ETHNOBOTANY AND DOMESTICATION IN XOCONOCHTLI, *STENOCEREUS STELLATUS* (CACTACEAE), IN THE TEHUACÁN VALLEY AND LA MIXTECA BAJA, MÉXICO[1]

ALEJANDRO CASAS, BARBARA PICKERSGILL, JAVIER CABALLERO, AND ALFONSO VALIENTE-BANUET

Casas, Alejandro *(The University of Reading, Department of Agricultural Botany, School of Plant Sciences, Whiteknights PO Box 221, Reading RG6 6AS, UK and Jardín Botánico, Instituto de Biología, Universidad Nacional Autónoma de México. Apartado Postal 70-614, México, D.F. 04510, México),* **Pickersgill, Barbara** *(The University of Reading, Department of Agricultural Botany, School of Plant Sciences, Whiteknights PO Box 221, Reading RG6 6AS, UK),* **Caballero, Javier** *(Jardín Botánico, Instituto de Biología, Universidad Nacional Autónoma de México Apartado Postal 70-614, México, D.F. 04510, México) and* **Valiente-Banuet, Alfonso** *(Centro de Ecología, Universidad Nacional Autónoma de México. Apartado Postal 70-275, México, D.F. 04510, México).* ETHNOBOTANY AND THE PROCESS OF DOMESTICATION IN THE XOCONOCHTLI *STENOCEREUS STELLATUS* (CACTACEAE) IN THE TEHUACÁN VALLEY AND LA MIXTECA BAJA, MÉXICO *Economic Botany 51(3):279–292, 1997. Ethnobotanical information is presented on use, management, folk nomenclature and classification of the "xoconochtli" (*Stenocereus stellatus*) as well as on the role of this plant in subsistence of the Nahua, Mixtec and Popoloca peoples from the Tehuacán Valley and La Mixteca Baja in Central Mexico. Among all three groups,* S. stellatus *was used for various purposes but mainly for its edible fruits. Different variants of this species were distinguished, named and classified by indigenous people according to characteristics of the fruit, particularly size, color and flavor of the pulp, spininess and thickness of the peel. Wild plants characteristically had small red sour fruits with many spines and thick peel, while individuals selected for cultivation usually differed in one or more of these characters. Three general forms of interaction between people and this species were found: 1) gathering of useful products from the wild; 2) management of wild populations* in situ *which involves the sparing and enhancing of individuals with more desirable characteristics and the removal of others during clearance of the land for agriculture; and 3) cultivation, mainly in home gardens, by propagation of vegetative parts from desirable individuals. Fruit yields per individual and per population were measured and compared in wild, managed* in situ *and cultivated populations from the Tehuacán Valley and La Mixteca Baja Wild and cultivated individuals from La Mixteca Baja yielded more than wild and cultivated individuals from the Tehuacán Valley. Within each region, fruit yields were similar in wild and managed* in situ *populations but significantly larger in cultivated populations Forms of management of this plant species are discussed in terms of availability of products and demand for them in the local economy.*

La Etnobotanica y el Proceso Domesticativo en Xoconochtli, *Stenocerus stellatus* (Cactaceae) in el Valle de Tehuacan y Lamixteca Baja, Mexico. *Se presenta información etnobotánica del "xoconochtli"* (Stenocereus stellatus) *sobre usos, manejo, nomenclatura y clasificación folk asi como su papel en la subsistencia de la población Nahua, Mixteca y Popoloca del Valle de Tehuacán y la Mixteca Baja, regiones localizadas en la parte central de México. Estos grupos indígenas utilizan al "xoconochtli" de diferentes maneras pero principalmente lo usan por sus frutos comestibles. Distinguen, nombran y clasifican diferentes variantes de esta especie de acuerdo con las características de sus frutos, especialmente por su tamaño, el color y sabor de la pulpa, asi como por la cantidad de espinas y grosor de su cáscara. Los individuos silvestres generalmente presentan frutos pequeños, rojos y de sabor agrio, con cáscara gruesa y espinosa, mientras que los individuos cultivados pueden diferir en una o varias de estas características. Se encontraron tres formas generales de interacción entre la gente y estas plantas· 1) recolección de productos utiles en poblaciones silvestres; 2) manejo de poblaciones silvestres* in situ, *el cual se lleva a cabo durante el aclareo de terrenos para agricultura, y en*

[1] Received 15 December 1995; accepted 25 March 1997

Economic Botany 51(3) pp. 279–292. 1997

el cual se dejan en pie y se promueven los individuos con las características mas deseables y otros son eliminados; y 3) cultivo, principalmente en huertas, a través de la propagación de partes vegetativas de individuos con características deseables. Se evaluó y comparó la productividad de frutos por individuo y por población en poblaciones silvestres, manejadas in situ *y cultivadas del Valle de Tehuacán y de La Mixteca Baja. En los individuos y poblaciones silvestres y cultivados de La Mixteca Baja la productividad de frutos fué mayor que en los individuos y poblaciones silvestres y cultivados del Valle de Tehuacán Dentro de cada región la productividad fue similar en poblaciones silvestres y manejadas* in situ, *aunque significativamente mayor en las poblaciones cultivadas Se discuten las diferentes formas de manejo en relación con la disponibilidad de recursos de esta planta y su demanda de acuerdo con su papel en la economía de la gente de la región.*

Key Words: Ethnobotany; Tehuacán Valley; Mixteca; domestication, *Stenocereus stellatus*, Cactaceae.

Stenocereus stellatus (Pfeiffer) Riccobono is a columnar cactus from central Mexico which is used for human food (fruits, seeds and stems), forage (stems and fruits), firewood (stems), living fences, and prevention of soil erosion (Bravo-Hollis and Sánchez-Mejorada 1991; Casas, Viveros, and Caballero 1994). The most common name for this cactus among the local people is the Nahuatl, "xoconochtli". After *Opuntia* spp., *S. stellatus* is among the most economically important species of fruit-producing cacti (Pimienta-Barrios and Nobel 1994; Sedgley and Gardner 1989). In some areas it is mainly gathered from the wild, while in other areas it is managed and cultivated as well as gathered. There is a considerable demand for its products in the markets of the regions where the species occurs.

Use of this species by humans appears to be very ancient. Smith (1967) reported remains of *S. stellatus* (as *Lemaireocereus stellatus*) from archaeological excavations in the Tehuacán Valley (Abejas phase, from approximately 3500–2300 B.C., and Palo Blanco phase, from approximately 200 B.C.–A.D. 700). The remains were not abundant, so Smith (1967) considered that this species was not a significant item of diet. However, when Callen (1967) studied coprolites from the excavations, he found that stem tissue and fruits of "*Lemaireocereus*" (*Pachycereus* spp. and *Stenocereus* spp. according to current nomenclature) were among the plant constituents of diet in all the phases analysed (from El Riego phase, 6500–5000 B.C., to Venta Salada phase, A.D. 700–1540) but especially in both Ajalpan (1500–900 B.C.) and Santa María (900–200 B.C.) phases. In the earlier Coxcatlán phase (5000–3500 B.C.), "*Lemaireocereus*" seeds had been eaten, apparently after roasting, while in the later Palo Blanco phase remains of "*Lemaireocereus*" stems in the coprolites lacked any epidermis, suggesting to Callen (1967) that they had been roasted and peeled. There is no evidence that any parts of any edible cacti were boiled during any phase in the prehistory of the Tehuacán Valley.

There is also no evidence from the archaeological remains that any of the columnar cacti were cultivated. However, at present wild and cultivated populations of *S. stellatus* coexist in arid and semi-arid regions of Central Mexico, mainly in the Tehuacán Valley and part of the Balsas river basin (Fig. 1). During August and September, both in the field and in traditional markets of these regions, a great variety of

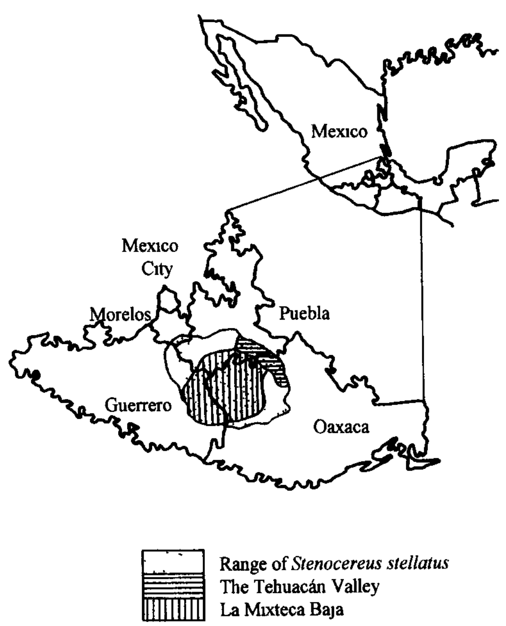

Fig. 1. Distribution of *Stenocereus stellatus*.

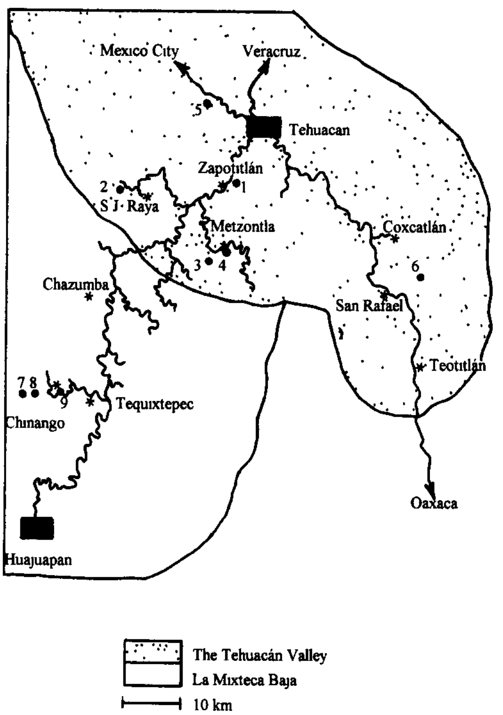

Fig. 2. *Stenocereus stellatus* study sites (1 = Zapotitlán; 2 = San Juan Raya; 3 = Metzontla-managed in situ; 4 = Metzontla-cultivated; 5 = San Lorenzo; 6 = Coxcatlán; 7 = Chinango-wild; 8 = Chinango-managed in situ; and 9 = Chinango-cultivated populations).

forms, sizes, colors and flavors of "xoconochtli" can be observed. This raises the question of whether this variability is a reflection of the great diversity of environments characterizing these areas, or whether it also results from human selection.

Here, we present ethnobotanical information on traditional classification, use, and management of *Stenocereus stellatus* in order to establish the usefulness of this species, the parts used, the characteristics preferred and selected, and the mechanisms of artificial selection. We also present a comparison of fruit yields among wild, managed, and cultivated populations in order to analyze the effects of different forms of management on availability of fruits of this plant.

Study Area

The Tehuacán Valley is a region of 10000 km^2, located in the southeast of the state of Puebla and the northwest of the state of Oaxaca (Fig. 2). It forms part of the Papaloapan river basin. It has an arid to semi–arid climate, with a mean annual precipitation of 400 mm (Dávila et al. 1993). Natural vegetation consists of tropical deciduous forest and several types of thorn-scrub forest (as defined by Rzedowski 1978). Dávila et al. (1993) report nearly 3000 species of flowering plants in the area, thirty percent of them being endemic. Popoloca, Nahua, Mixtec, Mazatec, Chinantec, Ixcatec and Cuicatec ethnic groups inhabit different parts of the Valley.

The Mixteca Baja region is located south of the Tehuacán Valley, in the northwest of Oaxaca, the southeast of Puebla and the northeast of Guerrero states. It is part of the Balsas river basin, which is an extremely complex mountainous region with altitudes ranging from 600 to 3000 meters above sea level and types of vegetation ranging from thorn-scrub and tropical deciduous forests in the lower dry and warm lands to pine forests in the higher wet and temperate areas. *Stenocereus stellatus* occurs in the thorn-scrub and tropical deciduous forests where precipitation is between 600 and 800 mm per year.

In both areas, most people are indigenous peasants or campesinos who subsist by cultivating maize, beans, squashes, and chili peppers and by gathering a wide spectrum of wild plants. Many of these wild plants are managed to different degrees (Casas and Caballero 1995; Casas, Viveros, and Caballero 1994; Casas et al. n.d.).

Two groups of villages were studied in the Tehuacán Valley (Fig. 2). The first group includes the Popoloca villages of Zapotitlán de las Salinas, San Juan Raya, and Los Reyes Metzontla. The second group includes the Nahua villages of Coxcatlán, near the well-known cave explored by MacNeish (1967), and San Lorenzo located on the Mesa de San Lorenzo, a travertine area which constitutes the roof of caves of another famous site also excavated by MacNeish (1967), El Riego, in the western limits of the City of Tehuacán. In La Mixteca Baja, the Mixtec village Santa Catalina Chinango, Oaxaca was studied. General information on environmental and cultural aspects of these sites is presented in Tables 1 and 2.

Methods

Ethnobotanical Studies

We surved the Nahua, Mixtec and Popoloca peoples in order to determine patterns of use, management, and mechanisms of artificial selec-

TABLE 1. LOCALITIES AND ENVIRONMENTS OF *STERNOCEREUS STELLATUS* POPULATIONS.

Population	Ecological condition	Elevation (m)	Annual mean temperature (°C)	Annual mean precipitation (mm)	Soils	Habitat
Tehuacan Valley						
Zapotitlán	Wild	1550	21.2*	450*	Derived from sandstones	Thorn-scrub forest
San Lorenzo	Wild	1700	19.1*	590*	Derived from limestones	Thorn-scrub forest
San Juan Raya	Wild	1800	20.9*	649.7*	Derived from limestones	Thorn-scrub forest
Coxcatlán	Wild	1000	23.8*	440.6*	Alluvial	Tropical deciduous forest
Metzontla-M	Managed in situ	2000	17.2**	527.9**	Derived from limestones	Thorn-scrub forest cleared for agriculture
Metzontla-C	Cultivated	1900	17.2**	527.9**	Alluvial	Home gardens
Mixteca Baja						
Chinango-W	Wild	1700	20.6*	720.5*	Derived from sandstones	Tropical deciduous forest
Chinango-M	Managed in situ	1700	20.6*	720.5*	Derived from sandstones	Tropical deciduous forest cleared for agriculture
Chinango-C	Cultivated	1600	20.6*	720.5*	Alluvial	Home gardens

* Based on García (1988)
** Based on Valiente (1991)

tion of *S. stellatus* in different human cultural contexts. Semi-structured interviews were conducted with a total of 26 constant key informants and nearly 45 occasional informants from the villages around the areas studied. Constant key informants were local people with experience in management of *S. stellatus,* suggested by local authorities or identified through the survey. Occasional informants were the owners of home gardens sampled at random for estimations of fruit yields. The following information was sought:

Folk Classification

Both living specimens and color photographs of "xoconochtli" and other species of cacti were shown to twelve of the key informants in order to elicit the Nahua, Popoloca and Mixtec folk nomenclature and classification of the different variants of *Stenocereus stellatus* in relation to other cacti.

Uses

Informants were asked about variants of xoconochtli present in the area and their uses; forms of preparation, consumption and storage of useful parts; morphological features preferred for different purposes. Specimens obtained during these interviews are deposited in the ethnobotanical collection of *Stenocereus stellatus* in the Jardín Botánico, Instituto de Biología, U.N.A.M., Mexico.

Management

Cultural and ecological factors affecting management of xoconochtli were assessed. Three situations were distinguished: wild, managed in situ, and cultivated. In managed in situ populations individuals with desirable characters are retained when land is cleared for agriculture, but all other individuals are removed. The cultivated populations were established in home gardens adjacent to the dwellings of the cultivators. Informants were asked how and on what characteristics people select particular individual plants during gathering and for cultivation, how they choose propagation materials for cultivation and how they treat propagating material before, during, and after planting.

FRUIT YIELDS AMONG POPULATIONS

Fruit production was studied during the producing season of 1995 in five wild populations,

TABLE 2. SOCIAL AND CULTURAL ASPECTS OF THE SITES STUDIED.

Site	Ethnic group	Population	Economy
Tehuacan Valley			
Zapotitlán	Popoloca	6000	Mining, craft manufacturing and sale of onyx
San Juan Raya	Popoloca	300	Seasonal cultivation of maize and beans; cattle and goat raising
Los Reyes Metzontla	Popoloca	5300	Manufacture and sale of pottery, seasonal cultivation of maize and beans, raising of goats
San Lorenzo	Nahua	200	Seasonal and irrigated cultivation of maize and beans; raising of goats; employment in Tehuacan City industries, commerce and services
Coxcatlán	Nahua	3000	Irrigated cultivation of sugar cane; seasonal cultivation of maize and beans; cattle and goat raising
Mixteca Baja			
Chinango	Mixtec	300	Seasonal cultivation of maize and beans; raising of goats; production and sale of fruits of *S. stellatus* and *S pruinosus*

two managed in situ populations, and two cultivated populations (details in Table 1). Fruit production per individual was evaluated within and compared between the populations. For samples of fruiting individuals, records were made of the total number of branches, the number and percentage of branches producing fruit and the mean number of fruits per branch. Five fruits from each individual were weighed. Analyses of variance were used to test for differences in these attributes between wild, managed in situ and cultivated populations from the Tehuacán Valley and La Mixteca Baja and within each of the two regions. For these analyses, data obtained by counting were transformed to their square roots, in order to adjust them to normal distributions. Similarly, logarithmic and arcsin transformations were applied to data of fruit weight and percentage of fruiting branches per individual respectively. Multiple range tests were carried out by 95% Tukey Highest Significant Difference (HSD).

Fruit production per population was estimated. In wild and managed in situ populations, individuals were studied along transects. In cultivated populations, 10% of the home gardens in each village were selected at random and one individual from different clones recognized by the cultivator in each selected garden were studied. The numbers of individuals in each sample which were producing fruit were counted. Fruit production was calculated as kilograms per individual (by multiplying number of fruits per individual and average weight per fruit) and kilograms per hectare (by multiplying average kilograms per individual and number of individuals per hectare estimated from the densities of populations along the transects and in the home gardens).

RESULTS

TRADITIONAL NOMENCLATURE AND CLASSIFICATION

When the Spaniards reached the Antilles, they saw cacti for the first time. They adopted the Antillean name *tuna* for fruits of *Opuntia* spp. and *pitahaya* for fruits of several columnar cacti and other cacti such as species of the genus *Hylocereus* (Berger) Britton & Rose. The term "pitahaya" means scaly fruit in the Antillean language (Pimienta-Barrios and Nobel 1994). These are the most common names today in Mexico, although the indigenous people have also preserved their own names and systems of classification.

The Nahua people, the most numerous Indian group in Mexico and in the Tehuacán Valley, distinguish columnar cacti from other cacti by grouping them in the category *nochcuauitl* (Table 3). This name is composed by the term *nochtli,* a word that designates the fruits of all the species of cacti (tunas and pitahayas) and

TABLE 3. PRIMARY LEXEMES FOR CLASSIFICATION OF CACTI BY THE NAHUA, MIXTEC, AND POPOLOCA PEOPLES.

Group	Nahua	Mixtec	Popoloca
Opuntia species	Nopalli	Vindia	Túchi
Columnar cacti	Nochcuauitl	Ndíchi	Túchi
Spherical cacti	Huitznahuac	Chimilóô	Lúchi

cuauitl which means tree. This term is used by the Nahua as a primary lexeme. An epithet which generally refers to some characteristic of a specific part of the plant provides a secondary lexeme (Table 4). However, more often the Nahua use only the term *nochtli* as a primary lexeme. This reveals the cultural importance of these fruits to the Nahua. Three species of *Opuntia* (*O. lasciacantha* Pfeiffer, *O. imbricata* (Haworth) De Candolle and *O. joconostle* Weber) are also commonly called *xoconochtli.* Normally, these species should be called *xoconochnopalli* Fig. 3, but the Nahua people often utilize only *nochtli,* qualified in different ways, (without the suffix *nopalli*) as short names for designating different species of *Opuntia.*

The first level of classification of *S. stellatus* by the Nahua is based on color of the pulp. In Spanish, people distinguish six variants: red, pink, white (or green), purple, orange and yellow. However, the Nahua people only name four variants (Table 5). They subsequently distinguish between sweet and sour flavors, using the words *necuti* and *xocotl* respectively, but these epithets never form part of the names of the plant. Similarly, they use *uitztli* and *amo uitztli* for spiny and non spiny fruits. There are no specific words for variants with thick or thin pericarp. The Nahua prefer variants with sweet flavored, non spiny fruits with thin pericarp.

Among the Popoloca people, the classification of xoconochtli follows a hierarchical pattern very similar to that of the Nahua. The term *túchi* (tuna or pitahaya) is used as the primary lexeme for grouping species of *Opuntia* and columnar cacti with big edible fruits. This term is distinguished from *lúchi* which includes spherical cacti (Table 3). The secondary lexeme *kánda* distinguishes the genus *Opuntia* while *Stenocereus pruinosus* is designated by the name *túchichina* and *S. stellatus túchikíshi,* a name composed from the roots "*túchi*" (tuna or pitahaya) and "*chikíshi*" (tree) that is, pitahaya tree (Table 4). In *Stenocereus* and *Opuntia,* further categories may be designated also by color (Table 5) or by flavor: *íisátu* (sour), *íishetu* (sweet) or *íisan* (insipid).

The Mixtec people of Chinango classify cacti in three great groups: *vindia* (*Opuntia* species), *chimilóô* (spherical cacti) and *ndíchi* (columnar cacti) (Table 3). Species are then distinguished by secondary lexemes (Table 4). The Mixtec distinguish between fruits of *Opuntia,* called *chíqui* and fruits of columnar cacti, called *ndíchi.* This resembles the Antillean classification of cactus fruits and differs from that of the Nahua and Popoloca. Fruits of spherical cacti are also called *chíqui,* but these are not included by the Mixtec in the classification.

Variants of *S. stellatus* are classified by the Mixtec on fruit characteristics. They distinguish two main categories of "xoconochtli" according to their color: the "red xoconochtli" (*ndíchi cââya cuaá*) and the "colored xoconochtli"

TABLE 4. SECONDARY LEXEMES FOR CLASSIFICATION OF COLUMNAR CACTI BY NAHUA, MIXTEC, AND POPOLOCA PEOPLES.

Species	Nahua	Mixtec	Popoloca
Myrtillocactus geometrizans	Tepepoa nochtli "aggressive hills pitahaya"	Ndíchi nóni "maize pitahaya"	Túchi lásha "small pitahaya"
Pachycereus weberi	Noch cuauitl "pitahaya tree"	Ndíchi quítu	absent in the area
Polaskia chichipe	Tepequio nochtli "hill pitahaya with scapes"	Ndíchi yáâ "silvery pitahaya"	Túchi cásha "scaled pitahaya"
Stenocereus pruinosus	Cuapetla nochtli "big tree pitahaya"	Ndíchi cuán "yellow pitahaya"	Túchi chína "big pitahaya tree"
Stenocereus stellatus	Xoco nochtli "sour pitahaya"	Ndíchi cââya "sandy pitahaya"	Túchi kíshi "pitahaya tree"

TABLE 5. CATEGORIES FOR CLASSIFICATION OF COLOR VARIANTS OF *STENOCEREUS STELLATUS* BY THE NAHUA, MIXTEC, AND POPOLOCA PEOPLES.

Variant	Nahua	Mixtec	Popoloca
Red	Chichi xoconochtli	Ndíchi cáâya cuaá	Túchi kíshi jatze
Pink	Chíchi xoconochtli	Ndíchi cáâya cuaá	Túchi kíshi jatze
Purple	Tlanec xoconochtli	Ndíchi cáâya ton*	Túchi kíshi katza
Yellow	Cotz xoconochtli	Ndíchi cáâya cuan*	absent in the area
Orange	Cotz xoconochtli	Ndíchi cáâya cuan*	absent in the area
White	Iztac xoconochtli	Ndíchi cáâya cúshi*	Túchi kíshi lúla

* Names of variants grouped in the more general category Ndíchi cáâya color by the Mixtec

(*ndíchi cáâya*-color) in which they group xoconochtli with fruits of the three other colors (including white) that they recognize. They consider the red color as a wild characteristic. The Mixtec also recognize variants within each color class according to the thickness of the pericarp, the abundance and persistence of spines, as well as sweet, sour or insipid flavor. However, for naming these variants, people do not use the complete hierarchical phrase name, but only that part which describes the fruits. For instance, they use the names *ndíchi dóô yáâdi* and *ndíchi dóô ndéê* for "xoconochtli" with thin and thick pericarp, respectively, and *ndíchi íño* and "*ndíchi má íño*" for spiny and less spiny fruits, respectively.

It is common to find in home gardens some individuals of "xoconochtli" with morphological characteristics resembling both *Stenocereus stellatus* and *S. pruinosus*. They resemble *S. stellatus* in general appearance, but have deep ribs, and vigorous spines, like *S. pruinosus*. They flower during the flowering season of *S. pruinosus* (February–May) and later during the flowering season of *S. stellatus* (June–August). Their Mixtec name is *ndíchi tucuéê* meaning "rabid xoconochtli". According to local people, these plants produce *S. stellatus* flavored fruits during the *S. pruinosus* flowering season, and *S. pruinosus* flavored fruits during the *S. stellatus* flowering season. These plants are called "xoconochtli aventureros" in Spanish (meaning adventurer xoconochtli) and are probably hybrids between the two species.

TABLE 6. NUTRITIONAL CHARACTERISTICS OF JUICE FROM FRUITS OF *STENOCEREUS STELLATUS* (BASED UPON BRAVO-HOLLIS AND SANCHEZ-MEJORADA 1991).

Characteristics	Amount
Brix degrees at 20°C	10.4°
Citric acid	0.64 g/100 ml
pH	3.95
Solids in suspension	0.685 g/100 ml
Solids in solution	9.1015 g/100 ml
Direct reducing sugars	7.9%
Total reducing sugars	8.1%
Vitamin C	11.72 mg/100 ml

USES AMONG INDIGENOUS PEOPLE

Stenocereus stellatus is used mainly for its sweet fruits. Fruits contain a sweet and juicy pulp formed by the seed funicles which, when mature, are full of sugary liquid (Table 6). They are in great demand as both fresh and dried fruits (xoconochtli pasados) and for preparing jams.

An alcoholic drink called "colonche" (from the Nahuatl word "nochoctli," which means prickly pear pulque) is very common among indigenous people of other states such as San Luis Potosí and Zacatecas, where "colonche" is prepared with juice of fruits of *Opuntia* spp., or Sonora, where the Pápago people prepare "colonche" with fruits of *Stenocereus thurberi* (Engelmann) Buxbaum, *Machaerocereus gummosus* (Engelmann) Britton & Rose, *Carnegiea gigantea* (Engelmann) Britton & Rose and *Pachycereus pringlei* (S. Watson) Britton & Rose (Bravo-Hollis and Sánchez-Mejorada 1991; Felger and Moser 1974). Colonche is sometimes prepared from *S. stellatus* in the Tehuacán Valley and La Mixteca Baja.

According to Bravo-Hollis and Sánchez-Mejorada (1991), seeds of all cacti are edible, but because of their small size and the hardness of their testa they are not a common food. However, some species were widely used as food by some Indian groups in prehistory (Callen 1967).

This use has persisted until the present among indigenous groups of the desert of Sonora in northern Mexico (Bravo-Hollis and Sánchez-Mejorada 1991; Felger and Moser 1974). These peoples extract seeds from fruits of several columnar cacti and *Opuntia* species. Then, they wash, dry and grind the seeds producing an edible oily paste. Seeds are extracted directly from fresh fruits but may also be retrieved from human feces.

In the Tehuacán Valley, the seeds of *Neobuxbaumia tetetzo* (Coulter) Backeberg, *Pachycereus weberi* and *S. stellatus* are still eaten by the Nahua, the Mixtec and the Popoloca people. Seeds obtained from fresh or dried fruits are washed, dried and roasted. The roasted seeds are ground with chili peppers, onion and tomatillo (*Physalis philadelphica* Lamarck) or tomato (*Lycopersicon esculentum* Miller) for preparing traditional sauces eaten with maize tortillas as the main component of the Indian diet. The basic components of the sauces can be other seasonal wild or cultivated products. For example, seeds of *Leucaena esculenta* (Moc. et Sessé ex A.DC.) Benth. are used between December and March, fruits of *Spondias mombin* L. between April and May, seeds of *N. tetetzo* in June, seeds of *Pachycereus weberi* between February and April, and seeds of *S. stellatus* between July and September. Alternatively, the cactus seeds may be ground into an edible paste which is eaten with tortillas. Bravo-Hollis and Sánchez-Mejorada (1991) report that seeds of *S. stellatus* contain approximately 22 and 23% of protein and fat respectively. This shows the importance of this resource in subsistence of local people and its potential value for human nutrition on a wider scale.

Stems and flowers are occasionally consumed. They are usually eaten during seasons when other food is scarce. Stems of columnar cacti are not often eaten at present but they seem to have been a very common food in the past (Callen 1967). Young stems are prepared by removing the spines, cutting them in longitudinal pieces and removing the medullar portion, and then roasting them. After roasting, the cuticle is easily removed. The flower buds are boiled and then fried with eggs. This is a common form of preparation of flowers of many species of cacti, *Agave, Yucca, Beaucarnea,* and other genera. The boiled flower buds may also be prepared with onion and vinegar. This is particularly common with *Neobuxbaumia tetetzo* but occurs also with flower buds of other columnar cacti, including *S. stellatus.*

Cultural value of all these edible products from xoconochtli can be studied in the markets. Thus, in some villages (e.g., Los Reyes Metzontla) and markets (e.g., Ajalpan), three to five fresh fruits or six to ten dried fruits of *S. stellatus* are exchanged for one liter of maize; one liter of flower buds for three liters of maize and one liter of seeds for fifteen liters of maize.

Young branches of *S. stellatus* and other species of columnar cacti are also cut and fed to goats, after removal of the spines. The plants are not killed and, relatively quickly, produce more branches which may grow 20 to 40 cm per year. Whole fruits or pericarp and seeds of fruits whose pulp has been used are also a very good forage.

For manufacturing pottery, a bed of hard wood with high specific heat is made by people from Los Reyes Metzontla from species such as *Acacia* spp., *Prosopis laevigata* (Humb. & Bonpl. ex Willd.) M.C. Johnston, and *Lippia graveolens* Kunth. Objects to be fired are put on this bed and covered with soft wood with a lower calorific value. *Ipomoea arborescens* G. Don, *Agave* spp., *Polaskia chichipe* and *S. stellatus* are among the most important sources of soft wood.

Individuals of *S. stellatus* along with *Myrtillocactus geometrizans, S. pruinosus, Pachycereus marginatus* and *P. hollianus* (F.A.C. Weber) F. Buxbaum are commonly grown as living fences and as barriers for soil protection in terraces around the borders of cultivated slopes.

Traditional Management

In the study area, people commonly gather fruits and stems of *Stenocereus stellatus* from wild populations. People collect fruits selectively, preferring variants with relatively sweeter flavor, thinner pericarp, fewer spines and bigger size. When the fruits are gathered for preparing jams or dried fruits (xoconochtli pasado), the harvest is less selective. Adults and children of both sexes collect the fruits during the season.

People in all the studied areas commonly protect naturally established individuals of *S. stellatus* when they clear new land for corn fields. They may also increase the numbers of this plant in the fields by planting branches from the protected individuals and taking care of them. People prefer individuals with big fruits, sweet flavor, thin pericarp and few spines. However, other phenotypes are tolerated, especially when no other useful species or phenotypes of *S. stellatus* are available. In Chinango, this form of management in situ includes pruning of the protected plants in order to improve the conditions for maize whereas in the Nahua and Popoloca areas we did not observe this practice.

Finally, *S. stellatus* may be cultivated, mainly in home gardens or as living fences around agricultural fields. Vigorous branches of 20–100 cm in length are cut from mature wild or cultivated individuals. They are left exposed to the sun for 10–15 days so that the cut surface may dry in order to reduce fungal and bacterial infection. After this period, and just before the rainy season the branches are planted either horizontally or vertically in holes 10–40 cm deep fertilized with cattle or goat dung. A few fruits may be obtained after one year, but during the second year the plants commonly do not produce. Thus, production does not really start until the third or even the fourth year after planting. *S. stellatus* is neither irrigated nor pruned, but ash is commonly deposited, as fertilizer, on the soil covering the main stems.

Individuals of *S. stellatus* cultivated in home gardens may also be derived from protected seedlings established from seeds dispersed through bird, bat or human feces. Generally, people do not recognize variants of xoconochtli by their vegetative characteristics. Therefore, decisions on eliminating or conserving individual plants are generally taken after four or five years, when the individuals produce fruits.

FRUIT YIELDS AMONG POPULATIONS

Among the first features likely to be affected by human selection or management in the domestication of a plant species used for food is yield (per individual, or per unit area or both). In *Stenocereus stellatus,* yield per individual depends on the mean weight per fruit, the number of fruits per branch, and the number of fruiting branches per individual, which is in turn determined by the total number of branches per individual and the proportion of these branches which bear fruits. Yield per unit area will depend in addition on the number of fruiting individuals per unit area, which depends in turn on the density of the population and the proportion of fruiting individuals which it contains. Table 7 shows the data on these components of yield from the nine populations studied (five wild, two managed and two cultivated). Table 8 contains the results of analyses of variance for these data. The number of individuals studied in each population varied from 5 to 46. This diversity in sample size, with respect both to individuals representing a population, and populations representing wild, managed and cultivated situations, means that generalisations must be drawn cautiously, even where the analyses suggest that differences are statistically significant.

Variation Between Wild Populations

In the Tehuacán Valley, the estimated yields of fruits in the four wild populations were small (1.4 kg per hectare in San Juan Raya to 70.1 kg per hectare in Zapotitlán). The number of fruiting individuals per hectare (which varied widely, from 6 to 160) had more effect in determining yield per hectare than the yield per fruiting individual (which varied from 0.2–0.9 kg). Mean weight per fruit ranged from 19–23 g, and the number of fruits per fruiting individual from 12–38.

In La Mixteca Baja, the estimated yield of the single wild population (51 kg per hectare) was within the range of yields estimated for wild populations in the Tehuacán Valley. The population was sparse (estimated as only 15 fruiting individuals per hectare), but the mean weight per fruit (42 g) and the number of fruits per plant (82) were larger than in any of the wild populations in the Tehuacán Valley.

Effects Associated with Management in situ

In the Tehuacán Valley, the single managed population studied yielded more (estimated yield 151 kg per hectare) than any of the wild populations. The number of fruiting plants per hectare was within the range of the wild populations, but the yield per fruiting individual (1.3 kg) was larger, and this in turn was associated with larger number of fruiting branches per individual and significantly heavier fruits (mean weight 34 g).

The managed population from La Mixteca Baja had an estimated yield of only 10.5 kg per hectare, less than the local wild population and much less than the managed population from the Tehuacán Valley. This population contained relatively few fruiting individuals (only 11 per hectare) and these plants bore relatively few

TABLE 7. COMPONENTS OF FRUIT YIELDS IN THE POPULATIONS STUDIED. BOLD CHARACTERS INDICATE RANGES WHICH DIFFER SIGNIFICANTLY ACCORDING TO THE TUKEY 95% HSD TEST. UPPER CASE BOLD LETTERS RELATE TO DIFFERENCES BETWEEN ALL POPULATIONS WITHIN EITHER THE TEHUACAN VALLEY OR LA MIXTECA BAJA. LOWER CASE BOLD LETTERS RELATE TO DIFFERENCES BETWEEN WILD POPULATIONS ACROSS BOTH REGIONS. GREEK LETTERS RELATE TO DIFFERENCES BETWEEN THE TWO MANAGED POPULATIONS. NUMBERS RELATE TO DIFFERENCES BETWEEN THE TWO CULTIVATED POPULATIONS.

	TEHUACAN VALLEY						MIXTECA BAJA		
Population/Character	Zapotitlán	Sn Lorenzo	Sn Juan R	Coxcatlán	Metzontla-M	Metzontla-C	Chinango-W	Chinango-M	Chinango-C
Cultural status	Wild	Wild	Wild	Wild	Managed	Cultivated	Wild	Managed	Cultivated
No individuals per ha. (estimate)	273	34	29	280	120	781	35	48	259
No fruiting indiv per ha. (estimate) (%)	160 (59%)	18 (53%)	6 (20%)	37 (13%)	120 (100%)	781 (100%)	15 (43%)	11 (22%)	244 (94%)
No. fruiting indiv. sampled	24	18	5	22	12	26	9	8	46
No branches per fruiting individual	7.0 ± 0.9	19 1 ± 4.8	11.2 ± 3 8	6.4 ± 1.3	19.0 ± 3.0	22.2 ± 2 3	14.2 ± 4 3	8.8 ± 1.4	21.5 ± 3.0
	A	**B**	**AB**	**A**	**B**	**B**	**A**	**A**	**B**
	a	**b**	**ab**	**a**	**β**	**1**	**ab**	**α**	**1**
% branches with fruits	43 7 ± 0 5	28 9 ± 1.4	23.2 ± 1.0	39.8 ± 0.6	39 0 ± 1.7	38.6 ± 1.1	50.0 ± 3.4	46 3 ± 0.9	72.2 ± 2.3
	A	**A**	**A**	**A**	**A**	**A**	**A**	**A**	**B**
	a	**a**	**a**	**a**	**α**	**1**	**a**	**α**	**2**
No fruits per branch	6.5 ± 0.9	6.9 ± 1 0	4.6 ± 1 3	5 0 ± 0.8	5.3 ± 0 7	11.5 ± 1 1	11.5 ± 2.1	8.0 ± 0.9	12.0 ± 0.8
	A	**A**	**A**	**A**	**A**	**B**	**A**	**A**	**A**
	a	**a**	**a**	**a**	**α**	**1**	**b**	**β**	**1**
Weight per fruit (g)	22 3 ± 1.9	23 2 ± 2 3	19.4 ± 2 4	18 7 ± 2.6	34.1 ± 2.8	38.8 ± 2.9	41 7 ± 6 1	37.9 ± 4.9	72.2 ± 4.1
	A	**A**	**A**	**A**	**B**	**B**	**A**	**A**	**B**
	a	**a**	**a**	**a**	**α**	**1**	**b**	**α**	**2**
No. fruits per fruiting ind	19.6 ± 3.4	37.7 ± 13.0	12 0 ± 7.5	12.8 ± 3.4	39.2 ± 10.7	98.9 ± 14.5	81 7 ± 37 7	25.1 ± 6.2	187.1 ± 29.8
Kg. fruits per fruiting ind.	0 4 ± 0.1	0.9 ± 0.5	0 2 ± 0 1	0.2 ± 0.1	1.3 ± 0.5	3.8 ± 0.6	3.4 ± 2.4	1 0 ± 0.3	13.5 ± 2.4
Kg fruits per ha (estimate)	70 1	15 8	1 4	8.8	151.3	2995.1	51.1	10 5	3298 8

TABLE 8. ANALYSIS OF VARIANCE FOR CHARACTERS RELATED TO FRUIT YIELDS BETWEEN POPULATIONS STUDIED (*$P \leq 0.05$; **$P \leq 0.01$; ***$P \leq 0.001$; NS = NO SIGNIFICANT DIFFERENCES).

	Differences related to locality across regions			Differences related to management within regions	
Character	All wild populations	Managed in situ populations	Cultivated populations	Tehuacán Valley populations	Mixteca Baja populations
No. branches per fruiting individual	*	**	NS	***	*
% branches with fruits per fruiting individual	NS	NS	***	NS	***
No fruits per fruiting branch	**	**	NS	***	NS
Mean weight per fruit	***	NS	***	***	***

branches, because they had been pruned by the local Mixtec people. Neither the number of fruits per branch nor the mean weight per fruit (38 g) significantly exceeded the values for the local wild population.

Effects Associated with Cultivation

In both the Tehuacán Valley and La Mixteca Baja, the estimated yields of the cultivated populations were much larger (about 3000 and 3300 kg per hectare respectively) than those of any wild or managed population. In both regions, the proportion of plants that bore fruits was extremely large (100% and 94% respectively), and the numbers of fruits per individual (99 and 187) were greater than in any wild or managed population. In the Tehuacán Valley, the cultivated population was very dense (estimated as 781 individuals per hectare) but fruits were not significantly larger than in the local managed population. In La Mixteca Baja, the cultivated population was less dense (estimated as 259 individuals per hectare), but the fruits were by far the largest encountered in this study, with a mean weight of 72 g.

The effects of cultivation are therefore both larger and more consistent than the effects of management. Yield, per unit area and per individual, has increased markedly. However, the effects of cultivation on the components of yield are not consistent in the two cultivated populations.

Differences Between Regions

The effects of environmental differences between the drier Tehuacán Valley and La Mixteca Baja, which is somewhat less arid, are mostly not consistent. Wild plants bore more fruits per branch in La Mixteca Baja than in the Tehuacán Valley, and these fruits were approximately twice as heavy. Cultivated plants also had much heavier fruits in La Mixteca Baja than in the Tehuacán Valley. These differences may reflect the more favorable growing conditions of La Mixteca Baja.

ROLE OF *S. STELLATUS* IN SUBSISTENCE OF INDIGENOUS PEOPLE

In the Popoloca region of Tehuacán, the people of Zapotitlán occasionally harvest fruits of xoconochtli from the small but dense wild populations (Table 7) spread as patches around the town. Home gardens contain a few individuals of *S. stellatus.* Fruits of xoconochtli are consumed only by members of the family and they are never marketed. Similarly, in San Juan Raya, there are a few individuals of xoconochtli in home gardens, but the main harvest of fruits is from wild populations, although here both density of population and fruit yield are very small. Fruits of both wild and cultivated xoconochtli are used only for home consumption. In Los Reyes Metzontla, wild populations of *S. stellatus* were not observed. However, this species is one of the most important plant elements in home gardens. In this village, most gardens are rainfed and only about 10% are irrigated. For this reason, the main components of home gardens are native plant species such as *Stenocereus stellatus, S. pruinosus, Pachycereus marginatus, P. hollianus, Opuntia* spp., *Agave* spp. and *Leucaena esculenta.* Fruit yields of *S. stellatus* are high in home gardens, and although people from Los Reyes occasionally market the products of xoconochtli, these are mainly used by local families. Fruits from managed in situ populations complement the production of the home gardens.

In the Nahua village of Coxcatlán (Tehuacán), most home gardens are irrigated and people prefer to cultivate in them species which need much water such as *Persea americana* Miller, *Diospyros digyna* Jacq., *Citrus* spp. and others. Introduced variants of cultivated *Opuntia* species are the only cultivated cacti. Products of other useful cacti (mainly *Escontria chiotilla, Myrtillocactus geometrizans* and *Stenocereus stellatus*) are harvested from dense wild populations. These products are consumed mainly by local families. They are marketed, but only locally.

In the second Nahua village, San Lorenzo (Tehuacán), home gardens contain a few individuals of *S. stellatus*. Local wild populations of *S. stellatus* are not dense but produce satisfactory yields of fruit per hectare (Table 7). At present, useful wild products of this forest are harvested occasionally by the Nahua and Mestizo people of San Lorenzo and Tehuacán for home consumption.

In Chinango (Mixteca Baja), the Mixtec people in part depend on production and marketing of fruits of *S. stellatus* and *S. pruinosus* (Table 2). In the home gardens, *S. stellatus* and *S. pruinosus* are by far the most abundant species cultivated. Wild and managed populations occur in natural and disturbed areas. The main portion of xoconochtli products is obtained from the home gardens, complemented by harvest from other populations. Xoconochtli fruits are harvested both for home consumption and for marketing in the main market of the municipality, and in the most important regional markets in San Pedro Chazumba and Huajuapan de León, Oaxaca.

Discussion and Conclusions

The fruits are the most significant parts of *Stenocereus stellatus* utilized in the area. Traditional classification of this species is based on characteristics of the fruits. Other parts such as seeds or stems are only occasionally utilized by people, and they are not used to define categories in folk classifications of this species.

Five fruit characters (pulp color, fruit size, flavor, thickness of the peel and spininess of the fruit) are used in classification of infraspecific variation among the three Indian groups studied. Pulp color is used to make a first division of categories within xoconochtli as well as in other cactus species. Red fruits are considered characteristic of the wild plants, while other colors occur only in cultivated individuals. White fruits are considered as the best cultivated variants of xoconochtli. People also distinguish between small and big fruits. Small fruits are considered to be a wild characteristic, while cultivated individuals generally have bigger fruits. Three different flavors of xoconochtli fruits are recognized by people: sweet, sour, and insipid. The first two are preferred for different purposes, but sweet flavor is identified with cultivated plants, while sour flavor is considered characteristic of wild plants. People distinguish between fruits with thin and thick pericarps, associating thin pericarps with cultivated plants. Spiny fruits are considered to occur commonly in wild individuals while fruits from cultivated plants have fewer spines.

Combinations of character states for these five traits provide the bases for selection by growers. In all three ethnic groups, people generally consider the best xoconochtli to be those with large fruits, white sweet pulp, thin peel and few spines. However, they continue to maintain variants with different characteristics because they are used for different purposes. For instance, sour fruits are good for preparation of drinks and jams; spiny fruits are more resistant to predators; fruits with thick pericarp resist rotting and are better for long distance transportation. Artificial selection thus seems to favor a number of different combinations of fruit characteristics, each playing a particular economic or cultural role. This pattern of selection may determine complex patterns of variation of xoconochtli associated with human manipulation.

According to local people, desired forms are identified from wild, managed in situ or cultivated populations and then maintained vegetatively by planting branches of the selected plants in home gardens. But selection apparently occurs also when, according to local people, plants of desired forms are preferentially spared or protected when land is cleared. A similar form of selection appears to occur when seedlings in cultivated populations are spared until their fruits can be evaluated, after which the plants either are retained or discarded. This last could explain why some variants are found in cultivation that are not seen in wild populations, for instance, fruits with pulp color other than red.

Fruit yields were evaluated in one year only, so the results obtained from this study should not be considered conclusive. Annual fluctuations in temperature and precipitation (García 1988) are likely to cause considerable fluctuations in productivity. Nevertheless, in both the Tehuacán Valley and La Mixteca Baja, yields from the cultivated populations were much larger than yields from either wild or managed populations. This is partly because individuals in the cultivated populations bore more fruits, possibly because more water and more nutrients were available in the soils of the home gardens. The increased yield of the cultivated plants also reflects the larger number of fruits per branch (in the cultivated population from the Tehuacán Valley) and the greatly increased weight per fruit (in the cultivated population from La Mixteca Baja), compared to local wild and managed populations. Both of these increases may relate to human selection.

Relatively few individuals were studied in the two managed populations. However, the Popoloca inhabitants of the village of Los Reyes Metzontla may have selectively retained large-fruited individuals, and selectively eliminated small-fruited individuals, to produce the increase in fruit weight observed when this managed population is compared to any of the wild populations in the Tehuacán Valley. Mixtec management of xoconochtli populations on agricultural land does not seem to have been directed towards increasing the yield of fruit. On the contrary, the Mixtec practice of pruning branches from these plants has reduced significantly the number of fruits produced per plant, and these fruits are no larger than those of the local wild plants.

Forms of management of xoconochtli seem to be influenced by the role of its products in the subsistence of people, by the availability of xoconochtli in the wild, and by environmental factors determining success in the establishment of this species, rather than by ethnic differences. In Coxcatlán (Tehuacán), for instance, xoconochtli is almost absent from home gardens. The Nahua people in this area are farmers but home gardens only complement the agricultural economy. People cultivate in home gardens several species of fruit trees, but not xoconochtli because, as they say, "there are a lot in the wild." In contrast, there are no dense wild populations of xoconochtli around the Nahua village of San Lorenzo (also Tehuacán) and people cultivate individuals of this species, although only on a small scale because xoconochtli is not important in their economy.

In the Popoloca village of Los Reyes Metzontla (Tehuacán), home gardens also increase the range of plant-derived foods, but they appear to be more important than in the Nahua villages because the yields of maize are very small because of high levels of soil erosion in agricultural areas. Along with this, the scarcity of wild xoconochtli strongly encourages its cultivation. In other Popoloca villages such as San Juan Raya (Tehuacán), where wild populations of xoconochtli are not as dense as in Coxcatlán (Tehuacán), xoconochtli plays a secondary role in human subsistence, and cultivation is not practiced. In Zapotitlán (Tehuacán), precipitation is less than in Metzontla but yields of maize are not so small because the irrigated area is larger. As in Coxcatlán, wild populations of xoconochtli are dense and people prefer to cultivate other plant species in the irrigated home gardens.

In Chinango, production, consumption and marketing of xoconochtli fruits are more important in the local economy than in the Tehuacán villages. In this area, although wild populations of xoconochtli are present, fruit yields are significantly larger in home gardens. Cultivation in Chinango is therefore a way of increasing the quantity and quality of fruits. The production of xoconochtli is more intensive and artificial selection is presumably more active than in the villages studied in Tehuacán. However, not all of the Mixtec villages of the area cultivate xoconochtli. In some villages *Stenocereus pruinosus* or *Escontria chiotilla* is cultivated rather than xoconochtli, and in other villages columnar cacti are not cultivated at all.

In Chinango, cultivated xoconochtli are of better quality than the wild xoconochtli, and the output is sufficient to cover requirements of people so that not all of the fruits produced on cultivated plants are harvested. In Chinango, wild and in situ managed populations are additional sources of fruit, but they do not seem to be an important complement. People therefore concentrate on management and artificial selection in home gardens.

So far, we have examined some apparent signs of artificial selection of *Stenocereus stellatus* by local people. However, it is still necessary to analyze more carefully whether the differences detected between cultivated and wild populations are differences in phenotype caused by environmental and agronomic conditions or whether human selection has caused cultivated populations to differ significantly from wild populations in the genotypes which they contain. If there are genotypes in the cultivated populations which are incapable of surviving in the wild, then *Stenocereus stellatus* qualifies as a domesticated, and not just a cultivated, species.

ACKNOWLEDGMENTS

This research was supported by the Comision Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO), Mexico, the Jardín Botánico Instituto de Biología, and the Centro de Ecología, UNAM, as well as the Department of Agricultural Botany of the University of Reading, U K The authors are grateful to MSc Miguel Angel Martínez-Alfaro, Dra Cristina Mapes, Dr Robert Bye, Professor Peter Caligari and Professor Hugh Bunting for their critical comments on the manuscript We thank the people of the villages where the study was carried out as well as José Antonio Soriano, Héctor Godínez, Noé Flores, Ariel Alcántara and Alberto Rojas for their valuable help during field work and data processing We also thank Dr Patricia Dávila for her collaboration in this research in many different ways

LITERATURE CITED

Bravo-Hollis, H., and H. Sánchez-Mejorada. 1991. Las cactáceas de México. Volume III. Universidad Nacional Autónoma de México. México.

Callen, E. O. 1967. Analysis of the Tehuacán coprolites. Pages 261–289 *in* D. S Byers, ed , The prehistory of the Tehuacan Valley. Volume one: environment and subsistence. University of Texas Press, Austin.

Casas, A., J. L. Viveros, and J. Caballero. 1994. Etnobotánica mixteca: sociedad, cultura y recursos naturales en la Montaña de Guerrero. México. Instituto Nacional Indigenista-Consejo Nacional para la Cultura y las Artes, México.

———**, and J. Caballero.** 1995. Domesticación de plantas y origen de la agricultura en Mesoamérica Ciencias 40:36–40.

———**, M. C. Vázquez, J. L. Viveros, and J. Caballero.** n.d. Plant management among the Nahua and the Mixtec of the Balsas river basin: an ethnobotanical approach to the study of plant domestication. Human Ecology. in press.

Dávila, P., J. L. Villaseñor, R. L. Medina, A. Ramírez, A. Salinas, J. Sánchez-Ken, and P. Tenorio. 1993 Listados florísticos de México. X. Flora del Valle de Tehuacán Cuicatlán. Universidad Nacional Autónoma de México, Instituto de Biología. México

Felger, R., and M. B. Moser. 1974. Columnar cacti in Seri Indian culture. Kiva 39 257–275

García, E. 1988. Modificaciones al sistema de clasificación climática de Köpen. Instituto de Geografía, Universidad Nacional Autónoma de México, México.

MacNeish, R. S. 1967. A summary of the subsistence. Pages 290–309 *in* D. S. Byers, ed., The prehistory of the Tehuacan Valley. Volume one· Environment and subsistence. University of Texas Press, Austin.

Pimienta-Barrios, E., and P. S. Nobel. 1994. Pitaya (*Stenocereus* spp., Cactaceae) an ancient and modern fruit crop of Mexico Economic Botany 48:76–83.

Rzedowski, J. 1978. Vegetación de México. Limusa. México.

Sedgley, M., and A. Gardner. 1989 International survey of underexploited tropical and subtropical perennials. Acta Horticulturae 250:1–26.

Smith, C. E. 1967. Plant remains. Pages 220–255 *in* D. S. Byers, ed., The prehistory of the Tehuacan Valley. University of Texas Press, Austin, Texas.

Valiente, B. L. 1991 Patrones de precipitación en el Valle semiárido de Tehuacán, Puebla, México. BSc dissertation. Facultad de Ciencias, Universidad Nacional Autónoma de México, México

BOOK REVIEW

Ferns of Hawai'i. Kathy Valier. 1995. University of Hawaii Press, 2840 Kolowalu Street, Honolulu, HA 96822. viii + 88 pp. (paperback). $14.95 ISBN 0-8248-1640-4.

Ferns of Hawai'i is an easy-reading reference manual apparently designed for fern enthusiasts and other naturalists who might desire a trail side reference The text begins with an interesting overview of the history and usage of ferns in Hawai'i. This is followed by a loose description of the taxonomic position of ferns and fern allies. Short discussions of fern growth forms, reproduction, nomenclature, and ecology are also provided The body of the handbook consists of treatments of each of the fern species of Hawai'i. Treatments list: a history of the fern group, and a description, habitat, and distribution of the species. One or more pictures are illustrated with each description. Weak points in the presentation include Fig. 1 which proposes several impossible/confusing relationships between ferns and other plant, animal and fungal life forms, and the placement of *Ophioglossum* (which is listed with the other "common" ferns rather than being separated into a pro-gymnosperm category) Positive points of this book include very good photographs (although a few are not), simply worded, yet useful descriptions of common and endemic ferns, and instructive comments about the groups of ferns found in Hawai'i.

WILL MCCLATCHEY
DEPARTMENT OF BOTANY
UNIVERSITY OF FLORIDA
GAINESVILLE, FL 32611-8526