

Prospects of Cactus Introduction for Improving Livelihood in Low Rainfall Regions of India

M.M. Roy, S. Kumar, P.R. Meghwal and A. Kumar
Central Arid Zone Research Institute
Jodhpur
India

Keywords: adaptability, coastal, fodder, fruit, *Opuntia ficus-indica*, rainfed

Abstract

Adoption and expansion of *Opuntia ficus-indica* in many countries due to its multiple uses as fruit, vegetable, fodder and medicinal compounds has prompted similar attempts in India, too. Since 1970 various research institutions in India have introduced it to study its adaptability, biomass and fruit yield with varying success. Though its potential was proven, its cultivation outside research farms has not picked up. In a renewed effort, its introduction and adaptability trials were initiated in the year 2010 with a larger number of cultivars from Italy and Tunisia through ICARDA. Results of these attempts in past three years as also those in the earlier years have been detailed in this paper. Introducing cactus pear in different bioclimates in India to see most suitable area and cultivar has revealed the coastal district of Bhuj in Gujarat state as the most appropriate for its growth, though results detailed in this paper show its encouraging growth in other parts of country, too. Preliminary utilisation studies of its cladodes as fodder for goat, sheep and cattle have given positive results while processing of its fruits yielded purple coloured squash. In view of its successful growth and utilisation potential, *O. ficus-indica* is emerging a future crop for rainfed regions of India.

INTRODUCTION

The Indian hot arid zone (31.7 m ha) experiences extremes of temperatures (50°C in summer to -4°C in winter), low and erratic rainfall (100-420 mm/year) with high coefficient of variation, high wind speed (30-40 km/h), high evapo-transpiration (1500-2000 mm/year), light textured soil having poor fertility and low water retention capacity and scarce water resources, brackish groundwater and declining water table.

Demographically, it is relatively thickly populated (108 people/km²) desert of the world. Human population has increased by 194% and livestock density by 72% in a span of about 50 years (1960-2010). Maximum land degradation in Rajasthan is in arid districts of Jaisalmer (2.77 m ha), followed by Bikaner (2.12 m ha), Barmer (1.92 m ha), Churu (1.38 m ha) and Jodhpur (1.24 m ha) (CAZRI, 2007). Wind erosion is a major contributor to land degradation (11.42 m ha) in Rajasthan. In view of above bioclimatic, anthropo-livestock and land deterioration scenario, *Opuntia ficus-indica* being such a useful plant in other low rainfall regions of the world is being prospected as a source to meet multiple requirements of food, fruit, forage and a host of other ecological benefits in Indian arid landscapes. Work on its various aspects in India is therefore, detailed here.

HISTORY OF CACTUS INTRODUCTION IN INDIA

Family *Cactaceae* is native to America. It has 122 genera and 1600 species and subfamily *Opuntioideae* has 250 species worldwide. *Opuntia elatior*, *O. monocantha* and *O. dillenii* are naturalised in arid and semiarid India. In 1987, 33 *Opuntia* clones were introduced at the Nimbaker Agricultural Research Institute at Phalton, Maharashtra state of India. In 1991, five accessions were introduced in CSSRI, Karnal (Singh, 2003). Some 51 accessions were brought from Texas, USA to Central Institute of Arid Horticulture, Bikaner in 1997. These included *Opuntia ficus-indica*, *O. amyclaea*, *O. megacantha*, *O. inermis*, *O. robusta*, *O. streptacantha* and *Nopelia cochenillifera* for use as fruits, vegetable and fodder. Its cultivation technique was standardized at CAZRI. Planted at

3 × 2 m, the three year old plantation produced 30 t/ha fresh weight computed on single plant basis (Shankar and Saxena, 1976). Another plantation (2 × 2 m) after sustaining four years of drought produced 28.5 t/ha fresh biomass in the year 1982.

PERFORMANCE OF RECENT ACCESSIONS

A total of 43 accessions were introduced in CAZRI, Jodhpur of which 21 were from Tunisia and 22 from Italy in January-February, 2010 (Table 1). Of these, 19 accessions survived. These were rescued from field and raised in the pots. Pot rooted plants of 19 accessions of cactus pear were transplanted in the field on 14th October, 2011 in Randomized Block Design with three replications and three plants per replication. Survival varied due to rotting (Table 1). The cultivar Rossa × Rossa-4 Pianta-25 had maximum survival (50%). In a large scale plantation trial the survival of accessions after one year is given in table1. The causal organism of rotting has been identified as *Enterobacter cloacae*. Treatment of cladode with fixed copper formulation/streptomycin before planting was advised though with limited success.

Effect of Cladode Age, Cultivar, Wax Treatment and Planting Media on Propagation

Interaction of different aged cladodes, planting media, the role of sealing the cut ends of cladode with molten wax was studied in twelve treatments (Table 2) both, in pots and beds. Soil and compost manure (7:1) was saturated with water and left for 48 h after which the entire mixture was pulverized with spade and left for another 24 h.

Thereafter, this mixture was filled in pots as well as in the beds. The moisture content of this mixture ranged from 7.77 to 8.77% as against 16.95 % in freshly irrigated soil of the same medium. The cladodes were planted on 26.2. 2012 in these media by keeping 1/3rd portion under the soil. No irrigation was given till 15 days after planting. Thereafter, a litre of water per pot was applied weekly while nursery beds were watered with the help of sprinkler at weekly intervals.

The bud sprouting began after 15 days of planting in nursery beds and 25 days after planting in case of pots. After four months of planting, more than 80% plants were rot free with maximum 100% rot free plants in six-month-old cladodes of accession no.1270 and 1308 (Table 3). No significant differences were observed between wax and non wax treated cladodes. The planting in pot was significantly better than bed in respect of getting rot free survival. Number of new leaves varied significantly (1-4.23) in different treatments. The rot free survival was comparatively more in six month old cladodes irrespective of media, cultivar and wax treatment; however, the differences were non-significant. No significant differences were also recorded between wax treated and untreated cladodes with respect to rot free survival, number of new leaves formed, root length and number of roots. The highest number of roots (30.33) was recorded in one year old accession no.1270 planted in pots without wax treatments while longest root length (13.53 cm) was recorded in one year old clone of the same cultivar in pot planted with wax treatment. The fresh weight of the plant along with leaves and roots after four months of planting declined from that at the time of planting. Inglese (2010) also concluded that 1-2 years cladodes seasoned for 10-12 days at 20-25°C lose 20% their fresh weights.

Products from Cactus Pear Fruits/Cladodes

Fruits of cactus pear in CAZRI/SK/BG cultivar (Fig. 1) having 42% juice (acidity 0.24%, TSS 8.2°Brix), were processed into a squash of purple colour, excellent aroma and sweet taste. The young immature, raw cladodes were also pickled. Contrary to the reports of presence of pulp in most of the cactus pear fruit, these fruits have more juice than pulp (Table 4). These values are much less compared to other accessions reported from Ethiopia (Gebresillassie et al., 2010).

Feeding Trials of *Opuntia ficus-indica*

Goat fed on *Opuntia ficus-indica* accession -1308 chopped and mixed in 50:50 ration and masoor ration (*Lens escularis*) revealed that kids lost the body weight of 1 kg during experimental period while lambs maintained their body weights (Patil et al., 2009). Tharparkar bull calves were fed *Opuntia ficus-indica* cladodes accession 1308 (Mathur et al., 2009) with pearl millet (*Pennisitum typhoides*) chaffed straw ad libidum. One group of four animals was offered 4 kg pelleted balanced cattle feed (manufactured by Rajasthan Co-operative Dairy Federation) daily having 22% CP and 70% TDN. The other group of four animals was additionally given chopped thorn less cactus (*Opuntia ficus-indica*) cladodes. The intake of cactus per animal in the first week was 3.07 ± 0.14 kg but increased to 13.8 ± 0.54 kg finally. Cactus fed group showed significantly higher live weight gain than control group. In another experiment, ten months old goat, four in each group, were fed 33% (Group-1) and 50% (Group-2) chopped *Opuntia ficus-indica* cladodes accession 1308, mixed with dry masoor straw for a period of 40 days (Patil et al., 2009). The Group-1 kids showed $66.75 \text{ g h}^{-1} \text{ day}^{-1}$ average daily gain (ADG) whereas in Group-2 kids body weight marginally declined. It emerged that 33% of feed as *Opuntia* with masoor straw favoured the growth rate of goats in arid region. Although cladode intake by goat kids, sheep and cattle in Indian condition is lower than that in Africa (5 kg by sheep, goat; 50 kg by cattle) (Nefzaoui, 2010), the need for feed supplementation and weight gain patterns are similar in both the situations. Similar findings were also reported by Mishra et al. (2006).

Adaptability and Performance of Cactus Pear in Bhuj, Gujarat

In the month of July 2012, 17 accessions received from CAZRI, Jodhpur, (Table 5) and three local germplasm collected from Kachchh region were planted in pots under net house conditions while five selected accessions were planted in field. Over 95% of accessions survived in pots in net house condition at Bhuj. Maximum fresh biomass was in CAZRI, Kukma 1 (7.74 kg/plant) followed by clone no. 1308 (5.36 kg/plant) and minimum in clone no. 1270 (2.84 kg/plant).

Performance of Cactus Pear at Punjab Agricultural University, Punjab

Opuntia ficus-indica, cultivar CAZRI/SK/BG was planted at 2×2 m spacing at Regional Research Station of PAU at Ballowal Saunkhri on 11/05/2013. After five months of plantation, 80% cladodes survived and gained an average height of 40 cm and produced two new cladodes on each planted cladode.

Performance of Different Accessions at Bikaner, Rajasthan

Cladodes of seven accessions of *O. ficus-indica* were planted in pots on 7th June 2013 at Bikaner. Maximum height growth in three months was observed in accession Texas 1308 (67 cm), followed by 1271 (65 cm), CAZRI/SK/BG (62 cm) and 1270 (53 cm). Remaining accessions had marginal height of 25-35 cm. The number of cladodes produced were maximum in CAZRI/SK/BG (12), followed by Texas 1308 (6), 1270 (5) and 1271 (4.5). Remaining accessions produced 1-2 cladodes (Table 6).

Performance of Cactus Pear at NRCC, Bikaner

Clone 1271 of *Opuntia ficus-indica* after two months of plantation had a survival of 89-93% in field and 100% in nursery (Table 7). The two fields had trees of *Tecomella undulata* and *Prosopis cineraria* planted at 5×5 m below which these fronds were planted. Average height growth was up to 20 cm in field and 58 cm in nursery. These produced 1-2 cladodes.

RESULTS AND DISCUSSION

Cactus pear introduced in India in past have been studied for their adaptability and survival, sporadically and in narrow climatic zone. Present study therefore is an attempt in larger prospective. Of the 43 accessions of cactus pear introduced in 2010, now 19 are

surviving. Mortality is due to bacterial rot. Control measures are being devised. In pots, survival of cladodes is excellent but in field, it is only 30%. Nursery experiments revealed that cladode age, cultivar and period of suberization affect survival. However intensive experiments on these aspects need to be carried out. Cactus pear fruit squash and cladode pickle have been successfully prepared. Feeding trials of cladodes gave encouraging results. Up to one third ration as cladode is acceptable to sheep, goat and cattles, though consumption is much less than by same animals in Africa. Adaptability and survival in Bhuj, Gujarat, SBS Nagar, Punjab and Bikaner, Rajasthan under shade condition have been satisfactory, though large scale planting is needed to confirm its potential. Scope of introduction of accessions from Italy or elsewhere need to be explored keeping in view the similarity in environmental conditions.

ACKNOWLEDGEMENTS

We thank Indian Council of Agricultural Research, New Delhi for providing facilities and support to carry out above work. Financial assistance from ICARDA and FAO-CACTUSNET for arranging transfer of cactus cultivars to India and subsequent guidance in growing cactus is gratefully acknowledged. Data reported in this paper has been very kindly shared with us by many colleagues in India for which we are grateful to them.

Literature Cited

- CAZRI, 2007. CAZRI Perspective Plan: Vision-2025. Central Arid Zone Research Institute, Jodhpur, 94p.
- Gebresillassie, M., Weldetsadik, K. and Belay, T. 2010. Diversity of cactus pear *Opuntia ficus-indica* L. (Mill.) in Tigray, Ethiopia, the case of Erobe in Improved utilisation of cactus pear food, feed, soil and water conservation and other products in Africa. Proceedings of International Workshop, Mekelle, Ethiopia, 19-21 Oct. 2009. p.59-77.
- Mathur, B.K., Patil, N.V., Mathur, A.C., Meghwal, P.R. and Bohra, R.C. 2009. Effect of feeding rich resource- thornless cactus (*Opuntia ficus-indica*) to Tharparkar cattle in arid region. Abstracts of International Conference on “Nurturing Arid Zones for people and the Environment: Issue and Agenda for the 21st Century” organized by Central Arid Zone Research Institute (CAZRI), Jodhpur, 24-28 November 2009. 271p.
- Mishra, A.K., Mishra, A.S., Tripathi, M.K., Chaturvedi, O.H., Vaithiyanathan, S., Prasad R. and Jakhmola, R.C. 2006. Intake, digestion and microbial protein synthesis in sheep on hay supplemented with prickly pear cactus [*Opuntia ficus-indica* (L.) Mill.] with or without groundnut meal. Small Ruminant Research 63:125-134.
- Nefzaoui, A., Inglese, P. and Belay, T. (eds.), 2010. Improved utilisation of cactus pear food, feed, soil and water conservation and other products in Africa. Proceedings of International Workshop, Mekelle, Ethiopia, 19-21 Oct. 2009. 224p.
- Patil, N.V., Patel, A.K., Bohra, R.C. and Meghwal, P.R. 2009. Comparative dry matter and water intakes in goats and sheep fed on mixed diets of *Opuntia ficus-indica* having thick fronds and masoor straw. Abstracts of International Conference on “Nurturing Arid Zones for people and the Environment: Issue and Agenda for the 21st Century” organized by Central Arid Zone Research Institute (CAZRI), Jodhpur, 24-28 November 2009. 268p.
- Patil, N.V., Patel, A.K., Khan, M.S., Kumar, S. and Bohra, R.C. Studies on dry matter and water intake in goats fed on mixed rations containing *Opuntia ficus-indica* having thin fronds. Ibid, 280p.
- Shankar, V. and Saxena, S.K. 1976. Spineless cactus as fodder reserve. Indian Farming, April 1976 issue.
- Singh, G. 2003. General review of *Opuntias* in India. J.PACD 5:30-39.

Tables

Table 1. Exotic cactus pear from Tunisia and Italy and other places at CAZRI, Jodhpur and their percent survival in April, 2013.

Sr. no.	Number	<i>O. ficus-indica</i> (source - Tunisia, received - January, 2010)	Survival (%)	Sr. No.	<i>O. ficus-indica</i> (source - Italy, received - February, 2010)	Survival (%)
1	EC 668321	Nudosa	0	1	IQ-27/10 white sencono	0
2	EC 668322	Rosa San Cono	0	2	IQ-26/10 white Roccapalumba	0
3	EC 668323	Giall × Giall	0	3	Rosalisa	0
4	EC 668324	Rossa San Sperate	0	4	IQ-26/21 Trunzara Red San Cono	0
5	EC 668325	Rossa × Rossa4 Pianta-31	0	5	Lyria(thorny)	0
6	EC 668326	Rossa × Rossa4 Pianta-17	0	6	IQ- 26/Seedless Roccapalumba	0
7	EC 668327	Rossa × Rossa4 Pianta-25	50	7	IQ-26/10 Horaddo	0
8	EC 668328	RossaValledoria	0	8	IQ-26/10ARL Spineless	50
9	EC 668329	GiallaMacomer	0	9	IQ-26/10 Red san cono	22.2
10	EC 668330	Gialla San Cona	0	10	Hillitello White	0
11	EC 668331	Bianca san sperate	0	11	IQ-27/10Fafyco	0
12	EC 668332	Rossamacomer (M2)	0	12	IQ-27/10Yellow	0
13	EC 668333	Bianca bonarcado	0	13	Reyna(thorny)	0
14	EC 668334	Morado	0	14	Cristallina(thorny)	11.1
15	EC 668335	Bianca san cono	0	15	IQ-27/10 Red Roseapolyma	0
16	EC 668336	Rossa castelsardo	22.2	16	IQ-26/10 Yellow Roccapalumba	0
17	EC 668337	Bianco macomer	22.2	17	Seedless Santamargretabalice	22.2
18	EC 668338	Giallasarroch	0	18	Israelihonstra	0
19	EC 668339	A. giant	11.1	19	IQ-26/10Blue Moto	0
20	EC 668340	Gymnocarpe	22.2	20	IQ-27/10 Zastrony	0
21	EC 668341	Rossa × bianco	0	21	IQ-26/10 AllerianA	0
				22	IQ-26/10 Plypoly	
Cultivars brought from other places before 2010						
	1270	Palma Redonada from Petrolina, Brazil	22.2		1287- Aqua Prieta from Mexquite, San Luis Potosi, Mexico	11.1
	1271	Palma Giganta from Petrolina, Brazil	22.2		1308- <i>O. cochnellifera</i> from Tamazunchale, San Luis Potosi, Mexico	11.1

Table 2. Effect of cultivar (C), cladode age (Y), and wax treatment (W) on % survival of cactus pear after four months of planting in nursery beds.

Treatments	Rot free survival (%)	No. of new leaves formed	No. of roots	Root length (cm)	Loss/gain in fresh weight after 4 months (%)
Y ₁ C ₁ W ₀	73.33	2.53	21.40	8.83	-1.78
Y ₁ C ₁ W ₁	80.00	2.83	23.67	7.10	-2.67
Y ₁ C ₂ W ₀	73.33	3.17	24.00	8.10	-9.53
Y ₁ C ₂ W ₁	93.33	1.67	14.00	10.20	-2.43
Y ₁ C ₃ W ₀	80.00	2.33	16.00	7.37	-2.50
Y ₁ C ₃ W ₁	93.33	2.77	13.67	9.90	-2.46
Y ₂ C ₁ W ₀	46.66	3.00	30.33	10.83	-4.35
Y ₂ C ₁ W ₁	93.33	1.87	24.00	13.53	+3.09
Y ₂ C ₂ W ₀	80.00	3.47	29.67	11.43	-1.69
Y ₂ C ₂ W ₁	73.33	3.07	15.33	12.83	-10.72
Y ₂ C ₃ W ₀	60.00	3.33	26.00	10.07	-3.27
Y ₂ C ₃ W ₁	53.33	4.23	27.33	11.87	-3.20
CD(P=0.05)	17.33	0.78	5.18	3.75	

C₁=CloneNo.1270, C₂=CloneNo.1308, C₃=CloneNo.1271, Y₁=6 months (<600 g), Y₂=1 year (>600 g), W₀=No wax treatment, W₁=Wax treatment.

Table 3. Effect of cultivar (V), cladode age (Y), and wax treatment (W) on % survival of cactus pear after four months of planting in pots.

Treatments	Rot free survival (%)	No. of new leaves formed	No. of roots	Root length (cm)	Loss/gain in fresh weight after 4 months (%)
Y ₁ C ₁ W ₀	100.00	2.67	32.33	8.17	+10.22
Y ₁ C ₁ W ₁	86.66	2.90	32.67	9.60	+4.5
Y ₁ C ₂ W ₀	100.00	2.73	32.33	9.07	-2.30
Y ₁ C ₂ W ₁	100.00	2.37	23.67	10.23	+18.75
Y ₁ C ₃ W ₀	100.00	3.07	22.67	10.50	-0.80
Y ₁ C ₃ W ₁	93.33	2.67	23.33	7.50	-2.49
Y ₂ C ₁ W ₀	86.66	2.03	21.33	8.43	-2.70
Y ₂ C ₁ W ₁	73.33	1.07	22.33	8.20	-2.65
Y ₂ C ₂ W ₀	86.66	1.00	21.00	7.17	-3.46
Y ₂ C ₂ W ₁	80.00	1.67	30.00	8.57	+6.18
Y ₂ C ₃ W ₀	86.66	1.83	29.00	8.33	+4.61
Y ₂ C ₃ W ₁	53.33	4.23	27.33	11.87	-3.20
CD(P=0.05)	17.33	0.78	5.18	3.75	-

C₁=CloneNo.1270, C₂=CloneNo.1308, C₃=CloneNo.1271, Y₁=6 months (<600 g), Y₂=1 year (>600 g), W₀=No wax treatment, W₁=Wax treatment.

Table 4. Physico-chemical parameters of fruit of cultivar CAZRI/SK/BG at Jodhpur.

Attributes of fruit (Avg. of 10 fruits)	Values
Weight	21.5 g
Length	5.16 cm
Diameter	2.94 cm
Volume	20.8 cc
Peel thickness	4.2 mm
Juice	42%
Specific gravity	1.03

Table 5. Survival under pots in net house and field condition in Bhuj.

Sr. no.	Identity	Survival after 180 days	
		In pots	In field
1	Clone no. 1270	45.5 (10)	5
2	Clone no. 1271	66.7 (18)	20
3	Clone no. 1308	36.0 (9)	60
4	CAZRI, Kukma 1 (Local from Bhuj, RRS)	95 (19)	90
5	CAZRI, Botanical Garden (Local)	95 (19)	75
6	Clone No.1287	100 (6)	
7	Roso San Cono	100 (1)	
8	Giall × Giall	100 (1)	
9	Trunzara Red San Cono	100 (1)	
10	Piantra-25	100 (2)	
11	ARL Spinless	100 (1)	
12	Red San Cono	100 (2)	
13	Militelo White	0.0 (0)	Not planted in field
14	Cristallina	100 (1)	
15	Rosa Castle Sardo	100 (1)	
16	BiancoMacomer	100 (6)	
17	Seedless Santa Margherita	100 (1)	
18	Gymnocarpe	100 (2)	
19	CAZRI, Kukma 2	100 (1)	
20	CAZRI, Kukma 3	100 (4)	

Table 6. Height and number of cladodes in different accessions at CAZRI, Regional Research Station, Bikaner, Rajasthan, India.

Sr. no.	Accession no, name	Plant height mean/range (cm)	No of cladodes mean/range
1	No-1270	53/39-61	5/4-6
2	No-1271	65/58-76	4.5/4-5
3	Texas 1308	67/62-73	6/4-8
4	Bot. Garden Jodhpur	62/58-68	12/11-14
5	Jodhpur Balesar	31/25-41	1.6/1-2
6	Mexico	35/24-42	2/2
7	Argentina	25/22-28	1.5/1-2

Table 7. Performance of *Opuntia ficus-indica* at National Research Centre on Camel, Bikaner, Rajasthan, India.

Cactus clone	DOP	Plantation site	Survival (%)	Height (cm)	Canopy (cm ²)	Cladodes number
1271	29.8.13	Rohira 5 × 5m	93.75	18.94±0.39	21.17±0.31	1.75±0.15
1271	28.8.13	Khejari 5 × 5m	89	17.38±1.11	12.2±1.21	0.75±0.08
1270	20.12.13	Nursery A	100	58.70± 5.07	42.10± 10.70	7.84±1.52
1270	20.12.13	Nursery B	100	4.48±2.47	15.73±4.17	10.42±5.86

Figures



Mature fruits of cactus pear



Juice of cactus pear



Pickle of cactus pear

Fig. 1. Products from cactus pear cultivar CAZRI/SK/BG at Jodhpur, Rajasthan, India.