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Evaluation for growth and yield performance of prickly pear cactus (*Opuntia ficus-indica (L.) Mill*) accessions in hot arid region of Bikaner, India

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Abstract
Growth and yield performance of seven accessions *viz*.,1269,1270, 1271, CAZRI Botanical Garden, Mount Abu, 1458 and AHCP-2 of prickly pear cactus (*Opuntia ficus-indica* (L.) Mill) was studied during 2013-14 at CAZRI, RRS, Bikanerwith the aim to find out most suitable accession for this region After 270 days study period, it was found that the accession CAZRI Botanical Garden produced maximum number of cladodes per plant (14.4) followed by the accession 1458 (5.4), 1270 (5.0) and 1271 (4.2). The number of cladodes was minimum in accession AHCP-2 (2.4). Regarding cladode length, the accession 1271 produced the longest (24.2 cm), whereas, it was lowest (12.6 cm) in AHCP-2. The accessions CAZRI Botanical Garden, 1270, 1458 and 1271 were higher yielder as compared to others. Highest green cladodes production (1260.7 g plant^{-1}) was recorded in the accession CAZRI botanical garden followed by accession 1270 > accession 1458 > accession 1271, while the accession AHCP-2 produced lowest biomass (163.8 g plant^{-1}).

Keywords: Arid, Cactus pear, Growth, Yield

Introduction

Hot arid region covers about 31.7 million hectare geographical area of India. Drought is the most common phenomenon of this region and irrigation water is scarce. Under these harsh conditions, inclusion of drought hardy perennials *viz*., tree/shrubs/grasses, into farming system approach is recommended to increase system productivity, enhancing fodder availability and checking soil erosion (Bhati, 1997; Sharma, 2014; Soni *et al*., 2006; Soni *et al*., 2013). Cactus pear (*Opuntia ficus-indica* (L.) Mill.), commonly known as prickly pear, has a marked capacity to withstand prolonged drought (Nobel, 1995; Felker *et al*., 1997), extreme heat (Sudzuki, 1995), highly efficient in water use (Nobel, 1995; De Kock, 2001; Reynolds and Arias, 2001; Snyman, 2004 ; Snyman, 2005), moderately tolerant to salinity (Gajendra *et al.,* 2014) and are considered as an important potential source of food and fodder (Mishra *et al*., 2006; Mathur *et al.,* 2009) in many desert areas of the world (Brutsch, 1979). It is considered as a natural reservoir of water and may reduce the water requirement of cattle (Flores-Hernández *et al.,* 2004). In addition to its remarkable value as cattle and human food, it can act as biological barrier to prevent and control top-soil loss (Nefzaoui and El Mourid, 2009) and increase fodder availability for animals (Alary *et al*., 2007). With these qualities in view, it may be considered as a potential crop species for the water-scarce arid parts of India.

The cultivation of cactus pear as a commercial crop is little known in Indian sub-continent. Only the wild cactus is found growing in wasteland and as a hedge around agricultural fields to protect the crops from wild animals. Over the last few years, a great interest in spineless cactus pear was shown in the drier areas of India in terms of fruit, fodder and vegetable production (Singh and Singh, 2003; Pareek *et al*., 2003; Singh, 2006; Singh and Felker, 1998). Recently, with the efforts of Central Arid Zone Research Institute (CAZRI) Jodhpur, the available material of Cactus pear is being evaluated at several locations in India including its Regional Research Station (RRS), Bikaner with the aim to increase its area which may meet the requirement of animal fodder, conserve the soil and increase biomass. The present study was aimed to evaluate growth and yield performance of prickly pear cactus (*Opuntia ficus-indica* (L.) Mill.) accessions in north-western hot arid Bikaner region of India.

Materials and Methods

Site characteristics: The study was conducted during June 2013- March 2014 in net house conditions at Central Arid Zone Research Institute, Regional Research Station, Bikaner (latitude 28.03^{0}N, longitude 73.19^{0}E and an altitude of 234.84 m above mean sea level) in north-western India. The average rainfall of the region is 275

mm with 57% coefficient of variation. Mean monthly maximum and minimum temperature ranged from 21 to 43 ^{0}C and 6 to 29 ^{0}C, respectively, in which the mercury touches 47^{0}C in summer and dipping down to freezing point in winter. Mean relative humidity in the morning (RH-I) ranges from 78% in January to 45% in April, and in the evening (RH-II) ranges from 50% in January to 18% in April. Mean evaporation during summer months may be as high as 16 mm day^{-1} and during winter; it may be 3 mm day^{-1}. The soils of the experimental site was alkaline (pH=8.3 in 1:2 soil water suspension), non-saline (EC=0.21dS m^{-1} in 1:2 soil water suspension), sand in texture (89.2% sand, 6.7% silt and 4.1% clay) with low soil organic carbon= 0.9 g kg^{-1}, low available N (72 kg ha^{-1}), low available P (9.1 kg ha^{-1}) and high available K (228 kg ha^{-1}). The water content at field capacity was 7.9 % (w/v). Physical and chemical characteristics of soil were analyzed by standard laboratory techniques (Gupta *et al*., 1999).

Planting materials: Mature cladodes of available accessions of *Opuntia ficus-indica* (L.) Miller *viz*., *1270, 1271, CAZRI Botanical Garden* were collected from CAZRI, Jodhpur and accession *1269, Mount Abu, 1458 and AHCP-2* from Central Institute on Arid Horticulture (CIAH), Bikaner (Table 1). The cladodes were dried for 4-5 days in the shade for suberization and then 10 cladodes of each accession were planted upright (with one quarter of cladode in the soil) in pots (100 X 100 mm and 200 mm deep) filled with soil. The bulk density of the soil was 1.52g cm^{-3} after filling the pots. The pots have 2 holes of 0.8 cm diameter at the bottom to ensure free water movement through them. The planting of cladodes was done on 7th June, 2013.The cut portion of cladodes was treated with Carbendizam fungicide @ 2 g lit^{-1} solution to check the rotting and fungal infection. The treatment with fungicide was repeated twice at an interval of 10 days by applying about half lit of 0.2% solution in each pot. For the purpose of data recording, five pots of each accession were randomly selected. Water was regularly applied equally to each accession.

Data collection and statistical analysis: At the end of two growing seasons (June-November, 2013 and November, 2013- March, 2014), the cladodes were harvested (Five plants per accessions) in March, 2014. At the harvest, the basal (Mother) cladodes were left in all the plants for further regeneration and growth. The plant height, number of cladodes plant^{-1}, maximum length (Distance from cladode base to its apex), width (longest distance across the obovate cladode), thickness, surface area of cladode, areoles cladode^{-1}, fresh and dry weight of all cladodes developed on mother cladodes was recorded. Plant height (cm) was measured with the help of Freemans measuring tape to get an indication of the vertical vegetative growth of the different cultivars. The thickness of the pads was measured with the help of Vernier caliper at three different points (Top, middle and bottom) and averaged. Areoles were counted on both faces and on the margins of the cladodes. Due to greater thickness of cactus cladodes, it was difficult to determine the surface area of cladodes with leaf area meter. Hence, surface area of cladodes were determined by actual tracing the area of fresh cladodes on green paper and then analyzed with the help of leaf area meter (Model-*Systronics 211*). Biomass of individual plant was recorded by removing all cladodes developed on mother cladode. For calculating cladode mass, all the harvested cladodes of an individual plant were weighed individually and totalled. The average mass per cladode was calculated by dividing the cladode yield plant^{-1}(kg) by the cladode number (*n*). Dry matter was determined by drying the cladodes in oven at 70°C until no further weight change occurred. To get quick drying; the cladodes were pierced with a sharp object before placing them in the oven. Statistical analyses were conducted using Indostat software.

Results and Discussion

Survival: Survival of all the accessions was 100% except accession 1270 in which 90% survival was recorded (Table 2). Singh (2006) reported that the survival of cactus depends upon method of their planting. They reported that erect planting gave 100% survival of plants after one year and was superior over flat planting method due to the fact that flat planted cladodes were completely covered by a layer of soil 2.5 cm while erect planted cladodes were partially buried in soil, which resulted in better survival of cladodes. Moreover, the better management practices, such as pre-treatment of cladodes against rotting/fungal disease (*Carbendizam* fungicide @ 2 g lit^{-1} solution) and soil application of fungicide at regular intervals of 10 days during the first two months resulted in better survival of cladodes. Maximum plant height was recorded in accession 1271 followed by CAZRI Botanical Garden as compared to all other accessions (Table 2). Minimum plant height was recorded in accession Mount Abu.

Areole number per cladodes: There was significant difference (P<0.01) in mean areole number per cladode (Table 2) among different accessions. Accession 1271

Table 1. Description of *Opuntia ficus-indica* accessions used in trial

Accession number	Description of collection	Spines	Type	Reference
1269	Collected from CIAH, Bikaner	No	Fodder, Vegetable	Pareek *et al.*(2003)
1270	Obtained from CAZRI, Jodhpur	No	Fodder and Fruit	Pareek *et al.*(2003) Singh (2003)
1271	Obtained from CAZRI, Jodhpur	No	Fodder and Fruit	Pareek *et al.*(2003)
1458	Obtained from CIAH, Bikaner	No	Fruit	Pareek *et al.*(2003)
CAZRI botanical garden	Obtained from CAZRI, Jodhpur	No	Fodder	Mathur *et al.*(2009) Mishra *et al.*(2006)
Mount Abu	Obtained from CIAH, Bikaner	No	ð	ð
AHCP-2	Obtained from CIAH, Bikaner (A collection from Balesar, Jodhpur)	No	Fruit	Pareek *et al.*(2003)

Table 2. Survival growth and dry matter production of different accessions of cactus pear

Accessions	Survival (%)	Plant Height (cm)	Areoles/ cladode	Number of cladodes/plant	Fresh weight/ cladode (g)	Dry Matter (%)
1269	100	46.0±2.8	76.0±13.9	3.2±0.37	63.8±4.32	4.97±0.08
1270	90	63.0±2.9	101.0±6.6	5.0±0.45	200.9±10.38	5.13±0.11
1271	100	78.6±0.6	105.0±2.9	4.0±0.45	182.4±20.80	4.88±0.23
1458	100	61.6±1.2	43.2±2.4	5.0±0.89	148.2±15.14	5.36±0.11
CAZRI botanical garden	100	67.0±3.8	52.0±1.2	14.4±0.51	86.8±1.75	5.34±0.25
Mount Abu	100	32.6±2.1	80.0±5.2	2.6±0.40	92.9±5.29	5.24±0.29
AHCP-2	100	40.0±1.9	42.2±1.6	2.0±0.00	57.1±9.68	5.44±0.21
LSD<0.05	ð -	6.99	13.55	1.45	33.10	NS

ranked first in mean areole number per cladode (105.0) followed by 1270 (101.0). Minimum areole number/ cladode was observed in AHCP-2 (42.2) , followed by 1458, CAZRI Botanical garden, 1269 and Mount Abu with average areole number of 43.2, 52.0, 76.0 and 80.0 per cladode , respectively. None of the accessions were found free of glochides (small hair like spines) which creates the problem during handling. However, the glochides on the areoles were very less and small in all the accessions except AHCP-2 and Mount Abu which are of Indian origin.

Number of cladodes per plant: The number of cladodes per plant varied significantly in different accessions. The accession CAZRI Botanical Garden produced the maximum (14.4) cladodes per plant (Table 2), followed by the accession 1458 (5.0), accession 1270 (5.0) and accession 1271 (4.0). The number of cladodes was minimum in accession AHCP-2 (2.4), followed by Mount Abu (3.6). Singh (2003) also reported higher number of cladodes in accessions 1270 and 1271.

Size and shape of cladodes*:* Size and shape of cladodes in different clones varied considerably (Table 3). It is important to emphasize that cladode dimension plays an important role because it works like a water reserve system for the plant. The accessions with higher reserves could have better adaptation potential to water stress. Regarding cladode length, it was found that the accession 1271 produced the longest (24.7 cm) and AHCP-2 produced the lowest (13.2 cm) cladode length (Table 3). Except accession 1271, rest of the accession produced cladodes length of less than 20-cm. Regarding cladodes width, it was observed that the accession1458 and 1270 had the largest cladode width of 10.6 and 10.8 cm., respectively which were significantly at par. The lowest cladode width (4.9 cm) was observed in the accession 1269 followed by AHCP-2 (5.2 cm), which were significantly at par. Such variation in size of cladodes among different accessions has also been reported from different parts of India (Singh, 2003; Pareek *et al*., 2003). Lower length to width ratio ofaccession1270 (1.80$\pm$0.03) and 1458 (1.88$\pm$0.06) impart them oval/round appearance (Plate 1). The accession CAZRI Botanical Garden, 1269 and 1271 have exceptionally higher length to width ratio (3.10$\pm$0.02, 3.00$\pm$0.30 and 2.98$\pm$0.24, respectively). In regard to the cladode thickness, it varied between 1.27 - 1.64 cm with highest value (1.64 cm.) in Mount Abu and lowest in accession CAZRI Botanical Garden.

Table 3. Growth attributing characters of different accessions of cactus pear

Accessions	Length (cm)	Width(cm)	Thickness (cm)	Length/width ratio	Area/cladode (cm^2)
1269	13.46±0.86	4.92±0.35	1.45±0.02	3.00±0.30	55.99±3.92
1270	19.41±0.31	10.79±0.29	1.44±0.11	1.80±0.03	170.7±8.42
1271	24.72±1.12	8.20±0.51	1.48±0.12	2.98±0.24	157.51±18.46
1458	19.61±0.97	10.58±0.79	1.35±0.03	1.88±0.06	145.55±16.62
CAZRI Botanical Garden	18.20±0.22	5.84±0.09	1.27±0.06	3.10±0.02	83.17±1.16
Mount Abu	13.62±0.63	7.19±0.36	1.64±0.07	1.94±0.18	73.70±4.04
AHCP-2	13.21±1.04	5.18±0.35	1.47±0.05	2.56±0.09	54.87±6.92
LSD<0.05	2.33	1.27	0.21	0.48	30.13

(Values are Mean ± SE)

Table 4. Correlation between different growth parameters with fresh weight of cactus pear

Parameters	n	r	p
Length (cm) vs Fresh weight of cladode (g)	165	0.33**	0.00001
Width (cm) vs Fresh weight of cladode (g)	165	0.70**	0.00001
Thickness(cm) vs Fresh weight of cladode (g)	165	0.59**	0.00001
No. of cladodes vs Fresh weight plant^{-1} (g)	35	0.81**	0.00001
Area of cladode (cm^2) vs Fresh weight of cladode (g)	165	0.89**	0.00001

** Values are significant at P<0.01

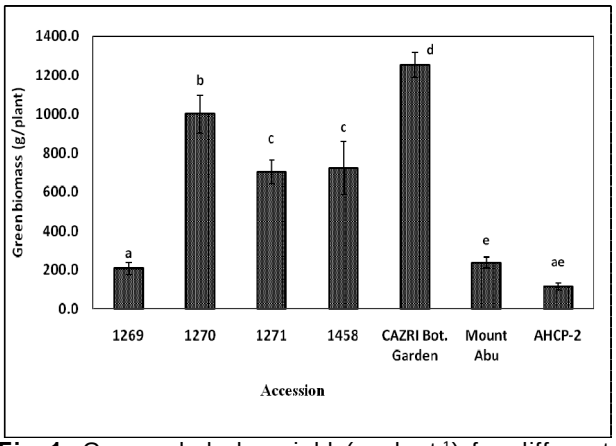

Fig 1. Green cladodes yield (g plant^{-1}) for different accessions of cactus pear under arid situation of Bikaner.Vertical bars represent standard errors of means. (Different superscript letters indicate significant (P<0.05) differences among accessions with LSD=214.96).

Average weight of cladodes: The average weight per cladode differed significantly among accessions (Table 2). Maximum weight of single cladode (200.9 g cladode^{-1}) was attained by the accession 1270 followed by 1271 and 1458 which attained a fresh weight of 182.4, 148.2 gcladode^{-1}, respectively. The accessions Mount Abu and CAZRI botanical garden attained 92.9 and 86.8 g cladode^{-1}, respectively which were significantly at par with each other. Minimum cladode weight (57.1 g cladode^{-1}) was recorded in accession AHCP-2.

Cladode biomass per plant: Biomass production of green cladodes showed significant differences. Accessions CAZRI Botanical Garden, accession 1270, accession 1458 and accession 1271 were greater yielder as compared to others. Highest green cladodes production (1252.4 g plant^{-1}) was recorded in the accession CAZRI botanical garden followed by 1270 >1458 >1271, while the accession AHCP-2 produced lowest biomass (114.2 g plant^{-1}). Accessions 1269 and Mount Abu was moderate yielder with 207.2 and 236.4 g plant^{-1}, respectively. Higher productivity of accessions 1270 and 1271 was also reported in earlier studies conducted in arid situation of Bikaner (Singh, 2003).

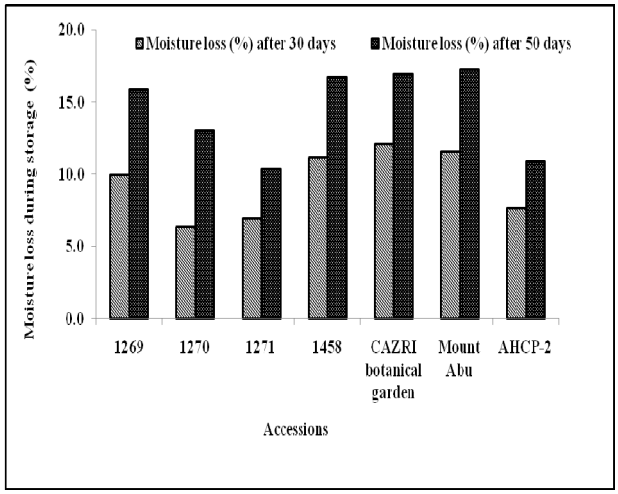

Fig 2. Moisture loss (%) during storage of cladodes at room temperature (28.4 ± 4.2^{0}C) at 30 and 50 days after harvest.

Per cent dry matter production: Dry matter in different accessions ranged from 4.88-5.44% with highest value in accession AHCP-2 and least value in accession 1271. However, no significant difference in dry matter percent among the different accessions was recorded (Table 2). The low dry matter percent in different accessions of cactus pear was due to the age of cladodes, which were about 9 months only. Liguori *et al.* (2014) reported that accumulation of dry matter depends upon the age of cladodes. The dry matter per cent was twice in >2 years old cladodes than in current year ones and 30% higher than in 1-year-old ones.

Significant positive correlation was observed in fresh weight of cladodes with length, width, thickness, number of cladodes and area of cladodes (Table 4). However, cladode area may be regarded as better biomass predictor due to its higher correlation with cladode weight. These findings are in agreement with those conducted by Lucena *et al.* (1999) who reported that total cladode weight and total cladode area were positively correlated. Pinto *et al.* (2002) reported a high correlation of cladode weight with cladode thickness.

Plate 1. A close view of shape, size and self-sprouted cladodes of different accessions [(A) 1269, (B) 1270, (C) 1271, (D) 1458, (E) CAZRI Botanical Garden, (F) Mount Abu and (G) AHCP-2] 50 days after harvest.

Loss of moisture during storage: Loss of moisture during storage of cladodes at room temperature (28.4±4.2^{0}C) recorded at25 and 50 days ranged between 6.3-12.1 and 10.4-17.3%, respectively in various accessions. This indicates that the cladodes of various accessions can be stored for a long time without appreciable loss in moisture content. At 50 days of harvest, Mount Abu accession incurred maximum loss in weight (17.3 %) followed by the accession CAZRI botanical garden (16.7 %), 1458 (16.7 %) and 1269 (15.9 %). All other accessions showed weight losses of between 10.1 to 13.4 %, with least weight losses in accession AHCP-2 and accession 1270 (Fig 2). Vegetable clones were more sensitive to weight loss than forage and fruit varieties (Singh, 2006).

Conclusion

The study suggests that there are possibilities of cultivation of cactus pear in the arid conditions of Bikaner. Of seven accessions, four accessions *viz*., CAZRI Botanical Garden, 1458, 1270 and1271 have been identified for higher green cladode production in arid conditions of Bikaner. Such accessions may be tested under field conditions for identifying the best material. Such material may find place in farming systems for enhancing income of the farming community in the region.

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