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Science for resilient livelihoods in dry areas

Enhancing Innovation and Technology Dissemination for Sustainable Agricultural Productivity in Arab Countries through consolidation of center of excellence across the region with focus on innovations and scaling in agro-pastoral farming systems in West Asia

Evaluate cactus accessions across different agro-ecological to enhance establishment of cactus orchards

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Introduction

The *Cactaceae* is an important family of plants, native to the American continent. Out of its 1,600 species, the genus *Opuntia* is the most relevant within the family for its important role in agriculture and land rehabilitation. *Opuntia* species are truly multipurpose crops. In addition to providing vitamin rich fruits, vegetables and feed, they represent also the source of the much-valued red dye, extracted from insects thriving exclusively on *Opuntia ficus-indica* plants. From their native distribution area, *Opuntia* species have spread throughout arid zones around the world, particularly in the Mediterranean Basin, Northern and Southern Africa, the Middle East, Australia and Northern India.

Why cactus pear is being cultivated in so many countries? The reasons behind the diffusion of *Opuntia* species around the world and in particular of the species *O. ficus indica*, are numerous, they include 1) the simple cultivation practices required to grow the crop, 2) its quick establishment soon after the introduction in a new area, 3) the easy multiplication practices that favour rapid diffusion and exchange of material among users, 4) the ability to grow in very harsh conditions characterized by high temperature, lack of water and poor soil, 5) the generation of income from the selling of much valued and appreciated fruits, 6) the use of its stems in the human diet and as fodder for the livestock, 7) the useful deployment of its plants for fencing farms, 7) the nutritional values of its juicy fruits, 8) the long shelf life of the fruits and 9) the many industrial derivatives produced from the fruits. These and other facts have contributed to such a wide distribution from its original areas in Latin America to remote areas across continents and across cultures and traditions.

After their introduction in new areas, cactus pear plantations have gained an important place in the agricultural systems as fruit, forage and fodder provider, particularly in subsistence agriculture where they have a comparative advantage for their capacity to grow with minimal agronomic inputs, for their resistance to drought, etc. In these countries they underwent processes of adaptation and selection which led eventually to new ecotypes and varieties, adapted to specific local habitats.

Under the collaboration program between the National Center for Agricultural Research (NARC) in Jordan and the International Center for Agricultural Research in the Dry Areas (ICARDA): more than 100 accessions of cactus pear were introduced and planted in Muchaqqar station between 2013 and 2017. These accessions have different genetic characteristics in terms of productivity, specifications and purpose of use and were collected from different countries such as Italy, Brazil, America, Argentina, Tunisia, Morocco, Mexico and other countries. This activity is sponsored by The Arab Fund for Economic and Social Development (AFSED).

There are different accessions for fruit production which showed good performance, they produce fruits with different flavors and colors ranging from red, yellow to green also they vary in terms of

colors, productivity and different in terms of days to maturity date: there are early, moderate and late maturity accessions.

These new cactus pear accessions offer an opportunity to help farmers to diversify their products and income. However, there is a high need to evaluate cactus accessions performance across different agro-ecological sites in order to select the most adapted accessions and promote cactus pear establishment at farm level.

Methodology

1. Sites description

To meet the study objective, 68 accessions were planted in Al-Karama Agricultural station (National Center for Agricultural Research (NARC) Station) located in south of the Jordan Valley (31° 55' 50.05" N 35° 34' 11.89" E). The annual precipitation is 155mm and falls primarily between November and March. The soil on-site is characterized as a silty clay loam. Soil pH, EC, sodium, chloride, phosphorous, potassium, nitrogen and soil texture are presented in Table 1.

Table 1. Soil characteristics including physical and chemical properties of cactus pear field in Al-Karama Agricultural station in Jordanian valley

Extract		Meq/L		ppm		%				Texture
PH	EC (dS/m)	Na	CL	P	K	N	Clay	Silt	Sand	
7.9	35.6	188.71	325.00	30.7	712.3	0.092	20.7	39.1	40.2	Loam

2. Plant materials

Five mature cladodes were selected from each of the 68 fruiting cactus pear accessions planted in Muchaqqer research station (Madaba). For better establishment and root growth under field condition the detached cladodes were kept under shade for two weeks so that proper healing and dehydration of cutting edge may take place. List of planting materials are provided in Table 2.

Table 2. List of cactus pear accessions planted in Al-Karama Research Station in Jordanian valley

Accession	Accession
RC Rossa di casttelsardo	8_Leavis_74010
RSS Rossa San sperate	47_Mornag B_74076
M2 Rossa di macomer	46_Mornag B_74076
Trunzara Red San Cono	34_Caref 58_69219
Algerian 3/2	20_Sbeitla_74071
15- Borj El Farag-69248	31_Burbank Azrou_69223
Red Santa Margherita Belice	15_Sicile Le folin_73063
Red San Cono	2_17_25
Red Roccapalumba	2_11_85
Trunzara red Bronte	2_25_15
Mezzojuso	2_21_68
Morado	N
Yellow Santa Margherita Belice	37_Thala_69241
Yellow San Cono	38_Sbeitla_74071
Yellow Roccapalumba	26_Montarnaud_69239
Yellow Belpasso	6_Ain Boudriess_96245
Trunzara yellow Bronte	22_El Borouj_75018
Trunzara yellow San Cono	13_Bab Toza_74115
GSH Gialla di sarroch	2_Leavis SP5_74112
M1 Gialla di Macomer	1364
10_Bianca_69235	2_26_21
Spineless	Seedless Margherita
Seedless Roccapalumba	V1_ COPENA V1
Bari Gialla	Muchaqqer
BB Bianca de Bonacardo	41_Sbeitla_69242
M3 Bianca di Macomer	30_Mdjez El Bab_73952
Tunzara Bianca bronte	29_Matmata_69242
White Roccapalumba	26_Djebel Bargou_68247
White San Cono	24_73058
Seedless Santa Margherita Belice	GS
Blue Motto	G
Zastron 4	Zelfeue
19_Algeria_69200	32_Matmata_69242
10_ FOZA10	R

3. Field selection, land preparation and establishment

Flat area was selected and mechanically cleared for the establishment of the cactus pear nursery. The rocks and bushes were removed, deep ploughing was used for loosening the soil followed by soil levelling at a particular level. Second plowing and harrowing were the two last operations before digging the holes using tractor-mounted soil drill according to the planned design. The depth of the holes was 30 cm, spaced in rows 4 meters apart with plants 4 meters apart. 5 kg of farm manure were applied in each hole and mixed with the soil before cladodes planting. A mix of farm manure with soil while planting. Planting cladodes took place on January 16th where half or two thirds of each cladode

was buried in the soil facing the sun and slightly tilted. Light watering was done after planting (Figure 1 and 2).

Figure 1 Cactus pear field preparation in Al-Karama Agricultural station in Jordanian valley

Figure 2. Cactus pear establishment in Al-Karama Agricultural station in Jordanian valley

4. Field management and maintenance

Fully established cactus pear plantation requires light irrigation for better growth; therefore, a drip irrigation system was set in the field to provide micro-irrigation based on plant requirements (in 2020 each plant was irrigated 10 times, 10 mm in each). The weeding was done twice by pulling the weeds by hand at the first and tenth month after plantation.

5. Field management and maintenance

The performance and survival rate of the 68 cactus pear accessions under Jordan valley environmental conditions were evaluated. Plant height and number of cladodes per plant, in addition to the plant condition using a rating scale of 1 to 5 relative to a completely healthy and strong plant.

Survival rate was assessed on 30 April 2020 and the damaged cladodes were replaced on 20 May 2020. Data on Plant height, cladodes number and plant condition were collected on October 21 and December 8th, 2020.

Data was performed using the JMP pro software to run hierarchical cluster analysis and measurement system analysis.

Cactus pear accessions performance

1. Survival rate

The cactus pear accessions recorded high survival rate; 100% survival rate was observed in more than 50% of the cactus pear accessions followed by 80% survival rate was recorded by 30 % of the planted cactus pear accessions. Only two accessions (32_Matmata_69242 and Algerian 3/2) recorded low survival rate 40 and 20 % respectively.

Cactus pear cladodes plantations survival rate depends on the soil and cultural management. In this field, the pant materials and soil preparation were managed correctly, however, the birds attached some of the cactus cladodes resulted in the rotting of the damaged cladodes.

Table 3. Survival rate (%) of 68 accessions planted in Karameh research station in Jordanian valley

Accession	Survival rate	Accession	Survival rate
RC Rossa di casttelsardo	100	8_Leavis_74010	60
RSS Rossa San sperate	100	47_Mornag B_74076	80
M2 Rossa di macomer	80	46_Mornag B_74076	80
Trunzara Red San Cono	60	34_Caref 58_69219	80
Algerian 3/2	20	20_Sbeitla_74071	100
15- Borj El Farag-69248	80	31_Burbank Azrou_69223	80
Red Santa Margherita Belice	60	15_Sicile Le folin_73063	80
Red San Cono	60	2_17_25	80
Red Roccapalumba	80	2_11_85	100
Trunzara red Bronte	80	2_25_15	60
Mezzojuso	100	2_21_68	80
Morado	100	N	60
Yellow Santa Margherita Belice	100	37_Thala_69241	100
Yellow San Cono	60	38_Sbeitla_74071	100
Yellow Roccapalumba	100	26_Montarnaud_69239	100
Yellow Belpasso	100	6_Ain Boudriess_96245	100
Trunzara yellow Bronte	100	22_El Borouj_75018	100
Trunzara yellow San Cono	100	13_Bab Toza_74115	100
GSH Gialla di sarroch	100	2_Leavis SP5_74112	100
M1 Gialla di Macomer	100	1364	100
10_Bianca_69235	80	2_26_21	100
Spineless	60	Seedless Margherita	80
Seedless Roccapalumba	100	V1_ COPENA V1	100
Bari Gialla	100	Muchaqqer	100
BB Bianca de Bonacardo	60	41_Sbeitla_69242	100
M3 Bianca di Macomer	100	30_Mdjez El Bab_73952	100

Tunzara Bianca bronte	80	29_Matmata_69242	80
White Roccapalumba	60	26_Djebel Bargou_68247	80
White San Cono	80	24_73058	100
Seedless Santa Margherita Belice	100	GS	100
Blue Motto	100	G	80
Zastron 4	100	Zelfeue	60
19_Algeria_69200	100	32_Matmata_69242	40
10_ FOZA10	80	R	80

2. Growth parameters and plant condition

Cactus pear accessions differed significantly in the plant height, plant condition and number of cladodes. The plant height ranged between 20-77 cm; average 44 m, plant condition score varied between 1.8- 5; average 3.45 while the range of the number was 1-10; average 6 (Figure.3). Blue Motto hass the highest with greatest number of cladodes while 2_Leavis SP5_74112 expressed the best plant performance resulted in the greatest plant condition. 47 % of the cactus pear accessions generated cladodes higher than the average, while accessions segregated 50: 50 above and below the average in terms of plant height and plant condition (Figure 3). As expected, there were significant correlations ($P < 0.001$) between plant height and both plant condition and number of cladodes and also for plant condition and number of cladodes (Figure 4).

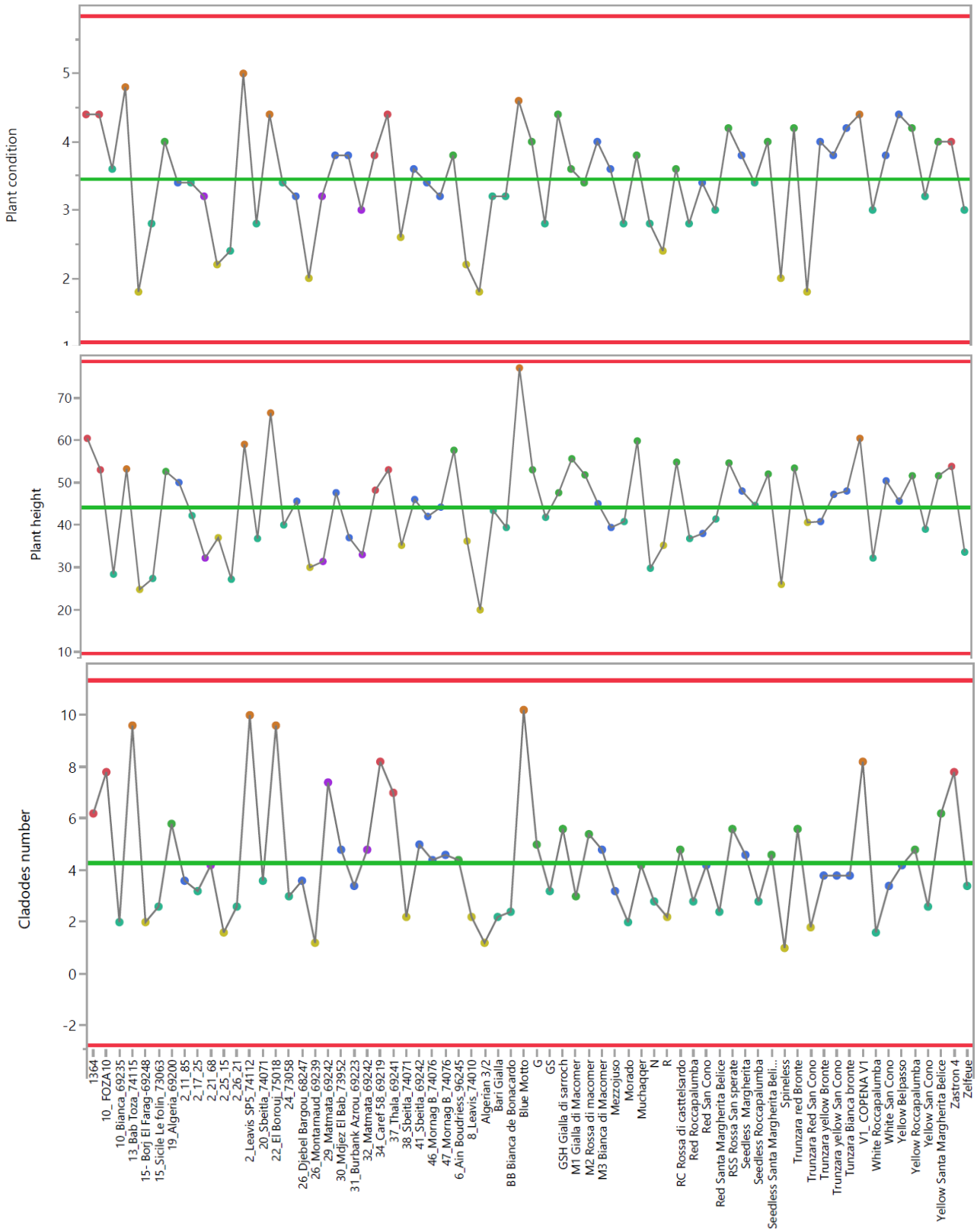

Figure 3. The plant height(cm), plant condition and number of cladodes of 68 cactus pear accessions planted in Karameh research station in Jordanian valley

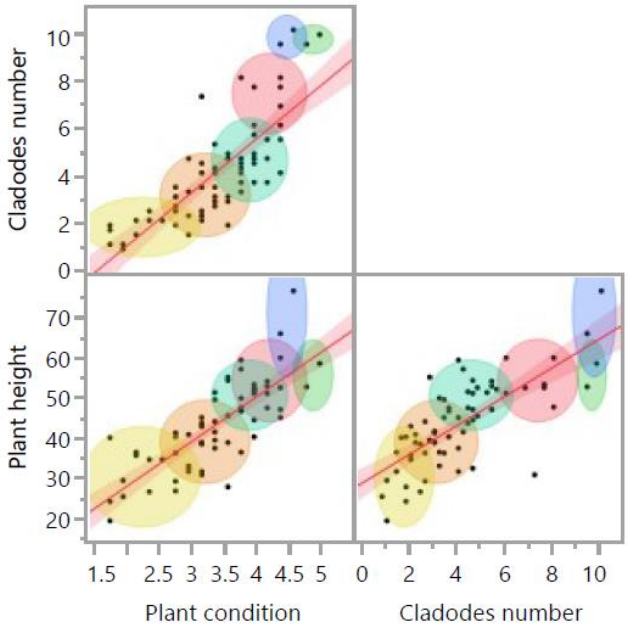

Figure 4. Scatterplot Matrix of the corelation between plant height(cm), plant condition and number of cladodes of 68 cactus pear accessions planted in Karameh research station in Jordanian valley

3. Hierarchical clustering analysis (HCA)

Cluster analysis resulted in grouping the accessories in 7 groups (Figure 5). Accessions in group 1 and 2 showed the highest adaptability to the Jordan valley environment these includes:

1364, 10_ FOZA10, 37_Thala_69241, 34_Caref 58_69219, Zastron 4 , 19_Algeria_69200, Yellow Santa Margherita Belice, RSS Rossa San sperate, Trunzara red Bronte , GSH Gialla di sarroch, G, Seedless Santa Margherita Belice, Yellow Roccapalumba , 6_Ain Boudriess_96245, Muchaqqer, M1 Gialla di Macomer, M2 Rossa di macomer and RC Rossa di casttelsardo. On the other hand, accessions in cluster 6 and seven didn't perform well under the conditions of Jordanian valley: 2_21_68, 32_Matmata_69242, 29_Matmata_69242, 15- Borj El Farag-69248, Algerian 3/2 , 26_Montarnaud_69239, Spineless, 2_25_15, 38_Sbeitla_74071, R, Trunzara and Red San Con (Table 4).

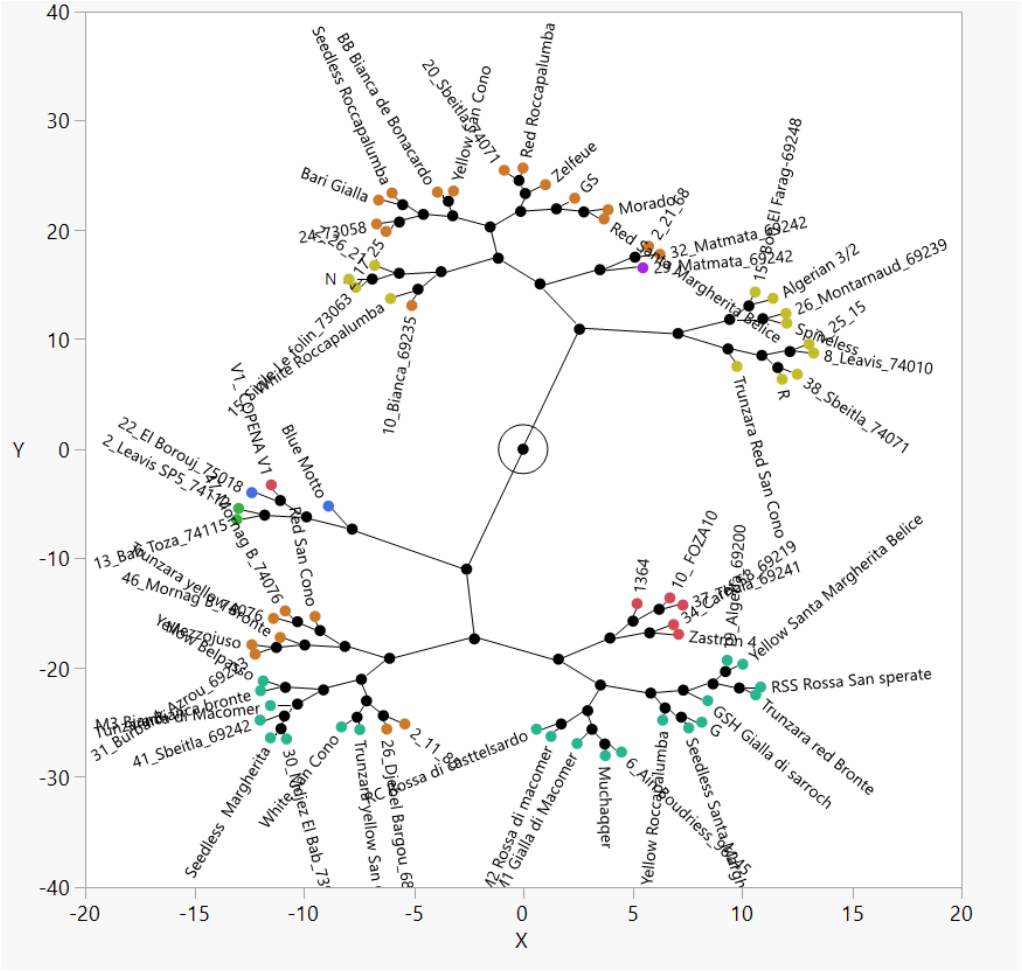

Figure 5. Constellation plot constructed by Euclidean distance using Ward's method of hierarchical cluster analysis, to study the relationships among the of 68 cactus pear accessions planted in Karameh research station in Jordanian valley

Table 4. Cactus pear accessions groups of the hierarchical cluster analysis to study the relationships among the of 68 cactus pear accessions planted in Karameh research station in Jordanian valley

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7
1364	19_Algeria_69200	2_11_85	13_Bab Toza_74115	10_Bianca_69235	2_21_68	15- Borj El Farag-69248
10_ FOZA10	Yellow Santa Margherita Belice	26_Djebel Bargou_68247	2_Leavis SP5_74112	White Roccapalumba	32_Matmata_69242	Algerian 3/2
37_Thala_69241	RSS Rossa San sperate	Trunzara yellow San Cono	22_El Borouj_75018	15_Sicile Le folin_73063	29_Matmata_69242	26_Montarnaud_69239
34_Caref 58_69219	Trunzara red Bronte	White San Cono	V1_ COPENA V1	N		Spineless
Zastron 4	GSH Gialla di sarroch	30_Mdjez El Bab_73952	Blue Motto	2_26_21		2_25_15
	G	Seedless Margherita		2_17_25		38_Sbeitla_74071
	Seedless Santa Margherita Belice	41_Sbeitla_69242		24_73058		R
	Yellow Roccapalumba	M3 Bianca di Macomer		Bari Gialla		Trunzara Red San Cono
	6_Ain Boudriess_96245	Tunzara Bianca bronte		Seedless Roccapalumba		
	Muchaqqer	Yellow Belpasso		BB Bianca de Bonacardo		
	M1 Gialla di Macomer	31_Burbank Azrou_69223		Yellow San Cono		
	M2 Rossa di macomer	Mezzojuso		20_Sbeitla_74071		
	RC Rossa di casttelsardo	Trunzara yellow Bronte		Red Roccapalumba		
		46_Mornag B_74076		Zelfeue		
		47_Mornag B_74076		GS		
		Red San Cono		Morado		
				Red Santa Margherita Belice		

Conclusion

The demand for cactus pear cultivation is increasing worldwide; thus, it is necessary to respect the requirements and level of adaptability of the available genetic resources to different growing regions. In this study we found significant differences between cactus pear accessions under Jordan valley environmental conditions. These differences are a good basis for providing resources that can be grown well under different environmental conditions. Further trials are needed to evaluate existing cactus germplasm across the kingdom of Jordan. In particular where drought and salinity conditions are prevalent. The ultimate objective would be to generate a land suitability map for cactus cultivation across Jordan based on spatial distribution of climatic and edaphic factors.