OPPORTUNITIES FOR
PROMOTION OF CACTUS (Opuntia spp.)
AS LIVELIHOOD SOURCE IN RAINFED AREAS

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Cover Photo:

Front: One potted plant of Cactus yielded about 3 kg. fruit after 30 months of planting at Karnal

Back: Wild Cactus plants on the boundary of an agricultural field

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CONTENTS

1. Introduction in India  2
2. Germplasm Multiplication  4
3. Introduction at Bikaner, Rajasthan  6
5. Evaluation of Cactus in Bundelkhand Region of Central India  7
6. Evaluation for Salt Tolerance  8
7. Management Practices  9
8. Thorns and Glochids  10
9. Cactus Use  11
10. Cactus for Fruit Production  11
11. Cactus for Livestock Feed  12
12. Cactus for Vegetable Production  14
13. Red Cochineal Dye Production from Cactus  16
14. Medicinal Use of Cactus  17
15. Mucilage Production for Binders and Thickening Agents  17
16. Relevance for Rainfed Areas in India  17
17. International Status  19
18. Present Status of Cactus Research and Development at Karnal  20
19. Further Reading  22
20. Acknowledgments  23
Cactus (Opuntia ficus indica) has been commercially exploited as fruit, vegetable, forage, energy, medicinal and dye yielding crop in the arid and semi arid areas of the world. Mexico is the largest producer of the cactus and is a global player in export of cactus to North America and Europe. The other countries where cactus is known as a cultivated crop and commercially exploited include Brazil, Argentina, South Africa, Israel, USA, Italy and many other Latin American countries. The cultivation of cactus as a commercial crop is little known in Indian subcontinent. Only the wild cactus is found growing in wasteland, as an hedge around agricultural fields to protect crops from wild life and as a decorative plant in parks and home gardens. Due to its highest water use efficiency per unit dry matter production (because of CAM mode of photosynthesis), the plant has ample scope for introduction and cultivation in rainfed and dry areas of India where 67% of the poor rural population is settled. Cactus has special significance in drought prone areas of the country where if planted will help in augmenting food and fodder requirement and thus halting cattle migration to other areas. In addition to its remarkable value as cattle and human food, it has a potential for soil and water conservation when planted on slopes in hilly terraces in rainfed areas of the country. With these qualities in view, several
attempts were made in the past to introduce this plant in India. However, national initiative on
promotion of edible cactus in dry areas of the country is lacking.

**Introduction in India**

It is reported that cactus was introduced into India by the British somewhere during 1940s to
raise insects for production of natural red dyes. It is also reported that those plantations
vanished because of insects and diseases and other problems of management and prolonged
waterlogging. The plant was introduced by the researchers at Central Arid Zone Research
Institute, Jodhpur in late 70s, but it is reported that the introduced varieties did not fruit under
Jodhpur type of climate. A scientist (Nandini Nimbkar) from Nimbkar Institute, Phalton near
Puna introduced several clones of cactus from Dr. Peter Felker's collection in Texas, USA. It is
reported that some of these clones fruited in dry areas of Maharashtra, but the crop did not
spread to other arid and semi arid areas of the country because of lack of the coordinated
network effort at national, state, regional or local level. The systematic work on cactus initiated
with the efforts made by the author of this compilation who worked with Peter Felker in Texas,
US for four months between July to November, 1991 as FAO visiting fellow. While returning
from Texas, after the training, the author brought five most promising clones (considered the
best in 1991) and planted at Karnal, first in pots, then in microplots followed by large scale
Germplasm multiplication and evaluation trials at Karnal
evaluation in the field. The clones introduced included 1270 (forage and fruit), 1271 (fruit), 1280 (fruit), 1287 (fruit) and 1308 (vegetable). These were multiplied on a large scale, evaluated for sodicity tolerance and developed agro-techniques for their cultivation. Based upon its success in trials at Karnal, the material was distributed to several research centres/organizations located in arid and semi-arid regions of India like National Research Centre on Arid Horticulture, Bikaner, Central Arid Zone Research Institute, Jodhpur, Indian Grassland and Fodder Research Institute, Jhansi for further evaluation and testing.

**Germplasm Multiplication**

The introduced five clones were planted in November, 1991 in 20 kg capacity ceramic pots filled with normal soil blended with farm yard manure @ one kg/pot for multiplication. After multiplication in the pots, sufficient material was generated in about a year. The potted plants were pruned to obtain the planting material for field scale multiplication. The vegetable clone 1308 was first to sprout after 57 days of planting whereas clone 1287 was last in sprouting and took 85 days. Two strips each about 40 m long of each clone were planted in the field in a normal soil for further multiplication of the germplasm and comparative productivity evaluation of different clones. All the clones which were planted in the pots started producing

![A field view of cactus germplasm at Karnal. Dr. Judith Ochoa, cactus expert from Argentina is inspecting the performance of introduced cactus material](image-url)
fruits about $3\frac{1}{2}$ years after planting. Maximum fruiting took place in clone 1270 and minimum in clone 1287. Each plant produced 15 to 30 oval shaped pale green coloured fruits and the yield per plant varied from 1 to 3 kg. Each cladode of clone 1270 bore 8 to 15 fruits and weight of each fruit ranged between 50 to 100 g. The potted plants were given no other inputs except nutrient solution of 2% urea, 0.5% superphosphate and 0.2% zinc sulphate annually. The plants in the field also started producing fruits after two years of planting. The maximum fruiting was observed in clone 1270 followed by 1280. The fruit size was much bigger in clone 1287. Even the taste of the fruit was much better compared to clone 1270, 1271 and 1280. The vegetable clone 1308 was difficult to establish and multiply because of its high irrigation and nutrition requirement. In the field, only few plants of clone 1308 survived. However, the plants maintained in the ceramic pots served as a germplasm source for several pot, green house and field scale investigations. The clones planted in the field developed into a full-fledged orchard at the age of about 5 years. This orchard served as a major source of germplasm for supply to different research centres in the country. However, this full blooming orchard was not properly maintained and even uprooted when the author shifted to National Research Centre (NRC) on Agroforestry at Jhansi on promotion. However, while shifting, the author took sufficient material of the five clones and planted at NRC, Jhansi and developed a new orchard in the rainfed Bundelkhand region. The orchard at Jhansi is quite well maintained and is currently serving a germplasm source for the country.
Introduction at Bikaner, Rajasthan

Five clones from Karnal were initially planted at the farm of National Research Centre for Arid Horticulture, Bikaner. It is reported that later on 51 clones were obtained from Texas in 1997 for the comparative growth and productivity evaluation. Few local clones were also collected by the researchers at Bikaner and planted in the field to have comparative performance evaluation of the introduced and indigenously collected germplasm. It is reported that 48 out of the 51 introduced have survived under Bikaner conditions. It is also reported that some of these clones are producing fruits also.

Introduction and Evaluation at Agra, UP

Three varieties of cactus 1271, 1280 and 1308 were introduced at Agra by a Ph.D scholar from Karnal for his Ph.D dissertation studies. The performance of clones was evaluated in spring (February-March) and post-monsoon (September-October) planting seasons. The clones were planted at 3 x 1m spacing between rows and plants respectively, following upright planting method. The scholar took observations for two years on the parameters: days taken to sprout after planting, cladodes formed per plant, length, width and weight of cladode at harvest,

A field view of cactus clones planted at the experimental farm of National Research Centre on Agroforestry, Jhansi (Bundelkhand Region)
moisture, titrable acidity, ascorbic acid (vitamin C), total sugars, reducing and non-reducing sugars in fresh cladodes. The results reported by the researcher indicated that clone 1308 sprouted after 23 to 26 days of planting during spring season whereas the same clone took 51 to 53 days for sprouting during post-monsoon season. Clone 1271 produced cladodes which have maximum length, width and weight whereas clone 1308 cladodes have the minimum length, width and cladode weight. However, the cladodes per plant were maximum in clone 1308 than in 1271 and 1280. The titrable acidity in the cladodes varied from 0.46 % to 0.82 % during spring season and 0.44 to 0.92 % in post-monsoon season. During both the seasons, the cladodes of clone 1308 had more ascorbic acid than in clone 1271 and 1280. The total sugar content in the cladodes was reported highest in clone 1280 followed by clone 1308 and clone 1271.

Evaluation of Cactus in Bundelkhand Region of Central India

Elite material from Karnal was introduced at National Research Centre for Agroforestry, Jhansi in 1998 and planted under rainfed situation on raised bunds in red soils of Bundelkhand. The cactus was planted with two methods: erect and flat. Erect planting gave 100% survival of plants in one year for clones 1270, 1271 and 1280 and clone 1308 and 1287 gave 83 and 75% success.
respectively. Cladodes of clone 1271 produced maximum (18.4) cladodes per plant after 2 years followed by 1270 type (18.1). Average weight of cladodes was maximum 555 g and higher than other types in case of clone 1271 followed by 1280 (460 g). Two years after planting, fruiting was reported in clone 1270 and 1287 when each plant produced 2-4 fruits in both clones. Ripe fruits of clone 1270 and 1287 were given to a tasting panel of 25 persons (scientists, advocates, students, technicians and farmers varying from 28 to 50 years old). Based upon sweetness on a scale of 0-10, six persons gave a score of 8 or more whereas two persons did not like the taste (scored less than 6). People suggested seeking seedless character and more sweetness.

**Evaluation for Salt Tolerance**

Fruit and forage clone 1270 was planted in 20 kg capacity ceramic pots filled with soil of pH ranging from 8.1 to 10.0. The survival, growth and fruit production was drastically reduced beyond pH 9.2. Growth initiation was affected markedly by the pH levels of the medium. At pH 8.1, the growth started after 54 days of planting, whereas at pH 10.0 the sprouting took about 90 days. Though the plant survived at soil pH of 10 also, but the biomass production was almost negligible. Even the survival was reduced to less than 50 per cent at this level of pH. The five
clones were also planted in the microplots filled with different pH soil varying from 8.0 to 10.2. Similar response to soil pH was observed in the microplots as was recorded in the pots.

Management Practices

Being drought tolerant prickly pears are suited to those areas, where rainfall is scarce and unreliable and irrigation water is limited. The optimum conditions for its growth are available in summer rainfall regions having average rainfall between 300 to 600 mm. Hot sunny days and cool dry winter where temperatures do not fall below maximum 5°C are most suitable for cactus production. Cactus thrives best on sandy and sandy loam soils. However, it does well even on heavy soils with adequate drainage. Gravelly or stony lands especially at the foot hill slopes are also suitable. Cactus plantation can work as an excellent vegetative barrier for soil and water conservation, when planted on hill slopes in rainfed regions. Further, it thrives well on slightly alkaline soils rich in calcium and potassium. This indicates that any type of soil which is not suitable for other crops can be planted with cactus provided that area is not subject to prolonged waterlogging. A large part of India is, thus, suitable for its cultivation to generate alternate source of livelihood and employment.

Cactus can be planted both from seed and vegetative parts. However, the most common method of propagating cactus is by leaves that are at least one year old. The best way of planting is upright method in which one third portion of the cladode is below the ground and two-third above. Cladodes before planting should be allowed to dry under shade for 4 to 6 weeks to reduce the moisture content. Before planting, the leaves should be dipped in some common fungicide solution to check root rot caused by soil borne pathogens. Immediately after planting, 8-10 litres of water to each plant should be applied. It is better to plant on ridges to avoid flooding during rainy season. Since most of the feeding roots of cactus are very superficial, it is important that the upper 30 cm of soil is in good physical condition to promote maximum root growth. Cactus can be planted throughout the year, but the best time for its planting is September-October and February-March. Spacing depends upon the type of cultivar and the purpose for which the plantation is being raised. In general, cactus is reported to give best production when planted in rows 4 m apart keeping distance between plants 3 m. Cactus does not require additional irrigation if well distributed rainfall of about 500 to 600 mm is available. In case of sub optimal rainfall, 2 to 3 irrigations especially during fruit formation stage enhances production and checks the problem of fruit cracking and fruit drop. One supplementary irrigation is required during frost period to negate/moderate frost impact in drought prone areas.

Pruning is an important practice to give proper shape to the plants, reducing competition for light, improving yields, fruit quality, fruit size and rejuvenation of the plantation. The best time
for pruning is when the crop has been reaped and the plant is no longer growing actively. The thumb rule for pruning is that low hanging leaves should be removed first. The damaged and diseased leaves should also be removed. Sometimes, more than 20 fruits are borne on a single cactus cladode. In case fruits are allowed to stay for ripening, fruit size and quality are adversely affected. Pruning of fruits is important and to maintain optimum production, 10 to 15 fruits may be retained on each cladode.

Several dishes made from the fruit and cladode of cactus

**Thorns and Glochids**

Cactus has both thornless and thorny species. The spines may range from 1 to 3 cm in length whereas glochids are very small in size. The vegetable clone 1308 is almost free of glochids. However, even this variety has glochids on its older stems and cladodes. Unlike spines which are easy to locate and remove for human and animal consumption, the very small glochids makes identification and removal quite difficult. These small cladodes pose a problem in picking the fruits and cladodes. However, equipment and machinery is now available to completely remove both spines and glochids from *Opuntia* cladodes and fruits to be used for human and animal consumption.
Cactus Use

Cactus is used for several purposes but the most significant uses include: as a fruit and vegetable for human consumption, forage for livestock and as a red dye. Several other minor uses of cactus are: control of diabetes, ethanol production, as live fence and for industrial use of its galactomannan mucilage. Mexico is the largest producer of fruits with more than 100,000 ha area under its cultivation. Similarly, Sicily is the largest exporter of fruits to Europe. Countries like Brazil and Argentina have several hundred thousand ha of thornless cacti grown for forage purpose. The consumption of cacti as vegetable nopalitos is limited to Mexico and USA. Bolivia, Peru, Chile and South Africa are reported the dominant countries producing the red cochineal dye.

Cactus for Fruit Production

The most important use of cactus is to produce fresh fruits for human consumption. The size of fruits varies according to varieties and management practices. The fruit of mostly commercially grown varieties range between 110 g per fruit to about 160 g per fruit. The fruit colour varies from red, orange, purple, yellow and lime green. The edible portion in a total weight of fruit is about half of the total weight of the fruit. Sugar content mainly glucose is reported to range
A scene of fruit harvesting and packaging in Mexico for marketing

from 12-15% with a pH of 6.5. The fruit has 2.1 to 6.3 g of seeds. In general, the hard seeds are the major limiting factor for the acceptance of the people who consume it for the first time. However, seedless varieties are also available which have much wider acceptability. That seeds are also reported to have a very good quality oil, which consists of about 60% linoleic acid. The total fruit yields from cactus varies depending upon soil, climate, variety and management practices. For example, in Kingsville, Texas, with a rainfall of about 500 mm, the fresh weight fruit production ranged from 0.5 to 55 tonnes per ha for the 130 clones tried. Seven clones are reported to have more than 20 t per ha fruit production. However, in case even the best clones are grown without weed control or fertilization, the yield ranged between 1-3 t per ha. The four clones planted at CSSRI, Karnal farm yielded between 5-15 kg of fruit per plant six years after planting. The fruit production was maximum in clone 1270 and 1287.

Cactus for Livestock Feed

Since cactus has a higher conversion efficiency of water to dry matter than any other kind of plants, hence is highly useful as forage for cattle, sheep and goats. Another remarkable characteristic of this plant is that it can persist during dry periods when all other forms of cultivated and naturally growing herbaceous forage have vanished. There are more than 150 districts in India which are highly drought prone, this crop has tremendous potential to
augment forage production in those areas. The forage quality is reported quite comparable with several other cultivated nutritious forages. It is a highly digestible source of energy with about 70% dry matter digestibility but normally low in protein content. The average tentative chemical composition of cactus cladodes as reported in literature is: moisture content 85-90%, crude protein 5-12%, phosphorus 0.08-0.18%, calcium 4.2%, potassium 2.3%, magnesium 1.4%, energy 2.6 Mcal/kg, carotenoids 29 μg/per 100 g and ascorbic acid 13 mg per 100 g. The in vitro digestibility values reported are 72% for protein, 62% for dry matter, 43% for crude fiber and 67% for organic matter. Though the cactus is low in protein but its protein content can be increased appreciably with the application of fertilizers. Several experiments have been conducted in Texas and elsewhere which indicated that protein content improved with the application of nitrogen and P fertilizers. Similarly, the vitamins and trace elements supplementation are of utmost importance when cattle are fed for longer period of time on cactus. The trials conducted in Brazil and elsewhere on non-ruminants like pigs and rabbits indicated that rabbits like Brazilian forage variety 1270 than nopalitos variety 1308. Indian experience indicates that cactus is a preferred forage species for blue bulls. The plantations at Jhansi were frequently browsed by the blue bulls and other wild life.
Both the thorny and thornless varieties of forage cactus have advantages and disadvantages. Thorny varieties are preferred as biofence. To make effective use of thorny varieties as forage for cattle, spines need to be burned off over fires or with propane torches before utilization. It has been studied in Texas that one man using an 8 L propane tank and propane torch, can burn enough cactus to feed about 100 heads of cattle per day. Even the sound of the propane torch attracts animals from as far as 700 m away where the person is burning spines of cactus. Most of the thornless *Opuntia* varieties are not as cold hardy as spiny varieties. Therefore, care must be taken in selection for planting stock of spineless cactus forage varieties. There will also be a need for intensive management of domestic and wild life to keep the cactus resource from being over utilized.

**Cactus for Vegetable Production**

Cactus has several varieties which are used as vegetables. In Spanish, vegetable part is called nopalitos. Nopalitos are generally between 12 to 16 cm long, about 10 cm wide and 0.5 to 0.8 cm in the thickness. The most important cactus which yields nopalitos is *Opuntia ficus-indica*, most of the nopalitos have immature spines which need to be removed prior to being eaten. Similarly, glochids are also a problem which needs to be removed before eaten/cooking. However, clone 1308 being grown at Karnal is almost free of spines and glochids. The nutrition value of nopalitos has been reported to be comparable to lettuce and spinach.
A view of promising vegetable clone ready for marketing and export in Mexico

Salad preparations from vegetable clone
Red Cochineal Dye Production from Cactus

Cactus is also used for producing natural red cochineal dye. The dye is produced by the insects (*Dactyloptus coccus*) which is raised on cactus cladodes. Wild cochineal appears as white fuzzy clumps about 3-8 mm in diameter on the surfaces of cactus cladodes. On squeezing of these clumps, the red dye appears. However, wild cochineal can be a problem in commercial plantations in reducing the growth and development of the plants. In case of commercial cochineal production systems specially bred cochineal insects strains are used that have higher dye contents and are easier to remove from the cladodes. The world price of cochineal dye is reported to range from $20 per kg to more than $60 per kg of the dried product. The cochineal yield per ha has been reported to range from 100 to 200 kg of course with good management. Since cochineal dye prices show a great variation in the world market, caution must be exercised while making recommendation for large scale cultivation of cactus for cochineal dye production. The author visited several small land holding houses raising cactus for dye production in Mexico. The interaction with these entrepreneurs revealed that the profession is quite profitable and sustainable.
Medicinal Use of Cactus

The most widely acclaimed medicinal use of cactus is the control of diabetes. It has been reported that when 300 g or more of *Opuntia* stems were ingested, either cold, heated, boiled or blended, blood glucose levels decreased about 30-40 mg per dl in three hours. The undesirable side effects reported in the literature include increase in stool volume and abdominal fullness.

Mucilage Production for Binders and Thickening Agents

In general, about 3% of the weight of cactus is reported to be composed of a galactomannan mucilage. This mucilage is reported to increase the viscosity of solutions. These mucilages may be used as thickening agents in soups, confectioneries and plastering type agents. However, this use of *Opuntia* is not commercially exploited on a large scale.

Relevance for Rainfed Areas in India

Planting of trees and bushes like cactus on all kinds of wastelands, on field boundaries, road and railway track sides etc. in all drought prone areas of the country has tremendous potential to
International delegates visiting cactus experiments at Karnal

Automatic machines for grading of cactus fruits in Mexico for export
generate livelihood opportunities. The low cost of cactus establishment and production as well as its tolerance to drought make it well suited to become a viable future industry in rainfed India. There is a need to import promising cactus material from Mexico, Brazil, South Africa, Italy and Argentina for evaluation in India. There is also a need to develop a network programme for evaluation and promotion of cactus in dry land areas of the country. It is also required to organize one international workshop on cactus in India to sensitize scientists, developmental agencies and policy managers about cultivation and use potential of edible cactus.

**International Status**

The Food and Agriculture Organization (FAO), Rome is coordinating activities of cactus research and development in the world. More than 20 countries are participating in the FAO CACTUSNET. The CACTUSNET facilitates organization of meetings/workshops/congresses on cactus to review the progress of research, development and extension activities in various countries. Dr. Enrique Arias is coordinating research and promotional activities of cactus at the FAO headquarters. So far five International Cactus Congresses have been organized. The 6th International Cactus Pear and Cochineal Production Congress is scheduled to be held in Brazil in October, 2007. The proceedings of all the cactus congresses held in the past have been published and contain state of the art information on all aspects of cactus research, development, extension, post harvest value addition and marketing information. An International Journal “JPACD” is also being published by the US Professional Association of Cactus Research and Development.
Present Status of Cactus Research and Development at Karnal

To promote research and development aspects of cactus, the following activities have been initiated:

- The five clones have been planted in the herbal garden as 'demonstration site' for farmers, visitors to the institute and school students. Every year, a large number of visitors and students visit the herbal garden. Clone 1271 started fruiting about 16 months after planting in the herbal garden.

- To multiply germplasm for distribution to various research and development organizations a separate orchard has been established at CSSRI experimental farm, Karnal. This orchard is serving as permanent germplasm source.

- Studies for exploiting cactus potential in rainfed saline vertisols have been initiated at CSSRI, Regional Research Station, Bharuch, Gujarat.

- The four clones have been planted at Hisar (Haryana) farm of the institute for standardizing planting methods and irrigation requirement. The area represents dry land salinity. The annual rainfall at Hisar is 30-40 cm and the underground water is saline. The experimental farm offers good scope for biosaline agriculture research.
A view of current cactus experiments at Karnal
• The performance of five clones is being evaluated with saline water irrigation treatments of 0, 8 and 16 dS/m. Effect of saline water irrigation on chemical composition of cladodes is being periodically monitored.

• All the five clones have been planted in 20 kg capacity ceramic pots for studying salt tolerance and impacts of salts on chemical composition of the cladodes and fruits.

Further Reading


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