There have been several studies undertaken on genetic diversity of cowpea populations not only in the past [14-15] but also recently [13, 16].

In Oman, a range of cowpea ecotypes is grown mainly for their dual food value, and local affinity due to varied ecological conditions. However, due to changing land use patterns and the gradual introduction of high-yielding varieties/crops of commercial value, the indigenous germplasm of various crop species, including cowpea is slowly getting extinct. Since almost three decades, several collecting missions were carried out to collect germplasm of different crops grown in Oman either independently or jointly with national and international organizations [17-19]. During these missions the most of the landraces of alfalfa, wheat, barley and grain legumes like chickpea, faba bean, cowpea, lentil, fenugreek etc. were collected and preserved in local conservation facilities. In continuation of these, a series of joint collection missions between the Sultan Qaboos University and the Ministry of Agriculture & Fisheries of Oman were undertaken from different sites within all the governorates of Oman from 2008 to 2009/2010 [17] to safeguard and maintain the genetic diversity of vast indigenous germplasm available in legume crops of Oman. This paper presents the results of cowpea germplasm collection in addition to a brief account of their diversity in respect of few seed traits because of their importance from marketing perspective.

2. MATERIALS AND METHODS

Materials and methods for germplasm collection and conservation adopted were as described by Al-Saady *et al*. [17]. Indigenous cowpea accessions were collected from 62 sites across all the governorates of the Sultanate (Table 1). Seed length and width (cm), test weight (1000 seed), seed color and nature of seed samples (pure or mixture) were recorded in the laboratory according to Ghalmi *et al.* [20]. The principal component analysis method was followed in the extraction of the components using correlated matrix from the crop collection data. Principal Component Analysis was performed using XLSTAT software [21].

3. RESULTS

During collecting mission of land races of legume crops, 64 seed accessions were collected from different governorates of Oman. The highest number of accessions were obtained from Sharqiya (Eastern) governorates (19), followed by Dhofar (Southern) governorate (17), Al-Dakhliyah (Interior) governorate (10), South Batinah (coastal) governorate (9), North Batinah (coastal) governorate (5) and Dhahira & Buraimi governorate (4) (Table 1).

Table 1: The sites/ locations in different villages, wilayats / districts and governorates/ states from where cowpea (*Vigna unguiculata* (L.) Walp. accessions were collected along with their latitudes, longitudes and altitudes

Sl. No.	Site No.	Accession No.	Governorate/ State	Wilayat/ District	Village/ location	Latitude (N)	Longitude (E)	Altitude (m)
1	3	OMA 10	Interior	Nizwa	Nizwa city	22° 57.80'	57° 31.67'	508
2	5	OMA 12	Interior	Manah	Al Mamarah	-	-	-
3	7	OMA 20	Interior	Manah	Manah Al Blaad	22° 47.88'	57° 35.98'	430
4	11	OMA 30	Interior	Adam	Al Belad	22° 22.65'	57° 31.70'	308
5	13	OMA 36	Interior	Bahla	AL-khtwah	22° 59.32'	57° 17.91'	363
6	17	OMA 47	Interior	Al Hamra	Musfat Al Abreen	-	-	-
7	18	OMA 48	Interior	Al Hamra	Al Qlaah	23° 05.28'	57° 17.40'	647
8	20	OMA 53	Interior	Al Hamra	Ghamour	23° 05.02'	57° 16.45'	663
9	29	OMA 90	Dhahira	Ibri	Bat	23° 15.22'	56° 45.23'	508
10	30	OMA 93	Dhahira	Ibri	Alablaah	23° 04.84'	56° 54.14'	580
11	31	OMA 99	Dhahira	Ibri	Baroot	23° 14.55'	57° 02.47'	716
12	45	OMA 140	Batinah South	Rustaq	Azammah	23° 13.48'	57° 24.79'	614
13	55	OMA 157	Batinah South	Rusaq	AL Dahir	-	-	-
14	57	OMA 169	Batinah South	Rustaq	Almahdooth	23° 30.52'	57° 11.42'	482

15	58	OMA 172	Batinah South	Rustaq	Almahdooth	23° 30.57'	57° 11.36'	476
16	61	OMA 184	Batinah South	Rustaq	Nezooh	23° 28.92'	57° 17.21'	344
17	63	OMA 186	Batinah South	Rustaq	Salm	23° 28.36'	57° 17.95	366
18	64	OMA 190	Batinah South	Wadi Al-Maawel	Alghubrah	23° 16.41'	57° 41.78'	536
19	65	OMA 193	Batinah South	ADC,Rustaq	-	-	-	-
20	66	OMA 197	Batinah South	Nakhal	Al-Qoorah	23° 05.38'	57° 44.20'	1322
21	83	OMA 219	Interior	Izki	Al-Humedian	22° 47.14'	57° 52.91'	422
22	84	OMA 226	Interior	Izki	Al-Aqil	-	-	
23	89	OMA 236	Buraimi	Buraimi	AL-Hail	24° 12.31'	56° 13.94'	501
24	96	OMA 245a	Sharqiya	AL-Qabel	Bateen	22° 45.42'	58° 41.40'	442
25	97	OMA 249	Sharqiya	AL-Qabel	Bateen	22° 39.25'	58° 41.13'	442
26	98	OMA 251	Sharqiya	AL-Qabel	AL-Neba	22° 43.72'	58° 41.01'	411
27	106	OMA 264	Sharqiya	Ibra	AL-Khoodood	22° 52.02'	58° 25.93'	565
28	108	OMA 269	Sharqiya	ADC, Ibra	-	-	-	-
29	109	OMA 271	Sharqiya	Mudhaibi	AL-Rawadah	22° 53.05'	58° 13.25'	617
30	110	OMA 276	Sharqiya	Mudhaibi	Wadi Endam	22° 52.71'	58° 00.31'	576
31	111	OMA 277	Sharqiya	Mudhaibi	AL-Kreesheefah	22° 16.75'	58° 02.70'	245
32	112	OMA 280	Sharqiya	Mudhaibi	AL-Kreesheefah	22° 16.52'	58° 02.83'	252
33	114	OMA 282b	Sharqiya	Wadi Atayeen	Asubal	23° 07.22'	58° 31.72'	439
34	115	OMA 283	Sharqiya	Wadi Atayeen	Asubal	23° 06.87'	58° 32.09'	434
35	116	OMA 287	Sharqiya	Wadi Atayeen	ALOmsa	22° 58.82'	58° 31.87'	550
36	117	OMA 288	Sharqiya	Wadi Atayeen	Sedab	22° 59.87'	58° 45.07'	320
37	118	OMA 291	Sharqiya	Wadi Atayeen	Maqtaa	22° 49.33'	58° 59.33'	1089
38	120	OMA 293	Sharqiya	Wadi bani Khalid	AL-Qaryah	22° 35.97'	59° 05.37'	611
39	122	OMA 297	Sharqiya	Wadi bani Khalid	AL-Hajrh	22° 35.93'	59° 04.87'	594
40	123	OMA 300	Sharqiya	Wadi bani Khalid	AL-Hajrh	23° 35.93'	60° 04.87'	595
41	*124	OMA 301	Sharqiya	Wadi bani Khalid	Halfah	22° 33.61'	59° 06.47'	529
42	124	OMA 303	Sharqiya	Wadi bani Khalid	Halfah	22° 33.61'	59° 06.47'	529
43	125	OMA 308	Batinah North	Liwa	Helat Shaik	24° 30.56'	56° 54.41'	26
44	126	OMA 311	Batinah North	Liwa	Helat Alhassan	24° 30.30'	56° 33.03'	28
45	128	OMA 316	Batinah North	Sohar	Wadi Aheer	23° 59.35'	56° 28.93'	467
46	131	OMA 319	Batinah North	Sohar	al-Mehab	24° 00.59'	56° 41.56'	228

47	134	OMA 321	Batinah North	Saham	Haret Al Gahafel	-	-	-
48	138	OMA 324	Dhofar	Salalah	Wadi Nahees	17° 10.67'	59° 05.09'	306
49	139	OMA 325	Dhofar	Salalah	Wadi nahees, jyam	17° 10.03'	54° 05.15'	295
50	140	OMA 326	Dhofar	Sheheet	-	17° 12.35'	54° 07.53'	513
51	141	OMA 327	Dhofar	Rakhyoot	Kazaat	16° 49.29'	53° 24.62'	916
52	142	OMA 328	Dhofar	Rakhyoot	Felkatta	16° 47.21'	53° 19.63'	798
53	143	OMA 329	Dhofar	Rakhyoot	Haar	-	-	-
54	144	OMA 330	Dhofar	Thalkoot	farooq	16° 41.65'	53° 08.76'	653
55	145	OMA 331	Dhofar	Thalkoot	Khazrafee	16° 41.74'	53° 09.95'	622
56	146	OMA 332	Dhofar	Thalkoot	Al-Ghaythoot	16° 43.36'	53° 13.63'	749
57	147	OMA 333	Dhofar	Taqah	Shehat	17° 06.37'	54° 24.57'	452
58	149	OMA 334	Dhofar	Taqah	Shebdate	17° 07.19'	54° 25.68'	487
59	151	OMA 336	Dhofar	Taqah	Geloy	17° 11.10'	54° 27.28'	628
60	152	OMA 339	Dhofar	Mirbat	Qadeeh	17° 04.53'	54° 27.80'	356
61	153	OMA 340	Dhofar	Mirbat	-	17° 06.94'	54° 32.58'	625
62	154	OMA 343	Dhofar	Mirbat	-	17° 06.21'	54° 33.70'	606
63	*155	OMA 344	Dhofar	Mirbat	Tharbad	17° 05.13'	54° 34.88'	504
64	155	OMA 347	Dhofar	Mirbat	Tharbad	17° 05.13'	54° 34.88'	504

- Indicates information not available as the seed samples were obtained at Agriculture Development Centers of respective wilayats/ districts.
* Locations where two seed samples were received from the farmers.

Variation in sites:

The sites of collections varied in their features and altitude. Altitude ranged from 26 m at site No.125 from Helat Shaik, Wilayat Liwa of Batinah North to 1322 m at site No. 66 from Al-Qoorah, wilayat Nakhal of Batinah South (Table 1). Similarly, collection sites also differed in soil texture from sands, sandy loam to sandy clay, sandy clay loam, clay and loam. Soils were either hard, firm or loose and had crust and friable features. In respect of drainage, soils were imperfect to be free or variable. Soil pH varied from 2.1 (Site No.58, Al-Mahdooth Hajer Bani Omer, wilayat Rustaq, Batinah South) to 9.5 (Site No. 13, Al-Khtwah, wilayat Bahla, Al-Dakhliya). Soil EC varied from 0.6 dSm^{-1} (Site No.7, Al-Blaad, wilayat Manah, Batinah South) to 9 dSm^{-1} (Sites No. 57 & 58, Al-Mahdoot, wilayat Rustaq, Batinah South). Soil color varied from light brown to brown.

Variability in seed characters:

The cowpea accessions had large variation for all the seed traits investigated such as seed length (cm) and width (cm), 100-seed weight (g) and seed color (Table 2). Seed length ranged from 0.425 cm (Collection No. 219 of Site No.83, Al-Humedian, Izki, Interior) to 0.850 cm (Collection No. 330 of Site No. 144, Farooq, Thalkoot, Dhofar); seed width varied from 0.295 cm (Collection No. 219 of Site No. 83, Al-Humedian, Izki, Interior) to 0.560 cm (Collection No. 324 of Site No. 138, Wadi Nahees, Salalah, Dhofar); 100-seed weight varied from 4.200 g (Collection No. 219 of Site No.83, Al-Humedian, Izki, Interior) to 16.300 g (Collection No. 327 of Site No. 141, Kazaat, Rakhyoot, Dhofar and No. 336 of Site No. 151, Geloy, Taqah, Dhofar) (Tables 1 and 2).

Table 2: Variation among seed characteristics of 64 indigenous cowpea genotypes/accessions

Sl. No.	Accession No.	Length (cm)	Width (cm)	100 seed weight (g)	Seed color	Color
1	OMA 10	0.675	0.51	9.4	Homogeneous	Tan, light green
2	OMA 12	0.575	0.37	5.5	Heterogeneous	Light green, light brown
3	OMA 20	0.61	0.41	8.7	Heterogeneous	Tan, light brown, dark brown
4	OMA 30	0.545	0.37	5.6	Heterogeneous	Light green, light brown
5	OMA 36	0.68	0.445	7.7	Heterogeneous	Light green, light brown, dark brown
6	OMA 47	0.65	0.405	8.7	Heterogeneous	Light green, light brown, dark brown

7	OMA 48	0.605	0.395	7.6	Heterogeneous	Light green, light brown, dark brown
8	OMA 53	0.65	0.41	8.1	Heterogeneous	Light green, light brown, dark brown
9	OMA 90	0.6	0.425	7.9	Heterogeneous	Light green, dark brown
10	OMA 93	0.6	0.4	7.7	Heterogeneous	Light green, brown
11	OMA 99	0.615	0.395	7.1	Heterogeneous	Light green, cream, light brown, dark brown, black
12	OMA 140	0.655	0.41	9	Heterogeneous	Light green, light brown, dark brown
13	OMA 157	0.605	0.4	7.1	Heterogeneous	Light green, light brown, dark brown
14	OMA 169	0.58	0.44	7.9	Heterogeneous	Light green, dark brown
15	OMA 172	0.65	0.415	10	Heterogeneous	Light green, Brown
16	OMA 184	0.66	0.495	8.8	Heterogeneous	Light green, cream, light brown, dark brown
17	OMA 186	0.605	0.425	7.7	Heterogeneous	Light green, dark brown
18	OMA 190	0.62	0.425	7.93	Heterogeneous	Light green, light brown, dark brown
19	OMA 193	0.675	0.445	9.4	Homogeneous	Light brown
20	OMA 197	0.575	0.375	5.6	Heterogeneous	Tan, light green, brown, yellowish brown
21	OMA 219	0.425	0.295	4.2	Heterogeneous	Tan, light brown, dark brown
22	OMA 226	0.635	0.395	7	Heterogeneous	Light green, light brown, dark brown
23	OMA 236	0.57	0.405	6.3	Heterogeneous	Light green, light brown, dark brown
24	OMA 245a	0.51	0.365	5.3	Heterogeneous	Light green, light brown, dark brown
25	OMA 249	0.57	0.415	5.9	Heterogeneous	Light green, light brown, dark brown
26	OMA 251	0.5	0.365	5.4	Heterogeneous	Light green, light brown, black
27	OMA 264	0.67	0.47	7.8	Heterogeneous	Light green, light brown
28	OMA 269	0.56	0.415	4.9	Heterogeneous	Light green, light brown, dark brown, black
29	OMA 271	0.555	0.395	4.5	Heterogeneous	Light green, cream, light brown, dark brown, black
30	OMA 276	0.64	0.485	7.8	Heterogeneous	Dark brown, blackish brown
31	OMA 277	0.555	0.375	5.4	Heterogeneous	Cream, brown
32	OMA 280	0.505	0.34	4.5	Heterogeneous	Light brown, dark brown
33	OMA 282b	0.525	0.39	5	Heterogeneous	Light green, light brown, dark brown
34	OMA 283	0.565	0.415	7.2	Heterogeneous	Light green, cream, brown
35	OMA 287	0.575	0.42	6	Heterogeneous	Cream, brown
36	OMA 288	0.575	0.41	5.2	Heterogeneous	Cream, light brown, dark brown
37	OMA 291	0.53	0.43	5.4	Heterogeneous	Light green, cream, brown
38	OMA 293	0.545	0.39	5.4	Heterogeneous	Light green, dark brown, blackish brown
39	OMA 297	0.54	0.42	5.4	Heterogeneous	Light green, cream, light brown, black
40	OMA 300	0.545	0.4	5.4	Heterogeneous	Cream, light brown, dark brown
41	OMA 301	0.545	0.41	5.4	Heterogeneous	Light green, light cream, light brown
42	OMA 303	0.565	0.38	4.6	Heterogeneous	Cream, dark brown, black
43	OMA 308	0.55	0.39	6.3	Heterogeneous	Light green, light brown, dark brown
44	OMA 311	0.58	0.405	7	Heterogeneous	Light green, light pinkish, cream
45	OMA 316	0.575	0.375	5.5	Heterogeneous	Light cream, cream, light brown, dark brown
46	OMA 319	0.62	0.425	6.4	Heterogeneous	Light green, light brown, dark brown
47	OMA 321	0.675	0.45	8.4	Heterogeneous	Light green, light brown, dark brown
48	OMA 324	0.84	0.56	15.8	Heterogeneous	Light cream, cream, light brown, dark brown
49	OMA 325	0.795	0.555	15.1	Heterogeneous	Cream, light purple, black pinkish
50	OMA 326	0.74	0.5	14.1	Heterogeneous	Light green, light pinkish, cream
51	OMA 327	0.82	0.52	16.3	Heterogeneous	Cream, pinkish cream, black
52	OMA 328	0.76	0.53	12	Heterogeneous	Light green, light brown, dark brown with white

						mottles
53	OMA 329	0.76	0.495	12.4	Heterogeneous	Light green, cream, light purple, dark brown
54	OMA 330	0.85	0.52	15.4	Heterogeneous	Light green, cream, light purple, dark brown
55	OMA 331	0.78	0.49	12.8	Heterogeneous	Light green, cream, light brown, dark brown with white mottles
56	OMA 332	0.76	0.345	12.9	Heterogeneous	Light cream, cream, black
57	OMA 333	0.795	0.555	15.1	Heterogeneous	Cream, light brown, black
58	OMA 334	0.74	0.5	14.1	Heterogeneous	Light green, light brown, dark brown
59	OMA 336	0.82	0.52	16.3	Heterogeneous	Light green, cream, pinkish brown, black
60	OMA 339	0.745	0.515	13.5	Heterogeneous	Cream, pinkish cream, brown with white mottles, black
61	OMA 340	0.765	0.51	13.8	Heterogeneous	Light green, light brown
62	OMA 343	0.76	0.335	13.2	Heterogeneous	Light green, light brown, cream
63	OMA 344	0.74	0.345	13.4	Heterogeneous	Light green, cream, pinkish brown, black
64	OMA 347	0.745	0.315	13.7	Heterogeneous	Light green, light pinkish cream, black
Statistical Parameters						
Minimum		0.425	0.295	4.200		
Maximum		0.850	0.560	16.300		
Mean		0.638	0.425	8.767		
S.E.(±)		0.012	0.008	0.457		

In respect of seed color, only one accession i.e. Accession No. 10 of Site No. 3, Nizwa City, Nizwa, Interior was homogenous (pure) with tan, light green seeds whereas remaining (63) were heterogeneous (mixture) with seeds of various colors ranging from light green, cream, light brown, dark brown, black to white mottles. The results of critical examination of pattern of seed colors found in different samples of the accessions clearly indicated the presence of as many as 31 groups of which the largest group had 16 seed accessions followed by a group with 4 accessions, 2 groups with 3 accessions each and 9 groups with each of 2 accessions. There were 19 seed accessions numbering 193, 197, 251, 269, 276, 280, 293, 297, 301, 303, 325, 327, 328, 331, 332, 333, 339, 343 and 347 which formed groups of their own due to a unique combinations of seed colors (Table 2).

Principal Component Analysis:

The Principal Component Analysis (PCA) was performed to comprehend which combination type of three seed characters contribute high quality of the indigenous cowpea germplasm in terms of their value in marketing. The scree plot of the PCA (Figure 1) showed that the first two eigenvalues had major proportion of the variance in the dataset. Similarly, the first two PCAs extracted from the components amounted to 96.515 % with PC 1 having eigenvalue of 2.388 and PC 2, just 0.507 (Table 3).

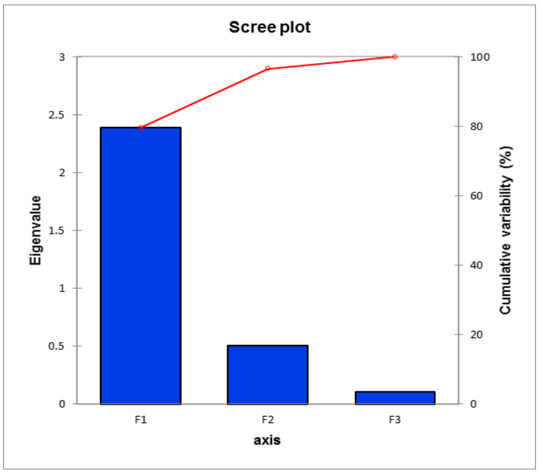

Figure 1: Scree plot showing eigenvalues in response to three principal components (F1 to F3) for three seed variables/ characters

Table 3: Eigen values and percent variance of principal components to total variation in indigenous cowpea germplasm

Principal Components (PC' s)	Eigen value	% Variance	Cumulative variance
PC 1	2.388	79.608	79.608
PC 2	0.507	16.907	96.515
PC 3	0.105	3.485	100.000

The PCA simplifies the complex data to transform the number of associated traits into a smaller number of principal components as PCs or factors (Fs). The first PC has maximum variability in the data-set in comparison with succeeding components. In the present study, the PCA grouped the estimated cowpea variables into three main components of which PC 1 accounted for 79.608% of the variation; PC 2 for 16.907% and PCA 3 for 3.485% (Table 3). The first PC was positively influenced by seed length with the value measuring 0.949 and 100-seed weight with 0.926 whereas the second PC was also influenced positively by seed width but with low value (0.608). However, third PC was also associated with seed length but had low value (0.237) (Table 4). Similarly, only positive and significant correlation values (r) were found between three seed traits, studied viz. seed length vs seed width (0.620*), seed length vs 100-seed weight (0.821**) and seed width vs 100-seed weight (0.555*) (Table 5).

Table 4: The principal component values of three seed size characters in 64 cowpea accessions

Variables/Characters	PC 1	PC 2	PC 3
Seed length (cm)	0.949	-0.208	0.237
Seed width (cm)	0.794	0.608	-0.029
100 Seed-Weight (g)	0.926	-0.307	-0.218

Table 5: Correlation coefficients between seed size characters of cowpea accessions in Oman

	Seed length (cm)	Seed width (cm)	100 Seed-Weight (g)
Seed length (cm)	1	0.620*	0.891**
Seed width (cm)		1	0.555*
100 Seed-Weight (g)			1

In terms of per cent contribution of seed traits to the PCs, both seed length and 100-seed weight together contributed to the extent of 73.63% to PC1 and 99.19% to PC3 whereas seed width alone had 72.82% contribution to PC2 (Table 6).

Table 6: The percent contribution of variables (three seed size characters) to three principal component values in 64 cowpea accessions

Variables/Characters	PC 1	PC 2	PC 3
Seed length (cm)	37.704	8.544	53.752
Seed width (cm)	26.371	72.821	0.808
100 Seed-Weight (g)	35.925	18.634	45.441

The scatter of 64 indigenous cowpea accessions in biplot graph of the first two principal components as X and Y –axes clearly showed pattern of clustering in all the four quadrants of the graph and separated into 14 clusters where the accessions belonging to the same cluster are closely positioned to form clusters in whichever quadrants of the graph they belonged due to their similarities (Figure 2 and Table 7). The number of accessions in clusters ranged from single (Cluster I and Cluster VIII) to the highest of 7 (Cluster XI and Cluster XII). The remaining 10 clusters had accessions ranging from 4 to 6. The accessions of the clusters either belonged exclusively to the same governorates like Shariya (Eastern) (Clusters II and IV) and Dhofar (South) (Clusters X, XII and XIV) or to different governorates (Clusters III, V, VI, VII, IX, X, XIII). Each cluster varied greatly with respect to means of seed characters, studied (Table 7).

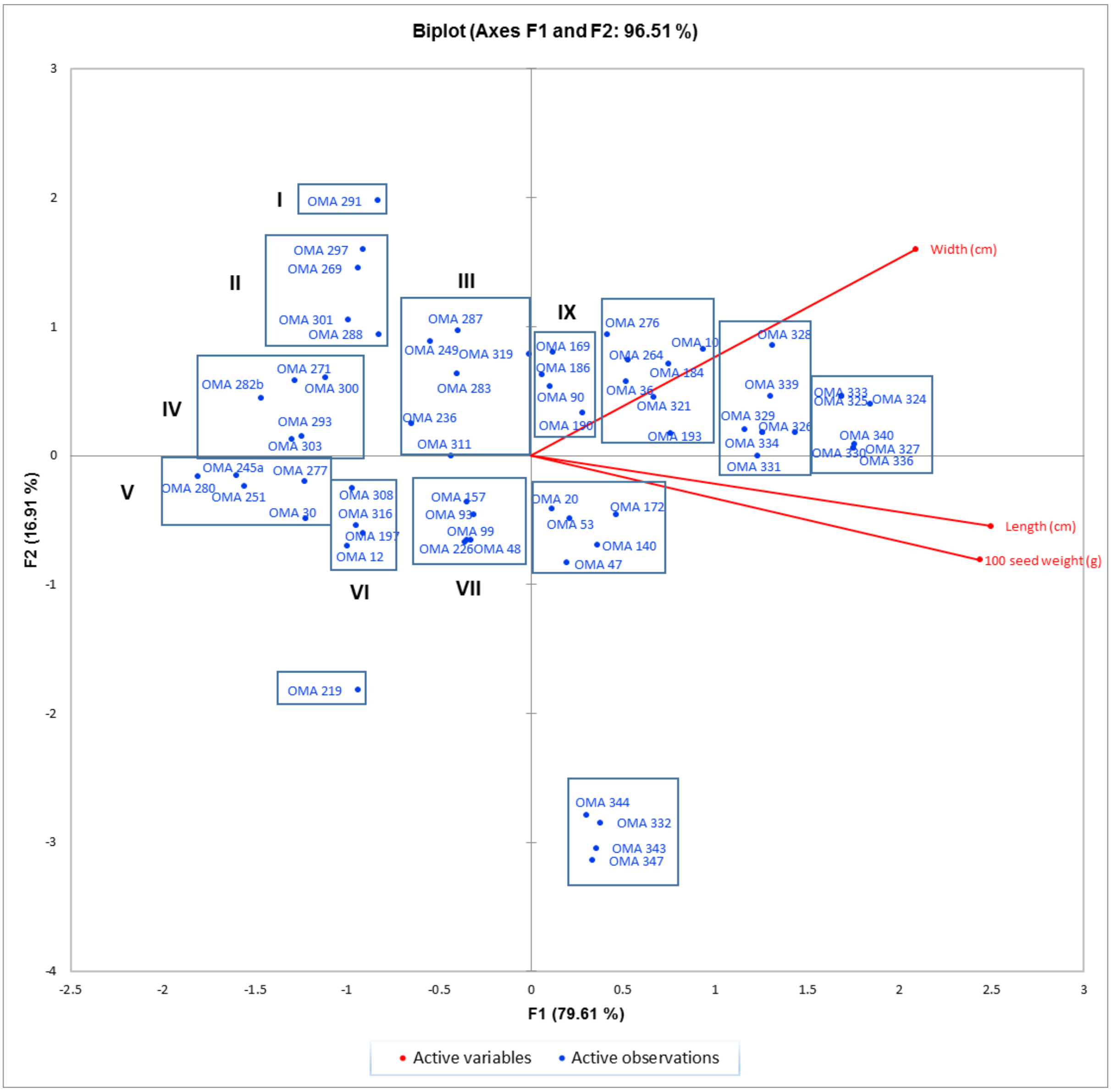

Figure 2: Principal component scores of PC1(F1) and PC2(F2) showing the overall variation/scattering among indigenous cowpea germplasm in terms of three seed traits

Table 7: Distribution of 64 accessions of cowpea in 14 clusters and cluster means of three seed characters

Cluster No.	Number of Accessions	Constituents (Accession Nos.)	Seed length (cm)	Seed width (cm)	100-seed weight (g)
I	1	OMA 291	0.53	0.43	5.4
II	4	OMA 269, OMA 288, OMA 297, OMA 301	0.55	0.41	5.22
III	6	OMA 236, OMA 249, OMA 283, OMA 287, OMA 311, OMA 319	0.58	0.42	6.65
IV	5	OMA 271, OMA 282b, OMA 293, OMA 300, OMA 303	0.54	0.39	5.10
V	5	OMA 30, OMA 245a, OMA 251, OMA 277, OMA 280	0.52	0.36	4.97
VI	4	OMA 12, OMA 197, OMA 308, OMA 316	0.57	0.38	5.72
VII	5	OMA 48, OMA 93, OMA 99, OMA 157, OMA 226	0.61	0.40	7.22
VIII	1	OMA 219	0.42	0.30	4.25
IX	4	OMA 90, OMA 169, OMA 186, OMA 190	0.60	0.43	7.86
X	7	OMA 10, OMA 36, OMA 184, OMA 193, OMA 264, OMA 276, OMA 321	0.66	0.46	8.35
XI	6	OMA 326, OMA 328, OMA 329, OMA 331, OMA 334, OMA 339	0.76	0.50	13.20
XII	7	OMA 324, OMA 325, OMA 327, OMA 330, OMA 333, OMA 336, OMA 340	0.81	0.53	15.15
XIII	5	OMA 20, OMA 47, OMA 53, OMA 140, OMA 172	0.65	0.41	8.95
XIV	4	OMA 332, OMA 343, OMA 344, OMA 347	0.75	0.33	13.30
Total	64				

4. DISCUSSION

A range of indigenous cowpea germplasm was collected during the collecting mission from the most of governorates of the Sultanate of Oman. Sharqiya governorates represented the most collections (29.69%), followed by Dhofar (26.56%), Al-Dakhliyah (Interior) (15.63%), South Batinah (coastal) (14.06%), North Batinah (7.81%) and and Dhahirah & Buraimi (6.25%) (Fig.3). Interestingly, Musandam governorate had no contribution to collections during this collecting mission (Figure 2) possibly because of irrigation water shortage in the area and farmers' switch over to greenhouse cultivation of vegetables [2].

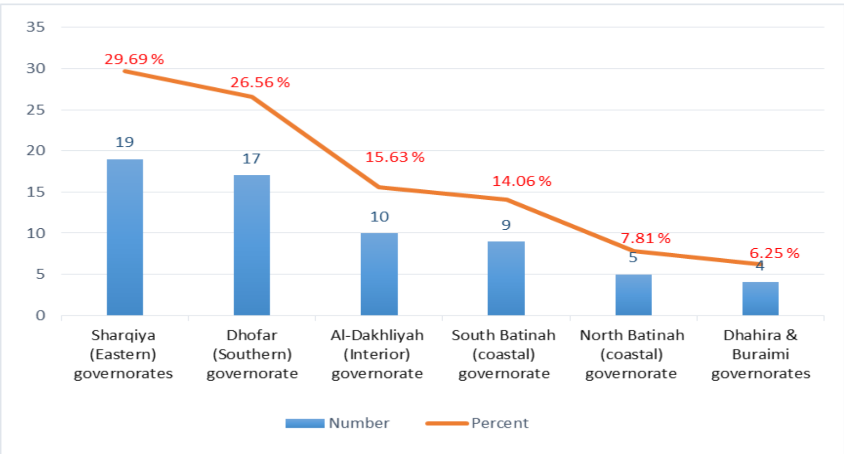

Figure 3: Percent contribution of different governorates of Oman for the indigenous cowpea accessions

The results of critical examination of seed samples of cowpea germplasm accessions at the laboratory revealed large variation not only in seed size characters but also in seed coat patterns (color). 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 germplasm [6, 9, 12, 13, 16, 24, 25] or core collections of large germplasm available at IITA, Nigeria, Africa [26]. In the this study, 113 accessions of cowpea obtained from the CSIR – PGRRI genebank at Bunso, Ghana and IITA, Nigeria, were classified into four main types namely black, big black eye, mottle and mottle eye and investigated their genetic diversity using SNP (Simple Nucleotide Polymorphism) markers [27]. In the present study, villages located closely to collecting sites had interestingly either similar or different patterns of seed coat color indicating the presence of large amount of heterogeneity through mixing at the farmers'level in the collected cowpea seed samples/ accessions. Hence, there is need for intensive purification of seed accessions into sub-groups with respect to seed color pattern [17].

The widespread exchange of landraces of cowpea between wilayats and neighboring governorates indicates that these landraces/accessions are the products of centuries of selection for adaptation to local climatic, edaphic and cultural factors to eventually have unique gene complexes, which reflect local agro-climatic differences and evolution [17-19, 22]. Constant availability of local landraces with the farmers indicates existence local conservation strategy for sustainable production [17]. Genetic erosion of landraces of cowpea was found in Musandam governorate, as there were no collections (Fig. 2). In other governorates like Al-Dakhliyah, Al-Batinah and Dhahirah & Buraimi lower number of samples were obtained than the collections made in other collecting missions in the past in Oman [23]. This is attributed to displacement of landraces by modern high-yielding crops, changes in land use pattern, erratic drought, and the lack of enthusiasm among present day farmers to grow non-commercial crops like cowpea.

The correlation analysis of seed characters showed their significant ($p<0.05$) and positive associations between each other. Selection of strongly associated characters like seed length and 100-seed weight can be used to improve seed quality characters that influence yield and their value in marketing [9, 12, 16].

The results of PCA analysis are expected to be valuable to the breeders in detecting the phenotypic characters that contribute higher genetic variations among the genotypes for selecting potential accessions as parents in crossing program to improve the traits of interest for productivity in quantity and quality [25]. In the present study, the results of PCA clearly showed that all the seed traits contributed positively to PCA1 indicating that this component reflected the potentiality of seed size in cowpea germplasm whereas only seed width contributed positively to PCA2. The existence of wider phenotypic variation among the indigenous cowpea germplasm was further explained by the biplot graph which indicated an overview of the similarities and differences among the cowpea accessions as well as of the interrelationships between the variables, studied. The graph characteristically demarcated the accessions about their scattering pattern based on the first two dimensions/ components into 14 clusters based on seed characters in all the four quadrants, indicating the existence of wide genetic variation for the traits, studied. The accessions OMA 291 from Wadi Atayeen, Sharqiya and OMA 219 from Izki, Al-Dakhliya (Interior) 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. The fact that accessions of certain clusters were similar or different in terms of their locations indicates the extent of inter-exchange of the accessions among the farmers of different governorates [17]. 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.

5. ACKNOWLEDGEMENT

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