Potential of forage cactus pear accessions under saline water irrigation in arid areas

Saleem K. Nadaf*, Safa'a M., Al-Farsi, Saleh A., Al-Hinai, Aliya S., Al-Hinai, Abdul Aziz S., Al-Harthy, Saif A., Al-Khamisi and Ahmed N. Al-Bakri

Directorate General of Agriculture & Livestock Research, Ministry of Agriculture & Fisheries, Sultanate of Oman. PO Box 50 PC 121 Oman.

*Corresponding author: saleem_nadaf@hotmail.com

Received: September 8, 2017; Accepted: June 20, 2018.

ABSTRACT

Forage cactus pear has potential in arid areas of the world to be as one of the alternate fodders in the existing forage/fodder production system. Thirty three cactus accessions introduced under Arabian Peninsula Research Program of International Center for Agriculture Research in the Dry Areas in Oman in 2005 with an objective to identify suitable species for the rehabilitation of degraded rangelands in arid and saline areas were planted in randomized complete block design under plant density of 40,000 ha^{-1} with three replications on a sandy loam site under drip irrigation on December 2011 at Rumais Livestock Research Center in Oman and evaluated annually during three consecutive years (2012 to 2014) following standard agronomic practices recommended worldwide for cactus cultivation. The irrigation water electrical conductivity was 5.37 dSm^{-1} at the beginning of the experiment while it was 6.01 dSm^{-1}, 10.45 dSm^{-1} and 14.75 dSm^{-1}, for the annual harvests on December 2012, 2013 and 2014, respectively. The observations on plant height (cm) at harvest, number of pads/plant, weight/pad (kg) and green matter weight/plot were recorded at each harvest. The dry matter weight was estimated based on dry matter percentage of green samples. Green and dry matter yield/ha were estimated for their respective weights from experimental plots (3m x 3m). The results revealed that the cactus accessions were different ($p<0.05$) with respect to all the characters, such as plant height (45.75 to 82.00 cm), number of pads/plant (2.00 to 10.56), weight/pad (0.32 to 0.59 kg), green matter yield (46.99 to 331.58 t ha^{-1}), dry matter yield (4.40 to 33.38 t ha^{-1}) and dry matter (8.29 to 13.00%). Ten cactus accessions had three-year fresh annual fodder yield over 150 t ha^{-1}. The accession No. 74112 from Mexico had significantly highest ($p<0.05$) annual pad yield (331.58 t ha^{-1}) of all other accessions studied. Other accessions which were not different ($p>0.05$) but with important production were 4321 from Tunisia (197.67 t ha^{-1}), 75018 from Morocco (195.33 t ha^{-1}), 68247 from Algeria (185.78 t ha^{-1}), 73049 from Mexico (180.78 t ha^{-1}) and 69241 from Tunisia (173.22 t ha^{-1}). Results indicated the potential of cactus for fodder production under saline water in arid conditions (from 5.37 to 14.75 dSm^{-1} during crop growth), with an average green fodder yield of 117.31 t ha^{-1} yr^{-1}, as compared with existing perennial Rhodes grass with an average of 80 to 100 t ha^{-1} yr^{-1}. Hence, these cactus accessions could be included in the existing fodder production system or used for

afforestation of degraded rangelands of Oman besides the farms affected by salinity to the extent of over 5.37 dSm^{-1}.

***Keywords*:** Cactus, *Opuntia* spp., arid areas, irrigation, growth attributes, pad yields, saline water.

INTRODUCTION

Forage cactus pear has potential as one of the alternate fodders in the existing forage/fodder production system in arid areas of the world (Guevara *et al*., 2011) as it not only withstands prolonged drought (Nobel, 2009; Nefzaoui *et al.,* 2014 and Sony *et al.,* 2015) but also is tolerant to extreme heat (Sudzuki, 1995) and highly efficient in water use (Snyman, 2005; Nobel, 2009). It is also known to be moderately tolerant to salinity (Gajendra *et al.,* 2014) and act as biological barrier to avert top-soil loss (Nefzaoui and El Mourid, 2009) and enhance fodder availability for animals (Alary *et al*., 2007; Nefzaoui *et al*., 2014).

Although forage cactus cannot replace already existing annual forage crops species like sorghum, maize, pearl millet, cowpea etc. and perennial forages like alfalfa, Rhodes grass, Buffel grass etc., as it contains very less crude protein (1.4 - 4.0%), its fodder utility lies through supplementary feed as mixture of cactus with other forage having high protein source like alfalfa, Rhodes grass and annual forages like cowpea, maize etc., in appropriate proportions (Nefzaoui and Ben Salem, 2001; Nefzaoui *et al*., 2014).

Annual cactus green forage (pad) and dry matter yields were found to range from 108 to 226 and 13.9 to 40 t ha^{-1} yr^{-1}, respectively, under irrigated conditions (Nefzaoui and Ben Salem, 2001; Sharafi *et al.,* 2012). Dubeaux Jr. *et al.* (2006) observed increased fodder productivity of cactus in the plant stands of populations ranging from 40,000 ha^{-1} to 50,000 ha^{-1}. There were no studies of variability and agronomy on cactus conducted in Oman until 2005 when studies were initiated to assess regeneration ability of 38 introduced spineless cactus pear accessions and identify high regenerating accessions under the Arabian Peninsula Research Program (APRP) of the International Center for Agriculture Research in the Dry Areas (ICARDA) in Oman (Nadaf *et al*., 2007a, b and c). In view of the above, 33 elite forage spineless cactus pear accessions introduced through ICARDA from various cactus growing countries like Tunisia, Morocco, South Africa, USA etc. were investigated for three years from December 2011 to December 2014 for their variability and productivity under irrigation with saline water (around 6 dSm^{-1}) in order to select promising high productivity cactus forage accessions, as well as for the rehabilitation of degraded rangelands of Oman.

MATERIALS AND METHODS

Cladodes from each of the 33 spineless cactus pear accessions were planted erect under plant density of 40,000 ha^{-1} on December 2011 in a randomized complete block design in plots of 3m x 3m with three replications on a sandy loam site under drip irrigation at Livestock Research Center of the Directorate General of Agriculture & Livestock Research of the Ministry of

Agriculture & Fisheries, Rumais, Oman. Standard agronomic practices were followed as per worldwide recommendations for cactus cultivation with organic manure (1.6% N) and compound fertilizer application 1 kg plant^{-1} and 50:50:50 kg N-P-K ha^{-1}, respectively (FAO, 2001). The plots were initially irrigated at 3-day interval for 10 days and afterwards in a week interval for four months, for half hour to enable cladodes regeneration and cactus pear plants establishment. Subsequently, irrigation was done once every 15 days for 15 min throughout growth period of the plants, which were subjected to annual harvest for three years, leaving two basal attached cladodes. The irrigation water electric conductivity (EC) was 5.37 dSm^{-1} at the beginning of the experiment while it was 6.01 dSm^{-1}, 10.45 dSm^{-1} and 14.75 dSm^{-1}, at the annual harvests on December 2012, 2013 and 2014, respectively. The observations on plant height (cm), number of cladodes per plant, weight per cladode, fresh/green weight per cladode, fresh/green weight m^{-2}, were recorded, at harvest. Two fresh cladode samples of each accession were taken to laboratory for computing dry matter (AOAC, 2004) and dry matter yield ha^{-1} (t). The data from above characters were subjected to ANOVA using MSTAT-C software developed adapting the methods of Gomez and Gomez (1984).

RESULTS AND DISCUSSION

The Tables 1 to 6 present the means of six agronomic characters of cactus accessions over three years of growth along with associated statistical parameters. The results revealed that both the effects of years and cactus accessions were highly significant ($p<0.1$) for all the characters studied, whereas the effect of interaction between year and cactus accessions were found highly different ($p<0.01$) only with respect to the number of cladodes per plant and weight per cladode. The cactus accessions outperformed during second year of growth significantly or insignificantly respect to green/fresh matter yield (159.33 t ha^{-1}; $p<0.05$), number of cladodes per plant (8.55; $p<0.05$) and plant height (73.77 cm; $p>0.05$) as compared to either the first or the second year. The lower green matter yield during the first year is attributed to the prolonged time taken to the cactus accessions to establish and start producing cladodes as against the second year where favorable conditions existed for cladode formation by most of the accessions. This is justified by the higher ($p<0.05$) number of cladodes per plant (8.55), cladode weight (0.44 kg), and cactus plants height (73.77 cm) during the second year in comparison to either, the first year (4.02 cladodes per plant; 0.42 kg cladode weight, and 70.73 cm plant height) or the third year (1.74 cladodes per plant; -0.53 kg cladode weight, and 58.49 cm plant height). The inferior performance of the cactus accessions during the third year was due to lesser number of cladodes formed with growth restriction due to sudden rise of salinity of irrigation water from 6 to 14.75 dSm^{-1}.

Plant height

The mean of cactus accession plants height studied over three years showed a highly significant range from 45.75 cm in accession No. Conlea-L19 of Algeria to the tallest, 82 cm for accession No. 4321 of Tunisia, which was the only significantly ($p<0.05$) superior accession with 67.66 cm over all accessions. As many as 17 accessions exceeded mean performance, which were significantly ($p<0.05$) superior to the lowest performing accessions (Table 1). Earlier studies of Albuquerque and Santos (2006), showed plant height ranging from 0.5 to 1.7 m

among 20 cactus accessions grown under rainfed conditions (250-400 mm), whereas Soni *et al.* (2015) found plant height from 32.6 to 78.6 cm among seven local Indian accessions of prickly pear cactus under irrigation in pot studies.

Table 1. Means of plant height (cm) of 33 forage cactus accessions during 2012 to 2014, in Rumais, Oman.

Sl. No.	Accession No.	Origin	Plant height (cm) 2012	2013	2014	Mean
1	4321	Tunisia	85.00	80.00	81.00	**82.00**
2	68247	Algeria	77.00	77.67	62.00	**72.22**
3	69199	Algeria	58.00	75.33	51.83	**61.72**
4	69210	Algeria	84.00	83.00	66.00	**77.67**
5	69217	Algeria	70.00	70.00	44.00	**61.33**
6	69220	Algeria	60.33	57.50	38.00	**51.94**
7	69223	Algeria	43.67	65.00	48.00	**52.22**
8	69233	Italy	64.00	46.00	45.00	**51.67**
9	69234	Italy	65.33	81.33	65.67	**70.78**
10	69236	Italy	73.00	83.00	51.00	**69.00**
11	69241	Tunisia	74.00	76.67	65.67	**72.11**
12	69242	Tunisia	67.00	80.00	82.50	**76.50**
13	69245	Tunisia	71.00	88.00	58.00	**72.33**
14	69246	Tunisia	85.00	88.00	55.50	**76.17**
15	69248	Tunisia	64.00	71.00	41.00	**58.67**
16	69219	Algeria	75.00	77.50	61.50	**71.33**
17	73049	Mexico	79.00	73.50	42.00	**64.83**
18	73054	Afrique Du Sud	49.00	62.00	48.00	**53.00**
19	73060	Tunisia	72.33	70.00	50.00	**64.11**
20	73062	Tunisia	98.50	83.00	55.50	**79.00**
21	74083	Morocco	63.00	80.00	49.00	**64.00**
22	74110	New Mexico	85.50	79.00	57.50	**74.00**
23	74111	New Mexico	60.33	89.00	70.53	**73.29**
24	74112	Mexico	70.33	71.00	71.83	**71.06**
25	75012	Tunisia	78.33	85.67	70.67	**78.22**
26	75018	Morocco	83.00	87.50	69.50	**80.00**
27	75019	Morocco	90.33	78.50	70.50	**79.78**
28	75032	Madagascar	73.33	67.00	57.00	**65.78**
29	Conlea-L19	Algeria	57.00	47.50	32.75	**45.75**
30	R-14	Unknown	84.33	72.33	74.83	**77.17**
31	NIL-I	Unknown	62.00	50.00	59.00	**57.00**
32	NIL-II	Unknown	46.00	65.00	54.00	**55.00**
33	74112	Mexico	65.33	73.50	81.00	**73.28**
Mean			**70.73**	**73.77**	**58.49**	**67.66**

Statistical parameters

Source of variation	F-test	LSD (5%)
Year	**	3.92
Accessions	**	13.01
Year × Accessions	NS	-
C. V. (%)	50.3	

However, recently Lima *et al*. (2016) reported the plant height of forage cactus to be 109.97 and 115.27 cm in year-1 and year-2, varying from 81.11 to 143.73 cm in their treatments with different cutting intensities.

Number of cladodes per plant

Cactus accessions studied were found to be diverse in respect of mean number of cladodes per plant over three years with minimum of two pads in case of accession No. 73054 of Afrique Du Sudand, and maximum of 10.56 cladodes from accession No. 69241 of Tunisia, followed by accession No. 74112 of Mexico which were significantly ($p<0.05$) superior to the following accessions: No. 4321 of Tunisia (7.22), No. 75018 of Morocco (6.78), No. 69236 of Italy and Nil-II of unknown origin (6.67). The overall mean of number of cladodes per plant was 4.77 (Table 2).

Sharafi *et al.* (2012) recorded 15.73 cladodes per plant at 7 day irrigation interval, but only 5 to 10 cladodes per plant with an irrigation interval of 15 and 30 days. Soni *et al.* (2015) found that the number of cladodes ranged from 2 to 14.4 per plant with mean of 5.17 among the Indian cactus accessions.

Cladode weight

The mean weight per cladode of the cactus accessions studied over three years had highly significant range from the lightest of 0.32 kg in respect to the accession No. 68248 of Tunisia to the heaviest of 0.59 kg from the accession No. 75018 of Morocco, that was only accession exceeding ($p<0.05$) the overall mean cladode weight of 0.46 kg. The other accessions were: No. 68247 of Algeria and 75019 of Morocco (0.57 kg), No. 68242 of Tunisia (0.55 kg) and No. 4321 of Tunisia (0.54 kg) (Table 3). Soni *et al.* (2015) with seven Indian cactus accessions grown under irrigated pot conditions showed cladode weight varying from 0.057 to 0.2 kg.

Cladodes dry matter

Cactus accessions presented a high variability dry matter content during the three years studied, having a maximum of 13% for accession No. 74112 of Mexico, and a minimum of 8.29%. accession No. 74112 of Mexico, followed by the accession No. 73060 of Tunisia. The next six accessions having dry matter content ranging from 11.16 to 12.50% which were significantly superior to the mean dry matter over all accessions and three years (10.22%) (Table 4). Azocar and Rojo (1991), reported mean dry matter of 15.04% whereas Singh (2003) and Albuquerque and Santos (2006) reported dry matter ranging from 6.4 to 7.3% and 9.5% to 12.2%, respectively. Soni *et al.* (2015), reported dry matter of as low as 4.98 to 5.36% in Indian accessions whereas Kangara and Gitari (2016), found less than 15% dry matter in their studied accessions in Kenya.

Fresh and dry matter yields (t ha^{-1})

The mean fresh matter yield of cactus accessions studied over three years had highly significant range from the lowest of 46.99 t ha^{-1} year^{-1} from accession No. 73054 of Afrique du Sud to the highest of 331.58 t ha^{-1} year^{-1} for accession No. 74112 of Mexico, which was superior

(p<0,05) to not only following accessions No. 4321 of Tunisia (197.67), No. 75018 of Morocco (195.33), No. 68247 of Algeria (185.78), No. 73049 of Mexico (180.78) and No. 69241 of Tunisia (173.22), but also to the overall mean fresh matter yield of 117.31 t ha^{-1} $year^{-1}$. Only two accessions, No. 74112 of Mexico and No. 4321 of Tunisia significantly out yielded grand mean performance of all the accessions (Table 5).

Table 2. Means of number of cladodes per plant of 33 forage cactus accessions during 2012 to 2014, in Rumais, Oman.

Sl. No.	Accession No.	Origin	No. of cladodes per plant			
			2012	2013	2014	Mean
1	4321	Tunisia	7.00	12.33	2.33	**7.22**
2	68247	Algeria	6.33	9.67	2.33	**6.11**
3	69199	Algeria	1.67	6.33	1.33	**3.11**
4	69210	Algeria	2.00	6.00	2.00	**3.33**
5	69217	Algeria	3.00	7.67	1.00	**3.89**
6	69220	Algeria	3.67	5.00	1.00	**3.22**
7	69223	Algeria	2.00	7.67	1.00	**3.56**
8	69233	Italy	2.00	9.00	2.00	**4.33**
9	69234	Italy	3.33	7.00	1.33	**3.89**
10	69236	Italy	7.00	11.00	2.00	**6.67**
11	69241	Tunisia	13.67	16.00	2.00	**10.56**
12	69242	Tunisia	5.00	7.00	1.00	**4.33**
13	69245	Tunisia	2.00	5.00	1.00	**2.67**
14	69246	Tunisia	5.00	11.00	1.00	**5.67**
15	69248	Tunisia	2.00	6.00	1.00	**3.00**
16	69219	Algeria	5.00	7.67	1.00	**4.56**
17	73049	Mexico	4.67	10.67	3.67	**6.33**
18	73054	Afrique Du Sud	1.00	4.00	1.00	**2.00**
19	73060	Tunisia	2.00	5.67	1.00	**2.89**
20	73062	Tunisia	5.00	6.67	1.00	**4.22**
21	74083	Morocco	2.00	7.00	2.00	**3.67**
22	74110	New Mexico	3.00	5.33	1.00	**3.11**
23	74111	New Mexico	4.00	7.33	1.67	**4.33**
24	74112	Mexico	3.33	5.67	1.00	**3.33**
25	75012	Tunisia	4.67	8.33	1.33	**4.78**
26	75018	Morocco	7.00	11.33	2.00	**6.78**
27	75019	Morocco	5.33	6.67	2.00	**4.67**
28	75032	Madagascar	2.67	5.33	1.33	**3.11**
29	Conlea-L19	Algeria	1.67	6.00	3.67	**3.78**
30	R-14	Unknown	6.67	11.33	1.67	**6.56**
31	NIL-I	Unknown	2.00	12.00	4.00	**6.00**
32	NIL-II	Unknown	1.00	17.00	2.00	**6.67**
33	74112	Mexico	6.00	17.33	3.67	**9.00**
	Mean		**70.73**	**73.77**	**4.02**	**8.55**

Statistical parameters

Source of variation	F-test	LSD (5%)
Year	**	0.7
Accessions	**	2.2
Year × Accessions	**	3.8
C. V. (%)	50.3	

Table 3. Means of weight per cladode (kg) of 33 forage cactus accessions from 2012-2014, in Rumais, Oman.

Sl. No.	Accession No.	Origin	Weight per cladode (kg)			
			2012	2013	2014	**Mean**
1	4321	Tunisia	0.45	0.55	0.62	**0.54**
2	68247	Algeria	0.46	0.56	0.69	**0.57**
3	69199	Algeria	0.29	0.24	0.56	**0.37**
4	69210	Algeria	0.58	0.36	0.33	**0.42**
5	69217	Algeria	0.50	0.39	0.43	**0.44**
6	69220	Algeria	0.40	0.29	0.48	**0.39**
7	69223	Algeria	0.25	0.40	0.58	**0.41**
8	69233	Italy	0.43	0.33	0.43	**0.40**
9	69234	Italy	0.42	0.54	0.61	**0.52**
10	69236	Italy	0.51	0.63	0.25	**0.46**
11	69241	Tunisia	0.33	0.36	0.61	**0.43**
12	69242	Tunisia	0.44	0.61	0.61	**0.55**
13	69245	Tunisia	0.36	0.50	0.71	**0.52**
14	69246	Tunisia	0.51	0.52	0.30	**0.44**
15	69248	Tunisia	0.20	0.33	0.43	**0.32**
16	69219	Algeria	0.52	0.43	0.55	**0.50**
17	73049	Mexico	0.44	0.42	0.65	**0.50**
18	73054	Afrique Du Sud	0.40	0.25	0.60	**0.42**
19	73060	Tunisia	0.52	0.47	0.61	**0.53**
20	73062	Tunisia	0.26	0.45	0.45	**0.39**
21	74083	Morocco	0.35	0.38	0.36	**0.36**
22	74110	New Mexico	0.45	0.34	0.81	**0.53**
23	74111	New Mexico	0.48	0.42	0.56	**0.49**
24	74112	Mexico	0.37	0.53	0.60	**0.50**
25	75012	Tunisia	0.35	0.49	0.62	**0.49**
26	75018	Morocco	0.60	0.57	0.60	**0.59**
27	75019	Morocco	0.49	0.62	0.61	**0.57**
28	75032	Madagascar	0.33	0.45	0.68	**0.49**
29	Conlea-L19	Algeria	0.36	0.20	0.57	**0.37**
30	R-14	Unknown	0.55	0.40	0.36	**0.44**
31	NIL-I	Unknown	0.35	0.42	0.44	**0.40**
32	NIL-II	Unknown	0.25	0.50	0.53	**0.43**
33	74112	Mexico	0.69	0.56	0.34	**0.53**
Mean			**70.73**	**73.77**	**0.42**	**0.44**

Statistical parameters

Source of variation	F-test	LSD (5%)
Year	**	0.03
Accessions	**	0.12
Year × Accessions	**	0.20
C. V. (%)	27.3	

Similarly cactus accessions were also diverse in respect of mean annual dry matter yield with a range from 4.40 t ha^{-1} $year^{-1}$ in respect of accession No. 73054 of Afrique Du Sud to the highest of 33.38 t ha^{-1} in respect to the accession No. 74112 of Mexico which was superior ($p<0.05$) to overall mean annual dry matter yield ha^{-1} (11.85 t ha^{-1}), among all the accessions studied over three years.

The accession No. 75018 of Morocco was superior ($p<0.05$) in dry matter yield (20.05 t ha^{-1} $year^{-1}$, followed by the accessions No. 68247 of Algeria (19.51 t ha^{-1}), No. 4321 of Tunisia (19.04 t ha^{-1}), Nil-I of unknown origin (16.99 t ha^{-1}) and R-14 of unknown origin (16.94 t ha^{-1}), which were the superior performers (Table 6).

Table 4. Means of dry matter per cent of 33 forage cactus accessions from 2012-2014, in Rumais, Oman.

Sl. No.	Accession No.	Origin	Dry matter (%) 2012	2013	2014	Mean
1	4321	Tunisia	8.12	8.33	15.10	**10.52**
2	68247	Algeria	7.94	8.03	14.74	**10.24**
3	69199	Algeria	8.20	7.93	13.55	**9.90**
4	69210	Algeria	8.34	8.20	12.96	**9.83**
5	69217	Algeria	8.23	9.10	12.79	**10.04**
6	69220	Algeria	7.79	9.27	13.43	**10.16**
7	69223	Algeria	7.48	7.63	15.72	**10.28**
8	69233	Italy	7.50	8.00	16.04	**10.51**
9	69234	Italy	7.47	8.53	14.50	**10.17**
10	69236	Italy	8.40	8.40	10.37	**9.06**
11	69241	Tunisia	6.89	7.30	11.72	**8.64**
12	69242	Tunisia	7.42	9.30	11.02	**9.25**
13	69245	Tunisia	7.00	8.80	13.30	**9.70**
14	69246	Tunisia	8.60	9.70	13.24	**10.51**
15	69248	Tunisia	8.22	8.90	16.50	**11.21**
16	69219	Algeria	8.57	8.63	16.47	**11.23**
17	73049	Mexico	8.32	7.87	11.88	**9.36**
18	73054	Afrique Du Sud	7.05	7.70	10.80	**8.52**
19	73060	Tunisia	16.66	9.70	12.63	**13.00**
20	73062	Tunisia	7.62	8.00	14.16	**9.92**
21	74083	Morocco	8.64	9.50	9.76	**9.30**
22	74110	New Mexico	9.42	9.23	16.86	**11.84**
23	74111	New Mexico	8.84	8.60	16.05	**11.16**
24	74112	Mexico	7.12	7.17	10.58	**8.29**
25	75012	Tunisia	8.48	12.07	17.11	**12.55**
26	75018	Morocco	7.96	8.10	17.93	**11.33**
27	75019	Morocco	8.06	8.93	14.76	**10.58**
28	75032	Madagascar	8.63	8.73	14.02	**10.46**
29	Conlea-L19	Algeria	7.90	8.57	11.31	**9.26**
30	R-14	Unknown	8.72	8.83	12.43	**10.00**
31	NIL-I	Unknown	8.65	10.50	11.44	**10.20**
32	NIL-II	Unknown	8.96	8.63	13.99	**10.53**
33	74112	Mexico	7.81	8.67	13.11	**9.86**
Mean			**70.73**	**73.77**	**8.33**	**8.69**

Statistical parameters

Source of variation	F-test	LSD (5%)
Year	**	0.586
Accessions	**	1.944
Year × Accessions	NS	-
C. V. (%)	20.5	

Table 5. Means of fresh matter yield (t ha^{-1}) of 33 forage cactus accessions from 2012-2014, in Rumais, Oman.

Sl. No.	Accession No.	Origin	Green matter yield (t/ha)			
			2012	2013	2014	Mean
1	4321	Tunisia	123.00	280.00	190.00	**197.67**
2	68247	Algeria	127.33	226.67	203.33	**185.78**
3	69199	Algeria	20.65	66.63	72.10	**53.13**
4	69210	Algeria	46.00	80.00	40.00	**55.33**
5	69217	Algeria	84.00	117.50	100.00	**100.50**
6	69220	Algeria	65.67	55.00	45.00	**55.22**
7	69223	Algeria	22.83	146.67	183.33	**117.61**
8	69233	Italy	34.00	120.00	140.00	**98.00**
9	69234	Italy	56.11	145.00	101.11	**100.74**
10	69236	Italy	149.27	266.55	66.64	**160.82**
11	69241	Tunisia	189.67	226.67	103.33	**173.22**
12	69242	Tunisia	80.00	170.00	80.00	**110.00**
13	69245	Tunisia	25.00	90.00	80.00	**65.00**
14	69246	Tunisia	92.00	220.00	40.00	**117.33**
15	69248	Tunisia	13.36	80.16	66.80	**53.44**
16	69219	Algeria	104.00	127.50	55.00	**95.50**
17	73049	Mexico	95.04	171.98	275.34	**180.78**
18	73054	Afrique Du Sud	21.28	39.90	79.80	**46.99**
19	73060	Tunisia	47.54	110.36	82.36	**80.08**
20	73062	Tunisia	50.17	125.00	60.00	**78.39**
21	74083	Morocco	23.38	108.55	50.10	**60.68**
22	74110	New Mexico	55.43	77.75	100.60	**77.93**
23	74111	New Mexico	88.90	145.00	101.67	**111.86**
24	74112	Mexico	55.00	138.89	99.11	**97.67**
25	75012	Tunisia	86.44	166.60	158.80	**137.28**
26	75018	Morocco	171.00	270.00	145.00	**195.33**
27	75019	Morocco	100.00	165.00	96.67	**120.56**
28	75032	Madagascar	40.87	100.96	97.24	**79.69**
29	Conlea-L19	Algeria	20.67	46.67	90.00	**52.44**
30	R-14	Unknown	149.78	187.78	181.11	**172.89**
31	NIL-I	Unknown	28.00	200.00	240.00	**156.00**
32	NIL-II	Unknown	10.00	385.00	60.00	**151.67**
33	74112	Mexico	161.99	400.27	432.48	**331.58**
Mean			**70.73**	**73.77**	**73.89**	**159.33**

Statistical parameters

Source of variation	F-test	LSD (5%)
Year	**	23.83
Accessions	**	79.03
Year × Accessions	NS	-
C. V. (%)	72.5	

Table 6. Means of dry matter yield (t ha^{-1}) of 33 forage cactus accessions from 2012-2014, in Rumais, Oman.

Sl. No.	Accession No.	Origin	Dry matter yield (t/ha)			
			2012	2013	2014	Mean
1	4321	Tunisia	9.62	21.68	25.83	**19.04**
2	68247	Algeria	9.79	18.36	30.37	**19.51**
3	69199	Algeria	1.51	5.24	10.92	**5.89**
4	69210	Algeria	3.84	6.58	5.18	**5.20**
5	69217	Algeria	6.87	10.60	12.95	**10.14**
6	69220	Algeria	4.81	5.17	5.98	**5.32**
7	69223	Algeria	1.75	11.26	34.23	**15.75**
8	69233	Italy	2.55	9.62	22.46	**11.54**
9	69234	Italy	4.41	12.20	14.62	**10.41**
10	69236	Italy	12.54	22.45	6.91	**13.97**
11	69241	Tunisia	13.95	16.42	12.70	**14.36**
12	69242	Tunisia	5.94	15.80	8.81	**10.18**
13	69245	Tunisia	1.75	7.93	10.64	**6.77**
14	69246	Tunisia	7.91	21.35	5.30	**11.52**
15	69248	Tunisia	1.10	7.13	11.02	**6.42**
16	69219	Algeria	8.91	10.97	9.10	**9.66**
17	73049	Mexico	7.59	13.39	26.44	**15.81**
18	73054	Afrique Du Sud	1.50	3.08	8.62	**4.40**
19	73060	Tunisia	7.31	10.54	10.68	**9.51**
20	73062	Tunisia	3.80	10.05	7.19	**7.01**
21	74083	Morocco	2.02	10.26	4.89	**5.72**
22	74110	New Mexico	5.60	7.12	16.58	**9.77**
23	74111	New Mexico	8.01	11.59	12.95	**10.85**
24	74112	Mexico	3.93	9.60	10.46	**8.00**
25	75012	Tunisia	7.08	16.96	26.71	**16.92**
26	75018	Morocco	13.34	21.54	25.27	**20.05**
27	75019	Morocco	8.26	14.41	13.73	**12.13**
28	75032	Madagascar	3.73	8.96	13.25	**8.65**
29	Conlea-L19	Algeria	1.64	4.08	10.61	**5.45**
30	R-14	Unknown	12.51	16.73	21.58	**16.94**
31	NIL-I	Unknown	2.42	21.09	27.47	**16.99**
32	NIL-II	Unknown	0.90	32.07	8.39	**13.79**
33	74112	Mexico	11.36	32.76	56.01	**33.38**
Mean			**70.73**	**73.77**	**6.01**	**13.54**

Statistical parameters

Source of variation	F-test	LSD (5%)
Year	**	2.36
Accessions	**	7.826
Year × Accessions	NS	-
C.V. (%)	71.0	

With respect to fresh matter yield, Santana in 1992, reported a range from 106.9 to 205 t ha^{-1} year^{-1}, while Nefzaoui and Bensalem in 2001 found in areas with 150 and 450 mm annual rainfall a production of 20 and 100 t ha^{-1} year^{-1}, respectively. Pinos-Rodriguez *et al.* (2010), obtained fresh matter yield of 227 t ha^{-1} year^{-1} in 75 days under plant density of 135,000 ha^{-1} and 450 t ha^{-1} in six months under hydroponics. Recently, the fresh matter yield of fodder cactus

was found to be 131.16 t ha^{-1} $year^{-1}$ (Queiroz *et al.,* 2015), and 75 to 249 t ha^{-1} $year^{-1}$ in different treatments of cutting intensity (Lima *et al.,* 2016).

With respect to dry matter yield, Garcia de Cortzar and Nobel reported early as in 1990 the dry matter yield of fodder cactus to be 40 t ha^{-1} $year^{-1}$ under irrigation, while Riveros *et al.* (1990), reported 8 t ha^{-1} $year^{-1}$ under rainfed conditions, and later, in 1992, Santana estimated dry matter yield of 16 to 31 t ha^{-1} $year^{-1}$ among his studied accessions. Other authors reported a dry matter yield, under irrigated conditions, from 25 (Lima *et al*., 2013) and 40-50 t ha^{-1} $year^{-1}$ (Nobel, 2011), whereas in Brazil, Dubeux Jr. and Santos (2005), using drip irrigation with a plant density of 40,000 ha^{-1} showed yields up to 10.1 and 11.3 t ha^{-1} $year^{-1}$ for Gigante and Miúda cultivars, respectively. Queiroz *et al.* (2015), found it to be 8.18 t ha^{-1} $year^{-1}$ with a plant density of 15,625 plants ha^{-1}.

In view of the above, in the present study forage cactus productivity in terms of fresh and dry matter yield was found to be as 117.31 and 11.85 t ha^{-1} $year^{-1}$, respectively, with a plant density of 40,000 ha^{-1} which were in consistence with amounts reported by other researchers (Garcia de Cortazar and Nobel, 1990; Riveros *et al.,* 1990; Santana, 1992; Nefzaoui and Ben Salem, 2001; Dubeaux Jr. and Santos 2005; Albuquerque and Santos 2006, Lima *et al.,* 2016, and Kangara and Gitari 2016) under favorable conditions. Thus, forage cactus proved to be productive under arid and saline (ranging from 5.37 to 14.75 dSm^{-1}) irrigated conditions of Oman during crop growth (from germination till final harvest). Thus, prickly pear forage cactus can contribute to the establishment of sustainable production systems based on cactus not only to the feed security of livestock populations in agriculturally marginalized areas, but also to improve soil conditions. Besides, cactus could be also considered as appropriate plant species in the rangelands for the afforestation of arid and semi-arid areas because of their potential to resist scarce and erratic rainfall and high temperatures.

CONCLUSION

The results indicated the equal potential of cactus for fodder productivity under saline water conditions as against average annual fresh matter yield of about 80-100 t ha^{-1} by existing popular perennial Rhodes grass under arid and saline conditions of Arabian Peninsula in particular, and in the world in general.

ACKNOWLEDGEMENTS

We thank Director General of Agriculture and Livestock Research and Director, Plant Production Research Center of the Ministry of Agriculture & Fisheries, Sultanate of Oman for their assistance and encouragement in conducting experiment and acknowledge ICARDA-APRP for initiating forage cactus component in its research activities.

REFERENCES

Alary, V., Nefzaoui, A. and Ben Jemaa, M. 2007. Promoting the adoption of natural resource management technology in arid and semi arid areas: modeling the impact of spineless cactus in alley cropping in Central Tunisia. *Agroforestry Systems* 94: 573-585.

Albuquerque, S.G. and Santos, D.C. 2006. Agronomic evaluation of *Opuntia sps.* varieties for fodder production in the semi-arid North Brazil. Proc. Vth International Congress on Cactus Pear and Cochineal. Eds. C. Mondragon Jacobo *et al. Acta Hort.* 728: 183-187.

Azócar, P. and Rojo, H. 1991. Uso de cladodios de tuna (*Opuntia ficus-indica*) como suplemento forrajero estival de cabras en lactancia en reemplazo de heno de alfalfa. *Avances en Producción Animal*, 16(1-2):173-182.

Dubeux Jr., J. C. B. and Santos, M. V. F. 2005. Exigências nutricionais da palma forrageira. In: Menezes, R. S. C.; Simões, D. A.; Sampaio, E. V. S. B. (Eds.). A palma no Nordeste do Brasil, conhecimento atual e novas perspectivas de uso. Recife-PE: Ed. Universitária/UFPE, 2005. p. 105-128.

Dubeux Jr., C.B., Santos, F.M.V., Andrade, L., Santos, M. D., Farias, I., Lima, L.E. and Ferreira, R.L.C. 2006. Productivity of *Opuntia ficus-indica* L.Miller under different N and P fertilization and plant population in north-east Brazil. *J. Arid Environments.* 67:357-372.

FAO. 2001. Cactus (*Opuntia spp.*) as Forage. Eds. Mondragon Jacobo, C and Perez Gonzalez, S. FAO Plant Production and Protection Paper. 169. FAO. 2001.

Gajendra, G., Gurbachan Singh, J. C. Dagar, Khajanchi Lal and Yadav, R. K. 2014. Performance of edible cactus (*Opuntia ficus-indica*) in saline environments. *Indian Journal of Agricultural Sciences* 84: 509-513.

García de Cortázar, V., and Nobel, P.S. 1990. Worldwide environmental productivity indices and yield predictions for a CAM plant, *Opuntia ficus indica*, including effects of doubled CO_2 levels. *Agricultural and Forest Meteorology* 49: 261–279.

Gomez, K.A. and Gomez, A.A. 1984. Statistical Procedures for Agricultural Research. Second Ed. The International Rice Research Institute, Philippines.

Guevara, J.C., Felker, P., Balzarin, M.G., Páez, S. A., Estevez, O.R., Paez, M.N. and Antúnez, J.C. 2011. Productivity, cold hardiness and forage quality of spineless progeny of the *Opuntia ficus–indica* 1281 x *O. lindheimerii* 1250 cross in Mendoza Plain, Argentina. *Journal of the Professional Association for Cactus Development* (2011) 13: 48–62.

Kangara, J.N.N. and Gitari, J.N. 2016. Exploiting fodder potentials of Cactus (*Opuntia* spp) in Kenya for pastoral livestock feeding under a changing climate. http://www.azrefs.org/exploiting-fodder-potentials-of-cactus-opuntia-spp-in-kenya-fo.html

Lima, G. F. C., Rêgo, M.M.T., Aguiar, E.M., Silva, J.G.M., Dantas, F.D.G. and Lobo, R.N.B. 2013. Situación actual de las técnicas de producción de nopal forrajero en Brasil: avances y limitaciones. In: Mondragón-Jacobo, C. (Ed.). Simposio Internacional Tuna Nopal. Puebla-México: SAGARPA. pp. 94-105.

Lima, G.F.C., Rego, M.M.T., Dantas, F.D.G., Lobo, R.N.B., Silva, J.G.M and Aguiar, E.M. 2016. Morphological characteristics and forage productivity of irrigated cactus pear under different cutting intensities. *Rev. Caatinga, Mossoró.* 29(2):481–488.

Nadaf, S.K., Al-Farsi, S.M., and Al-Hinai, S.A. 2007a. Nature of regeneration of cactus (*Opuntia spp.*) accessions in cactus nursery in Oman. Annual Report 2007. Directorate General of Agriculture & Livestock Research. Ministry of Agriculture & Fisheries. Sultanate of Oman. pp.123-133.

Nadaf, S.K., Al-Farsi, S.M., and Al-Hinai, S.A. 2007b. Influence of propagation material on regeneration of cactus (*Opuntia spp*.) in Oman. Annual Report 2007. Directorate General of Agriculture & Livestock Research. Ministry of Agriculture & Fisheries. Sultanate of Oman. pp.134-138.

Nadaf, S.K., Al-Farsi, S.M., and Al-Hinai, S.A. 2007c. Influence of method of planting on regeneration of cactus (*Opuntia spp*.) in Oman. Annual Report 2007. Directorate General of Agriculture & Livestock Research. Ministry of Agriculture & Fisheries. Sultanate of Oman. pp.139-142.

Nefzaoui, A.Y. and Ben Salem, H. 2001. *Opuntia spp*: a strategic fodder and efficient tool to combat desertification in the WANA region. In: Mondragon, C. and Gonzalez, S. (Eds.). Cactus (*Opuntia* spp.) as Forage: FAO Plant Production and Protection Paper, 169. pp. 73-90.

Nefzaoui, A. and El Mourid, M. 2009. Cacti: A key-stone crop for the development of marginal lands and to combat desertification. In: F.A.P. Campos, J.C.B. Dubeux Jr. and S. de Melo Silva (eds.) Proc. *Sixth International Congress on Cactus Pear and Cochineal. Acta Horticulture* 11:365-374.

Nefzaoui, A., Louhaichi, M. and Ben Salem, H. 2014. Cactus as a tool to mitigate drought and to combat desertification. *Journal of Arid Land Studies*. 24:121-124.

Nobel, P. S. 2001. Biologia Ambiental. In: Barbera, G.; Inglesa, P.; Pimienta-Barrios, E. (Eds.) Agroecologia, cultivo e usos da palma forrageira. Roma: FAO/Sebrae-PB, 2001. pp. 36-48.

Nobel P.S. 2009. Desert Wisdom, Agaves and Cacti, CO_2, Water, Climate Change. Universe, New York, Bloomington. ISBN: 978-1-4401-9151-0. 198 p.

Pinos-Rodríguez, J.M., Velázquez, J.C. González; S.S., Aguirre; J.R. García; J.C. Álvarez; G. and Jasso, Y. 2010. Effects of cladode age on biomass yield and nutritional value of intensively produced spineless cactus for ruminants. *South African Journal of Animal Science*, Hatfield. 40:245-250.

Queiroz, M.G., Da Silva, T.G.F., Zolnier, S., E Silva, S.M.S., Lima, L.R. and Alves, J.D.O. 2015. Características morfológicas e produtividade da palma forrageira em diferentes lâminas de irrigação. *Revista Brasileira de Engenharia Agrícola a Ambiental*, Campina Grande. Vol. 19, No. 10, 931-938 pp.

Riveros, E.V., García de Cortázar, V. and García, G. 1990. Uso de cladodios de tuna (*Opuntia ficus indica*) como suplemento forrajero estival para ovinos en crecimiento. *Avances en Producción Animal*, 15(1-2):81-88.

Santana, P. 1992. Tunas forrajeras (*Opuntia ficus-indica* y *Nopalea cochellinifera*) *en el* nordeste brasileño. Actas del II Congreso Internacional de Tuna y Cochinilla. Facultad de Ciencias Agrarias y Forestales. Santiago, Chile.

Sharafi, S., Ghasemi, S., Jouyban, Z. and Akhlaghi, S. 2012. Effect of water stress on agronomic traits of cactus pear (*Opuntia ficus indica* L.). *Life Science Journal.* 1(s):83-87.

Singh, G. 2003. General review of *Opuntias* in India. *Journal of the Professional Association for Cactus Development.* 5:30–46.

Snyman, H. A. 2005. A case study on *in situ* rooting profiles and water-use efficiency of cactus pears, *Opuntia ficus-indica* and *O. robusta*. *Journal of the Professional Association for Cactus Development.* 7:1–21.

Soni, M.L., Yadava, N. D., Kumar,S. and Roy, M. M. 2015. Evaluation for growth and yield performance of prickly pear cactus (*Opuntia ficus-indica L. Mill*) accessions in hot arid region of Bikaner, India. *Range Management & Agroforestry.* 36(1):19-25.

Sudzuki, F. H. 1995. Anatomy and morphology. In: G. Barbera; P. Inglese; and E. Pimienta-Barrios (Eds.). *Agro-Ecology Cultivation and Uses of Cactus Pear*. FAO Plant Production and Protection Paper No.132, FAO, Rome. pp. 28-34.