Cactus an Emerging Fodder Crop of Arid and semi Arid India

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Cactus plantation at CRS, Urulkanchan, Pune (Maharashtra)

Cactus plantation at Nanodara (Gujarat)

Cactus plantation in desert sandy soil at Barmer (Rajasthan)
The challenge of arid and semi-arid regions is both that of preventing further ecosystem degradation as well as finding avenues for better livelihoods for the people. The search for appropriate vegetation/crops suitable for these areas is therefore of paramount importance.

Almost 53.4 per cent of India's land area comprises arid and semi-arid regions. The climato-vegetational scenario of the arid and semi-arid zone indicates extreme conditions; extreme temperature (-4°C to 50°C), very low and erratic precipitation (25 to 450 mm), high wind speed (30 to 40 km/hour), high evapotranspiration (1500 to 2000 mm/year), scarcity of water, low content of organic matter and presence of soluble salt in the soil leading to very low productivity of agriculture crops. This badly affects the livelihood of the people. Land degradation accompanied by acute shortage of water, perpetual drought, which is near famine situation, lead to food insecurity and poverty that force the people to migrate to other areas for their survival.

Cactus (*Opuntia ficus indica*) is a well-known crop for arid climate and is being cultivated in many countries of the world. Its cultivation in India is at nascent stage. Efforts have been made to introduce this crop at farmer's level by BAIF in arid and semi-arid regions of India. Cactus which is also known as Prickly Pear or Cactus pear, has emerged as one of the most suitable crop species to meet multiple requirements of food, fruit, forage and host of other ecological benefits. It has high water use efficiency which makes it an excellent crop species suitable in water stressed condition.

Keeping in view the potential of Cactus crop in arid and semi-arid climate, a research study was undertaken at BAIF, with the support of NABARD, to standardize the nursery and production technology of the cactus for fodder, evaluate the nutritional status of different accessions and performance of the cactus feeding in small ruminant (goat). Based on the outcomes of this research a booklet on cactus for Fodder has been brought out by BAIF.

Hope this booklet will act a good resource material to introduce this crop by all the stakeholders associated with the promotion and development of agriculture in arid and semi-arid regions of India.

August 24, 2017

Girish G. Sohani
President
BAIF
1. Introduction

i) About Cactus Plant

The word "Cactus" derives, from the Ancient Greek word *kaktos*, a name originally used for a spiny plant whose identity is not certain. Cactus (plural: *cacti*, *cactuses*, or *cactus*) is a member of the plant family Cactaceae.

*Cactus* (*Opuntia ficus indica*) is a long-domesticated cactus crop that has emerged as one of the most suitable crop species for arid and semi-arid climate for not only for its better Water Use Efficiency (WUE) and Rain Use Efficiency (RUE) but also a source to meet the requirements of food, forage and host of other benefits along with ecological advantages. This has made this crop as an integral part of agricultural economy especially in arid and semi-arid regions of the world.

DNA analysis: *Opuntia ficus indica* indicated that it was domesticated from *Opuntia* species native to central Mexico. The village of Valtierrilla is a town in the Mexican state of Guanajuato in the city of Salamanca, which is the largest producer of *Opuntia* and is considered to be the world capital of Nopal.

Some of the common English names for the plant and its fruit are Indian fig opuntia, barbary fig, cactus pear, spineless cactus, and prickly pear. The other names of *Opuntia ficus indica* are Cactus Flower, Cactus Fruit, Cactus Pear Fruit, Nopal, Nopal Cactus. Although this last name has also been applied to other less common *Opuntia* species.

Plant Description:

Cactus have fleshy succulent stems that are major organs of photosynthesis. They have small or transient leaves. The plants flower in three distinct colours: white, yellow and red. They have flowers with ovaries that lie below the sepals and petals, often deeply sunken into a fleshy receptacle (the part of the stem from which the flower parts grow). The flowers first appear in early May through the early summer in the Northern Hemisphere, and the fruit ripen from August through October. All cacti have areoles—highly specialized short shoots with extremely short internodes that produce spines, normal shoots and Flowers.

Rational for introduction of Cactus in Arid and semi Arid India

- Has capacity to produce good biomass throughout year using minimum water
- Multipurpose plant
  - Drought tolerant
  - Easy to establish
  - Potential for rangeland and pastureland management
  - Helps in soil and water conservation
- Source of a variety of agri-foods available in more than 50 products
  - Marmalades, juices, nectars, candies, frozen pulp, alcoholic beverages, pickles, sauces, shampoos, soaps and lotions.
ii) Uses of Cactus:

**Fruit:**

The most commercially valuable use for *Opuntia ficus-indica* today is for the large, sweet fruits, called tunas. The name "tuna" is used for the fruit of this cactus and also for *Opuntia* genus in general.

The fruit has to be peeled carefully to remove the small spines on the outer skin before consumption. If the outer layer is not properly removed, glochids can be ingested, causing discomfort of the throat, lips, and tongue, as the small spines are easily lodged in the skin. Native Americans, like the Tequesta, would roll the fruit around in a suitable medium (e.g. grit) to "sand" off the glochids. Alternatively, rotating the fruit in the flame of a campfire or torch has been used to remove the glochids. Today, parthenocarpic (seedless) cultivars are also available.

The fruit are typically eaten after chilling in a refrigerator for a few hours. They have a taste similar to a juicy, extra sweet watermelon.

Tuna Jams and jellies are produced from the fruit, which resemble strawberries and figs in colour and flavour.

**Vegetables:**

Mexican and other southwestern residents eat the young cactus pads (nopales, plural) (nopal, singular), usually picked before the spines harden. The nopal pads can be eaten raw or cooked, used in marmalades, soups stews and salads. They are sliced into strips, skinned or unskinned, and fried with eggs and jalapeños, served as a breakfast treat. Nopales are generally sold fresh in Mexico, cleaned of spines, and sliced to the customer's desire on the spot, they can also be found canned or bottled, and less often dried, especially for export. Cut into slices or diced into cubes, nopales have a light, slightly tart flavour, like green beans, and a crisp, mucilaginous texture. In most recipes, the mucilaginous liquid they contain is sometimes included in the cooking. They are at their most tender and juicy in the spring.

**Fodder:**

Cacti have a better Water Use Efficiency (WUE) and Rain Use Efficiency (RUE) than any other conventional fodder crops. It is even better than acacia trees. *Opuntia* uses 267 kg of water per kg dry matter (DM) produced, while pearl millet (one of the prominent drought tolerant cereal crop) uses 400 kg water per kg DM produced. The RUE of *Opuntia* is 40 kg DM/mm/year, while pearl millet is 25 kg DM/mm/yr.
Opuntia being a CAM* plant has potential for producing a large amount of forage to feed large and small ruminant animals in dry regions. In Tunisia under rain fed condition, spineless Opuntia yields 20 t/ha/year of fresh paddles as reported in areas with 150 mm/year rainfall and 100 t/year in areas with 400 mm/year rainfall.

The dry matter content of Opuntia is less than 15%. It has low protein content about 4% CP, low phosphorus and fiber content about 10% of the DM. However, it is rich in energy, calcium and ash. As such, cactus is energy feed source. Since fiber content is low and protein is lower than the maintenance requirement for ruminants (about 7% of the DM), Cacti need supplementation with nitrogen sources and fibrous feed like straws from cereals for optimum animal performance.

Since paddles are highly succulent (about 85% water), animals can survive for a long time without water in areas where water is a problem. A cow consuming 40 kg of fresh cactus per day will also consume 35 litres of water per day simultaneously. Thus, cactus is an appropriate fodder in arid and semi-arid Regions.

(*)NOTE: In a CAM (Crassulacean Acid Metabolism) crop, the stomata in the leaves remain shut during the day to reduce evapotranspiration but open at night to collect Carbon dioxide (CO₂). The stored CO₂ is then used during photosynthesis in the day time. Due to this physiological character, Cactus has high efficiency in the use of water and makes it an excellent crop species in Water stressed condition of arid and semi-arid climates.)

Industial use - Alcoholic Beverages

- Mexicans have used Opuntia for thousands of years to make an alcoholic drink called colonche.
- In the center of Sicily, in the Province of Enna, in a small village named Gagliano Castelferrato, a prickly pear-flavoured liqueur is produced called "Ficodi".
- In Malta, a liqueur called Bajtra (the Maltese name for prickly pear) is made from this fruit.
- On the island of Saint Helena, the prickly pear also gives its name to locally distilled liqueur, Tungi Spirit

Medicinal Uses:

Antioxidant: The stems and fruits of Opuntia ficus-indica contain eight flavonoids, which have antioxidant properties and the fruit is reportedly better than Vitamin C.

Inflammation: Ethanol extracts from prickly pear cactus fruit and stems were prepared and used to evaluate the pharmacological activities of the plant. A study from Korea, found that both extracts suppressed paw edema in laboratory animals and had a potent inhibitory effect against leukocyte migration, which is an important mechanism in the development of inflammatory diseases.

Cholesterol: In studies on this fruit suggest that prickly pear pectin decreased LDL concentrations and led to a 28 percent drop in total cholesterol levels. Furthermore, Mexican researchers found that animals fed raw nopal had lower weight gains and a 34 percent reduction in LDL cholesterol levels.

Diabetes: Nopal has been studied for its effects on blood sugar levels. It has been reported that the cactus extracts caused a significant decrease in blood glucose values by almost 18 percent.
Ulcers: The *Opuntia ficus indica* (nopal) cactus has been used in Sicily folk medicine for years to treat gastric ulcers.

The fruit of *Opuntia ficus indica* can cause constipation if consumed with the seeds, without the seeds it is laxative.

Other uses of cactus crops:

- **Waterproof**: It is as an ingredient in adobe (to bind and waterproof). Fluid (cactus juice) extracted from *Opuntia* pads and stems, especially *Opuntia ficus indica*, is one of the most commonly used additives in Earthen wall plaster.

- **Natural Dye**: *Opuntia ficus indica* (as well as other species in *Opuntia* and Nopalea) is cultivated in nopalries to serve as a host plant for cochineal insects, which produce desirable red and purple dyes. This dye was extremely valuable to early 16th century through late 19th century.

- **Dietary Mineral**: The high levels of Selenium in *Opuntia* are comparable to those found in Brassicaceae.

- **Dispersant for oil spills**: A University of South Florida engineering professor and a team of researchers have found that mucilage from the prickly pear cactus works as a natural, non-toxic dispersant for oil spills.

- **For water treatment**: The flesh (mucilage) of the cactus has been found to purify water. A project at the University of South Florida is investigating its potential for low-cost, large-scale water purification.

2. Cactus- World scenario

Countries growing *Opuntia ficus indica* are Mexico, Malta, Spain, Sicily, Italy, Greece, Libya, Tunisia, Morocco, Algeria, Lebanon, Syria, Egypt, Saudi Arabia, Yemen, Israel, Chile, Brazil, Turkey, France, Bulgaria, Portugal, Albania, Cyprus, United States.

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<thead>
<tr>
<th>Regions/countries</th>
<th>Area cultivated (x1000 ha)</th>
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<tbody>
<tr>
<td>Brazil</td>
<td>600</td>
</tr>
<tr>
<td>Other South American Countries</td>
<td>75</td>
</tr>
<tr>
<td>Mexico</td>
<td>230 + 3 M</td>
</tr>
<tr>
<td>Other North American countries</td>
<td>16</td>
</tr>
<tr>
<td>Tunisia</td>
<td>600</td>
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<tr>
<td>Algeria</td>
<td>150</td>
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<tr>
<td>Morocco</td>
<td>150</td>
</tr>
<tr>
<td>Italy</td>
<td>70</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1891 + ~ 3 M</strong></td>
</tr>
</tbody>
</table>

3. Cactus- Indian scenario

Though Cactus is being cultivated in many countries of the world for quite some time, its commercial cultivation in India is yet to start. It is still at the research stage with limited field trial initiated by CAZRI in Kutch district of Gujarat and in some select areas with the support of ICARDA. The limited research on Cactus was initiated by ICAR- CAZRI, Jodhpur, in seventies but the comprehensive work on Cactus was started by NARI with the collection of good number of imported accessions. However the work could not be pursued to its logical end. During the last two decades the research was conducted by many public sector research Institutes in India especially those are working in arid agricultural crops, but the outcome of this work is yet reach to the famers.

Some of the recent works on Cactus that has been undertaken by various Research Institutions in India are indicated hereunder;

Central Arid Zone Research Institute (CAZRI) is the nodal agency for cactus research in India supported by International Center for Agricultural Research in the Dry Areas (ICARDA) network programme. The cactus research work is in progress at Jodhpur as well as its Regional station, Bhuj in Kutchh, Gujarat. 70 cactus accessions have been received from ICARDA during the year 2012. They are undertaking trials on various aspect of Cactus like production, propagation, post-harvest management and molecular identification. They have also initiated trials in the farmer's field in a limited scale.

Indian Grassland and Fodder Research Institute (IGFRI), Jhansi is a network partner of ICARDA for cactus research. 15 cactus accessions received from ICARDA during 2013 are under testing. The accessions are originally from Mexico, Brazil and Italy. Trials on planting seasons and irrigation management, inclusion of cactus in various crop production systems are in progress at this center.

Research on performance of various cactus accessions, planting methods, biomass production was made in CAFRI - Jhansi, CSSRI - Karnal and CIAH - Bikaner. Farmers field adaptation trials are being conducted through ICARDA programme by CAZRI and in Bundelkhand region by IGFRI and CAFRI. NDDB actively involved in spreading cactus among dairy farmers of Gujarat.

4. Research at BAIF

In this backdrop, BAIF Development Research Foundation, a Non Govt. Organisation, initiated a comprehensive work on Cactus (*Opuntia ficus indica*) with the financial support of NABARD in 2015. The whole approach of this work was to take the cultivation of this new crop to the farmer’s field after standardizing the production technology at BAIF’s Research station. Though the cultivation of cactus is primarily aimed for food and fodder, the research at BAIF was focussed on providing an alternate Fodder crop to the farmers of arid and semi-arid regions of India to address their livelihood issues.

The specific objectives of the Research project were i) to standardize the nursery techniques and production technology of the cactus for fodder through agronomy trials, ii) to evaluate the nutritional status of different cactus accessions and iii) to evaluate the performance of the cactus as fodder for small ruminant (goat) through feeding trial at farmers field in surrounding area of Urulikanchan.
I) Cactus Germplasm and Arboretum

The Research work started with the establishment of Cactus Arboretum where the Cactus germplasm was collected from various Govt. (ICAR) and private research institutes as well as collection of locally available accessions by personal visits during 2015 to 2017. Presently there are 82 cactus accessions that are being maintained in the cactus arboretum at BAIF, CRS, Urulikanchan. Most of the accessions are thorn less and locally collected accessions are thorny. The four fodder type cactus accessions 1270, 1271, 1280 and 1308 were utilized for cactus research on development of nursery and production technology as well as cactus feeding trial in goats. The Arboretum was used for the repository of research material for undertaking various trials to evaluate the growth and yield performance as well as nutritional content of various cactus types, it also acted as research field for assessing the performance of different accessions.

II) Cactus Nursery Management

The nursery propagation was undertaken both in shade net house having 50 % shade to create suitable environment and also under open condition. Following techniques needs to be adopted for undertaking nursery propagation of cactus.

i) Curing of cladodes: Initial moisture content in fresh cladodes is very high (> 85%) therefore it is necessary to brought down the moisture content upto 65-70% before planting in the nursery/field. Keep the fresh cladodes under shade for curing after removing from the mother plants. A curing period of 15 days is ideal before planting in the nursery/field.

ii) Nursery media: Nursery media plays key role in success of the propagation in cactus. As cactus is known to be very sensitive to water logging condition, selection of suitable nursery media is important. Soil, sand and FYM in 40:40:20 proportions is the best media for cactus nursery raising.

iii) Season of planting: Planting the cactus during post rainy season i.e. October onward till March is the ideal time where maximum plant survival will be observed.

iv) Cladode pieces: Cactus could be propagated by planting single cladode, however under limited availability of good planting material, cladode pieces may be used for propagation. The cactus cladode of 6 months of age and above should be selected for nursery propagation. The matured cladodes may be cut into 2, 4, 6 and 8 pieces for multiplication. However the survival and growth of single cladode is faster but 1/8th piece of cladode, can be multiplied into a new plant though it takes longer time to become a mature plant.
v) **Planting in nursery:** Black plastic pots or polythene bags of suitable size filled with soil sand and FYM (40:40:20) could be used for nursery propagation. The cladodes/pieces should be treated with fungicide (Mancozeb) @ 2g/liter water before planting. The cladodes should be planted erect keeping 1/3rd portion below media. In case of cladode pieces the uncut portion should be kept above media while planting in the pot/bag.

vi) **Water management:** The cactus is very sensitive to moisture therefore optimum watering should be provided during nursery stage. Do not water the plants immediately after the planting. After a week time, water the plant lightly (1 liter/pot or bag) and subsequent watering may be provided at 10 days interval.

vii) **Hardening the propagules:** The sprouting and development of new cladodes and roots will take around 60 days. At this stage the propagules should be exposed to sunlight by taking them outside the shade net for hardening. A period of 30 days is sufficient for hardening the propagules. Therefore the propagules will be ready for field planting in 90 days.

viii) **Micro-propagation in cactus:** The micro-propagation of cactus is useful in mass multiplication of the good cactus accessions for field plantation. The protocol for mass multiplication of cactus through tissue culture is developed at BAIF, Urulikanchan. The overall plant survival was observed above 60% under field conditions.

ix) **Establishment of Cactus Nursery Unit:** Based on the outcome of the Research conducted at BAIF Research stations at three different locations, economics of a small unit of Cactus Nursery has been prepared. Keeping in view the demand of matured cladodes, the establishment of nursery has been conceived in open condition. (*The details are furnished in Annexure I*)

**III) Cactus Cultivation and Management**

The cactus establishment and package of practices for production technology has been developed through agronomy trial. The following package of practices needs to be followed for successful cactus plantation.
i) **Site selection and land preparation:** The degraded, poor quality land, where other crops cannot be grown, could be utilized for cactus cultivation. The raise bed of 2 feet width and 1 feet height and convenient length should be prepared for cactus planting. The planting spacing of 3 m x 2 m is recommended.

ii) **Planting season:** Planting the cactus during post rainy season starting from October to March is the best time for successful establishment and survival of cactus in the field.

iii) **Selection of the cactus accessions:** The selection of cactus accessions depends upon the purpose of plantation i.e. fruit, fodder or vegetable. The thorn less accessions should be selected for fodder purpose. The accessions 1270, 1271, 1280 and 1308 are tested for its survival growth, biomass and nutritional content at BAIF and are recommended for fodder purpose planting.

iv) **Establishment of cactus plantation:** The matured cladode of identified accessions should be selected for planting. Curing of freshly harvested cladodes is necessary under shade for 15 days before planting in the field. The cladodes should be treated with fungicide (Mancozeb) @ 2g/liter water before planting. Though the cactus can be grown at a close spacing of 2 m x 1 m, plant spacing of 3 m x 2 m was adopted for BAIF plantation. The cladode should be planted erect keeping 1/3rd portion below ground.

v) **Manuring and fertilizer application:** Application of 5 MT well decomposed Farm Yard Manure and 60:30:30 kg NPK per hectare is recommended at the time of planting. Application of 20 kg Nitrogen is useful in enhancing the new sprouting after every harvest for biomass.

vi) **After care and maintenance:** Keep the plot weed free during initial plant growth period by hand weeding or application of herbicide (Glyphosate @ 5 ml/liter water). Provide the optimum moisture for initial plant establishment period of one year. Therefore watering the plants at 15 days interval during post rainy season is very much essential. Needless to mention that regular watering the plants at 15 days interval will enhance the growth and biomass yield in cactus.

vii) **Biomass harvesting:** The biomass harvesting in cactus should be initiated after one year of the plantation. Keeping the basal cladode, the other cladodes may be harvested by cutting with sharp knife. The average of 15 to 37 cladodes and fresh biomass yield of 15 to 17 kg per plant was recorded at 12 months after planting. The biomass yield increases with increase in age of the plants and 27 to 29 kg biomass per plant was observed at 21 months after planting.
viii) **Fruiting in cactus:** Though the planted cactus accessions were fodder type, flowering was observed at around 20 months after planting. Fruiting was completed in two months from flowering (22 months after planting). The fruit weight ranged from 38.75 to 83.00 g, fruit diameter 3.40 to 4.47 cm and fruit sweetness (brix) 12.16 to 12.37%.

ix) **Cactus adaptability and multiplication in arid and semi arid regions:** The adaptability and multiplication trial was undertaken at two locations namely Nanodara in Gujarat and Barmer in Rajasthan. These plantations could be utilized in future as a source of planting material for dissemination of cactus in the farmer's field.

**Nanodara:** The weather of Nanodra is normally hot semi-arid with a maximum temperature of 46°C during summer and a minimum temperature of 7°C during winter having average rainfall of 850 mm. Soil of the experimental field was sandy having 84% sand and 8.9 pH. The plant survival was observed above 91% and the plant growth was satisfactory.

**Barmer:** Primarily a desert district where average annual rainfall is 277 mm. The seasonal temperature variation is quite high (46 °C to 51 °C in summer and it drops to 0 °C in winter). Soil was typical desert with coarse sand texture having 8.7 pH. The growth of six months old plantation indicated 100% survival and new sprouts and cladodes are well developed.

x) **Cost of Cactus Cultivation:** Based on the experiences of cultivating the cactus across three locations of BAIF research stations the economics of cactus cultivation has been worked out and furnished in Annexure II.

**IV) Performance of cactus as Fodder in Goat**

Scarcity of fodder in India is the major challenge in raising animal production including small ruminants like goat. Availability of feed and fodder is drastically reducing during drought period. The small ruminants like Sheep and Goats are extensively grazed throughout the year. Arid and semi-arid areas are characterized by limited resources, herbaceous and rare green forage production particularly during hot summer season. Tree fodder form the major part of a diet for goats.

**Nutrition of Cactus:**

The *Opuntia ficus indica* is the most widely used species as animal feed world over. The cladodes consist mainly of water (>85%) on fresh weight basis depending on growth conditions. Despite of fact that cactus plants are high in carbohydrates and vitamin A, protein content is ranging from 5% to 9%. It is characterized by a high palatability, digestibility, high content of water, soluble carbohydrates, ash, Ca and K and vitamin A.
Feeding of Cactus:

A livestock species like goat are already grazing the cactus in certain part of India particularly in dry land systems. Cactus can be fed to cattle and small ruminants like Goat by mixing it in Total Mixed Ration (TMR). Many farmers prefer and are encouraged to cut the cactus into smaller pieces and supplement with hay or straw. The cladodes, the fresh cactus pads or water storing segments of the plant, are rich in easily fermentable carbohydrates which aid digestion in the rumen. The assorted accessions of spineless cactus (1270, 1271, 1280 and 1308) is an important substitute to farmers due to its considerable survival, propagation capacity and production potential under conditions of little rain and high temperatures. A Cactus should be cut into smaller pieces for ease of feeding.

The cactus feeding studies were conducted on adult goats and kids at farmer's field at Urulikanchan. The results indicated that cactus feeding in Goats enhanced the performance of goats in terms of total body weight and average daily gain in body weight. Goats may consume on an average 3 kg of the Cactus daily and can maintain their body weight without any adverse effect on their health. Cactus can be used as a fodder for replacement of 25% dry matter with their regular grazing. Cactus feeding in Osmanabadi kids also enhanced the performance of kids in terms of total body weight gain and average daily gain in body weight without any adverse effect. It may constitute a potential effective fodder for weaned kids in semi-arid areas.

V) Nutritional Evaluation of selected cactus accessions

The nutritional evaluation of four cactus accessions namely 1270, 1271, 1280 and 1308 was undertaken at BAIF laboratory, Urulikanchan and is given in the table.

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<thead>
<tr>
<th>Parameters</th>
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<tr>
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<td>Crude Fiber %</td>
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<td>Ether Extract %</td>
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<td>K %</td>
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<td>Mg %</td>
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<tr>
<td>Na %</td>
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<tr>
<td>NDF%</td>
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<tr>
<td>ADF %</td>
<td>17.66</td>
</tr>
</tbody>
</table>
5. Promotion of cactus

Based on the initial findings of the cactus trial at BAIF research stations, the cladodes of identified accessions were provided to about 20 select farmers in Maharashtra and Rajasthan and also to KVK’s of Chaswad (Bharuch) and Baramati (Pune). The performance in the farmer’s field and in KVK’s are being monitored closely. The interested farmers can also approach BAIF for the limited quantity of planting material for their own use.

6. Way forward

a) Research need

i) **Exploration of medicinal properties of Cactus:** Though there are evidence of various medicinal importance of cactus besides its use as food and fodder, not many Indian institutions are engaged in exploring this opportunity. Proper collaborative research with organization like CIMAP, Lucknow or any other private/Govt. Research organizations need to be explored for this work.

ii) **Possibilities of coordinated cactus development programme:** Like other coordinated research work of ICAR-AICRP’s on different crops, the scope for coordinated research work on cactus on the similar line may be explored. This will facilitate to establish a Networking for collaborative work.

iii) Though there is potential to exploit this crop as fruit crop, as has been done in Mexico, Israel and many other countries, very little work on this has been undertaken in India. There is an urgent need to explore this area.

iv) Development of location specific cactus inclusive cropping models.

v) Standardization of feeding module for small and large ruminants with cactus as a supplementary feed.

vi) A breeding work in *Opuntia* Spp. need to be started.

b) Promotion and Development Need

i) **Introducing cactus as supplementary fodder in farmer's field:** The identified suitable accessions along with standard package of practices developed through this project needs to be demonstrated on degraded waste land at the farmer’s field as a source of green fodder to improve the fodder availability for the livestock in dry areas of arid and semiarid regions. The income from this crop can ensure insurance to the farmers against the losses of main crop which has become more frequent these days due impact of climate change.

ii) **Development of decentralize cactus nursery:** Presently there is hardly any cactus nursery in the country that can provide planting material to cater the requirement of the farmers interested to grow cactus for fodder and fruits. Hence such Cactus nurseries may be established at different location by various institutions. Once the cultivation of Cactus gets popular, private nurseries may come to provide quality material.
iii) Promotional programme:

a) The BAIF’s pan India presence may be utilized for technological intervention for promoting cultivation of cactus in collaboration with ICAR institutes like CAZRI and IGFRI.

b) State Govt. especially in the arid and semi-arid regions, may be influenced to take up this new crop as an alternate fodder in all degraded land. They may be requested to incorporate cactus in their ongoing fodder development programmes.

c) NABARD may like to promote the cultivation of this crop by organizing workshop at National /State / District level in association with BAIF and other relevant Institutions to disseminate the technology developed by BAIF with their support.

d) With a view to increase the Institutional Credit in the farm sector NABARD may consider to develop a model Bankable Project for the banks especially in the waste land, dry land areas.

7. List of Institutes involved in Cactus work

a) International Institutes

1. International Center for Agricultural Research in the Dry Areas (ICARDA), Amman, Jordan
   Phone: +962-6-5903120 Website: www.icarda.org
   Email: ICARDA-Jordan@cgiar.org, m.louhaichi@cgiar.org

2. Dry Grow Foundation, Italy
   Phone: +39 333 188 3425 Website: www.drygrow.org Email: info@drygrow.org

3. Food and Agriculture Organization (FAO), Rome
   Phone: +39 06 57051 Website: www.fao.org
   Email: FAO-HQ@fao.org, Makiko.Taguchi@fao.org

4. Cactus Net
   Website: www.cactusnetwork.org Email: cactusnet@dgroups.org

b) National Institutes

1. Central Arid Zone Research Institute (CAZRI), Jodhpur, Rajasthan
   Phone: +91 291 2786584 Website: www.cazri.res.in
   Email: director@cazri.res.in

2. Indian Grassland and Forage Research Institute (IGFRI), Jhansi, UP
   Phone: 0510-2730666, 2730158 Website: www.igfri.res.in Email: igfri.director@gmail.com

3. Central Soil Salinity Research Institute (CSSRI), Karnal, Haryana
   Phone: 91-184-2290501 Website: www.cssri.org
   Email: director.cssri@icar.gov.in

4. Central Agro Forestry Research Institute (CAFRI), Jhansi, UP
   Phone: 91-510-2730214 Website: www.cafri.res.in
   Email: director.cafri@gmail.com
Acknowledgement:
The financial support provided by National Bank for Agriculture and Rural Development (NABARD), Mumbai, for undertaking the cactus research and bringing out this publication is gratefully acknowledged. The authors are also thankful to Dr. S. S. Roy, Dr. Ashok Pande, Sr. Vice President, Dr. Jayant Khadse, Research Director, Mr. Sagar Kadao and BAIF’s Cactus Advisory Group members for their technical guidance and support during the research work and bringing out this publication.

Package of Practices for Cactus

<table>
<thead>
<tr>
<th>#</th>
<th>Particulars</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Planting season</td>
<td>Post rainy season; October onward to March</td>
</tr>
<tr>
<td>2</td>
<td>Site selection and land preparation</td>
<td>Degraded light soil with good drainage. Prepare raised beds of 2 feet width and 1 feet height.</td>
</tr>
<tr>
<td>3</td>
<td>Curing of cladodes</td>
<td>After removing one year old fresh matured cladodes from mother plants, cure them for 15 days under shade before planting.</td>
</tr>
<tr>
<td>4</td>
<td>Cladode treatment</td>
<td>Treat the cladodes by dipping in fungicide (Metalaxyl + Mancozeb) @ 5 gm/lit of water before planting.</td>
</tr>
<tr>
<td>5</td>
<td>Planting spacing</td>
<td>Plant the single cladode erect facing flat portion to east on raise bed by fixing 1/3rd cladode part underground at a spacing of 3 m × 2 m (667 plants/acre).</td>
</tr>
<tr>
<td>6</td>
<td>Manure and fertilizers</td>
<td>Apply 5 MT well decomposed FYM and 60:30:30 kg NPK per hectare at the time of planting. Application of 20 kg Nitrogen is useful in enhancing the new sprouts after every harvest for biomass</td>
</tr>
<tr>
<td>7</td>
<td>Water management</td>
<td>Do not water plants till 10 days after planting. Then after apply 1-2 lit water/plant at 15 days interval.</td>
</tr>
<tr>
<td>8</td>
<td>Weed control</td>
<td>Keep the field weed free by manual weeding or spraying of herbicide (Glyphosate) @ 5 ml /lit of water.</td>
</tr>
<tr>
<td>9</td>
<td>Harvesting and biomass yield</td>
<td>The matured cladodes may be harvested at the age of 1 year by keeping basal cladode. Biomass yield- 15-20 kg/ plant. Biomass yield will increase in subsequent years.</td>
</tr>
<tr>
<td>10</td>
<td>Biomass utilization</td>
<td>The freshly harvested thorn less cladodes may be fed to goat/sheep/cattle as 30 % replacement to other green fodder.</td>
</tr>
</tbody>
</table>
Annexure I

Establishment of Cactus Nursery

Assumptions considered for the nursery are as under

1. Area - 200 sq. meter
2. Planting spacing - 2 m x 1 m
3. Number of plants - 100
4. Accessions - Assorted
5. Fencing - Low cost live hedge/dry fencing
6. Plant nutrition - Organic (FYM)
7. Irrigation - Protective during post monsoon
8. Type of produce - Matured cladodes
9. Yield - 15, 25 and 35 cladodes/plant in 1st, 2nd and 3rd year respectively
10. Sale price - Rs. 10/cladode

<table>
<thead>
<tr>
<th>#</th>
<th>Particulars</th>
<th>Unit</th>
<th>Qty</th>
<th>Rate</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Raised bed preparation</td>
<td>Mandays</td>
<td>10</td>
<td>350</td>
<td>3500</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>FYM (2,3,4 kg/plant/year respectively)</td>
<td>Kg</td>
<td>200</td>
<td>2</td>
<td>400</td>
<td>600</td>
<td>800</td>
</tr>
<tr>
<td>3</td>
<td>Planting material (10 % extra)</td>
<td>No.</td>
<td>110</td>
<td>10</td>
<td>1100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>Live fencing</td>
<td>m²</td>
<td>200</td>
<td>-</td>
<td>3000</td>
<td>0</td>
<td>1000</td>
</tr>
<tr>
<td>5</td>
<td>After care (irrigation, weeding)</td>
<td>Mandays</td>
<td>10</td>
<td>350</td>
<td>3500</td>
<td>5250</td>
<td>7000</td>
</tr>
<tr>
<td>6</td>
<td>Harvesting</td>
<td>Mandays</td>
<td>2</td>
<td>350</td>
<td>700</td>
<td>1400</td>
<td>2100</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td>12200</td>
<td>7250</td>
<td>10900</td>
</tr>
</tbody>
</table>

**Income (Rs.)**

<table>
<thead>
<tr>
<th>#</th>
<th>Gross income: sale of matured cladodes (16, 25, 35 cladodes/plant /year resp.)</th>
<th>No.</th>
<th>1600</th>
<th>10</th>
<th>16000</th>
<th>25000</th>
<th>35000</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Net Income (Gross income - expenditure)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3800</td>
<td>17750</td>
<td>24100</td>
</tr>
</tbody>
</table>

*Note:* In the light of the research recommendation on standardizing the nursery technique it is advised that fully matured cladode can be utilized for new plantation with cutting into two pieces which will reduce the cost of planting material. However number of pieces per cladode can be increased up to four with proper technical backup.
## Annexure II

### Cost of Cultivation of Cactus

Crop cycle: Perennial  
Unit Size : 1 Acre (0.40 Ha)  
(Amount in Rs.)

<table>
<thead>
<tr>
<th>#</th>
<th>PARTICULARS</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A.</td>
<td>MATERIAL COST</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Planting material (10% extra)</td>
<td>6670</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>FYM</td>
<td>3000</td>
<td>3000</td>
<td>3300</td>
<td>3300</td>
<td>3500</td>
</tr>
<tr>
<td>3</td>
<td>Irrigation</td>
<td>2800</td>
<td>2800</td>
<td>2800</td>
<td>2800</td>
<td>2800</td>
</tr>
<tr>
<td>4</td>
<td>Fungicide</td>
<td>450</td>
<td>450</td>
<td>450</td>
<td>450</td>
<td>450</td>
</tr>
<tr>
<td>5</td>
<td>Fencing (live hedge)</td>
<td>5000</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Sub Total</td>
<td>17920</td>
<td>6250</td>
<td>6550</td>
<td>6550</td>
<td>6750</td>
</tr>
<tr>
<td>B.</td>
<td>OPERATION &amp; LABOUR</td>
<td>9630</td>
<td>11100</td>
<td>13000</td>
<td>15000</td>
<td>17000</td>
</tr>
<tr>
<td></td>
<td>Grand Total</td>
<td>27550</td>
<td>17350</td>
<td>19550</td>
<td>21550</td>
<td>23750</td>
</tr>
<tr>
<td></td>
<td>Requirement of Investment for 3 Yrs.</td>
<td>64450</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Yield & Income

<table>
<thead>
<tr>
<th>Years</th>
<th>Biomass Yield (kg/acre)</th>
<th>Gross Income (Rs/acre)</th>
<th>Benefit Cost ratio</th>
<th>Sale rate (Rs/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10000</td>
<td>15000</td>
<td>0.54</td>
<td>1.50</td>
</tr>
<tr>
<td>2</td>
<td>15000</td>
<td>22500</td>
<td>1.30</td>
<td>1.50</td>
</tr>
<tr>
<td>3</td>
<td>20000</td>
<td>32000</td>
<td>1.64</td>
<td>1.60</td>
</tr>
<tr>
<td>4</td>
<td>25000</td>
<td>40000</td>
<td>1.86</td>
<td>1.60</td>
</tr>
<tr>
<td>5</td>
<td>30000</td>
<td>51000</td>
<td>2.15</td>
<td>1.70</td>
</tr>
</tbody>
</table>

## ASSUMPTIONS

### I. TECHNICAL PARAMETERS

<table>
<thead>
<tr>
<th>#</th>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Varieties</td>
<td>1270, 1271, 1280 &amp; 1308</td>
</tr>
<tr>
<td>2</td>
<td>Spacing</td>
<td>3 X 2 m</td>
</tr>
<tr>
<td>3</td>
<td>Plant Population</td>
<td>667 per acre</td>
</tr>
<tr>
<td>4</td>
<td>Type of Planting Material</td>
<td>Cladode</td>
</tr>
<tr>
<td>5</td>
<td>Economic parts</td>
<td>Cladode</td>
</tr>
</tbody>
</table>

### II. FINANCIAL PARAMETERS

<table>
<thead>
<tr>
<th>#</th>
<th>Parameters</th>
<th>Amount (Rs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Planting Material (Rs./cladode)</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>FYM (Per kg.)</td>
<td>1.5</td>
</tr>
<tr>
<td>3</td>
<td>Labour (Rs./man day)</td>
<td>350</td>
</tr>
<tr>
<td>4</td>
<td>Sale Price (Rs./kg)</td>
<td>1.50 to 1.70</td>
</tr>
</tbody>
</table>
Important Visits to
BAIF, CRS, Urulikanchan

Visit of Dr. Uriel Safriel,
Ecologist, Israel

Visit of Mr. R. Amalorpavathan,
Dy. MD, NABARD

Visit of Dr. A. K. Roy,
Project Coordinator, IGFRI, Jhansi

Visit of Dr. Louhaichi Mounir,
ICARDA, Jordan
Various Cactus Types

Accession 1270

Accession 1271

Accession 1280

Accession 1308

For cactus planting material contact