



Evaluation of cactus pear (*Opuntia ficus-indica*) accessions for various growth characteristics under arid region of north western India

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Abstract

Dry lands are characterised by high variability in the intensity and amounts of rainfall and occurrence of frequent and prolonged periods of droughts. Scarcity of fodder for animals and migration are common in these ecosystems. Twenty nine accessions of cactus pear (*Opuntia ficus-indica*) were imported through International Centre for Agricultural Research in the Dry Areas, South Asia and China Regional Program, India and one promising local spineless accession was collected from Kachchh area. These accessions were evaluated during 2013-2015, for performance under Indian arid conditions for growth and productivity for use as fodder resource. Different accessions varied significantly with respect to various growth characteristics and yield. After one year of growth in field, different accessions of cactus pear produced 2 to 21 cladodes per plant and aboveground biomass of 0.59 to 3.15 kg plant⁻¹. The cactus pear can serve as a potential fodder crop for rehabilitation of degraded arid lands by providing green fodder throughout the year.

Keywords: Cactus pear, Fodder resource, Range lands, Yield

Dry lands cover about 41% of the global land area and inhabited by 40% of the global population, 90% of which are located in developing countries (White and Nackoney, 2003). Dry lands are characterised by the scarcity of water with reduced length of growing period (LGP) of 1–179 days (Bot *et al.*, 2000) and a P/PET between 0.05 and 0.65 (Koohafkan and Stewart, 2008). Increased population growth and continuous pressure on limited natural resource base along with increased frequency of drought events led to degradation of natural resources in dry lands. Degradation of resource base in dry lands has severe impact on livestock population. Livestock rearing and breeding is an important activity adopted by the inhabitants of dry lands given the low productivity of

agricultural enterprises. Increased livestock population however fastens the resource degradation, by overgrazing natural rangelands and ultimately decreasing the availability of feed resources leading to annual migration of pastoralists (Dixit *et al.*, 2015; Hazra, 2014). The productivity of degraded lands in dry areas can be revived with the introduction of fast growing plant species that are palatable for livestock. Cactus pear [*Opuntia ficus-indica* (L.) Mill.], a perennial succulent plant native to Mexico, due to its ability to produce increased dry matter under limited water condition through specialized photosynthetic mechanism called Crassulacean Acid Metabolism (CAM) was considered as a future forage crop in the dry lands of India (Felker *et al.*, 1997). High water-use efficiency makes Opuntias ideal crop for arid and semi-arid regions where drought is common and animal food is scarce (Lahsasni *et al.*, 2003). The cactus is rich in energy and water and poor in protein (Sirohi *et al.*, 1997). Nefzaoui *et al.* (2001) reported that Opuntias are cultivated for fodder purpose in Africa, Italy, Israel, Spain, United States, Mexico, Columbia, Brazil, Peru, Bolivia, Chile and Argentina. Wild spiny species of cactus are distributed throughout India in rocky areas and wastelands. In India cactus is used in the field boundaries and as ornamental plants (Singh, 2003; Gajender *et al.*, 2014). Several spineless varieties of cactus are available that have promising multipurpose use as fodder and forage for livestock consumption, fruit and vegetable use for human, and other industrial uses (Singh, 2004). Shankar and Saxena (1976) reported that spineless cactus grown under arid conditions of Jodhpur, India produced fresh biomass of 30 t ha⁻¹ under 3×2 m spacing and 28.5 t ha⁻¹ under 2 × 2 m spacing.

The ecosystem in arid north west India is very fragile which is threatened by increased human activities in terms of overgrazing, urbanization and rapid industrialisation. The region was once famous for finest grassland of Asia, the Banni grasslands (Dayal *et al.*,

2015). These natural rangelands of north west India are under degradation due to overgrazing and invasion of tree species like *Prosopis juliflora*. The present study was undertaken to evaluate the performance of introduced cactus pear accessions for various growth characteristics under arid conditions of north west India.

The studies were carried out at the experimental farm of ICAR-Central Arid Zone Research Institute, Regional Research Station, Bhuj, India from 2013 to 2015 (23° 122 to 23° 132 N latitude and 69° 472 to 69° 482 E longitude). The plant materials consisted of twenty nine accessions of cactus received from the International Centre for Agricultural Research in the Dry Areas (ICARDA), India office for South Asia and China Regional Programme and one promising local spineless accession was collected from Kachchh area.

The cladodes were initially raised in plastic pots filled with potting mixture (1:1:1 sand, soil, farm yard manure), by keeping one-third portion of the cladode under the soil and two-thirds above the soil surface. Prior to planting, the cladodes were treated with carbendazim (0.2%). The nursery raised plants were transplanted to field after three additional cladodes are emerged from the basal cladode. The plants along with potting material was released from pots carefully and planted in the field during first week of August 2014 at the spacing of 3x1.5 m. Seven days after transplanting, 5 litres of water was added to each plant. The plants were irrigated once in a month during dry season.

The soil of the experimental site was loamy sand in texture with 8.8% clay and 7.0% silt content. The soil at upper 30 cm layer had a pH of 8.6, electrical conductivity of 0.47 dSm⁻¹ and organic carbon content of 0.24%. The region has an arid climate with very low and erratic rainfall with average rainfall of 346 mm (average of data from 1998 to 2015) with average 13 rainy days in a year. The coefficient of variation of rainfall was 72%. During experimental year, most of the rainfall occurred between the months of July to September in 2-4 days. The annual minimum temperature varies from 1 to 8°C and maximum temperature from 39 to 45°C.

The observations on growth traits such as plant height, number of cladodes, plant spread, circumference and thickness of primary and secondary cladode were recorded. The cladode area was calculated as, Cladode

area = Length x Width x 0.632 in line with de Cortázar and Nobel (1991). The cladode area was multiplied with the number of cladodes to obtain total cladode area. Plants were uprooted one year after transplanting and observations on growth and biomass were recorded. The statistical software package Genstat (v. 14) was used for analysis of variance (ANOVA).

All the thirty accessions survived well under the prevailing climatic conditions with survival rate of 90-100% (data not shown). Four accessions (Red Santa Margherita Belice, Morado, Red San Cono and White Roccapalumba) showed 90% survival and the remaining 26 accessions showed 100% survival. The height of plants varied significantly ($P < 0.001$) exhibiting wide variability with respect to growth characteristics (Table 1). The lowest height was recorded for Yellow Roccapalumba (27.7 cm) and highest for Blue Motto (103.9 cm). The accession CAZRI Botanical garden was the most spreading type (70.1 cm), followed by accessions Red Roccapalumba (68.4 cm) and accession no. 1308 (65.7 cm). The accessions with less spread were Morado (24.2 cm) and Yellow San Cono (28.8 cm).

The accession, CAZRI Botanical Garden produced maximum number of cladodes (18.4 plant⁻¹), closely followed by local collection CAZRI, Kukma (18.3 cladodes plant⁻¹). Other accessions producing more than 10 cladodes were Algerian and Roly Poly. The accessions Yellow Rocapalumba (3.1 plant⁻¹) and Crystallina (3.9 plant⁻¹) produced lowest number of cladodes. In the primary cladode, the length was highest for the accession Bianco Macromer (42.5 cm) and lowest for Morado (13.5 cm) (Table 2). The highest breadth (16.4 cm) and circumference (95.7 cm) for the primary cladode was recorded for the accession Gymnocarpe. The growth parameters of secondary cladode also varied significantly among different accessions. Longer secondary cladode was observed in Seedless Santa Margherita Belice (34.8 cm), followed by Giall x Giall (27.5 cm). The circumference of secondary cladode was also highest for Seedless Santa Margherita Belice (74.6 cm). The initiation and growth of cladodes were seasonal as reported elsewhere (Acevedo *et al.*, 1983) and it was during March to September for the study area. Thicker cladodes (both primary and secondary) were present in White San Cono. Piantra-25 produced thinner primary cladode and Trunzara Red San Cono and Red Santa Margherita Belice produced thinner secondary cladodes.

Evaluation of *Opuntia ficus-indica* accessions

Table 1. Growth characteristics of various accessions of *Opuntia ficus-indica*

Accession No/Name	Plant height (cm)	Plant spread (cm)	No. of cladodes /plant	Fresh weight /plant (kg)	Total cladode area / plant (cm ²)	Root volume (cm ³)	Dry matter (%)
1270	39.2	41.8	7.2	1.63	1875.6	5.9	9.3
1271	87.6	49.8	7.4	1.47	1488.0	7.6	6.8
1308	68.4	65.7	9.1	2.32	2950.3	18.4	12.6
1287	62.4	52.7	6.3	1.68	1313.0	6.2	14.5
Roso San Cono	58.4	58.5	6.4	1.26	985.6	1.0	11.0
Giall x Giall	70.6	50.9	7.6	2.42	1920.9	9.2	6.0
Trunzara Red San Cono	60.3	46.5	5.4	1.42	1247.1	10.5	7.3
Piantra – 25	40.1	40.2	5.6	1.04	1183.3	6.3	4.37
ARL Spineless	79.7	58.3	7.3	2.32	2107.1	9.5	17.7
Crystallina	31.4	31.7	3.9	1.37	615.3	9.8	7.5
Rosa Castle Sardo	50.5	48.6	7.7	1.83	1670.3	14.3	7.2
Bianco Macromer	56.2	48.3	8.5	2.28	2374.0	28.4	8.5
Seedless Santa Margherita Belice	71.6	30.0	5.8	1.45	1240.7	42.9	7.0
Gymnocarpe	65.7	53.8	6.1	2.67	1833.3	21.6	5.7
Algerian	75.5	60.5	13.2	2.35	2282.6	10.6	8.3
Trunzara Red Bronte	67.1	60.9	6.6	1.95	1183.3	12.4	7.8
Yellow San Cono	38.6	28.8	5.2	0.87	958.9	3.8	5.0
Red Santa Margherita Belice	52.7	54.7	9.4	1.52	1269.9	7.7	6.5
Zastron	61.2	59.6	6.3	1.84	923.1	19.5	4.8
Yellow Roccapalumba	27.7	58.6	3.1	1.56	369.2	27.5	8.6
Morado	44.8	24.2	4.3	0.59	341.3	2.3	9.7
Red San Cono	60.4	48.4	5.1	1.16	641.9	5.5	7.6
Roly Poly	62.8	50.7	10.4	2.20	1544.6	23.2	7.1
Seedless Roccapalumba	66.3	53.4	6.7	1.72	1037.1	10.3	12.0
White Roccapalumba	39.0	39.9	4.3	0.86	530.3	0.9	5.7
Red Roccapalumba	64.6	68.4	5.2	1.62	969.6	7.8	8.3
Blue Motto	103.9	44.6	9.2	2.87	1182.8	9.7	6.2
White San Cono	69.7	48.4	9.3	2.27	1728.3	10.8	4.3
CAZRI Botanical garden	52.1	70.1	18.4	2.89	2835.7	17.1	9.0
CAZRI Kukma	70.5	60.5	18.3	3.15	2598.8	24.6	17.2
MS	732.6	354.0	34.8	1.1	1365783	235.2	33.2
F _{1,56}	15.9	9.9	7.8	7.1	3.2	130.1	2.5

The fresh and dry weight of *Opuntias* varied significantly among different accessions ($P < 0.001$; Table 1). The fresh weight of above ground biomass in different accessions ranged from 0.59 to 3.15 kg plant⁻¹. The highest biomass accumulation was recorded in CAZRI Kukma (3.15 kg plant⁻¹), followed by CAZRI Botanical Garden (2.89 kg plant⁻¹) and Blue Motto (2.87 kg plant⁻¹). The lowest biomass was recorded by Morado (0.59 kg plant⁻¹) followed by White Roccapalumba (0.86 kg plant⁻¹). By accommodating 2500 plants in one hectare at spacing of 2x2 m, it is possible to obtain 0.43 to 8.68 t ha⁻¹ in the first year itself. Guevara *et al.* (2001) obtained above ground biomass of 2.1 to 2.4 t ha⁻¹ in sandy soils in Argentina. Soni *et al.* (2015) obtained green fodder yield

of 1.3 kg plant⁻¹ for the accession CAZRI Botanical Garden after 270 days of growth. Under high density with good management, above ground biomass yields of 30-50 t ha⁻¹ could be realised (de Cortázar and Nobel, 1991; de Cortázar and Nobel, 1992). Compared to aboveground part, the root growth was low in all the accessions and the root volume varied from 0.7 to 44 cm³. Shallow root system is a distinct feature of cactus. The dry matter content among the 30 accessions ranged from 2.6 to 22.2%. The accessions with highest dry matter contents were ARL Spineless (17.7%), CAZRI Kukma (17.2%) and accession 1287 (14.5%). The lowest dry matter content was recorded in White San Cono (4.3%), Piantra-25 (4.4%) and Zastron (4.8%).

Table 2. Growth characteristics of cladodes of various accessions of *Opuntia ficus-indica*

Accession No/Name	Length (cm)	Breadth (cm)	Circumference (cm)	Thickness (cm)	Length (cm)	Breadth (cm)	Circumference (cm)	Thickness (cm)
1270	26.3	13.8	60.6	1.3	18.3	15.7	47.2	0.8
1271	27.7	9.9	54.2	2.0	31.8	11.7	68.7	0.9
1308	41.9	13.8	87.4	1.5	32.3	13.3	70.9	0.6
1287	34.2	11.3	80.3	1.0	23.7	11.2	54.2	1.0
Roso San Cono	18.7	7.8	39.5	2.5	32.9	10.8	68.5	1.0
Giall x Giall	30.0	12.6	67.7	3.0	27.5	14.9	60.0	1.0
Trunzara Red San Cono	38.4	11.2	77.6	2.0	26.1	12.2	59.6	0.5
Piantra – 25	31.8	10.5	65.1	0.9	24.9	12.1	53.1	0.7
ARL Spineless	33.7	12.7	84.0	3.0	30.3	15.4	68.8	0.8
Crystallina	31.5	12.9	29.9	1.1	0.0	0.0	0.0	0.0
Rosa Castle Sardo	27.4	10.7	62.3	2.2	27.4	14.8	62.3	0.9
Bianco Macromer	42.5	16.3	93.4	1.2	17.2	10.6	42.5	1.2
Seedless Santa Margherita Belice	22.8	10.5	50.3	2.7	34.8	13.2	74.6	1.9
Gymnocarpe	38.6	16.4	95.7	1.5	22.0	13.7	53.1	1.1
Algerian	23.4	11.7	50.6	3.0	21.2	12.3	50.5	1.7
Trunzara Red Bronte	23.7	11.0	46.4	2.0	25.2	10.7	50.9	2.0
Yellow San Cono	20.8	10.9	42.5	1.1	24.6	13.4	56.7	0.6
Red Santa Margherita Belice	26.5	11.4	56.9	1.9	12.1	9.9	30.8	0.5
Zastron	28.7	11.4	65.4	2.5	17.9	8.5	38.2	2.3
Yellow Roccapalumba	32.3	10.6	70.2	0.9	0.0	0.0	0.0	0.0
Morado	13.5	8.7	32.7	1.6	15.7	7.2	34.0	1.2
Red San Cono	20.8	9.52	40.0	2.0	21.4	8.9	46.7	1.2
Roly Poly	23.2	6.7	50.9	2.5	22.2	13.7	54.6	1.0
Seedless Roccapalumba	20.5	11.4	44.6	2.7	26.3	9.6	58.4	1.7
White Roccapalumba	18.9	7.8	44.3	1.6	22.1	11.4	50.3	0.7
Red Roccapalumba	22.7	12.9	52.1	2.6	22.9	12.3	53.2	1.0
Blue Motto	19.6	10.7	42.7	4.0	22.4	9.7	46.1	4.2
White San Cono	26.8	12.1	53.4	3.0	28.3	10.0	32.2	2.0
CAZRI Botanical garden	23.6	10.6	58.8	1.8	23.4	9.9	52.9	0.9
CAZRI Kukma	42.3	6.7	90.1	2.8	21.7	8.5	50.5	0.8
MS	156.3	15.8	891.0	1.6	172.9	36.2	821.5	1.7
F _{1,56}	4.3	1.6	8.0	19.3	14.1	6.9	10.5	70.1

The present study revealed the high potential for growing cactus as a fodder resource. The cactus accessions such as CAZRI Kukma, CAZRI Botanical garden and Blue Motto gave higher yields. The fresh biomass yield ranged from 0.59 to 3.15 kg plant⁻¹. The study indicated the potential for use of cactus as fodder resource in the arid region of India to tackle the problem of barren land and fodder deficiency.

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