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RESEARCH FELLOWSHIP REPORT

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Title of Research Fellow Project:

Cactus pear as multiple purpose crop to improve provisioning of ecosystem services

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Introduction

Semi-arid and arid regions are a challenge to conventional cropping systems because of limited or erratic rainfall, poor soils, and high temperatures (Le Houérou, 1996). These characteristics have resulted in low yields from the cultivation of conventional crops such as cereals and pulses (Russell and Felker 1987). However, productivity in these areas can be increased by the cultivation of adapted crops such as cactus (*Opuntia* species), especially cactus pear (Pimienta-Barrios and Muñoz-Urias, 1995). Cactus pear is increasingly being cultivated in these areas since it can tolerate water-limited conditions, high temperatures, and poor soils (FAO, 2016). *Opuntias* have developed phenological, physiological, and structural adaptations to the arid areas characterized by drought, erratic rainfall and poor soils. As an ideal plant for arid and semi-arid area growth and cultivation, this plant is capable of growing in rocky areas (Felker et al., 2006). It is also capable to be planted in rocky areas or in areas where the soil volume is limited due to the high level of soil erosion resulting from the loss of plant cover that is associated with land degradation. (Felker and Inglese, 2003).

Opuntia is used as a source of food, forage, fuel wood, cash income, raw material for various industrial products (pharmaceutical and cosmetic products), as live fences and for soil conservation purposes (Brutsch, 1997; Mitiku et al., 2002; Felker and Inglese, 2003). Cactus pear is consumed, mainly as fresh fruit, flowers and mature cladodes low lignified are used as forage (Corrales-García et al., 2004; Felker et al., 2006). The multi-functionality of this crop identifies it as a plant that developing countries in arid and semiarid regions will benefit from and, if developed further, this crop could contribute to sustainable food production in countries with large areas of semiarid and arid land (Felker and Inglese, 2003).

However, this fruit crop is not developed as in case of other fruit and fodder variety agricultural crops, due to several obstacles such as; lack of adequate characterization and evaluation of the available germplasm of cactus pear (Mashope, 2007). Few germplasm collections of cactus pear are maintained at several locations around the world (Chapman et al., 2002), difficulties and high cost of preservation because of its perennial habit and large plant size, and the difficulty in genotype identification, all hindering the systematic collection and evaluation of cactus pear germplasm material (Chessa and Nieddu, 1997). This is evidenced by the scarcity of published accounts of the breeding history, characterization and evaluation data of this crop (Chapman et al., 2002). Consequently, cactus pear identification, descriptor evaluation and conservation is currently a priority for all scientists and conservationists involved in the economic utilization and promotion of this plant as both a crop and a source of land rehabilitation strategy.

In Jordan, accessions for fruit and fodder production can be distinguished by different criteria such as the colour of the fruit peel and ripe flesh, which can be purple-red, yellow-orange, white-cream or greenish (Chessa and Nieddu, 1997). Red, yellow and white fruits are present in all the cactus cultivated areas whilst green fruits, with a white-greenish flesh, can be found only in Chile and Peru (Mondragon-Jacobo and Pimienta Barrios, 1995). Accessions also differ in terms of plant shape, vigour, fertility, cladode and fruit size, fruit ripening time, seed count and ability to reflower (Barbera and Inglese, 1993; Pimienta Barrios, 1990; Wessels, 1988). In Italy, the germplasm of Sardinia and Sicily have been investigated and described with major differences occurring for fruit size, flesh firmness, fruit ripening time (Pimienta-Barrios and Muñoz-Urias 1995). However, the absolute lack of any commercial nursery activity accounts for most of field variability, which is usually encountered in the Sicilian industry. No more than 12 accessions have been described in Sicily, including a low seeded one and a spineless accession, which are considered unstable mutations. The best-appreciated fruits by the international markets have a yellow-orange flesh, such as *Gialla*. However, consumers unfamiliar with this fruit are highly fascinated by the red fruits, which they buy first, because of their intense colour. Fruits with white or greenish flesh are relevant only for regional or local markets, and their international trade is not relevant.

Description of Research Project

The objectives of this research were:

- to investigate morphological characterization of vegetative organs of 109 *Opuntia ficus indica* (OFI) accessions to contribute to cladodes variability knowledge,
- to identify the main characteristics contributing to discriminate OFI accessions.
- to investigate the effect of soil volume restriction on above ground growth of *Opuntia ficus-indica* through understanding the limit imposed by root confinement via different soil volumes on canopy growth.

It was hypothesized that reiterative selection by farmers, consumers, and continuous cultivation reduce morphological variability (induce homogeneity) between *Opuntia* types, but the morphometric analysis of vegetative characteristics allows group separation and highlights the distinctive characteristics in a *Opuntia ficus indica* collection.

Materials and Methods

This study was conducted in Jordan, Muchaqqar Regional Research Center, approximately 25 km, south of Amman. The main crops cultivated in the villages surrounding the research center are barley and wheat, while cactus pear and some olive and almond shrub species are common as a source of food, forage and income generation. The climate is typical Mediterranean semi-arid, with an average annual rainfall of approximately 300 mm falling between November and March. The dry period of the year can extend to seven months (April–October).

A. *Opuntia ficus-indica* (cactus) characterization (descriptor)

More than 100 cactus accessions imported from different countries (Italy, USA, Brazil, Tunisia, South Africa, Mexico, Morocco, etc.) have been established during 2013 in a field Genebank at Muchaqqar Research Station. The accessions were identified for description and listed to determine their plant characters. Single cladodes were established at a plant spacing of 3m x 4m in rows orientated E/W, with recommended standard orchard practices followed during the planting.

Non-random, purposive sampling techniques were employed in the identification and collection of the samples. For the purpose of fruit, cladode and plant characterization, five plants from each accession were considered as replicates and the accessions as treatments. Plant characterization methods description of accessions for vegetative, cladode and fruit characters was done following the internationally accepted and standardized descriptors developed by Chessa and Nieddu (1997).

These descriptors were developed by scientists who participated in the Food and Agricultural Organization of the United Nations' International Technical Co-operation Network on Cactus Pear in 1996, specifically by members of the working group for Plant Genetic Resources Collection, evaluation and conservation (Mashope, 2007) (Figure 1).

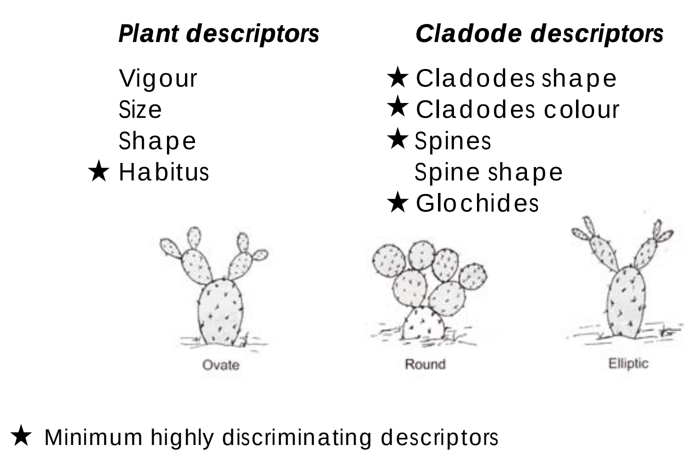

Figure 1. The descriptive growth characteristics used to differentiate individual whole cactus plants as well as individual cladodes, according to their location and origin.

These descriptors involve plant descriptors, alternate bearing descriptors, habitus descriptors, cladodes descriptor. The other descriptors include outstanding or disadvantageous characteristics of the varieties and their use.

Plant shape was determined by dividing plant width (W) by plant height (H) for 2 plants per entry, where flat was determined as:

$W>H$; round: $W=H$; elongate: $W<H$. Habitus was determined by evaluating plant shape.

Plants are usually either upright or spreading, which are distinct types. If the plants fall between these classes they were then classified as medium. These measurements were all done in wintertime (February/March) when the plants were dormant.

Plant width and plant height (cm) were measured in wintertime (February), just before the plants were pruned. Plant width was measured to evaluate specific plant growth allocation strategies under the growth conditions, whereas plant height (cm) was measured to get an indication of the vertical vegetative growth rate of the different accessions, as described below.

***Opuntia* CHARACTERISATION AND EVALUATION**

Plant size

1 = small (height <1.5 m)

2 = medium (height 1.6-2.0 m)

3 = large (height >2.1 m)

Plant shape

1 = flat (width>height)

2 = round (width = height)

3 = elongate (width<height)

Plant habit

1 = upright

2 = medium

3 = spreading

4 = prostrate

5 = shrubby

6 = arborescent

Plant vigour

1 = very weak

2 = weak

3 = medium

4 = strong

5 = very strong

Cladodes *Shape*

1 = ovate

2 = round

3 = elliptic

Cladodes Colour

1 = silver

2 = grey

3 = yellow-green

4 = green

5 = deep green

Cladodes Spine shape

1 = emergent

2 = sunken

Cladodes Glochides

0 = absent

3 = few

5 = medium

7 = many

B. Effect of soil volume on canopy growth of *Opuntia ficus-indica*.

One-year-old *Opuntia ficus-indica* cladodes obtained from the station were cut and dried for two weeks in the shade to allow healing of the wounded areas. Four different sizes of pots, 50, 35, 20 and 5 *l*, were filled with dry fine, sandy loam soil. At the end of May 2015, cladodes were planted in pots with half of their length in the soil. Plants were watered regularly throughout the season (when the temperature increased from spring through summer) to maintain soil water content and to avoid any visible signs of water stress. Five planted replicates for each pot size were set up, thus in total, there were 5 x 4 = 20 pots. The experimental design was a completely randomized design with five replications.

In February, plants from each pot size were cut and, depending on the age, cladodes of each plant were counted and numbered according to their age. Cladodes were clustered into two groups: mother cladodes and first generation cladodes.

For each cladode in each group, the length and width of each cladode were measured. The maximum cladode width (W) was regarded as the widest point perpendicular to the half part of the cladode, while the length (L) was the distance from one end to the other end along the longest axis of the cladode. These values were used to estimate the area of the cladode using the formula of the ellipse while the cladodes thickness was measured in mm with a vernier caliper. The fresh weight of each cladode was obtained through weighing three subsamples of each cut cladode and drying these in a forced-draft oven at 75 °C for 72 h, to estimate the dry weight.

Results

A. *Opuntia ficus-indica* (cactus) characterization (descriptor)

The results of the characterization of the 109 cactus accessions are documented in Table 1.

B. Effect of soil volume on canopy growth of *Opuntia ficus-indica*.

Total number of the cladodes

Plants placed in the largest soil volume pots (50 *l* pots) significantly ($p<0.05$) produced the highest number of the first generation cladodes, when compared with the lowest volume pots (5 *l* pots). The highest value was in the highest soil volume (5 cladodes) while the lowest number (2 cladodes) was for the plants growing in 5 *l* pots (Figure 2). Nevertheless, plants in all pots did not produce new second-generation cladodes.

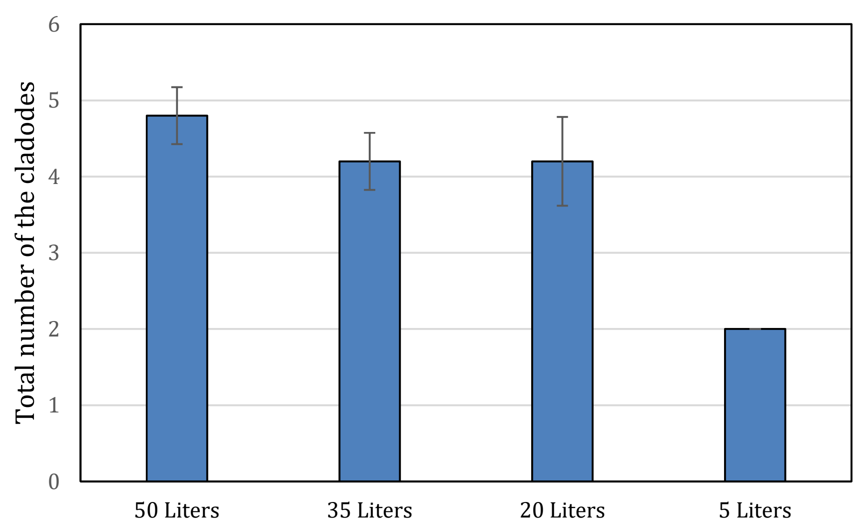

Figure 2. Effect of the four different soil volumes (50, 35, 20 and 5 liters) on the total number of the cladodes per plant of *Opuntia ficus-indica*.

Total canopy fresh mass

Linear and positive effects of the soil volume on canopy fresh mass was observed; with plants growing in the highest soil volume (50 *l*) producing the highest fresh mass (396 g) compared to fresh mass from the 5 *l* pots (186 g) sampled after six months of planting. (Figure 3).

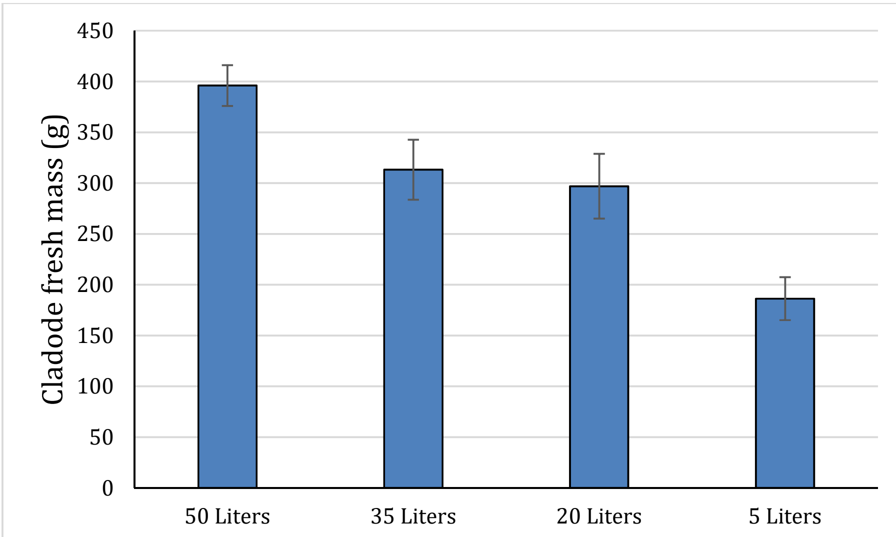

Figure 3. Effect of the four different soil volumes (50, 35, 20 and 5 Liters) on canopy dry mass (g) of *Opuntia ficus-indica*.

Cladode surface area

Total cladode surface area was affected significantly by the soil volume; a linear and positive relationship was observed, as the total surface area varied from 504.2 cm^2 (highest soil volume) to 300 cm^2 (lowest soil volume) (Figure 4).

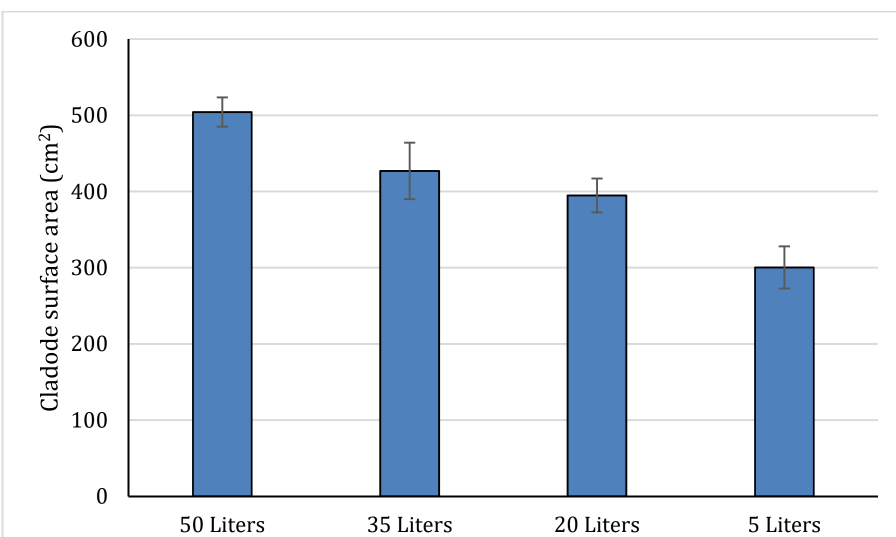

Figure 4. Effect of the four different soil volumes (50, 35, 20 and 5 Liters) on total canopy surface area (cm^2) of *Opuntia ficus-indica*.

Cladode dimensions (cm)

Soil volume showed a significant effect ($p<0.05$) on the cladode dimensions; with cladodes of plants growing in the highest soil volume recording the highest values of the length and width (23.1 and 13.8 cm respectively). The lowest values of the cladode length and width were recorded in plants growing in the lowest soil volume (17.3, 10.9 cm respectively) (Figures 5 and 6).

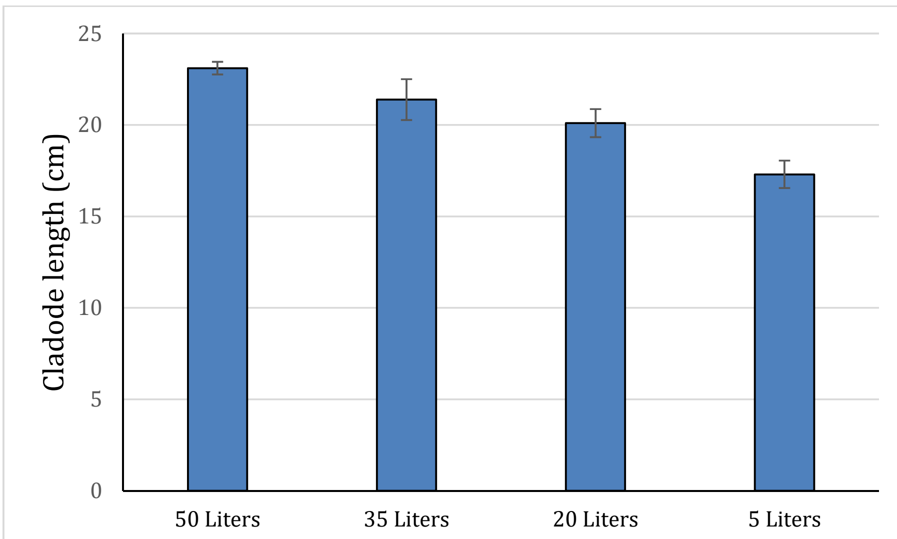

Figure 5. Effect of the four different soil volumes (50, 35, 20 and 5 Liters) on cladode length (cm) of *Opuntia ficus-indica*.

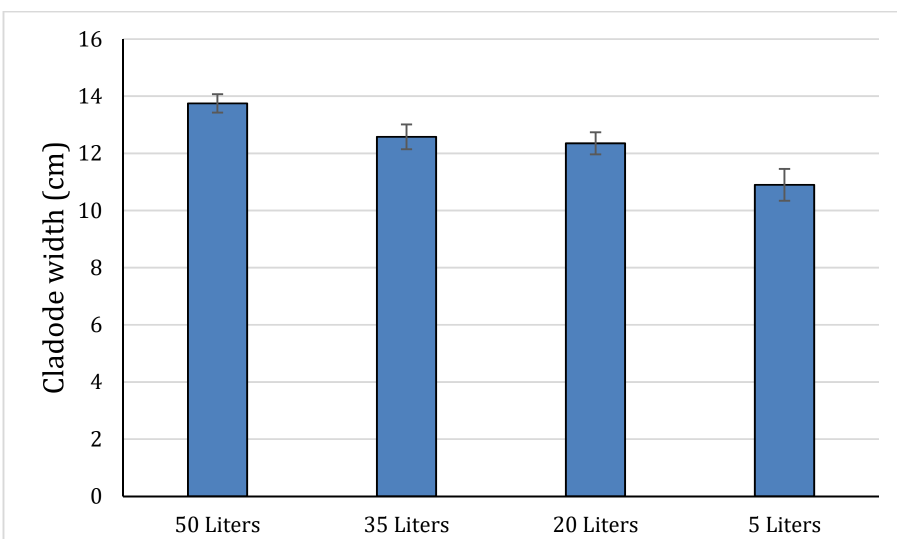

Figure 6. Effect of the four different soil volumes (50, 35, 20 and 5 Liters) on cladode width (cm) of *Opuntia ficus-indica*.

Cladode thickness (mm)

No clear effect of the soil volume on the cladodes thickness was observed in this study. Cladodes of plants growing in the smallest soil volume (5 *l*) had the lowest thickness value (12.9 mm), while no significant differences were found in cladode thickeness when comparing the three other soil volumes (Figure 7).

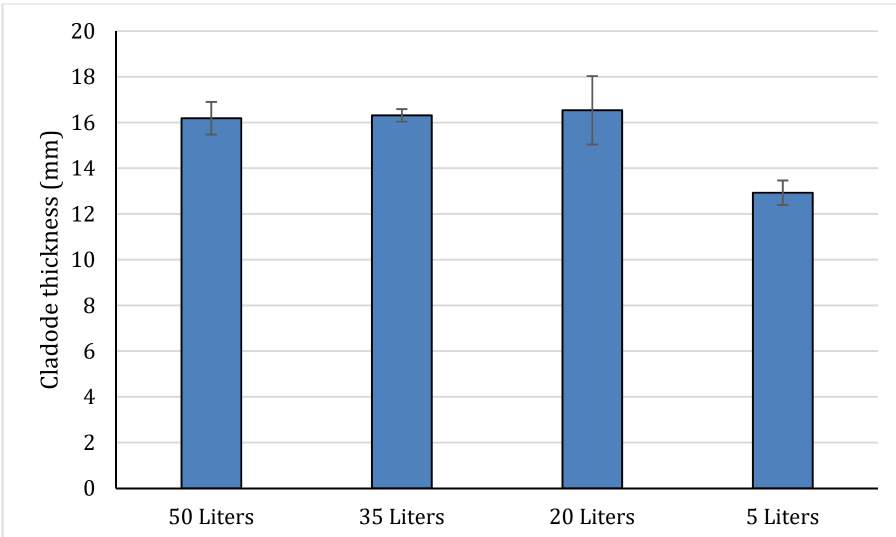

Figure 7. Effect of the four different soil volumes (50, 35, 20 and 5 Liters) on cladode thickness (mm) of *Opuntia ficus-indica*.

Table 1. The main criterias of 109 accessions *of Opuntia ficus-indica* (cactus) planted in Muchaqqar Research Station

		FT				cm			1 year old				2 year old				3 year old			
	shape Plant	size FT Plant	colour	spine shape	vigour	elevation Plant	Plant habit	Cladodes-Shape	length	width	spines	Thickness	length	width	spines	Thickness	length	width	spines	Thickness
J_ Jalpa	elongate	9.8	light green	emergent	weak	106	upright	elliptic	25.7	13.9	180	18.37	33.4	21.7	189	20.82	34.3	17.9	191	30.41
V1_ COPENA V1	elongate	13.1	light green	emergent	medium	131	upright	elliptic	34.1	27.0	187	34.98	36.8	27.6	185	36.40	43.8	28.2	199	34.61
VN_ Villanueva	elongate	16.3	light green	emergent	medium	169	upright	elliptic	31.3	23.6	191	29.44	42.5	31.3	159	31.42	43.7	36.1	177	33.87
F1_COPENA F1	elongate	14.3	light green	emergent	medium	165	upright	elliptic	39.7	26.4	200	19.88	41.8	24.2	127	30.28	45.1	25.8	96	40.86
9_ FOZA9	elongate	12.5	light green	emergent	medium	161	upright	elliptic	33.3	19.6	105	31.27	31.4	21.6	110	39.12	43.1	22.5	116	60.98
10_ FOZA10	elongate	9.5	green	emergent	medium	143	medium	elliptic	20.1	17.3	109	33.58	41.3	15.5	167	35.58	44.2	16.7	161	45.40
Morado	elongate	9.4	light green	emergent	weak	101	medium	elliptic	25..9	14.8	165	19.93	36	19.8	140	29.65	43.4	29.9	139	33.39
Zastron 4	elongate	14.7	light green	emergent	weak	166	medium	elliptic	32.7	19.6	134	21.88	38.6	21.5	107	27.94	55.2	25.8	141	40.07
Trunzara Red San Cono	elongate	10.4	light green	emergent	weak	85	upright	elliptic	30.3	18.5	171	20.74	37.2	16.7	123	24.7	31.1	25.6	68	39.37
Algerian 3/2	elongate	14.5	light green	emergent	weak	90	upright	elliptic	24.7	13.3	145	23.51	35.9	22.4	185	23.48	33.1	18.9	91	34.20
Blue Motto	elongate	9.1	light green	emergent	weak	150	medium	elliptic	37.1	16.4	151	17.70	40.1	16.9	172	37.34	46.7	18.5	170	44.86
Roly Poly	elongate	16.9	light green	emergent	weak	127	medium	elliptic	26.5	13.2	79	32.15	29.4	12.6	77	41.52	38.6	16.1	108	43.56
Seedless Santa	elongate	8.1	green	emergent	weak	82	upright	elliptic	25.2	10.8	143	21.39	37.6	14.6	141	24.78	39.4	24.7	88	33.11

Margherita Belice																				
Red Santa Margherita Belice	elongate	10.8	light green	emergent	weak	86	upright	elliptic	27.7	15.6	122	15.33	31.1	20.8	135	21.38	42.7	25.2	101	33.58
Yellow Santa Margherita Belice	elongate	13.4	green	emergent	weak	123	upright	elliptic	29.6	14.8	140	15.25	37.7	24.9	121	25.7	43.4	24.6	99	32.18
White Santa Margherita Belice	elongate	11.3	green	emergent	weak	106	upright	elliptic	28.2	15.3	155	16.5	38.1	25.4	123	26.11	43.1	24.3	115	26.52
Red San Cono	elongate	10.9	green	emergent	weak	112	upright	elliptic	25.6	14.8	141	20.25	35.5	24.2	144	25.68	40.5	22.7	133	30.71
Yellow San Cono	elongate	9.8	green	emergent	weak	104	upright	elliptic	24.8	16.3	157	19.78	32.3	25.7	151	26.3	42.1	20.7	129	33.45
White San Cono	elongate	12.4	green	emergent	weak	107	upright	elliptic	23.9	15.5	163	20.27	33.9	23.2	121	25.5	43.6	21.9	110	35.37
Red Roccapalumba	elongate	11.2	green	emergent	weak	93	upright	elliptic	23.4	15.9	175	18.15	37.1	24.3	126	24.32	34.2	22.7	106	30.19
White Roccapalumba	elongate	9.6	green	emergent	weak	88	upright	elliptic	20.0	13.2	130	12.65	30.1	18.9	151	21.86	31.9	19.7	115	34.23
Yellow Roccapalumba	elongate	8.1	green	emergent	weak	68	upright	elliptic	22.6	14.3	135	14.59	33.20	18.1	167	26.7	37.4	22.6	115	29.90
Seedless Roccapalumba	elongate	12.7	green	emergent	weak	96	upright	elliptic	29.3	13.6	157	17.33	32.1	17.2	183	26.2	40.2	23.7	183	36.7
Red San Cono	elongate	13.6	green	emergent	weak	85	upright	elliptic	25.6	17.5	178	16.93	40.3	26.5	185	25.0	36.4	25.6	163	35.39
Trunzara red Bronte	elongate	12.5	green	emergent	weak	112	upright	elliptic	27.2	16.9	189	18.22	33.5	25.9	200	21.66	35.7	25.1	149	29.41

Yellow Belpasso	elongate	10.8	light green	emergent	weak	80	upright	elliptic	24.6	15.3	182	16.67	30.9	18.6	165	20.88	37.4	25.2	123	27.59
Trunzara yellow Bronte	elongate	12.0	green	emergent	weak	100	upright	elliptic	25.1	16.8	149	13.69	33.2	22.4	210	20.1	36.7	23.1	145	35.58
Tunzara Bianca bronte	elongate	9.1	green	emergent	weak	79	upright	elliptic	22.3	13.5	185	12.34	32.3	23.0	195	19.99	42.2	25.2	137	32.54
Trunzara yellow San Cono	elongate	13.5	green	emergent	weak	112	upright	elliptic	31.0	16.0	188	19.10	35.6	18.1	129	25.8	42.2	24.6	109	30.2
Tunzara Bianca San Cono	elongate	9.71	green	emergent	weak	81	upright	elliptic	27.5	12.9	179	18.31	37.9	18.7	115	28.1	35.78	18.7	110	32.62
Red Roccapalumba	elongate	12.42	green	emergent	weak	102	upright	elliptic	33.2	17.9	135	13.24	35.7	24.3	151	25.49	32.81	19.2	105	31.51
Mezzojuso	elongate	11.3	green	emergent	weak	105	upright	elliptic	30.3	18.3	159	19.44	37.1	20.4	175	25.16	34.2	22.6	192	29.53
White Roccapalumba	elongate	12.1	light green	emergent	weak	90	upright	elliptic	32.3	16.1	121	19.38	28.8	18.7	105	28.66	30.6	20.7	93	37.83
2_21_68	elongate	12.8	green high	sunken	medium	138	upright	ovate	23.3	15.6	193	24.26	34.1	19.5	180	27.84	37.6	22.4	163	43.81
2_25_15	elongate	13.6	light green	emergent	medium	161	upright	elliptic	29.1	18.2	170	26.68	36.5	20.7	165	28.95	33.8	16.7	157	34.27
2_11_85	elongate	12.3	light green	sunken	medium	165	upright	elliptic	31.3	15.4	138	20.53	46.1	22.5	141	29.84	49.5	24.8	138	38.51
2_26_21	elongate	17.5	light green	sunken	medium	168	upright	elliptic	29,4	16.1	175	21.17	43.0	24.8	160	23.37	42.2	20.9	143	26.15
2_17_25	elongate	14.7	green	sunken	medium	176	medium	elliptic	24.3	15.2	188	31.91	33.5	21.7	183	38.52	34.2	24.1	181	44.29
N	elongate	12.9	light green	emergent	medium	103	medium	elliptic	26.8	21.3	198	17.99	30.1	28.6	199	18.42	37.3	29.9	199	26.19
4	elongate	13.9	light green	emergent	medium	134	medium	elliptic	22.2	17.9	195	28.84	32.5	20.3	193	33.28	29.5	16.8	182	42.83
1364	elongate	7.2	light green	emergent	weak	55	upright	elliptic	26.3	16.5	188	24.58	25.8	16.1	180	26.62	29.9	17.8	190	29.19
15	elongate	13.4	green	emergent	medium	136	upright	elliptic	25.6	16.3	165	24.53	36.4	15.3	178	29.53	29.7	19.3	159	45.22
31	elongate	10.7	green	emergent	weak	110	medium	elliptic	21	17.3	136	24.89	28.2	20.5	181	28.39	28.5	19.8	175	36.51
R	elongate	13.4	green high	emergent	weak	115	medium	elliptic	30.4	19.5	165	19.90	42.2	19.1	155	29.80	29.7	15.9	130	30.36

20	elongate	11.8	green	emergent	weak	110	upright	elliptic	29.3	16.0	169	15.60	39.0	23.9	167	21.60	35.4	19.9	205	34.61
34	elongate	13.3	green	emergent	weak	164	upright	elliptic	26.0	15.8	173	23.29	41.1	21.3	164	26.83	38.6	23.3	185	36.45
46	elongate	12.2	green	emergent	weak	139	upright	elliptic	35.5	19.7	169	14.03	38.4	28.2	165	21.27	35.3	22.1	195	34.72
47	elongate	10.10	green	emergent	weak	95	upright	elliptic	30.4	17.2	167	22.27	35.9	23.6	172	30.26	37.1	25.5	191	30.28
6	elongate	10.8	green	emergent	weak	102	upright	elliptic	30.1	18.0	159	16.01	36.6	22.3	175	25.06	34.8	16.6	199	32.57
	elongate		green	emergent	weak		upright	elliptic												
26	elongate	10.1	green high	emergent	weak	98	upright	elliptic	31.3	12.6	196	34.77	40.2	18.7	201	39.87	47.1	17.5	189	41.63
32	elongate	8.2	green	hard	weak	79	upright	elliptic	28.9	16.3	191	24.67	29.1	16.4	185	25.47	24.6	14.3	181	39.18
10	elongate	7.9	light green	emergent	weak	77	upright	elliptic	21.0	16.6	210	11.66	35.1	19.8	200	12.54	31.8	19.7	176	39.47
19	elongate	9.4	green	emergent	weak	132	upright	elliptic	24.2	14.3	120	31.27	33.6	20.4	206	45.91	41.9	22.8	191	61.17
8	elongate	10.9	green	emergent	weak	83	upright	elliptic	26.3	16.4	139	15.35	32.3	19.6	157	24.77	35.8	20.8	175	38.04
GSH Gialla di sarroch	elongate	11.1	light green	emergent	weak	90	upright	elliptic	25.6	18.5	197	12.60	33.8	24.3	203	25.89	36.4	25.7	190	32.39
M1 Gialla di Macomer	elongate	9.3	green	emergent	weak	89	upright	elliptic	28.7	15.9	191	12.41	33.5	24.7	219	20.58	34.7	20.1	197	29.30
RC Rossa di casttelsardo	elongate	8.5	light green	emergent	weak	68	upright	elliptic	21.3	11.6	180	12.38	25.1	18.4	185	11.84	31.8	20.3	189	17.05
RSS Rossa San sperate	elongate	11.9	green	emergent	weak	92	upright	elliptic	24.1	13.8	185	12.02	35.1	16.7	177	24.69	36.5	22.7	170	25.05
M2 Rossa di macomer	elongate	10.8	green high	emergent	weak	78	upright	elliptic	19.9	13.5	187	10.48	27.3	18.4	189	11.75	26.9	17.2	181	19.83
M3 Bianca di Macomer	elongate	11.10	green	emergent	medium	96	upright	elliptic	24.3	15.8	201	13.79	34.9	18.3	197	16.34	36.5	27.1	205	25.55
BB Bianca de Bonacardo	elongate	12.9	green	emergent	medium	105	upright	elliptic		15.1	172	10.92	40.4	20.7	179,00	14.35	37.3	22.9	189	23.93
Rossa Bari	missing	missing	missing	missing	missing	missing	missing	elliptic												
Bari Gialla	elongate	7.10	green	sunken	weak	76	upright	elliptic	22.2	14.5	181	12.55	35.1	22.8	165	19.08	31.4	24.0	164	30.35
Spineless	elongate	10.4	green	emergent	weak	85	upright	elliptic	28.4	18.7	199	13.92	34.4	18.8	151,00	20.26	46.2	24.8	173	33.14
seedless Margherita			green high	emergent	medium	65	upright	elliptic	25.3	12.0	195	15.14	39.2	19.4	159	24.92	35.3	19.0	133	28.70

120	elongate		green	emergent	weak	45	upright	round	24.3	19	200	23,22	0	0	195	0	0	0	0	0
80	elongate		green high	emergent	medium	101	upright	elliptic	39	18	200	24,73	38.0	20	199	23.49	34.7	25.9	205	32.19
1233	elongate		light green	emergent	medium	86	upright	elliptic	30.4	13	192	20.33	31.3	15.4	193	23.43	33.5	19.0	211	39.87
42	elongate		light green	emergent	medium	159	upright	elliptic	26.5	17.2	210	24.49	33.0	27.5	201	23.89	34.8	22.7	196	30.84
1364	elongate		light green	emergent	medium	95	medium	elliptic	30.4	21.3	185	16.90	23.9	19.3	193171	28.98	35.1	20.5		29.19
94	elongate		green	emergent	medium	83	medium	elliptic	31.8	20.2	173	15.28	36.2	17.5	142	23.41	26.1	17.2		44.26
117	elongate		light green	emergent	medium	153	medium	elliptic	28.6	17.9	175	37.03	30.6	20.7	153	44.15	30.3	20.5		30.70
75	elongate		light green	emergent	weak	96	upright	elliptic	27.4	17.5	200	17.13	38.7	19.0	170	26.1	29.1	22.9		22.50
66F	elongate		light green	sunken	medium	56	upright	elliptic	15.1	11.5	95	15.44	23.0	16.0	101	24.32	27.1	14.5		46.95
41A	elongate		green	sunken	weak	91	medium	round	24.2	21.6	101	30.78	26.8	23.7	125	37.01	32.5	22.9		33.47
53C	elongate		green	sunken	weak	90	medium	ovate	29.3	19,5	147	27,97	27.49	18.5	129	30.66	29.1	25.3		35.45
45B	elongate		green high	sunken		125		round	29.5	20.3	169	34.63	27.5	30.1	150		23.7	11.9		33.11
13	elongate							elliptic												
45	elongate				weak		upright	elliptic								20.83				
22	elongate		green	emergent		75		round	28.5	21.5	80	12.11	30.2	29.3	75		23.7	25.5		16.47
20 – O.F.I, Chico – 73056 – S. AFRICA	elongate		green	emergent	weak	95	upright	elliptic	27.1	14.7	185	13.11	31.9	19.6	181	32.40	29.5	28.8		29.40
32 – Ain Jimaa - 75019	elongate		green	emergent	weak	97	upright	elliptic	24.3	16.5	159	12.91	32.9	23.1	164	21.67	33.6	24.7		31.48
White San Cono	elongate		green high	hard	weak	119	upright	elliptic	31.2	15.1	157	19.58	32.3	17.4	155	23.16	41.2	28.7		24.08
Nepal	elongate		green	emergent	weak	106	upright	elliptic	28.2	19.1	170	19.27	30.6	20.4	179	23.79	40.9	21.5		33.81
Syria	elongate		light green	emergent	weak	96	upright	elliptic	28.3	13.5	159	14.32	32.2	20.1	181	14.21	41.1	28.0		32.31
25 - Tunisia	elongate		green	sunken	weak	95	upright	elliptic	26.4	17.2	162	12.79	33.6	25.2	156	15.77	36.8	23.6		22.40
15- O.F.I, Borj El Farag-	elongate		green	emergent	weak	87	upright	elliptic	32.0	15.9	191	11.66	33.5	20.9	195	15.55	27.9	22.5		32.62

69248-TUNISIA																				
22- O. TOMENTOSA -73060-TUNISIA	elongate		light green	sunken	weak	58	upright	elliptic	24.6	15.5	165	12.50	31.9	21.5	171	14.91	32.5	22.1		22.75
23- O. MAXIMA-73062-TUNISIA	elongate		green	emergent	weak	149		elliptic	31.3	15.9	173	27.09	44.1	23.9	164	23.32	37.20	20.5		30.18
30- DJ-Solah-75012-TUNISIA	elongate				weak		upright	elliptic												
18 - Mexico/ New Mexico	elongate		green	sunken	weak	107	upright	round	27.3	15.5	199	26.68	27.3	17.9	169	36.88	37.3	22.6		43.31
4- O. tomentosa - 69210-ALGERIA	elongate		green high	emergent	medium	99	upright	elliptic												
5- O. Maxima-69217-ALGERIA	elongate		green	emergent	medium	83	upright	elliptic	30.7	17.2	183,00	21.63	31.6	23.9	155	23.99	32.6	18.1		36.17
6- O.F.I, V.Lengissima -69220-ALGERIA	elongate		green	emergent				elliptic	22,80	13.3	157,00	15.15	27.3		189	33.06	31.9	17.8		28.06
	missing				weak	104	upright	elliptic												
17- Carefin - 1, 69198-ALGERIA	elongate		green	emergent	weak	107	upright	elliptic	22.3	10.4	177,00	14.76	31.6	23.1	199	19.98	33.3	25.9		34.28

Conclusion

Crops such as cactus pear are very important for the areas of arid climate due to their ability to resist droughts, as well as being able to grow in less fertile soils. However, there is a lack of characterization and maintenance of this plant in areas such as Jordan, where this research was conducted. Significant differences were observed in all measured plant characteristics, with an increase in soil volume yielding positive growth characteristics of cladodes, such as the highest fresh mass as well as the highest number of cladodes per cactus plant. Data obtained from these accessions has exhibited that there is no superior cultivar amongst all the measured accessions, and this could be ascribed to the fact that comparisons were made without considering individual cladodes, which seems to be a commercial determinant for the quality of the cladodes. However, this information may not be enough to characterize the cactus pear varieties found in the area, and it may be necessary to characterize all the varieties based on morphological, chemical and molecular techniques.

Evaluation of data collected from this genebank will be used by various researchers involved in cactus pear around the Middle East and abroad. In addition, plant material of described accessions from these germplasm blocks will be used to establish additional germplasm blocks in other provinces, in order to monitor the performance of various accessions in the different agro-ecological regions of world. It is therefore recommended that the accessions be evaluated on a yearly basis in order to have long term data that will assist in future decision making. More research still needs to be done in order to assess factors affecting the plant quality characteristics.

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