



Agro-morphological Characterization of Cactus Pear Accessions for Fodder Purposes in Arid Gujarat

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Abstract: Belonging to the cactaceae family, *Opuntia ficus-indica*, popularly known as prickly pear or cactus pear has been recommended as a drought-resilient arid crop. In Kachchh, an arid zone in the western part of India, *Opuntia ficus-indica* has been increasing cultivated as a fodder resource, mainly for its water-rich cladodes. In this regard, sixty-two accessions of cactus pear were collected from ICAR-CAZRI, Kukma and ICARDA and were maintained in ICAR-CAZRI, RRS-Bhuj. To conduct an agro-morphological study aiming to understand the growth behaviour of these cactus accessions under arid soils and the climate of Kachchh, nine phenotypic characteristics were recorded. Based on the quantitative traits, the results of PCA showed three groups of cactus accessions based on their growth performance. The best five accessions selected for promotion in the Kachchh region were CAZRI Botanical Garden (CBG), No. 1270, No. 1271, No. 1308 and Bianca Macomer. Although CBG performs the best out of all these accessions, proper care must be taken to avoid waterlogging in and around the root zones of CBG. Therefore, cactus pear can be successfully cultivated as a fodder crop in arid Kachchh and can address the unavailability of green fodder in dry seasons and poor soils of Kachchh.

Keywords: Bianca Macomer, CAZRI botanical garden, *Opuntia ficus-indica*, prickly pear.

One of the main challenges in arid lands is the limited water availability that further prevents the growth of high-quality fodder resources (Bailey and Brown, 2011). Under the climate-changing scenario, higher frequency and intensity of drought in arid zones are expected (Cook *et al.*, 2015). Since the vegetation cover in arid soils is relatively lesser than in humid zones, it is important to introduce fodder crops with high water use efficiency and can tolerate the extreme abiotic stress prevailing in arid soils. Prickly pear cactus (*Opuntia ficus-indica*) is a desert plant native to the Americas and is been promoted as a drought-resilient fodder resource in several parts of the world (Nobel *et al.*, 1992). The specialized photosynthetic mechanism, known as Crassulacean Acid Metabolism (CAM), helps in increasing the dry matter under water-limiting conditions and therefore it can be considered a future forage crop in the dry arid soils. *Opuntia ficus-indica* has multiple uses in agriculture, cosmetic industries, dye industries, medicines etc. It has been grown not only for livestock consumption but also for human consumption in the form of

pickles, salads, vegetables, jams etc. (Shetty *et al.*, 2012). In arid regions with less rainfall and low-quality water, where irrigation is hardly possible, cactus pear can be an excellent fodder crop since it is easy to cultivate and propagate. Supplementation of livestock feed with chopped cactus cladodes will not only improve the health of the animals but also reduce the cost of production. However, it must not be fed as a sole feed since it has high water content (McMillan *et al.*, 2002). Kachchh, located in the state of Gujarat, is one of the largest districts in India. It is characterized by an arid climate with several issues such as frequent droughts, high temperature, saline soils, poor quality of irrigation water, less vegetation cover, poor soil nutrient status etc. In this regard, 62 accessions of spineless cactus (*Opuntia ficus-indica*) have been introduced in Kachchh through ICAR-Central Arid Zone Research Institute, RRS-Bhuj and The International Center for Agricultural Research in the Dry Areas (ICARDA). The experiment aims to characterize and evaluate these 62 accessions based on the morphological parameters and select the best five accessions that are suitable to grow as a fodder crop in arid soils of western India.

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Materials and Methods

The field experiment was conducted at ICAR-Central Arid Zone Research Institute, RRS-Bhuj (23°12' 47.0" N latitude and 69°47'31.2" E longitude). The soil was characterized as sandy loam with the surface soil (0-30 cm) showing a soil pH of 8.45, the electrical conductivity of 0.53 d Sm⁻¹, exchangeable calcium content of 305±12.44 me/L, sodium content of 55 ppm and soil organic carbon of 0.19%. The studies were conducted from a time period of three years (2019 to 2022). 62 accessions of cactus pear were laid out in randomized block design (RBD) in the field having five replications of each accessions.

One-year disease free good quality cladodes were harvested and collected from germplasm block of ICAR-CAZRI. The planting materials were robust and healthy medium size cladodes. After the harvest, cladodes were kept under shade for one week till the cut portion is completely healed and no leakage was observed. The experimental plot was selected owing to its well-drained sandy loam soil receiving ample amount of sunlight during daytime. The cladodes were planted diagonally as a sole crop in pits at a spacing of 1m (within the rows) X 2 m (between the rows). A wide spacing of the plants was maintained to avoid the competition of cactus plants for soil moisture since Kutch is a dry and arid region with low precipitation.

The depth of each pit was 30 cm. No herbicide was applied during the experiment. Only hand weeding was followed throughout the experiment. Supplementation irrigation were given once in one week through drip irrigation. Farmyard manure was applied during planting at the rate of 2.5 t ha⁻¹.

The morphological parameters such as plant height (cm), number of cladodes, cladode length (cm), cladode width (cm), cladode thickness (mm), survival rate (%) and fresh weight (kg). The morphological observations were taken after three years of planting. The statistical analysis and visualizations were carried out through R software (R Core Team, 2020).

Results and Discussion

The high survival rates (>80%) of all the 62 accessions indicate the good performance of cactus pear in arid soils of Kachchh region. Cactus pear prefers coarse-textured soils, with no problems of waterlogging and normal to low saline soils. This might be the probable reason for the high survival rate of the cactus pear accessions. In terms of plant height, CAZRI Botanical Garden (CBG) showed the highest average value of 112.23 cm while the lowest was found in IPA-90-115 (Table 1). The plant height of CBG was significantly higher than No. 1271, No. 1270 and No. 1308 (P<0.05) (Table 1). Farmers prefer crops with vertical spread to

Table 1. Average values of plant growth parameters of the 62 accessions grown in arid soils of Kachchh

Accessions	Plant height (cm)	Cladode number	Cladode length (cm)	Cladode width (cm)	Cladode thickness (mm)
Cristallina	74.52 _{defg}	40 _{defghi}	19.86 _d	8.64 _b	16.29 _b
Trunzara Gialla Bronte	73.81 _{efg}	38 _{efghi}	19.08 _d	8.04 _b	15.8 _b
Yellow Roccapalumba	75.68 _{defg}	42 _{cdefghi}	21.23 _{abcd}	7.98 _c	15.08 _b
No. 1287	92.93 _{bc}	48 _{bcd}	29.93 _a	8.08 _c	19.03 _a
Piantra 25	77.70 _{defg}	40 _{defghi}	22.66 _{abcd}	8.27 _b	16.19 _b
Bianca Macomer	78.19 _{defg}	36 _{fghi}	22.13 _{abcd}	8.19 _b	14.47 _b
Red San Cono	80.22 _{defg}	37 _{fghi}	18.96 _d	8.09 _c	15.31 _b
Rosa San Cono	72.95 _{fg}	38 _{defghi}	20.91 _{abcd}	8.16 _b	15.23 _b
Orelha de onca	83.59 _{cd}	40 _{defghi}	19.88 _d	8.05 _c	15.46 _b
ARL Spineless	79.06 _{defg}	40 _{cdefghi}	19.69 _d	8.07 _c	15.01 _b
White Roccapalumba	79.83 _{defg}	40 _{defghi}	21.76 _{abcd}	8.01 _c	16.08 _b
Gymnocarpe	76.09 _{defg}	37 _{efghi}	19.31 _d	8.47 _b	15.48 _b
Zastron	77.16 _{defg}	37 _{efghi}	19.22 _d	8.36 _b	15.99 _b
White San Cono	73.33 _{efg}	35 _{ghi}	19.49 _d	7.99 _b	15.52 _b
No. 1270	95.74 _b	50 _{bc}	29.60 _{ab}	8.28 _b	18.80 _b
Yellow San Cono	82.30 _{def}	43 _{bcddefghi}	22.51 _{abcd}	8.06 _c	15.33 _b
Trunzara Red Bronte	81.20 _{defg}	39 _{defghi}	20.85 _{abcd}	8.29 _b	15.34 _b
Giall x Giall	80.55 _{defg}	34 _i	21.56 _{abcd}	8.20 _b	15.48 _b

Table 1. Cont...

Accessions	Plant height (cm)	Cladode number	Cladode length (cm)	Cladode width (cm)	Cladode thickness (mm)
Seedless Santa Margherita Belice	82.16 _{def}	45 _{bcd}	20.60 _{abcd}	7.93 _c	15.38 _b
Red Santa Margherita Belice	78.83 _{defg}	41 _{cdefghi}	19.61 _d	8.49 _b	15.95 _b
Blue Motto	73.73 _{efg}	42 _{cdefghi}	19.39 _d	8.28 _b	15.46 _b
Red Roccapalumba	80.34 _{defg}	34 _i	19.50 _d	8.02 _c	15.64 _b
Roly Poly	80.25 _{defg}	39 _{defghi}	20.15 _{abcd}	8.54 _b	16.05 _b
Algerian	76.21 _{defg}	41 _{cdefghi}	18.35 _d	7.99 _c	15.86 _b
CAZRI Kukma	76.56 _{defg}	39 _{defghi}	19.84 _d	8.10 _b	15.32 _b
Trunzara Red San Cono	82.59 _{de}	44 _{bcd}	22.50 _{abcd}	8.82 _b	15.41 _b
Seedless Roccapalumba	80.06 _{defg}	42 _{cdefghi}	19.10 _d	8.12 _b	15.14 _b
No. 1308	93.67 _b	50 _{bc}	29.52 _{ab}	8.13 _b	19.04 _a
Morado	73.59 _{efg}	37 _{efghi}	18.71 _d	7.95 _c	15.29 _b
Rosa Castle Sardo	75.38 _{defg}	39 _{defghi}	20.55 _{abcd}	8.21 _b	15.94 _b
Gialla Roccapalumba	81.29 _{defg}	40 _{cdefghi}	19.07 _d	8.30 _b	15.22 _b
Trunzara Bianca San Cono	73.62 _{efg}	41 _{cdefghi}	19.46 _d	8.06 _c	15.88 _b
Rosa Roccapalumba	81.75 _{defg}	36 _{fghi}	19.62 _d	8.16 _b	15.66 _b
Bianca Roccapalumba	76.98 _{defg}	39 _{defghi}	19.88 _{cd}	7.83 _c	15.04 _b
Mexico fodder	77.67 _{defg}	37 _{efghi}	20.78 _{abcd}	8.60 _b	15.05 _b
IPA-90-115	72.18 _g	37 _{efghi}	20.73 _{abcd}	8.33 _b	15.63 _b
Macmillion fodder	75.32 _{defg}	38 _{efghi}	21.33 _{abcd}	8.10 _b	15.68 _b
Trunzara Rossa Bronte	75.02 _{defg}	37 _{efghi}	19.33 _d	7.86 _c	15.61 _b
No. 1271	97.73 _b	52 _b	29.97 _a	8.42 _b	19.27 _a
Trunzara Bianca Bronte	77.87 _{defg}	40 _{cdefghi}	18.17 _d	8.19 _b	16.02 _b
Trunzara Gialla San Cono	74.39 _{defg}	40 _{cdefghi}	21.74 _{abcd}	8.36 _b	15.57 _b
Mexico unknown	75.10 _{defg}	37 _{efghi}	19.78 _d	8.09 _c	15.48 _b
Jalpa	83.63 _{cd}	39 _{defghi}	20.21 _{abcd}	8.14 _b	14.78 _b
Gialla San Cono	76.30 _{defg}	38 _{efghi}	21.70 _{abcd}	8.42 _b	15.08 _b
Bianca San Cono	76.08 _{defg}	38 _{efghi}	22.67 _{abcd}	8.60 _b	15.10 _b
Palma Grande	79.68 _{defg}	36 _{fghi}	19.70 _d	8.31 _b	15.31 _b
Palma Redonda	75.50 _{defg}	39 _{defghi}	18.29 _d	8.41 _b	16.36 _b
Palma miuda ou doce	72.46 _g	35 _{hi}	20.85 _{abcd}	7.66 _c	15.12 _b
IPA 20 ou clone 20	76.18 _{defg}	41 _{cdefghi}	18.97 _d	8.25 _b	15.17 _b
IPA Sertania ou baiana	75.28 _{defg}	39 _{defghi}	21.26 _{abcd}	8.27 _b	14.93 _b
CAZRI Botanical Garden	112.23 _a	67 _a	29.50 _{abc}	10.06 _a	19.05 _a
Orelha de elefante Mexicana	77.17 _{defg}	39 _{defghi}	18.42 _d	8.15 _b	15.40 _b
Orelha de elefante Africana	77.95 _{defg}	44 _{bcd}	22.26 _{abcd}	8.42 _b	15.26 _b
F8- Forrageira	80.50 _{defg}	45 _{bcd}	20.51 _{abcd}	8.21 _b	15.76 _b
Copena F1	77.00 _{defg}	35 _{ghi}	18.62 _d	8.44 _b	16.33 _b
Copena VI	74.68 _{defg}	42 _{cdefghi}	23.59 _{abcd}	8.27 _b	14.92 _b
IPA-90-18	79.55 _{defg}	37 _{efghi}	18.47 _d	7.79 _c	15.71 _b
IPA-90-73	80.96 _{defg}	35 _{ghi}	18.53 _d	8.16 _c	15.23 _b
IPA-90-92	77.77 _{defg}	35 _{ghi}	21.03 _{abcd}	8.32 _b	16.61 _b
IPA-90-111	73.05 _{efg}	37 _{efghi}	22.36 _{abcd}	8.40 _b	15.51 _b
IPA-90-156	77.41 _{defg}	41 _{cdefghi}	20.61 _{abcd}	7.76 _c	16.50 _b
Palma Azul	76.69 _{defg}	41 _{cdefghi}	18.93 _d	8.16 _c	15.46 _b

The values are the average of five replicates in each accessions. The subscripts (a,b,c,....) indicate significant differences. For a particular variable, means with different subscripts are significantly ($P<0.05$) different. Means with same subscripts are not significantly ($P<0.05$) different.

horizontal spread since it allows them to use the inter-row spaces for other crops. The number of cladodes per plant was significantly highest

in CBG (mean= 67.33) and lowest in Giall x Giall (mean=34.33) and Red Roccapalumba (mean=34.33) ($P<0.05$) (Table 1). It is important

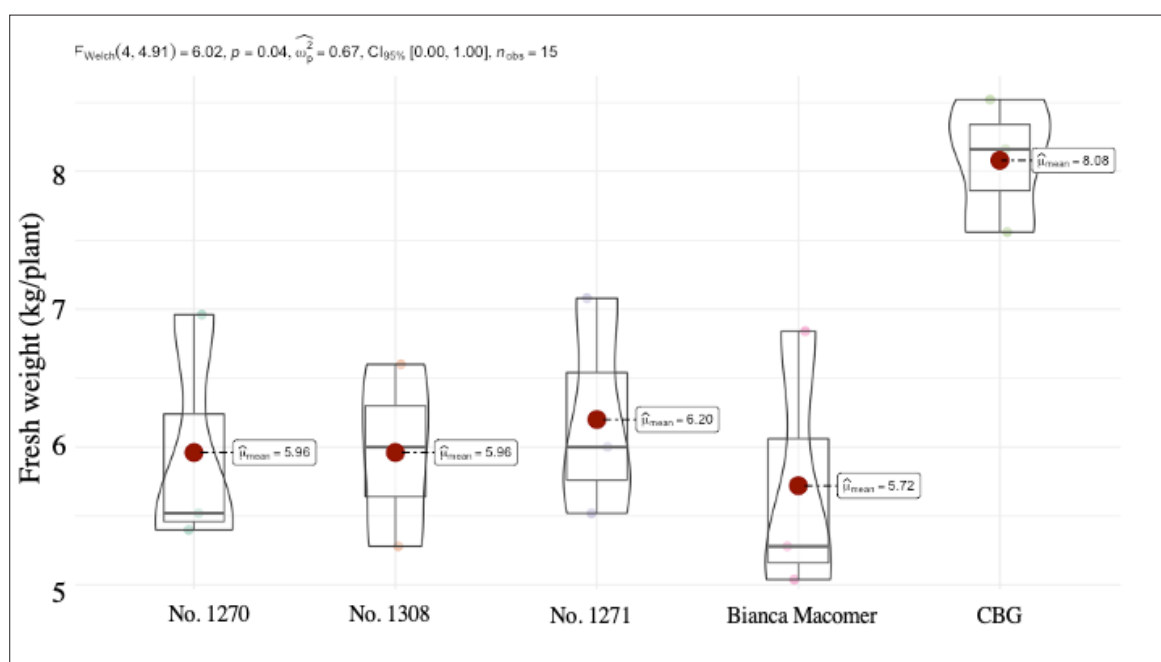


Fig. 1. Fresh weight (kg plant^{-1}) of the five best performing cactus pear accession.

to select the accession with a greater number of cladodes per plant since there must be enough cladodes to harvest for feeding the livestock. The maximum value of cladode length was found in No. 1271 (mean=29.97 cm), and No. 1287 (mean=29.93 cm) followed by No. 1270 (mean=29.60 cm) (Table 1). Longer cladodes can be cut into sections and each section can be used for propagation or as planting materials. The

cladode thickness (mm) was highest in No. 1271 (mean=19.26) and CBG (mean=19.05) (Table 1). The thickness of the cladode indirectly depicts the water content, which is one of the important factors in determining high-quality fodder resources in arid regions. The fresh weight of the cladodes (kg plant^{-1}) was significantly highest in CBG (mean value of 8.08 kg plant^{-1}) ($P < 0.05$) (Fig. 1). The morphological parameters

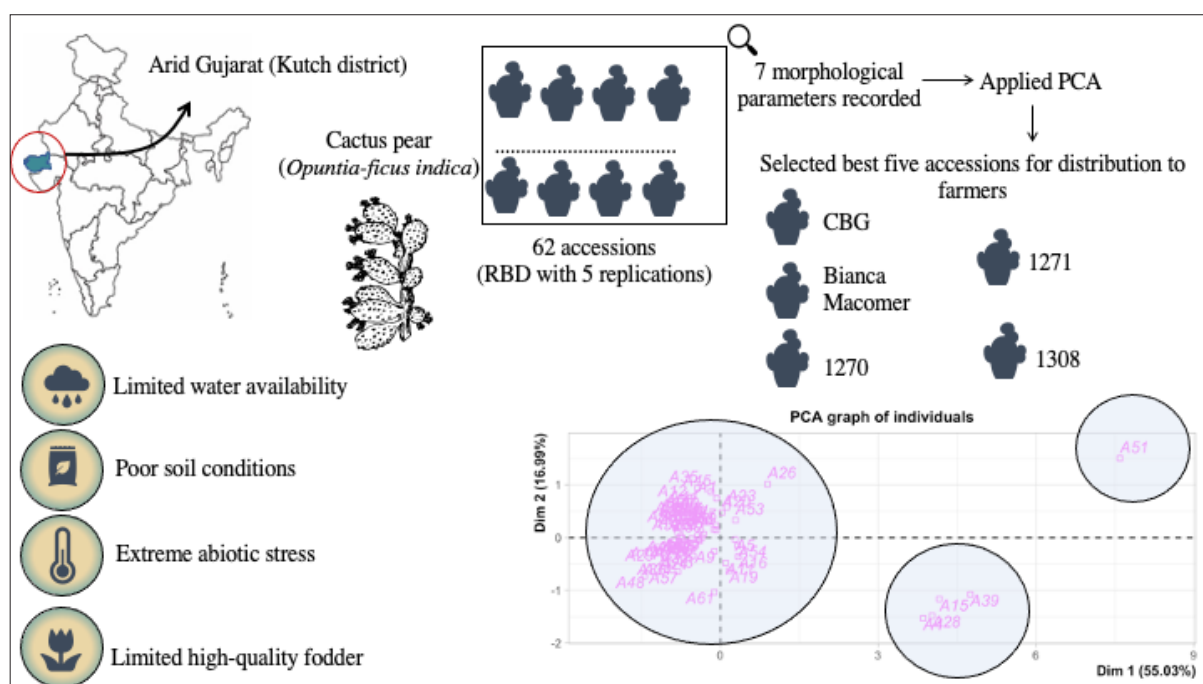


Fig. 2. Evaluation of the best performing cactus pear accessions in arid soils of Kachchh.

of each cactus accession were run through PCA and three clusters of accessions were identified. The first group comprise CBG only, indicating its best growth performance in the Kachchh region out of the 62 accessions. The second group consists of No. 1270, No. 1271, No. 1308 and Bianca Macomer (Fig. 2). The rest of the accessions were clustered under the third group. These three clusters highlighted the five best accessions that can be promoted as a drought-resilient fodder resource in the Kachchh region. The data highlighted that CBG, No. 1270, No. 1271, No. 1308 and Bianca Macomer must be recommended as best-suited accessions for the Kachchh region. However, since cactus pear prefers well-drained soil, waterlogging in and around the root zones of cactus pear must be avoided. It is frequently observed in CBG accession. As reported by Acevedo *et al.* (1983), climatic factors considerably affect the initiation and growth of cladodes. In our case, it is reported during April to July. Several authors have reported varying values of above-ground biomass (de Cortázar and Nobel, 1991; Guevara *et al.*, 2001; Soni *et al.*, 2015). Our results also demonstrated that the fresh weight can vary between the accessions. This is attributed to the changes in soil quality, climatic parameters, management practices and quality of the planting material.

Conclusions

Opuntia ficus-indica has shown promising results and thus could be a drought-resilient fodder crop, especially during the driest seasons of the year when there is low availability of green fodder. These findings could provide new insights into better understanding of cactus as a crop. These five best accessions (CBG, 1270, 1271, 1308 and Bianca Macomer) can be cultivated in Kutch region. After selecting the mature cladodes, chopped cladodes are used as a supplement to low-quality feed. Therefore, keeping all the immense potential of cactus pear in the agricultural sector, the cactus can be called a future crop. It must be promoted in areas with less vegetative cover and poor soils. It can be easily grown as an intercrop with other conventional crops. However, there are several research gaps in cactus research concerning its potential in the food industry. Understanding whether cactus pear can aid in solving food crisis in the near future under a climate-changing scenario is one of the crucial steps

that need to be addressed soon. We believe that this evaluation of cactus pear accessions merits further research to discover or explore more potential of cactus pear in meeting the livestock feed demand. Further investigations must be conducted on its forage quality and animal health study based on cactus feed.

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