Deceptive barrenness

the desert conceals food sources that prehistoric people knew how to exploit. Will modern man do as well?

by Richard S. Felger and Gary Paul Nabhan

Only seven species of plants keep the majority of humanity from starvation: wheat, rice, maize, barley, the soybean, the common bean and the potato. The major crop plants of the world include another dozen or so species. Most of these domesticated species are genetically vulnerable to long-associated diseases and pests, and none are particularly adapted to arid lands. However, one third of the world's land mass falls within arid and semiarid climates. Thus arid-adapted crop plants become more necessary as agriculture expands to meet the world's food requirements, and as fresh water and energy become even more limited.

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In contrast to the major cultigens, there exists a great diversity of food plants that have evolved in arid environments and which, for millennia, have formed the basis of subsistence of native desert peoples. In the Sonoran Desert of southwestern North America, there are more than 375 species of wild food plants. About 40 of these species were utilized as major staples by the native peoples of the region. Rather than basing all arid-land agriculture on imported, temperate or tropical cultigens which depend on costly supplements of water and energy-intensive technology, we would do better to select and develop certain of these indigenous desert plants for twenty-first century agriculture.

An ideal food plant design

Desert plants have evolved strategies for coping with the extreme conditions of their environment. For instance, ephemerals — short-lived desert annuals — germinate quickly if sufficient soil moisture suddenly becomes available. Their life cycles are completed in a single season or less. Ephemerals avoid extended drought by remaining dormant as seeds for prolonged periods. Certain perennials, such as cacti, have extensive water-storage tissue and are therefore drought-evading. Some deep-rooted desert trees or shrubs are also drought-evading because they are

Table I **Characteristics of selected food plants from the Sonoran Desert**

Life-form	Scientific name	Common name	Edible part	Weight or size of edible part	% Protein	% Oil or fat	% Carbohydrate
Columnar cactus	*Pachycereus pringlei*	Cardon, Sagueso	Seed	6.3 mg	22.6	32.2	0.95
			Fruit pulp		Low	Low	High
Tree or shrub	*Prosopis juliflora*	Mesquite	Seed	7-8x5 mm	34-39	6.6-7.6	—
			Mesocarp (pulp)	pod 10-25 cm long	Low	Low	High
Root perennial	*Cucurbita foetidissima*	Buffalo gourd, Calabazilla	Seed	40 mg	22.2-35.1	25.6-42.8	Low
			Root	Up to 70 kg	Low	Low	56.0 (starch)
Ephemeral	*Phaseolus acutifolius*	Tepary, Tepari	Seed	140 mg (dry); 8.56x5.68 mm	23.2-32.2	1.1	—
			Foliage (fodder)	—	14.45	3.19	47.31
Seagrass	*Zostera marina*	Eelgrass, Trigo del Mar, Sacate del Mar	Seed	3.0-3.5 mm long; 3.1 mg dry, 6.5 mg fresh	13.2	1.0	50.9 (starch)

able to tap underground soil moisture. Other desert perennials lose their leaves in response to drought. Thus, these perennials endure lengthy rainless periods by means of a variety of physiological and morphological adaptations, which allow them to store moisture and reduce transpirative water loss.

Current research indicates that desert plants may maximize food energy in storage organs such as seeds and roots. Seeds of desert plants are often smaller than their temperate or tropical counterparts, but this does not necessarily render them inferior as food. Rather, it has been shown with beans (*phaseolus*) that seed size is inversely proportional to protein value.[1]

This concentrated food energy is one of the characteristics of desert plants that gives them an "ideal food plant design." Another important characteristic is high-efficiency photosynthesis, e.g., the C_4 pathway, which certain ephemerals and other desert species utilize.[2] On a theoretical basis, it appears that desert ephemerals may put a higher percentage of their energy into seed productivity than any other plant. Both the desert ephemerals and most of the major crop plants of the world (the economic annuals) have evolved or have been selected from perennial ancestors.[3] This quickened life cycle is of primary agronomic significance. Many desert plants produce their crops over a relatively short time, and this all-at-once attribute can allow rapid, energy-saving harvest techniques. A number of the major wild food plants of the Sonoran Desert produce protein-rich seeds, carbohydrate-rich fruit or pods, and, in some cases, foliage usable for fodder and green manure. Desert legumes with nitrogen-fixing nodules are soil enriching and may be partially self-fertilizing.

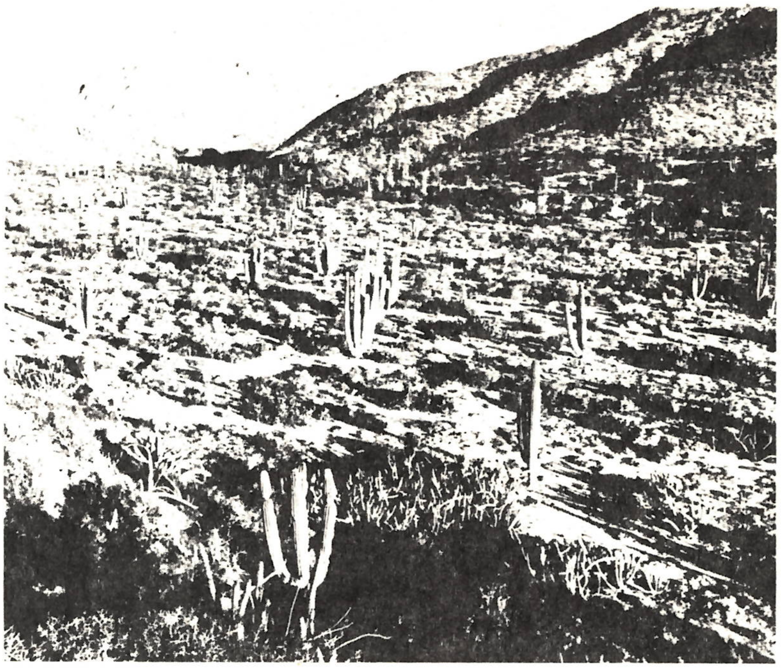

Figure 1

San Esteban Island, Gulf of California, Mexico. The thick-stemmed cacti are cardon. The smaller cacti in the foreground are *pitahaya dulce (Machaerocereus gummosus)*, which bear delicious tart and juicy fruit during the warmer months of the year.

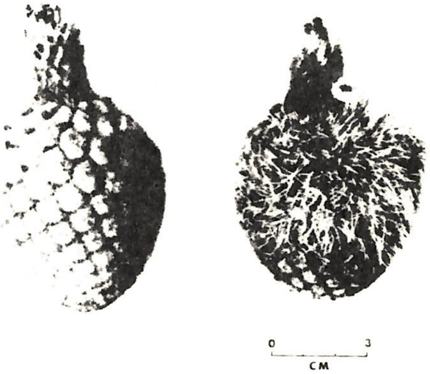

Figure 2

Cardon *(Pachycereus pringlei)* fruit.

	Maximum yield per plant/year	Possible productivity (kg per ha/year)
	Hundreds of fruit	—
	140 000 seeds	900-1 000 (pods)
	3 000-7 000 pods	
	60 000-90 000 seeds	3 000 (seeds)
		70 000 (root, fresh weight)
	300-1 500 seeds	2 000 (dry farmed) 3 700 (irrigated)
	50-150 g (dry weight)	1 700 (dry farmed) 7 200 (irrigated)
	60-250 seeds/ stem (turion)	1 200 (seed)

Unfailing resource species

Certain drought-evading perennials, such as the mesquite tree with its very deep taproots, and cacti with their succulent water-storage tissues, produce fruit even during drought years, although the yield may be reduced. Plants growing in the ocean, such as eelgrass, are independent of fresh water. Food plants such as these may be termed "unfailing" resource species. Many of the major unfailing resource species from the Sonoran Desert are of potential agronomic value also because their crops can be harvested during the premonsoon dry season (late spring and early summer) — a time of great food shortage in many regions of the world with prolonged dry seasons.[4]

To further illustrate the agronomic potential of certain desert plants, a few species with particular promise are briefly described below and in Table 1. Many others could be added to this list.[4] Preliminary information indicates that in most cases these species are as nutritious, and potentially as productive, as some of the world's major cultigens. Still, genetic selection and improvement have been attempted in only a very few isolated cases, e.g., the buffalo gourd.

Most of these plants provide several products and were reliable staples, which desert peoples have tradi-

Figure 3

Mesquite tree in natural setting with dense undergrowth, on Tiburon Island, Gulf of California. *Photo by George Huey*

Figure 4

Cluster of mesquite pods, stony pit (endocarp) and seed, and spiny branch with leaves. *Drawings by Cathy Moser and Francis Runyan*

tionally harvested and prepared with a minimal, though labour-intensive technology. Industrial agriculture has hardly adapted itself to relatively small-seeded plants. Yet, the benefits of producing low maintenance, nutritious crops may outweigh the cost of adapting contemporary agricultural systems to small-seeded crops. In the future, with the intermediate technology now being developed by the herb and range plant industries to accommodate small seeds, much more efficient harvesting and processing will be possible. These plants would be particularly suited for marginally arable lands of developing countries where large-scale irrigation and mechanization are unavailable, as well as for all arid zones when excessive fresh water and petrochemical inputs are no longer feasible.

Cardon (*Pachycereus pringlei*) is a many-branched cactus commonly reaching 10 to 15 metres in height and weighing many tons (*Figure 1*). It is endemic to Baja California and Sonora, Mexico, where average annual rainfall is only 100 to 200 mm. This cactus produces edible fruit (*Figure 2*) even in years without rainfall. It is tolerant of mildly saline or alkaline soils, and grows on both rocky and sandy soils.

Prodigious quantities of large, juicy fruit are produced in early summer; and several hundred fruit may be found on a single cactus at any one time. This fruit was one of the most important foods of early inhabitants of Baja California and Sonora.[5] The sweet, succulent fruit can be eaten fresh, cooked, fermented in wine, or dried and stored. The numerous small seeds within the fruit are very high in protein and edible oil content, and can be ground into a delicious buttery paste. Edible seed and pulp make up as much as 50 percent by weight of the fresh fruit, which weigh up to 150 g each.

Myriads of hybrids

Although cardon is very slow growing, mature plants should be productive for a century or more in extremely arid, hot climates. Moreover, hybridization potential in the cactus family is great so there is ample opportunity to develop myriads of new hybrids. There exists a natural, intergeneric hybrid between cardon and a "dwarf" columnar cactus (*Bergerocactus emoryi*) — the hybrid being less than 4 m tall. Another species, very closely related to cardon, *echo* (*Pachycereus pecten-aboriginum*), has seeds more than 2.5 times larger by weight than those of cardon, and is relatively fast growing but not as drought-resistant. Natural hybrids between these two species occur in Baja California. Furthermore, there are several hundred species of columnar cacti in the various dry tropical and subtropical regions of the New World, which merit investigation as potential crop plants. There is a great range in size and taste of the fruit and all are edible.

Species of the legume genus *Prosopis* in the section *Algarobia*, with about 6 species in North America and 20 in South America, have considerable agricultural potential. In North America

they are known as mesquite (*Figure 3*), and in South America as algarroba or carob. From early prehistoric times until recent years, mesquite was extensively utilized in southwestern North America as a primary source of food, drink, fuel, shelter, weapons, tools, medicine, dye and for many other purposes.[6] As an unfailing wild food resource, mesquite pods (*Figure 4*) were harvested in enormous quantities, processed and stored in special granaries. Mesquite is also a valuable honey plant, and the wood is hard, easy to work, strong and resistant to decay.

Mesquite is often relatively independent of short-term drought because of its deep roots, which penetrate to 10 m or more to reach groundwater. The seed pods are produced in great abundance in early summer, and variously throughout the rest of the summer, or again in early fall. When fully ripe the pods fall to the ground, facilitating harvest. Significantly, they do not split apart at maturity, as do many legumes, so that the seeds and pulp (mesocarp) are not lost during harvest.

Considerable variation

Mesquite pods are readily processed after being oven heated or parched, a method that also effectively controls the ever-present bruchid beetles, which otherwise devour large quantities of the seeds. Carbohydrate-rich, sweet flour obtained from the pods can be made into beverages or bread. Mesquite bread can be made directly from the flour without cooking, thus saving cooking fuel. Difficulties with separating the true seed from the encasing inedible stony pit (endocarp) apparently limited the use of the seed. Yet, the prehistoric inhabitants of the extremely arid Pinacate region of Sonora devised stone gyratory crushers,[7] which can still be used to grind large quantities of the mesocarp tissue into flour as well as break open the endocarp to free the seeds (*Figure 5*). Modern industrial gyratory crushers could certainly process large quantities of mesquite pods (*Figure 6*).

There is considerable variation in size, taste and yield of pods. Various American Indians discovered certain superior trees and groves, and these were often sought out year after year. However, no attempt has ever been made at selection, hybridization and domestication, either in ancient or modern times. The tree is readily propagated by seed and is fast growing. Grafting of select genotypes should be simple, and at least some species can be grown from cuttings. Some of the species have nitrogen-fixing root nodules, which supply the plant with nitrogenous nutrients and are particularly important to newly established plants.

Grazing pressure and seed dissemination by livestock have contributed to the increase and spread of mesquite in modern times, and it is now generally considered a pest species, with far greater amounts of money and energy expended on attempted control and eradication than on research for utilization as a food crop.

Outproduces the common bean

An arid-land root perennial in the gourd or cucurbit family, the buffalo gourd (*Cucurbita foetidissima*), is currently being domesticated by an international research team coordinated by Dr. William Bemis of the University of Arizona.[8] A potential arid-land crop for the production of protein, oil and starch products,

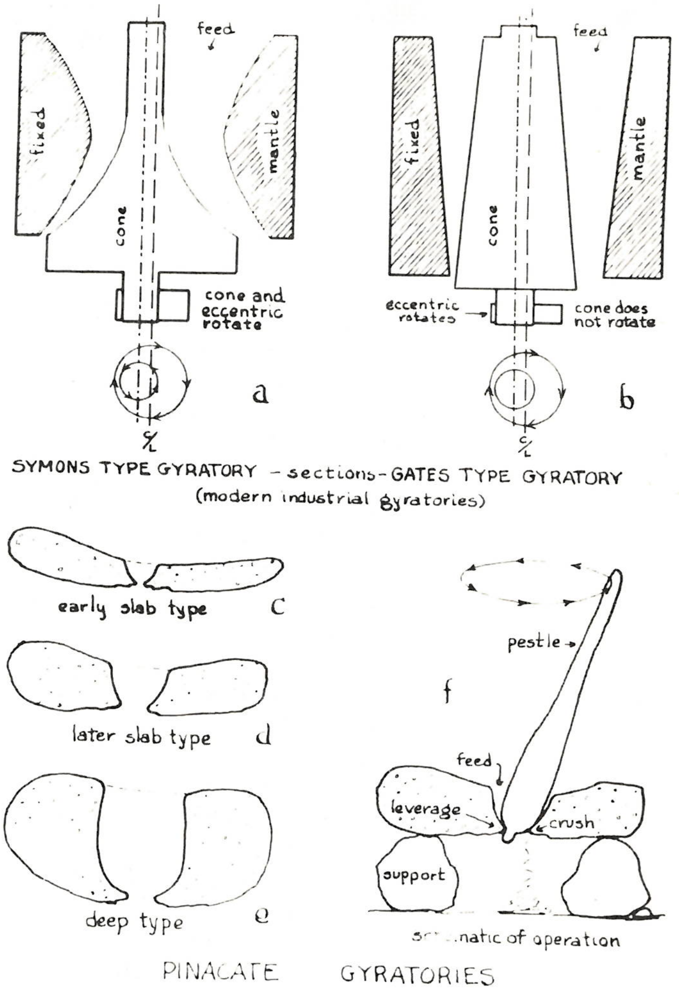

Figure 6

Modern and prehistoric gyratory crushers, in section, for comparison *(from Hayden, 1969, p. 155).*

Figure 5

Prehistoric gyratory crushers from the Sierra Pinacate, Sonora, Mexico, in situ. *Photo by Julian D. Hayden*

Figure 7

Buffalo gourd and tepary. Upper, buffalo gourds; middle, buffalo gourd seeds; lower, tepary pods and seeds.

the buffalo gourd has fleshy storage roots and seeds with considerable food value. The starchy root may weigh as much as 72 kg. As many as several hundred trailing, leafy stems are produced annually, each about 3 to 10 m in length. High-yielding plants produce numerous roots and 200 to 300 fruit each per year, with about 300 seeds per fruit (*Figure 7*).

The seeds of buffalo gourd were eaten by native American peoples, and breeding work is being directed toward increasing seed productivity and oil content. The quality of the oil compares favourably with commercial cooking oils. Genetic improvement should ensure the buffalo gourd a place in the growing oil-plant industry of arid and semiarid lands.

The tepary bean (*Phaseolus acutifolius*) is an ephemeral legume with both wild and domesticated varieties, which have been harvested by North American Indians for thousands of years. Teparies were cultivated by more than 15 tribes in the southwestern part of the North American continent. During prehistoric times in the desert, cultivation of teparies was probably surpassed only by that of maize. These beans have long been known to outproduce the common bean (*Phaselous vulgaris*) and most other field crops under dry-land farming conditions. With only minimal irrigation, two crops can easily be produced per year in the Sonoran Desert, since teparies are usually harvested within 60 to 90 days after planting. Field experiments also indicate that tepary hay is palatable to livestock, is comparable to alfalfa in nutritive quality, and outproduces other legume hays in the arid region of southwestern North America.[9]

Farming the sea

Of the bewildering number of local stocks once cultivated in the river valleys of the southwestern United States and northwestern Mexico, most have become extinct during this century. Conservation of surviving varieties of domesticated and wild teparies is now being coordinated with the United States National Seed Storage Laboratory, so that teparies might again be made available. Because of their drought resistance, high productivity and protein content, teparies deserve revival as a modern crop.

Agriculture has yet to penetrate much of the area adjacent to the 30 000 km of shoreline along the hot coastal deserts of the world. Growth of cultigens in such areas has been limited by the high salt contents of soils and meagre available fresh water. These limitations could be overcome if halophytes,[10] such as eelgrass (*Zosiera marina*), were brought into agronomic development along desert coasts. Eelgrass (*Figure 8*) grows in pure seawater, and in some places even in hypersaline waters. This and several other Sonoran Desert halophytes produce substantial quantities of edible seeds. With these plants, "farming the sea" might become a reality.[11]

Eelgrass grows along the shallow coastal seas of much of the Northern Hemisphere. While its leafy stem bases were used by a few temperate climate tribes as a minor vegetable, it was significant as a food plant only in the Gulf of California. There, along the coast of Sonora, in sharp contrast to other known forms of eelgrass, 100 percent of the stems produce seeds.[12] The Seri Indian took advantage of this productivity, harvesting seed from the great masses of eelgrass drifting ashore each spring. The seeds, about 3 mm in length, were parched, winnowed and ground into a flour that was one of the most important foods of the Seri. The protein and starch content of the seed compares favourably with that of major terrestrial economic grains.

A crop plant that can be grown with pure seawater, and presumably requiring no fertilizer or pesticide, would be of great value. The yet unsolved and untested problems of maintaining and harvesting a crop plant submerged in tidally active waters offers a considerable challenge to mariculture and wetland agronomists.

While the potential for genetic improvement of this seagrass is unknown, there are about half a dozen closely related species of *Zostera*. However, no hybrid has ever been attempted for any seagrass.

Reversing the perilous trend

Agricultural systems based on plants adapted to arid environments would reduce many problems plaguing food production in desert regions. Presently much agriculture in dry, marginally arable lands depends on the limited supplies of fossil groundwater. The increasing expenses of fuelling water pumps and countering salt buildup in soils, as well as the drastic lowering of water tables, already threaten to terminate irrigated agriculture on much land recently brought into cultivation. Potential crop plants such as the examples described here require substantially less or even no fresh water, so that soil and water resources need not be depleted. For terrestrial crops, recent innovations in crop irrigation and minimum or no-tillage cultivation would enable further resource conservation.

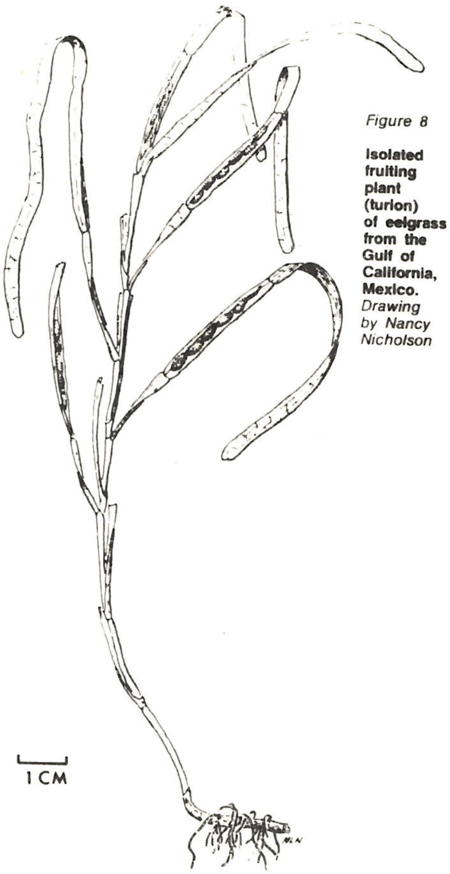

Figure 8

Isolated fruiting plant (turion) of eelgrass from the Gulf of California, Mexico. *Drawing by Nancy Nicholson*

Samples of the range of naturally occurring genetic material of these wild food plants should be collected and preserved by propagation in botanic gardens, seed banks, or by other appropriate means. Yet the real promise of new arid-land food crops lies in the possibility of breeding new cultivars. If nutritional quality, productivity or drought resistance in these plants can be improved through plant breeding and selection, arid-land agriculture may find a vital new direction. Food production might be maximized by taking advantage of adaptations that plants have already evolved in arid regions. By reversing the present perilous trend of decreasing agricultural diversity, greater ecological adaptation of the world's crop plants can be achieved. If it is possible to stabilize world population, then it may even be possible for twenty-first century agriculture to achieve ecological equilibrium. ◆

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