The Prickly-pears (Opuntia spp., Cactaceae): A Source of Human and Animal Food in Semiarid Regions

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The Prickly-pears (*Opuntia* spp., Cactaceae): A Source of Human and Animal Food in Semiarid Regions[1]

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The Cactaceae contain many economically promising species primarily in the genus Opuntia. *This genus appears to have its center of genetic diversity in Mexico where it is widely used as fodder, forage, fruit, and a green vegetable. In southwestern United States, the prickly-pears have been considered as both weeds and valuable forage plants. During the frequent, unpredictable droughts, propane torches known as "pear burners" are used to singe the spines off cactus pads so that they can be eaten by livestock. Although spineless varieties of* Opuntia *can be consumed directly by domestic livestock, they are extremely susceptible to herbivory by wildlife. The Cactaceae possess Crassulacean Acid Metabolism, which can be four- to five-fold more efficient in converting water to dry matter than the most efficient grasses. Some* Opuntia *strains grow rapidly with fresh-fruit yields of 8,000–12,000 kg/ha/yr or more and dry-matter vegetative production of 20,000–50,000 kg/ha/yr.*

The Cactaceae contain about 130 genera and perhaps 1,500 species, which were originally native to the New World (Benson 1982; Monjauze and Le Houérou 1965). Cacti have a special carbon dioxide fixation pathway, known as Crassulacean Acid Metabolism (CAM), and can have a four- to five-fold greater efficiency in converting water to dry matter than even C-4 plants such as maize (Kluge and Ting 1978). Being so water-use efficient, they should be useful in arid and semiarid regions. In addition certain genera, such as *Opuntia* and *Nopalea,* have economically useful plant parts.

The fruits of domesticated *Opuntia* cultivars (Fig. 1), known as prickly-pears in the southwestern United States or *tunas* in Latin America, can be very sweet and are highly regarded. They are sold as a dessert fruit in the markets of California and other states with large Latin American and Mediterranean populations, Chile (Felker, unpubl. obs.), Mexico (Hernández X. 1970), Brazil, North Africa, and many Mediterranean countries, such as Spain, Italy, and Greece (Monjauze and Le Houérou 1965). The tender young pads (vegetative portions) of *Opuntia* and *Nopalea* species, known as *nopalitos,* are extensively used as a fresh green vegetable in Mexico and southern Texas.

The pads of *Opuntia* and *Nopalea* (depending on the taxonomic treatment) can be spiny or spineless and are widely used in semiarid regions for animal fodder and forage. (We use "fodder" to indicate plant material grown and harvested for livestock; "forage" is plant material that range animals seek and consume on the range.) Before the spiny varieties can be safely consumed by livestock, the spines must be burned off with a propane torch known as a "pear burner."

Although cacti are often low in protein, their digestible-energy production per unit of rainfall is high. Thus cactus growth should be less nitrogen limited than

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Fig. 1. Prickly-pear (*Opuntia lindheimeri*) in South Texas. Note the fruits (*tunas*) on the old pad in the foreground and the 3-mo-old pads in background without fruit.

other plants, and cacti should provide a good complement to semiarid-adapted, nitrogen-fixing, high-protein plants such as *Leucaena* (Brewbaker and Hutton 1979) and *Prosopis* (Felker and Clark 1982).

Felger (1979) described three major growth forms of economically important cacti: the large columnar cacti, the shrub- to small-tree-sized prickly-pears and chollas, and the small, pin cushion cacti. The large columnar cacti such as saguaro (*Cereus giganteus* Engelm.), which possess sweet fruits, grow too slowly to be economically useful (Crosswhite 1980).

The shrub- to small-tree-sized prickly-pears and chollas probably contain the most promising germplasm for economic development. The subgenus *Opuntia* contains 150–300 species, depending upon the taxonomic treatment (Monjauze and Le Houérou 1965). Contained in this subgenus are *O. lindheimeri* Engelm., a species native to South Texas, *O. phaeacantha* Engelm., the Sonoran Desert prickly-pear with sweet, juicy fruits (Felger 1979), and *O. ficus-indica* (L.) Mill., a large, spineless, domesticated prickly-pear (Felger 1979).

The third major growth form of cactus is the small, pin-cushion type exemplified by *Mammillaria microcarpa* Engelm. This cactus has fleshy, sweet and tart, spineless fruits about 2.5 cm long. Felger (1979) recommended commercialization of this species as a strawberry-like specialty crop.

Felger (1979) cited work indicating a high degree of hybridization potential within the Cactaceae. *Opuntia* species are diploid with $2n = 22$, and they readily form diploid, tetraploid, or octoploid interspecific hybrids, which can be propagated vegetatively (Hernández X. 1970).

Opuntia ficus-indica was introduced into Spain by Christopher Columbus on his first return trip from the New World. Within a short time it became naturalized throughout Spain. In 1610, when the last remaining Moors were expelled from Spain, they took it to North Africa, where it became widely naturalized. Due to Spain's influence, *O. ficus-indica* had spread throughout Italy, Greece, and other Mediterranean countries by the end of the 18th century (Monjauze and Le Houérou 1965). In the Canary Islands the cochineal dye industry became so important that between 1831 and 1874 whole grain fields and vineyards were converted to cactus plantations to grow the cochineal insect (Evans 1967). In 1965, *O. ficus-indica* plantings occupied 100,000 ha in Sicily, 6,000 ha in Sardinia, and 60,000–80,000 ha in Tunisia (Monjauze and Le Houérou 1965). In 1984, commercial *Opuntia* plantings for fodder, forage, fruit, or vegetable existed in Argentina, Brazil, Chile, Mexico, Algeria, South Africa (Russell and Felker, unpubl. obs.), and presumably other semiarid regions of Latin America and Africa.

Although cacti are associated primarily with dry subtropical areas, *Opuntia fragilis* grows as far north as about 56° in Alberta (Moss 1983) and *O. polyacantha* Haw. naturally occurs at 53°N latitude in that province. *Opuntia australis* Weber occurs at 50°S latitude in Patagonia, Argentina. *Opuntia rafinesquei* Engelm. has become naturalized in the mountains of Switzerland and is undoubtedly one of the *Opuntia* species with the greatest cold tolerance (Monjauze and Le Houérou 1965).

In this paper we review the uses of the prickly-pears based on our collection of published and unpublished literature and on our field work in Mexico and South America. We have found the taxonomy of the group to be confusing, no doubt

due to the asexual propagation of interspecific hybrid swarms, as well as its propagation as a crop in so many arid and semiarid regions. Where possible we have attempted to follow the taxonomic treatment of Benson (1982). However, some of the names mentioned in European and South American literature are not listed by him.

PRICKLY-PEARS AS A FRUIT CROP

Griffiths and Hare (1907) reported that, in 1905, Italian varieties of prickly-pear fruits were available on the markets in Washington, DC, for several months. Cactus fruits in commercial use were typically 2–7 cm in diameter, pear- or fig-shaped, and yellowish green to dark purple. The amount of pulp in these early varieties was reported to range from 30 to 60% with the best-tasting varieties containing the largest amount of pulp.

We have purchased red fruits in supermarkets in southern California and yellow-green fruits in Santiago, Chile; we have observed cactus fruits on sale in Bellagio, Italy, on the Swiss border; and we have been served a delicious light yellow *tuna* with a commercial airline meal in Chile.

The fruits are swept through grass or rubbed on an abrasive surface to remove small spines called glochids. They are then peeled and sliced prior to being served. The pulp-to-seed ratio and the shelf life compare favorably with traditional fruits on the commercial U.S. market. Thus consumer acceptance should not be a problem if prickly-pears were commonly available in this country.

Griffiths and Hare (1907) described various cottage industries that prepared products from juices squeezed from prickly-pear fruits. Among those products were *miel de tuna* (*tuna* honey); a molasses-like product, *queso de tuna* (*tuna* cheese); a product similar to pulled taffy; *colonche,* a fermented drink; and *tunas secas* or dried *tunas.* They also reported on growth habits, fruit sizes, and fruit composition of 23 locally domesticated fruit-producing cultivars. These cultivars had common names such as *tuna mansa morada* (mulberry colored), *tuna agua-mielilla* (honey water), *tuna camuesa* (pippin apple), and *tuna durasnilla colorada* (red peach), suggesting positive flavorful associations.

Chemical analysis by the U.S.D.A. Agricultural Products Quality Research Laboratory in Weslaco, Texas, of a commercial Chilean cultivar that we grew in our greenhouse, revealed that the fruits had a pH of 5.8 and the following sugar composition on a fresh weight basis: sucrose, 0.2%; glucose, 7.0%; and fructose, 4.8%. Additionally, a taste panel of 10 individuals gave the fruits an average rating of 7.6 on a scale of 0–9.

Hernández X. (1970) reported that in Mexico 8 metric tons (t) of top quality fruit can be expected within 4 yr of plantation establishment at a plant density of 2,000 per hectare (ha). Full production is reached in about the 12th yr and continues for at least 20 yr thereafter. In May 1984, a 2.5-yr-old plantation in San Luis Potosí, Mexico, had a plant density greater than 2,000/ha and was bearing its first crop (Russell, unpubl. obs.). The selected varieties in this plantation were coming into production a full year sooner than those cited by Hernández X. (1970).

It thus appears that there is ample diversity within commercially accepted varieties for adapting prickly-pear fruit production to different climatological,

management, and soil conditions. Given current agricultural land values in semiarid areas, it is probable that cactus fruit production could substantially increase returns to landowners.

PRICKLY-PEARS AS A VEGETABLE CROP

Nopalitos are the tender, young pads of prickly-pear cacti eaten as a vegetable in Mexico and the southwestern United States where there are large populations of people with a Mexican heritage. The pads are prepared during the Lenten season as a cooked green vegetable, particularly during Holy Week, and as a marinated vegetable throughout the year. The production of *nopalitos* as a vegetable crop in Mexico is centered in the areas of Milpa Alta, Distrito Federal; San Martín de las Pirámides; and the states of México and Puebla.

Milpa Alta was visited in May 1984 at the suggestion of E. Hernández X., and crop production was discussed with several growers (Russell, unpubl. data). Milpa Alta (which means high cornfield) is a small valley at about 2,400–2,600 m elevation in the shadow of Popocatépetl about 25 km southeast of Mexico City. At the time of the visit the entire cropping area of the valley was in *nopalito* production with a cactus known as *nopal de Castilla* (*O. ficus-indica*). Plantations for vegetable production had about 40,000 plants/ha planted about 30 cm apart within rows and 80 cm between rows (Fig. 2). The first crop can be harvested in 2 or 3 mo, and well-established plantations yield 80–90 t/ha (Anonymous 1981). Material not sold on the vegetable market is used for dairy cattle fodder. In exchange for this fodder the local dairy operations supply fresh manure, which is liberally applied to the fields for moisture conservation and is the only source of fertilizer.

The local dairy operators maintain that the cactus pads are essential to their production. They believe that the fodder is important for good lactation, imparts a better flavor and quality to the milk, and enhances the color of the butter. Dairy products coming from cattle fed with cactus pads get a premium price in the local market. Thus the dairy operators are willing to transport the fresh manure up the valley to Milpa Alta and to carry the pads down as a backhaul.

In 1984, Milpa Alta appeared to be a remarkably prosperous area. The reason given by the local growers for changing from growing maize to growing cactus was that maize was frequently a marginal crop, dependent on the highly variable rainfall, and they could consistently produce a cactus crop regardless of annual precipitation. Thus the steep, semiarid land at Milpa Alta might serve as an example of converting marginal land into productive land by simply growing an ecologically appropriate crop—an *ecocrop*.

PRICKLY-PEAR WATER-USE EFFICIENCY AND DRY-MATTER PRODUCTIVITY

Due to the greater water-use efficiency of the cactus photosynthetic pathway compared to that of grasses and legumes, it is worthwhile to examine dry-matter productivity estimates for cactus. The fresh and dry weight yields of cactus pad production are presented in Table 1. The yields are not from randomized replicated field experiments but, at least in the data in Griffiths (1915), are derived from harvested weights of plantings of known spacings. Dry-weight yields were

Fig. 2. The prickly-pear *Opuntia ficus-indica* grown in well-organized plantations for vegetable production at Milpa Alta, Mexico. Note the background vegetation and stony soil of this high, semiarid region.

generally not reported; therefore, we took a typical dry-weight percentage of 13% from a review of 13 cactus productivity reports by Monjauze and Le Houérou (1965).

The fresh-weight yields are very high, but even after correction for moisture content the dry-weight productivities are high for semiarid ecosystems. The highest dry-weight yield of 52 t/ha/yr is from a well-established and tended experimental plot at Chapingo, Mexico (Riquelme, pers. comm.). The dry-matter production values are in accord with values predicted using previously described water-use efficiency coefficients. Fisher and Turner (1978) summarized water-use efficiency coefficients as 670 kg H_2O/kg dry matter for C-3 plants, 300 kg H_2O/kg dry matter for C-4 plants, and 50 kg H_2O/kg dry matter for CAM plants. The 18 t/ha/yr yield at 300 mm annual rainfall reported by Monjauze and Le Houérou (1965) is equivalent to a 167 kg H_2O/kg dry-matter water-use efficiency and is not so efficient as reported for other CAM plants. However, one must remember that rain-use efficiency and water-use efficiency are not identical.

Even with the higher water-use efficiency of cactus over C-3 or C-4 plants, dry-matter productivity estimates greater than 20 t/ha/yr must be considered suspect until replicated field plots with adequate control over border effects have been published. Nevertheless, these water-use efficiencies and dry-matter productivities are most encouraging and point to the need for statistically sound field productivity trials.

Mature cactus pads are often less than 1% nitrogen on a dry-weight basis, which

TABLE 1. SUMMARY OF *OPUNTIA* SPP.

Location	Rainfall (mm/yr)	Cultivation	Fresh weight t/ha/yr	Dry weight[a] t/ha/yr	Source
Mexico	—	—	400	52	Riquelme V., pers. comm.
Mexico	—	—	200	26	Hernández X. 1970
Italy	—	—	60	7.8	Monjauze & Le Houérou 1965
Sicily	—	—	60–65	7.8–8.5	Monjauze & Le Houérou 1965
Algeria, Morocco, South Africa	—	—	100–300	13–39	Monjauze & Le Houérou 1965
Brazil	300	—	140	18	Monjauze & Le Houérou 1965
Tunisia	150–400	No	25–102	3.2–13	Monjauze & Le Houérou 1965
Brownsville, TX	—	—	44	123	Griffiths 1915
San Antonio, TX	700	Yes	51	6.6	Griffiths 1908
San Antonio, TX	700	No	6.3	0.81	Griffiths 1908

[a] The 13% dry-matter content used here was typical of 13 dry-matter values reported in Monjauze and Le Houérou 1965.

is perhaps fortunate, otherwise their leverage of water to dry-matter production would be nitrogen limited. However, fertilizer trials in Tunisia with 20 kg/ha of N, P_2O_5, and K_2O showed a 250% increase in cactus production, indicating that cactus responds to increased fertility (Monjauze and Le Houérou 1965). We suggest that nitrogen-fixing trees and/or shrubs could be managed in rotations with cactus, either in space or time, to avoid nitrogen limitations to cactus productivity in the field. Such a system would integrate the water-use efficiency of prickly-pears with the nitrogen-fixing power of the woody legumes to stabilize and increase the productivity of semiarid regions. Perhaps it is the water-use efficiency of these cacti and the nitrogen-fixing power of the legumes that accounts for the fact that the predominant vegetation of much of the southwestern United States and northern Mexico is mixed tree legume/cactus/brush ecosystems.

PRICKLY-PEARS AS FODDER AND FORAGE

The Tamaulipan biotic province of South Texas and northeastern Mexico is a semiarid to subhumid environment. The growing season exceeds 300 days, and the average rainfall ranges between 380–720 mm with a bimodal precipitation regimen. Although the average rainfall can be calculated, the area is characterized by pronounced variability with no predictable rainfall (Norwine 1981; Russell 1986). Local ranchers maintain that 3 or 4 out of 7 years will be drought years from the standpoint of obtaining a grass crop on rangelands. This unpredictability creates problems for range management that frequently result in rangelands being severely degraded by overgrazing. This is further exacerbated by cattlemen generally equating rangeland with grassland regardless of its ecological validity in the local environment (Russell 1986).

Large sums of money are frequently spent to convert coastal plain and chaparral into grassland that can be maintained only for limited periods. Stocking rates based on the estimated forage production of the introduced grasses generally use the average rainfall estimate, which is not predictable for the anticipated growing season.

In light of the known variability of the precipitation regimen, we believe that prickly-pear should be included in any range management scheme in the Ta-

maulipan biotic province and similar areas of the world. During favorable forage production years, these cacti—protected from herbivory by their spines—would sequester minerals and water while producing carbohydrates and vitamins, which could be made available during drought years more economically than alternative feeds by burning off their spines (Russell 1986).

In South Texas, prickly-pear (e.g., *O. lindheimeri*) is widely known as an emergency drought feed for cattle. In drought periods when grasses have been overgrazed or have become senescent, this cactus remains succulent and green, with a normal complement of vitamins and carotenoids (precursor to vitamin A). During the drought of the 1950s in Texas, prickly-pear was held in high esteem by cattlemen.

We suggest that prickly-pear can be grown as a fodder crop on land presently deemed marginal for other crops (e.g., maize and sorghum) because of its greater water-use efficiency. This fodder can be of either the spiny or spineless varieties (Griffiths 1908). As an alternative to burning off the spines with pear burners, harvested spiny pads can be mechanically tumbled and chopped to remove the spines for confined cattle in a feed lot or dairy operation (Griffiths 1905, 1906).

Finally, prickly-pear can be used to provide greater sustained carrying capacity to drought-prone rangelands. By incorporating it into a more diverse range ecosystem it can assure abundant emergency stock feed during drought seasons. In South Texas, in 1984, it cost about 33 cents per animal unit (AU) per day to maintain cattle on prickly-pear, whereas "relief" corn supplied by the federal government from its reserves was 78 cents/AU/day and alfalfa was 109 cents/AU/day. If cattle must be carried for an extended period on corn or cactus they need an additional 24 cents worth of cottonseed meal per day (Maltsberger, pers. comm.). Since it is not uncommon to carry cattle 100 or more days before unpredictable rains allow other forages to return, the economics (e.g., 50 cents/AU/day) are clearly in favor of prickly-pear over alfalfa or "relief" corn (Russell 1986).

OTHER WORK ON PRICKLY-PEARS IN LATIN AMERICA

Prickly-pear can be found in a semicultivated condition in the semiarid regions of many countries in Latin America. However, there is surprisingly little documentation of its uses and potential. Three examples of the uses of prickly-pear of which we are personally aware will be discussed; many similar examples must surely exist.

Mexico has the greatest tradition of use of cacti in Latin America. Since prehistoric times cacti have played an important role in the life of inhabitants of that country. The founding of Mexico City in 1325 on an island in Lake Texcoco was based on a prophecy containing reference to *nopal* or cactus. In his book *The Discovery and Conquest of Mexico,* Bernal Díaz del Castillo (1956) described the fruits and pads of cacti as common food when he and Hernando Cortes entered Tlascala in September 1519. References to cacti abound in the mythology and art work of ancient and present-day Mexico, where a cactus is part of the emblem of that nation.

Most of northern Mexico is considered arid or semiarid. In this area cacti make up a large part of the vegetation and are used extensively for human food as well

as for fodder and forage. Thus it is appropriate that our work on cacti began in Mexico where scientists such as Roberto Nava C. at the Universidad Autónoma Agraria, Antonio Narro at Saltillo, as well as Efraim Hernández X. and Ernesto Riquelme V. at the Colegio de Postgraduados, Chapingo, were able to suggest sites to visit and to provide information and data on the ecology and uses of cacti. These investigators have assembled more than 60 clones of domesticated varieties and have initiated a genetic improvement program, including cytological studies, controlled pollination, development of field cultural practices for optimum production of fruit and fodder, and animal feeding trials.

In Chile there are active research programs at both the Pontificia Universidad Católica, led by Antonio Lizana M., and the Universidad de Chile, under David Contreras T. and Fusa Sudzuki H. on *tuna* production, marketing, postharvest physiology, and utilization. In Chile, selections of *O. ficus-indica* are grown in well-organized plantations either in monoculture or, intercropped with almonds, apricots, and olives (Russell, pers. obs. 1984). It is reported that plantations on the better sites produce 9–15 t of table quality fruit/ha/yr (Toroni C. and Zúñiga O. 1983). In the *tuna* producing areas of Til-Til, Pudahuel, and Noviciado, where irrigation is available, fertilized plantations produce two crops per year: a summer crop from February through April and a smaller but economically important winter crop in October. In response to questions about growing *tunas* where tree fruit or grapes could be grown, the growers indicated that with fewer infrastructural costs *tuna* production is as profitable as tree fruit or grapes on their marginal lands. This is especially true on sloping land or where they do not have irrigation for other crops.

Perhaps the most extensive utilization of prickly-pear occurs in northeastern Brazil where *O. ficus-indica* has been grown as a fodder crop for about 80 years (Domingues 1963). Presently there are about 300,000 ha in cactus plantations, about 95% of which are located in the states of Paraiba, Pernambuco, and Alagoas. At the EMBRAPA/CPATSA (Empresa Brasileira de Pesquisa Agropecuária/Centro de Pesquisa Agropecuária do Trópico Semi-Arido) experiment station near Petrolina, Pernambuco, Severino Gonzaga de Albuquerque has been conducting field trials on various intercropping regimens with cactus. In drier areas *Opuntia* is intercropped with mesquite (*Prosopis* spp.) and buffelgrass (*Cenchrus ciliaris* L.). In wetter areas and during the rainy season *Opuntia* and/or *Nopalea* are intercropped with beans, corn, cotton, groundnuts, sorghum, squash, etc. (Russell, pers. obs. 1984). Rows of spineless *Opuntia* are established 3–5 m apart with *Prosopis* being planted at 5–15 m intervals within the row. In the rainy season and wetter areas the intercrops are planted within the 3–5 m wide space between the rows of cactus and mesquite (Fig. 3).

A field trial in northeastern Brazil examined intercropping of mesquite with buffelgrass (Felker, unpubl. obs.). Here newly transplanted mesquite seedlings were overseeded with buffelgrass. Three different levels of weeding were provided for the mesquite: no weeding, ring weeding for 1 m around the trees, and complete weeding of the plots. An excellent buffelgrass stand was established; however, after 9 months the mesquite trees in the plots with no weeding suffered 90% mortality. In contrast, in the ring-weeded plots the trees had only 10% mortality; in the completely weeded plots their survival was nearly 100%, and the trees were

Fig. 3. A mesquite/prickly-pear system at EMBRAPA/CPATSA, Petrolina, Pernambuco, Brazil, intercropped with sorghum during the short rainy seasion.

over 1 m tall at the end of the first season. No such competition occurred between *Opuntia* and *Prosopis*. Thus, these taxa seem to be a much more compatible energy/protein-producing system than the corresponding grass/mesquite system.

PRICKLY-PEARS AS A WILDLIFE RESOURCE

In a ranking of the top 40 plant species in white-tailed deer (*Odocoileus virginianus*) diets in South Texas (by an examination of the rumen of sacrificed wild deer), *Opuntia lindheimeri* was found to have the highest percent volume and frequency of any species in the diet (Arnold and Drawe 1979). Everitt and Gonzalez (1981) found that *O. lindheimeri* had greater dry matter digestibility than forbs (17 species) or woody browse (15 species) in a seasonal study of the diets. Where this prickly-pear occurs on the King Ranch of South Texas, it is the principal food of the javelina (*Pecari tajacu*) (on the basis of 50 paunch examinations; Lehmann n.d.). Bobwhites (*Colinus virginianus*) and scaled quails (*Callipepla squamata*) readily use prickly-pear for refuge cover. Ripe prickly-pear fruits are extensively used by curve-billed thrashers (*Toxostoma curvirostre*), Chihuahuan ravens (*Corvus cryptoleucus*), mourning doves (*Zenaida macroura* L.), scaled quails, white-winged doves (*Zenaida asiatica*), wild turkeys (*Meleagris gallopavo*), coyotes (*Canis latrans*), raccoons (*Procyon lotor*), and thirteen-line ground squirrels (*Spermophilus tridecemlineatus*) (Lehmann 1984).

In addition to the intrinsic values of wildlife, hunting leases on mixed prickly-pear/mesquite communities provide two to three times greater revenue to the

landowner than the $5–$7/ha/yr obtained by cattle grazing, suggesting that ranchers should consider the other benefits of prickly-pear on their rangelands (Arnold and Drawe 1979; Everitt and Gonzalez 1981; Ramsey 1965; Teer 1975).

PEST MANAGEMENT PROBLEMS

Not a great deal is known of the diseases affecting cacti. However, during "wet" years in South Texas *O. lindheimeri* is apparently afflicted by plant pathogens. *Erwinia aroideae,* a bacterial soft-rot organism, has been tentatively identified as a serious problem on some cacti in Texas (Lehmann n.d.). A rust fungus (*Phillostica opuntiae*) attacks 2-yr-old cacti in humid zones of northern Africa but can be controlled by copper applications (Monjauze and Le Houérou 1965). *Phytophtora cactorum* causes a black rot and foul odor on pads and fruits of sensitive species in northern Africa (Monjauze and Le Houérou 1965). A black spot fungus (*Perisporium wrightii*) has been reported in South Texas (Griffiths 1908), but resistant strains of cacti are available. In Texas, the red spider mite (*Tetrancychus opuntiae*) caused considerable damage to cultivated prickly-pear stands but apparently not native stands (Griffiths 1908). The insect *Ceratitis capitata* can be a serious problem on the fruits if not controlled with insecticides (Monjauze and Le Houérou 1965). *Cactoblastus* insects have been used for biological control of escaped *Opuntia* spp. in Australia (Andres and Goeden 1971). Cochineal insects (*Dactylopius opuntiae*) are specific to cacti and have been used for biological control of prickly-pear infestations of rangeland in North America (Andres and Goeden 1971). We have collected the yellow striped army worm (*Spodoptera latifascia*) on our germplasm collection in Kingsville. Snails (*Helix tortensis*) can also be a problem on some cactus species but can be controlled with sprays of lime (Monjauze and Le Houérou 1965).

CONCLUSION

We have discussed the potential of prickly-pear as fodder, forage, fruit, and vegetable crops. Its water-use efficiency and long history of use in Mexico suggest that it would also be valuable in semiarid ecosystems in the United States and elsewhere. Prickly-pear holds exceptional promise as a forage crop in drought-prone areas. During favorable years these plants, protected from herbivory by their spines, would sequester water and mineral nutrients while producing carbohydrates and vitamins, which could be made available during drought seasons more economically than alternative feeds. Prickly-pear appears to be especially amenable to agroforestry and silvopastoral systems in semiarid regions with tree legumes such as *Prosopis* and *Leucaena* and with annuals such as beans, peas, and sorghum.

In addition to feed for domestic livestock, prickly-pear provides food and cover for wild animals. In some areas of the southwestern United States and northern Mexico, hunting revenues equal or exceed the income from livestock production, suggesting that ranchers should consider the other benefits of prickly-pear on their rangelands.

Despite the widespread use of cacti in the arid regions of Mexico and other parts of the world, there has been little applied research on their use since the pioneering works of Griffiths and Burbank from 1900–1915 (Benson 1982). Fur-

thermore there appears to be no single living germplasm bank that contains adequate worldwide germplasm representation. Similarly, throughout Latin America there appears to be a considerable volume of regional, non-refereed publications (e.g., newspapers, theses, and extension level publications) on practical cultural methods for cacti, but we know of no systematic method to retrieve this literature. In 1984, with the assistance of the U.S. National Science Foundation, we established the world collection of economically important cacti and began field trials to: (1) evaluate the response of a native prickly pear (*O. lindheimeri*) to nitrogen and phosphorus fertilization, (2) evaluate the response of this species to pre-emergence herbicides, and (3) compare *Opuntia* and *Nopalea* cultivars from North and South Africa, Mexico, Chile, Brazil, Argentina, and the United States for fruit and fodder production, cold tolerance, and pest resistance.

Benson (1982) stated that a major factor contributing to the failure of Griffiths' and Burbank's cultivars was their lack of cold tolerance. Indeed in the 120-yr-record freeze of 22–31 Dec 1983 in which there were 165 hr below 0°C with a record low of −12°C (Glumac 1985) in Kingsville, Texas, all the spineless cacti in use as ornamentals around residences froze to the ground. In contrast, the native *O. lindheimeri* was essentially undamaged. Fortunately, *Opuntia* species hybridize readily and thus it may be possible to breed cold tolerance into desirable cultivars. Strategies for genetic improvement, including in vitro propagation and in vitro rescue techniques for sterile hybrids, have greatly improved since 1905. Use of traditional selection techniques from a good germplasm base when combined with breeding, hybridization, and tissue culture techniques should produce cultivars with considerable potential for semiarid lands.

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