

## Opportunities for Development of Cactus (*Opuntia* spp.) in Arid and Semi-arid Regions

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**Abstract:** Cactus, a CAM plant, grows extensively in arid and semi-arid parts of the world. It possesses a very high water to dry matter conversion efficiency and has immense economic value as fruit, vegetable, fodder, medicine, etc. The importance of cactus pear as livestock feed has been discussed in detail, giving techniques for utilization as forage. Since the quality of the cactus cladodes does not deteriorate on storage and as they maintain green color as well as vitamin A level, they can provide an excellent source of fodder during the drought periods. The red/orange fruits of the cacti are edible, range in weight from 110 to 160 g and contain 12 to 15% sugar. The cladodes of the nopalito cacti are used as vegetable. Some of these types are known to reduce blood sugar level in the human body. Cactus pear is also a source of red cochineal dye and mucilage for binders and thickening agents. The status of recently introduced cactus pear clones in Indian arid and semi-arid regions has been discussed.

**Key words:** Cactus pear, CACTUSNET, CAM plant.

Cacti hold great promise, especially for arid lands, due to their greater conversion of water to dry matter than either C<sub>3</sub> or C<sub>4</sub> plants. This greater conversion efficiency is due to their specialized photosynthetic mechanism, known as Crassulacean Acid Metabolism (CAM). The primary attribute of this system is that carbon dioxide is taken up at night when the water gradient from inside to outside the leaf is the lowest, thus achieving greater carbon dioxide fixed per unit water transpired. Two recent works have validated the greater efficiency of CAM plants in field studies (Silva and Acevedo, 1995; Han and Felker, 1997),

showing the conversion of water to dry matter is as low as 162 kg water kg<sup>-1</sup> dry matter. For example, with 662 mm of rainfall, 285 mm was actually transpired by the slow growing spineless *Opuntia elisiana* to produce 17,670 kg dry weight ha<sup>-1</sup>. It is also significant that the total fresh weight growth of 194,200 kg ha<sup>-1</sup> contained 170,000 kg ha<sup>-1</sup> of water that would greatly reduce the water needs for livestock in drought periods.

While cacti are lower in protein than many other plants, the protein content of the cladodes can be increased with fertilization, use of different clones or through

association with free-living N fixing bacteria such as *Azospirillum*. As discussed later, Gonzalez (1989) has shown that with N fertilization every other year, the protein content of wild *Opuntia* increased from 6% to nearly 11%. Gregory and Felker (1992) found that forage clones varied greatly in their protein and phosphorus contents, with some clones having nearly 11% protein when other clones had only 6%. The possibility of increasing the protein content of the cladodes is through association with N fixing bacteria, i.e., *Azospirillum*. An Indian (Rao and Venkateswarlu, 1982) and a Mexican study (Mascarua-Esparza *et al.*, 1988) both confirmed N fixation with a symbiotic association between *Opuntia* and *Azospirillum*.

In addition to the high conversion efficiency of water to dry matter, there is great genetic diversity in cacti for economically useful characters. There are about 200 species of the flat stemmed *Opuntia*, native to the Western Hemisphere, that occur naturally from Alberta, Canada to 40°S latitude in Argentina. However, most of the useful fruit cultivars have their origins in Mexico. While there are few chromosomes in *Opuntia* ( $n=22$ ), diploid, tetraploid and octaploid *Opuntias* are common. Pimienta-Barrios (1994) has hypothesized that the commercial fruit cultivars in Mexico today have resulted from asexual propagation by early man of natural tetraploid and octaploid hybrids.

*Opuntia* has both spineless and spiny species. In addition to spines which may range from 1 to 3 cm in length, *Opuntia* also has glochids. These glochids, which are nearly microscopic "spines" arise from the areole where the spines, if present,

also arise. While there are numerous cacti which lack spines, only the Texas A&M 1308 nopalito variety has a tendency to be free of glochids. Even the 1308 variety has glochids on its older stems and cladodes. Unlike spines which are easy to locate and remove, the very small size of the glochids makes identification and removal quite difficult. Fortunately, equipment has been developed to completely remove both spines and glochids from cactus cladodes to be used for human consumption.

A major distinction must be made between succulents of the New World family Cactaceae and succulents of the Old World family Euphorbiaceae. As a result of convergent evolution, many of the cacti and euphorbias have very similar external appearance. However, unlike the milky latex of the euphorbias that can cause serious damage to the eyes, there are no compounds in normal doses of flat stemmed *Opuntia* that can cause serious health hazards. However, some of the small, columnar cacti possess hallucinogenic compounds. No doubt, the great aversion of farmers in the old world to human consumption of cacti arises from associations with euphorbias.

There are four major uses of *Opuntia*, i.e., as a fruit, a vegetable, livestock feed, as a red dye and several minor uses, i.e., for use in control of diabetes and for industrial use of its galactomannan mucilage. Mexico is the largest producer of fruit with over 100,000 ha in fruit production. Sicily is the largest exporter of fruits to Europe. Brazil has several hundred thousand ha of spineless cacti planted for forage. Only in Mexico, and to a limited extent in the

United States are nopalitos consumed as a vegetable. Bolivia, Peru, Chile and South Africa are the main countries producing the red cochineal dye.

### Cactus for Livestock Feed

*Opuntia* is useful as forage for cattle, sheep and goats, primarily because cactus has a higher conversion efficiency of water to dry matter than any other class of plants, and because cactus can persist during dry periods when all other forms of herbaceous forage have vanished.

#### *Nutritional properties and supplementation requirements*

While the composition of cactus may vary considerably, it is a highly digestible source of energy with about 70% dry matter digestibility that is normally low (about 6%) in protein. Typical ranges for cactus are: 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<sup>-1</sup>, carotenoids 29 µg per 100 g and ascorbic acid 13 mg per 100 g. The *in vitro* digestibility values are 72% for protein, 62% for dry matter, 43% for crude fibre and 67% for organic matter.

While native cactus is low in protein, i.e., about 6%, the protein content of unselected native *Opuntia lindheimerii* was increased from 6% to 10% with N and P fertilization. The higher protein percentage should be adequate for livestock without protein supplementation.

Texas rancher Bill Maltzberger of Cotulla, Texas, has spent many years developing protein and mineral supplements for his Santa Gertrudis cattle. When cattle are fed cactus that has its spines burned off (as discussed later) and that is supplemented with protein cubes and mineral supplements, excellent weight gain, body conformation and 90% conception rates have been achieved. The protein, mineral and daily rations are provided in Tables 1, 2 and 3.

Table 1. Protein supplement for cattle

Ingredient	Amount (kg)
Cottonseed meal	427.0
Soybean meal	405.0
Manganese sulfate	2.5
Zinc oxide	1.35
Copper sulfate	1.1
Vitamin E-20	2.8
Cobalt sulfate	0.072
Ethylenediamine dihydriodide	0.022
Selenium oxide mixture (0.02%)	0.056
Masonex (Clay binder)	11.2
Molasses	48.0
Total	900.0

Data courtesy Bill Maltzberger, Rancher, Cotulla, Texas.

Table 2. Mineral supplement for cattle for cactus supplementation

Ingredient	Amount (kg)
Bone meal	410.00
Meat and bone meal	136.00
Sodium chloride	272.00
Manganese sulfate	20.00
Zinc oxide	10.00
Copper sulfate	9.00
Vitamin E-20	22.00
Cobalt sulfate	0.56
Ethylenediamine dihydriodide (EDDI)	0.18
Selenium mixture (0.02%)	0.45
Vitamin A-30	3.30
Molasses	23.00
Total	900.00

Data courtesy Bill Maltzberger, Rancher, Cotulla, Texas.

Since cacti are rarely fertilized in rangeland situations, it is essential to provide significant quantities of protein supplement for cattle. If the cacti were fertilized or obtained from prunings of well fertilized cactus fruit orchards, the amount of protein supplementation required would be greatly reduced. The protein ration in Table 1 is formulated in the form of 2 cm cubes and contain both soybean and cottonseed meal, trace elements, vitamin A-30, Vitamin E, molasses and the clay binder masonex to give it form. These cubes are only fed during drought periods when no other forage is available. The mineral supplement in Table 2 contains additional phosphorus and calcium in the form of meat and bone meal that is not contained in the protein

supplement. This mineral supplement is made available all the year round, regardless of drought status.

The vitamin and trace element supplementation are of utmost importance when cattle are fed for extended periods of time on cactus (even longer than 1 year). Since no one plant has a balanced mineral and/or vitamin concentration, and since after many months of drought conditions herbaceous forage is not available, it is absolutely critical to supplement the cattle with protein and mineral supplements during these extended drought periods when no other forage is available.

While the feed rations have been well worked out for cattle it is reasonable to

Table 3. Daily ration for adult cow with calf

Fresh cactus	40.0 kg
Protein supplement	1.4 kg
Mineral supplement	0.1 kg

(The mineral supplement is fed all year long while the protein supplement is fed during droughts)

expect that these rations could be easily adapted to other ruminants such as goats, sheep and deer. There are some very old reports of cactus being fed to pigs. However, well replicated trials feeding cactus to non-ruminants like pigs have not been conducted. Lukefahr and Ciro-Ruiz (pers. comm.) have successfully fed an *Opuntia* strain (1270) from Brazil (palma redonda) to rabbits. It is interesting that rabbits did not like the nopalito variety *O. cochinillifera* 1308, but they liked Brazilian forage variety 1270.

#### *Thornless vs thorny cactus forage varieties*

There are significant advantages to both thorny and thornless cactus varieties. Thornless varieties must be fenced to prevent cattle and wildlife from total consumption of plantings less than 2 years old. In Texas, deer, javelina and rabbits will completely consume new thornless plantings.

In contrast, thorny varieties do not have to be fenced, but the spines must be burned off over fires or with propane torches before utilization. By purchasing propane in large truck loads (40,000 L truck<sup>-1</sup>) in Texas it is possible to purchase propane for \$0.11 L<sup>-1</sup>. In good stand of native *Opuntia lindheimerii* one man, using an 8 L propane tank and propane torch, can burn enough cactus to feed 100 heads of cattle per day using 1.0 to 1.3 L propane per animal. While it takes labor to burn spines from cactus, there are some useful management options that result from burning spines from cactus. Since the cattle do not eat cactus that is not burned, burning allows control over the amount of cactus that is used per day. Additionally, cattle quickly become acquainted with the sound of the propane burner and can be drawn for up to 700

m in the brush to the sound of a propane cactus burner. This conditioning to the sound of the cactus burner allows cattle to be drawn into corrals and pens.

Thornless cactus varieties offer the advantage of not having to burn off the spines, but intensive management of domestic stock and wildlife is necessary to keep the cactus resource from being overutilized. As the thornless *Opuntia* varieties are not as cold hardy as spiny varieties such as *Opuntia lindheimerii*, care must be taken in selection for planting stock of spineless cactus forage varieties.

If freezing weather is not a concern (minimum temperatures not lower than -5°C for a few hours), the Brazilian forage variety 1270 is especially promising as it was found to have rapid growth and nearly 10% crude protein vs 6-9% protein for other varieties (Gregory and Felker, 1992). A spineless variety, that is possibly a hybrid between the Texas native *Opuntia lindheimerii* and some *O. ficus-indica* type (accession 1233), suffers minor damage from temperatures as low as -12°C that causes complete mortality to accession 1270. This variety 1233 is almost as fast growing as Brazilian clone 1270. In areas where extended temperatures of -18°C routinely occur, the only spineless type that is cold hardy, is the slow growing *Opuntia ellisiana*. On a 1.2 by 1.2 m spacing with good care this selection will only produce 1600 kg ha<sup>-1</sup> dry matter the first year and 4400 kg dry matter the second year. However, once its leaf area index reached 1, the dry matter produced was 11,000 kg ha<sup>-1</sup> in the third year, and 17,670 kg ha<sup>-1</sup> in the fourth year.

Given yearly fresh weight production rates in excess of 100,000 kg ha<sup>-1</sup> after a leaf area index of 2 has been achieved, and cattle consumption rates of 40 kg day<sup>-1</sup>, it would appear that at a stocking rate of 1 cow ha<sup>-1</sup>, livestock could never consume cactus faster than it grows. Thus it would seem possible to plant, cultivate and care for cactus until it is about 1 m in height, at which time livestock could be admitted to the cactus pastures at stocking rates of 1 head ha<sup>-1</sup>.

#### *Comparison of cactus to hay*

Spiny or spineless cactus has been compared by farmers to "hay in the barn". With up to 200 t ha<sup>-1</sup> of fresh weight, several ha of cactus can provide a considerable reserve of animal feed during drought periods. Unlike hay stored in the barn, the cactus in the field does not deteriorate in quality with storage and there are no problems with rats eating the hay in storage. Even during drought periods in the summer or winter, cactus is green with vitamin A and only needs to have the spines burned off or cattle admitted to the fenced area. In drought periods cattle have to walk a long way to get water. If they are supplemented at one location by the rancher they must walk to this location every day. By consuming 40 kg of cactus per day, containing about 85% water, cattle are also consuming 35 L of water/day which can be beneficial in drought periods.

Either spiny or spineless *Opuntia* clones when planted in rows, fertilized and weeded, can achieve annual dry matter and fresh weight yields of 17,000 kg ha<sup>-1</sup> and 170,000 kg ha<sup>-1</sup>, respectively, with crude protein concentrations about 10%. When properly

supplemented with protein, trace elements and critical vitamins, excellent growth and conception rates are possible.

#### **Cactus for Fruit Production**

The most widely known use of cacti is to produce fresh fruits for human consumption. The fruits of commerce range from about 110 g fruit<sup>-1</sup> to about 160 g fruit<sup>-1</sup> with many colors, i.e., red, orange, purple, yellow and lime green. The edible portion is slightly more than half the fruit weight and is located in the interior of the fruit. At maturity the fruit has a sugar content (mainly glucose) of 12-15%, pH of 6.5 and from 2.1 to 6.3 g of seeds fruit<sup>-1</sup>. The hard seeds are the primary deterrent to acceptance by first time consumers.

*Opuntia* seeds contain a very good quality oil, consisting primarily of linoleic acid (60%). Unfortunately, since the seeds are very hard and the oil content is quite low (from 6 to 20% of the seed weight, Pimienta, 1991), it is difficult to commercially extract this oil. Even so, a noted Texas Chef, Jay McCarthy, has found the ground seeds to be an excellent food additive since it has a chocolate, cumin flavor.

When intensive dryland farming operations are performed for cactus fruit production, the yields can be quite high. In 1996 in Kingsville, Texas, with a rainfall of 500 mm, the fresh weight fruit production ranged from 0.5 to 55 t ha<sup>-1</sup> for the 130 clones. Seven clones had more than 20 t ha<sup>-1</sup> production and 15 clones had fruit production greater than 10 t ha<sup>-1</sup>. In 1996, the total soluble sugar content of all clones with productivity greater than 10 t ha<sup>-1</sup> ranged from 11.6 to 14.6. The Texas work

(Karim *et al.*, in review) suggests that NPK fertilization and perhaps Mg fertilization can increase the total soluble sugar content of the fruits.

When even the best fruit clones are grown without weed control or fertilization the yield will typically be of the order of 1-3 t ha<sup>-1</sup> with low sugar contents.

The major difficulty in growing cactus fruit varieties in Texas is due to severe freezing weather that comes from Canada about once every 10 years. These severe events are associated with below freezing temperatures for 2-3 days consecutively with absolute minimum of about -12°C. Following disastrous freezes of -12°C in 1983 and 1989, we have concentrated our efforts in genetic improvement in locating clones with superior cold hardiness. Since 1989, we have made an additional 70 collections for cold hardiness and fruit production.

### Cactus for Vegetable Production

Cacti are also managed to produce a green vegetable, called nopalitos in Spanish (nopal=cactus, ito = little). Historically nopalitos were harvested in the spring as new tender regrowth, despined and then eaten. Consumption of nopalitos came to be associated with the Christian season of Lent in Mexico when meat was to be avoided. Nopalitos are typically from 12 to 16 cm long, about 10 cm wide and 0.5 to 0.8 cm thick. Nopalitos mainly come from *Opuntia ficus-indica*, but some nopalitos arise from *Opuntia cochenillifera*. On most nopalitos there are immature spines that must be trimmed prior to being eaten. Glochids are also a problem on nopalitos and must be removed. However, the young

tender regrowth of a recently released variety "Texas A&M 1308" contains almost no glochids or spines and does not require despining.

Due to CAM metabolism, in which carbon dioxide is taken up at night, stored as malic acid and converted to sugars during the day time, nopalitos are quite tart when harvested in the morning (like a green apple). In contrast, the nopalitos have much less acidity when harvested in the afternoon when their taste is more like a bell pepper.

Nopalitos also contain about 3% mucilage by dry weight. This mucilage is a galactomannan polymer, which has a mouth feel similar to okra. As this mouth feel is liked by many consumers, nopalitos are typically boiled and the water, containing the galactomannan mucilage, is discarded as a first step in cooking. However, the 1308 nopalitos have less mucilage and can be eaten fresh in salads without first boiling and discarding the mucilage.

The nutritional value of nopalitos has been described by Cantwell (1995) as intermediate between lettuce and spinach. However, it must be pointed out that cultivation of either lettuce or spinach in arid regions with temperatures exceeding 35°C is most difficult. The young tender growth of cacti, necessary for nopalito production, will not occur during extended hot dry periods without water. However, the plants will not die during this extended drought period. Comparing the water/heat requirements for nopalito production and other green vegetables, i.e., spinach, lettuce, green beans, clearly nopalito production is the most tolerant of high temperatures and drought conditions.

## Cactus for Production of the Red Cochineal Dye

The Spanish conquerors of Mexico became enamored with the red dye produced by an insect on cactus and sent large quantities back to Spain (Flores-Flores and Tekelenburg, 1995). This cochineal dye produced by the insect (*Dactylopius coccus*) was the first color-fast red dye in Europe. The royal red color of British red coats has been attributed to use of cochineal dyes.

With the advent of synthetic dyes in the early part of the 20th century, the usage of the cochineal dyes greatly declined. However, today there is a resurgence of interest in cochineal dyes for uses in cosmetics and in the food industry. As cochineal is a naturally occurring compound, it is not subject to the same food additive regulations in the United States as the synthetic dyes. These reduced regulation requirements have been a major impetus to use of cochineal dyes in the United States.

Wild cochineal appears as white fuzzy clumps about 3-8 mm in diameter on the surfaces of cactus cladodes. If these clumps are squeezed the red dye will appear. Wild cochineal can grow on both the fruit and the cladodes. Wild cochineal can be a problem in commercial plantations in reducing the vigor of the plants. In open fields, wild cochineal generally occurs near the bottoms of the plant and on its interior portions where it is protected from the wind and the rain. Inside greenhouses, where there is no rain or wind, cochineal can severely damage and kill some *Opuntias*.

In commercial cochineal production systems, specially bred cochineal insect strains are used that have higher dye contents and that are easier to remove from the cladodes. In very low rainfall areas of Chile, fields of *Opuntia* are infected with advanced cochineal strain by physically attaching small packets of eggs directly to the cladodes. After the entire cladode becomes covered with cochineal, the cladodes are harvested and the cochineal insects are blown off the cladodes with compressed air. In South Africa, where higher rainfall would wash the cochineal insects from the cladodes, the cladodes are cut from plants and incubated indoors with special strains of cochineal.

The world price of cochineal dye has undergone considerable fluctuation from a low of \$20 kg<sup>-1</sup> to more than \$60 kg<sup>-1</sup> of the dried product (Flores-Flores and Tekelenburg, 1995). The cochineal yield per hectare has been reported to range from 100 to 200 kg ha<sup>-1</sup> with good management. Due to the high labor requirements, \$20 kg<sup>-1</sup> is not economical even in countries with low labor costs. In 1996, cochineal prices were greater than \$60 kg<sup>-1</sup> which made cultivation economically very attractive even in advanced countries like Chile. Due to the very large oscillations in world market prices for cochineal, caution should be exercised in recommending this venture to farmers with low cash reserves.

## Medicinal Uses of Cacti

While cactus is probably used for many medical problems, consumption of nopalitos to control type II diabetes is the most widely used medical application. Throughout the

culture of rural Mexico, it is a widely held belief that consumption of nopalitos will reduce blood sugar levels and insulin levels in people with type II diabetes (Felker, unpub. obs.). Frati *et al.* (1990) has been the leader in the examination of use of *Opuntia* to control diabetes.

When 300 g or more of *Opuntia* stems were ingested, either cold, heated, boiled or blended, blood glucose levels decreased about 30 to 40 mg per dl in three hours. Undesirable side effects were only an increase in stool volume and frequency and abdominal fullness (Frati, pers. comm.).

#### **Cacti as a Producer of Mucilage for Binders and Thickening Agents**

Ting (1994) has reviewed the uses of gums and mucilages in cacti. About 3% of the weight of cactus is composed of a galactomannan mucilage. This mucilage increases the viscosity of solutions in a pH-dependent manner reaching an optimum viscosity of 58 cps at pH 6.6 (Saenz-Hernandez, 1995). These mucilages may be useful as thickening agents in soups, confectioneries and other food products. There are popular articles that describe use of mucilage (macerated cacti) to facilitate "plastering type agents" adhering to churches in southwestern United States.

There has been no effort devoted to examination of mucilage from *Opuntia* as an industrial or food product. Due to the massive quantities of *Opuntia* possible per hectare and desirable by-product use for animal feed, it would seem reasonable to explore uses of mucilages in opuntias.

#### **Planting, Cultivation, Fertilization and Care**

The most common problem with new cactus plantings is rot of the plant material at the surface where it was cut or broken off. Cactus cladodes should either be dried in the shade for several days to allow the cut surface to "heal over" or the new cladodes treated with a lime/copper sulfate solution to control bacterial rots. The soil should be ploughed and cultivated as well as for any other crop. Cladodes should be planted about 1/3 of their height with the flat surface facing east-west.

During their initial growth stages, the growth of cactus can be severely retarded by grass and other herbaceous vegetation. Thus it is important to provide good weed control, until the cactus is well established. Preemergent herbicides such as karmex, simazine and triflan provide good weed control without harming cactus. If no pre-emergence herbicides are available, it is essential to plant the cactus in such an arrangement that provides for easy and frequent mechanical weed control such as disking. If a 2.5 m wide disk is available for weed control, it is suggested to plant the cactus on a 1 m by 4 m row spacing to allow easy access of the disk and tractor down the rows. As discussed later, after the cacti reach a height of more than 1 metre, livestock can be admitted at rates of 1 cow per ha. At this time the cattle will consume both the grass (weeding the cactus) and the cactus, thus no longer requiring weed control for the cactus.

While *Opuntia* has the appearance of a drought resistant plant, it is not as tolerant of severe drought conditions as *Prosopis juliflora*. The noted cactus authority, Henri

LeHouerou believes that cacti cannot be grown in Sahelian Africa where temperatures of 45°C and air humidities less than 30% occur due to low night time humidities. Thus it remains to be seen if the economically useful cacti will grow and thrive under the harsh conditions (>45°C and rainfall, <300 mm yr<sup>-1</sup>) of the Rajasthan desert.

When the Texas native, spiny *Opuntia lindheimerii* was fertilized with 224 kg N ha<sup>-1</sup> and 112 kg P ha<sup>-1</sup>, the crude protein increased from 4.5% to 10.5% and the dry matter productivity increased from 7 t ha<sup>-1</sup> yr<sup>-1</sup> to 60 t ha<sup>-1</sup> yr<sup>-1</sup> (Gonzalez, 1989). Gonzalez (1989) recommended fertilizing cactus with 224 kg ha<sup>-1</sup> N every 2 years to maintain crude protein levels about 10% with dry matter productivities in the 50 t ha<sup>-1</sup> yr<sup>-1</sup> range.

### International Collaborative Networks on Cactus

FAO coordinates an International CACTUSNET with about 22 participant countries. There have been 3 international FAO CACTUSNET congresses in Santiago, Chile, Guadalajara, Mexico, and South Africa. The excellent 215 page reference (Barbera *et al.*, 1995) produced by the CACTUSNET is a most welcome contribution.

A society of cactus professionals, including chefs, medical researchers, growers, food technologists, marketers and scientists, has been formed to promote development of cactus worldwide. This Professional Association for Cactus Development (PACD) is intended to compliment the work of FAO as a professional society. The PACD publishes the Journal of the Professional As-

sociation for Cactus Development, and also assists with a computer e-mail network.

### *Opuntia* Germplasm Introduction in India

In anticipation of an Indo-US collaborative research program on *Opuntia* in India, 33 *Opuntia* clones were taken to the Nimbkar Agricultural Research Institute at Phalton, India, about 1987. All these clones grew well under the semi-arid agroclimate of western Maharashtra and some have also produced fruits. In 1991, Karnal obtained 5 fruit, forage and nopalito clones from Texas. In January 1997, 51 additional *Opuntia* clones were shipped from Texas A&M University-Kingsville to the National Research Centre for Arid Horticulture in Bikaner. The last germplasm exchange contained thorny and thornless varieties of red, orange, yellow and lime green fruits that ranged up to 200 g in fruit size. As less than 1 cladode of each clone was shipped to reduce air freight costs, several years will be required to produce sufficient material for distribution. The Indian authors of this publication will discuss the current status of the multiplication and evaluation of these materials in India.

#### *Introduction in Bikaner*

Since cactus pear has several uses and can grow well with low inputs even under wasteland conditions, great potential was recognized for its adoption as a commercial crop in arid region of India. Forty one clones of cactus pear (39 exotic and 2 local collections) introduced in 1987 at Nimbkar Agricultural Research Institute, Phalton (Maharashtra) and 5 exotic clones introduced in 1990 at Central Soil Salinity Research Institute, Karnal, were planted at

Bikaner during 1996. These clones established well and have started growing. In general, fruiting type clones were slower in initiating growth compared to nopalitos and fodder types. So far, flowering has not been observed except in clone 1269. Of the 51 clones obtained from Texas A&M University, Kingsville, in January 1997, 48 have survived. Some local clones have also been collected.

Studies are in progress laying emphasis on identification of suitable clones having high productivity potential under rainfed as well as intensive cultivation systems and standardization of agrotechniques and post-harvest uses. The compatibility under agroforestry systems in this region should also be assessed. Since consumption of cactus pear fruits and nopalitos is almost unknown in this region, a strong extension effort would be necessary to create awareness regarding nutritive value and different methods of utilization. A good extension service must also take into account not only the need for multiplication and supply of planting material but also popularization of the package of practices for cultivation.

#### *Introduction in Karnal*

Keeping in view the potential uses of cactus and its low water requirements promising clones from Texas A&M University were introduced at Karnal (Table 4). The clones were planted in ceramic pots having 20 kg soil blended with 1 kg FYM in 1991 for germplasm evaluation and multiplication. The vegetable clone 1308 took nearly 57 days for sprouting, while the fruit clone 1287 took 85 days and was last to sprout. Cactus performance was also

evaluated in soils having pH from 8.1 to 10.0. The growth initiation was delayed with increasing sodicity in the growth medium. For example, at pH 8.1 the growth started after 54 days while at pH 10.0 the sprouting took 90 days. The number of cladodes formed declined significantly with increasing pH. In April 1995, after three and a half years of planting, flowering started and fruits developed. The fruits ripened by the first fortnight of June and harvested by July 20, 1995. The fruiting was maximum in clone 1270 and minimum in 1287. The fruits were oval in shape, pale green in color, and 50-100 g in weight. The clone 1270 bore 8 to 15 fruits with a total yield of 2 kg plant<sup>-1</sup>. Based on the results obtained at Karnal it is concluded that cacti can be grown as a companion crop with low water demanding and highly salt tolerant trees of the genus *Prosopis* to augment fuelwood, forage, fruit and vegetable needs of the inhabitants in the arid environments.

#### **Conclusions**

Cactus has a very high water conversion efficiency of water to dry matter, is drought hardy and can be used as a fruit crop, a vegetable crop, a source of dyes, a medicinal, a source of industrial chemicals and to provide a critical source of dry season forage for arid regions. A great diversity of useful genetic materials is now being multiplied for distribution and evaluation in India. The resourcefulness of India's farmers when combined with excellent technical skills in its universities and research institutions will undoubtedly make great advances in economic development of arid lands with these new materials.

Table 4. Days taken for growth initiation and number of cladodes formed by different cactus clones at Karnal, India.

Clone	Uses	Days taken for sprouting	Cladodes per plant
1308	Very fast growing vegetable variety	57	6
1270	High protein forage and fairly pale green fruits	68	4
1271	Fast growing and fairly sweet fruits	91	3
1280	Thornless with pretty good yellow fruits	98	2
1287	Thorny but best fruit variety	100	1

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