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Plant Management Among the Nahua and the Mixtec in the Balsas River Basin, Mexico: An Ethnobotanical Approach to the Study of Plant Domestication

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Different forms of management of wild, weedy, and domesticated plants carried out by the Nahua and the Mixtec in the Balsas River Basin, Mexico, are described. Along with cultivation of domesticated plants, these forms of plant management include gathering from wild populations; in situ *tolerance of plant individuals during clearings of natural vegetation;* in situ *enhancement and protection of particular plants among populations of some species; as well as sowing or planting of propagules and transplantation of complete individuals of weedy and wild plants in controlled* ex situ *environments. Processes of artificial selection and possible routes of domestication occurring in these forms of plant management are discussed.*

KEY WORDS: ethnobotany; plant management; domestication; Nahua; Mixtec.

INTRODUCTION

The cultural area known as Mesoamerica, in southern Mexico and Central America, has been considered one of the most important centers of plant domestication in the world (Harlan, 1975; Hawkes, 1983; Vavilov, 1926). This can be explained by the co-existence of two factors: a great natural biodiversity and a long social and cultural history. Toledo (1988) estimates that approximately 30,000 vascular plant species exist in Mexico. This country is therefore considered one of the richest floristic regions of

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the world (Rzedowski, 1978). In addition, there are 56 indigenous ethnic groups living today in the Mexican territory (Toledo, 1988) whose subsistence is based on the use and management of no fewer than 7000 plant and animal useful species (Cases *et al.,* 1994).

Ethnobotanical studies such as those of Caballero and Mapes (1985), Casas *et al.* (1994), Vázquez (1986), and Zizumbo and Colunga (1982), among others, have shown that at present a large segment of the indigenous Mexican population subsists by cultivating corn, beans, chili, squash, and other crops, and through gathering a wide number of plant resources. According to Caballero (1984), indigenous people in Mexico use and manage more than 5000 species of wild, weedy, and cultivated plants. Indigenous people maintain different forms of interaction with all these plants. Such interactions are a valuable source of information for the study of the evolution of plants under domestication.

Domestication is an evolutionary process, in which human intervention through artificial selection operates as the principal evolutionary force. This process may cause changes in morphology, physiology, phenology, life cycles, or reproductive systems of plants. All these changes are designed and regulated according to the different requirements of human cultures.

In order to understand the process of domestication of plants, it is necessary to analyze both biological variation in plant populations as well as social and cultural aspects involved in the use and management of this variation. Disciplines such as population genetics, ecology, and systematics may generate important information for the analysis of genotypic and phenotypic variation caused by domestication in plant populations, while disciplines such as ethnobotany and human ecology, which analyze the interactions and interrelationships between humans and plants, make possible the study of the different forms of manipulation of plants. Thus, ethnobotany and human ecology may make significant contributions to the understanding of how artificial selection is occurring, and its consequences for the evolution of plants. In addition, information generated in these areas may be helpful in explaining how domestication occurred in the past.

When the process of plant domestication is analyzed, a problem that commonly arises is how to determine if the plant populations under study are wild or domesticated. Also, when a domesticated plant is studied it is difficult to determine the degree of domestication (incipient or advanced) the plant has. This issue becomes more problematic when populations of a given species are distributed in a continuum from natural wild sites to man-made habitats. In other cases, relatives of cultivated plants may be either wild plants, weeds, or hybrids between the crop and its sympatric wild or weedy relatives. The resolution of these problems may involve complex systematic and ecological studies. However, in the search for answers it may be helpful to consider the general characterization of wild, weedy, and domesticated plants proposed by De Wet and Harlan (1975). These authors classified plants according to their ecological responses to different environments. Plants were classified as:

(1) Wild plants, as plants growing naturally outside habitats disturbed by humans, and which cannot successfully invade habitats permanently disturbed by human beings (De Wet and Harlan, 1975).

(2) Weeds, as plants growing in permanently human-disturbed habitats but which do not depend on human beings for the reproduction and survival (De Wet and Harlan, 1975). In this paper, we include under this category both true weeds, plants growing in agricultural fields and gardens, and ruderal plants, those growing along roadsides.

(3) Domesticated, as plants growing in human-made habitats, and having a strong dependence on human beings to reproduce and survive. As a consequence of artificial selection, these plants usually present gigantism in the parts used by humans, a wide range of morphological variation, phenological changes, suppression of natural mechanisms for dispersion and protection, reduced competitivity, and other features of domestication (see De Wet and Harlan, 1975; Harlan, 1975; Hawkes, 1983; Schwanitz, 1967).

Evolutionary changes can be recognized as changes in phenotypic and genotypic frequencies in populations. Human interactions with plants may influence not only populations but also communities. In all these cases, the rates of evolutionary change in plants depend upon the nature of the relationships between them and humans. These forms of interaction determine the level of intensity at which allelic frequencies are manipulated and modified.

Based on studies of plant manipulation among Mesoamerican peoples such as those of Alcorn (1981), Bye (1985, 1993), Caballero (1994), Caballero and Mapes (1985), Casas (1992), Casas et al. (1987, 1994), Colunga et al. (1986), Davis and Bye (1982), Vázquez (1986, 1991), Williams (1985), and Zizumbo and Colunga (1982), it is possible to distinguish two main forms of interaction between human beings and plants: *in situ* and *ex situ* management.

In situ management involves interactions that take place in the spaces occupied by populations of weeds or wild plants. At this level, humans may take products from nature without significant perturbations, as in some forms of gathering. But also they may alter, consciously or unconsciously, the phenotypic or genotypic structure of plant populations in order to increase numbers of particular desirable plant phenotypes. The main *in situ* management strategies are:

(1) Gathering, which is the taking of useful plants or plant parts directly from natural wild plant populations or weedy plant populations. Har-

vest of plant products from domesticated cultivated plants is not considered here as gathering. Gathering is the most elementary form of interaction between humans and plants in order to obtain useful products. Under this interaction, manipulation of plant populations or communities is not always obvious. However, gatherers sometimes may carry out gathering strategies such as rotation of gathering areas in order to prevent the decrease or loss of some resources. Sometimes, gatherers also practice activities such as digging, clearing of vegetation around desirable plants, and cutting of branches or other parts of the plants whose products are gathered that may cause alterations in plant population structure (see Bye, 1985; Casas and Caballero, in press; Hallam, 1989). This could be also the case when there is massive collection of particular plants or plant parts or the selective collection of products of particular phenotypes, as practiced in some forms of gathering observed in this study. For these reasons, gathering may be considered a form of plant management.

(2) Tolerance or sparing, including practices directed to spare, within human-made environments, useful plants that existed before the environments were transformed. Plant communities managed in this way may change strongly their original composition and structure. In some areas, this practice may favor an increase of number of individuals of a particular plant species or particular phenotypes. Examples of tolerance among edible weeds or "quelites" has been reported by several ethnobotanical studies in Mexico (Caballero and Mapes, 1985; Casas et al., 1987; Davis and Bye, 1982; Vázquez, 1986, 1991; Williams, 1985). Among studies of perennial weeds and wild plants those with *Opuntia* spp. conducted by Colunga et al. (1986), and with *Leucaena esculenta* (Moc. et Sessé ex A.DC.) Benth. by Casas (1992) are notable.

(3) Enhancement consists of different strategies directed to increase the density of population of useful plants. This type of management includes the sowing of seeds or the intentional propagation of vegetative structures in the same places occupied by populations of wild or weedy plants. Steward (1938) recorded a good example of enhancement of useful plants *in situ* among the Paiute in California. These people used channels to inundate meadows aimed at increasing productivity of a wild cereal. Similar examples can be found in Schneider (1972), Bye (1985), Groube (1989), Shipek (1989), Hallam (1989), Hillman (1989), and Pearsall (1989).

(4) Protection includes conscious care activities such as the elimination of competitors and predators, fertilization, pruning, protection against frosts, etc., to safeguard critical wild or weedy plants. Bye (1985) describes an example of this interaction in the management of wild onions practiced by the Tarahumara in the north of Mexico.

Ex situ management, on the other hand, includes interactions taking place outside spaces occupied by natural wild populations or weedy plant populations, in habitats created and controlled by man. It usually occurs with domesticated plants, but it is possible to find it also with wild, weedy, and ruderal plants. There are two main forms of *ex situ* management of weeds and wild plants:

(1) Sowing or planting includes artificial propagation of sexual or vegetative reproductive structures taken from wild or weedy plant populations.

(2) Transplantation of complete individuals taken from wild or weedy populations.

Practices such as enhancement and protection of plants as described above are included in these two forms of *ex situ* management.

This article describes different forms of management of plants by the Nahua and the Mixtec in the basin of the Balsas river in Mexico. These forms of plant management are discussed as examples of current routes of plant domestication.

STUDY AREA

Ethnobotanical studies were carried out among the Nahua in two villages, Xochitepec and Mitepec of the Jolalpan municipality, in the southwest of the state of Puebla; and among the Mixtec in four villages, Alcozauca, Amapilca, Ixcuinatoyac, and San José Laguna of the Alcozauca municipality, in the northeastern region of the state of Guerrero (Fig. 1). The two municipalities are characterized by mountainous landscape, with deep slopes, numerous small intermontane valleys, and narrow fluvial plains. Such irregular topography is due to the location of these sites between two important geographical systems: the Balsas river depression in the north, and the Sierra Madre del Sur in the south. Table I summarizes environmental information about Alcozauca and Jolalpan.

Approximately 70% of the human population in Jolalpan are Nahua people, while in Alcozauca 90% of the people are Mixtec. In the two municipalities, indigenous subsistence depends basically on seasonal cultivation of corn, beans, and squashes. This is complemented by the raising of goats, cattle, pigs, and barnyard fowls in home gardens. Other important subsistence practices are gathering, hunting, fishing, and handicraft activities based on forest exploitation and annual migration to cities and agroindustrial centers in Mexico and the United States for seasonal employment.

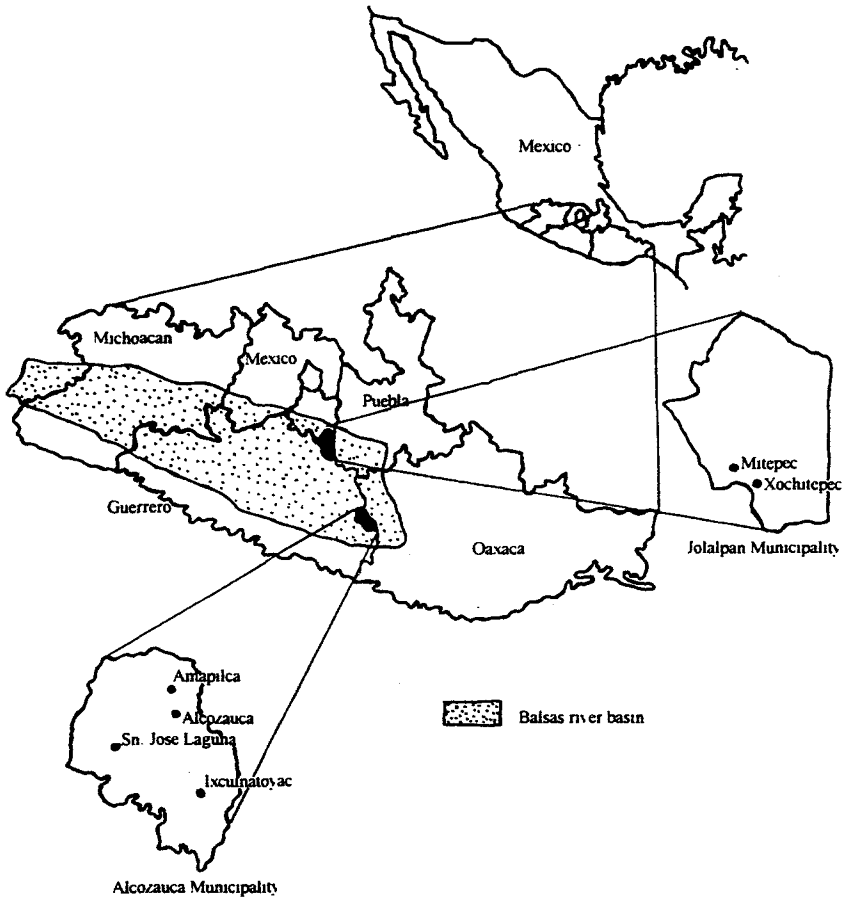

Fig. 1. Study area: Alcozauca, Guerrero and Jolalpan, Puebla in the Balsas river basin, Mexico.

METHODS

The study was carried out in three main phases. First, inventories of plant resources were made in the two sites during 1 year of fieldwork. Specimens of useful plants were collected in natural vegetation, markets, crop fields, and home gardens. During the collecting, 40 Nahua and Mixtec *campesinos* provided ethnobotanical information about plant uses, forms of management, ethnoclassification, social and cultural role of plants, and some ecological data such as distribution, phenology, competitors, predators, etc. All this information was complemented with interviews and direct

Table I. General Environmental Information of Alcozauca, Guerrero and Jolalpan, Puebla, Mexico

Site	Altitudinal range (m)	Annual mean temperature	Annual mean precipitation	Dry season	Rainy season	Vegetation
Alcozauca	1200–2900	20.4°C	846 mm	Nov.–Apr.	May–Oct.	(1) Riparian vegetation (2) Tropical deciduous forest (3) Oak forest (4) Oak-pine forest
Jolalpan	800–1900	25.6°C	840 mm	Oct.–Apr.	May–Oct.	(1) Riparian vegetation (2) Tropical deciduous forest

observations. Plant specimens were deposited in the National Herbarium of Mexico (MEXU).

The second phase comprised more specific interviews to obtain detailed information about the forms of management of the most important edible plants, and some evaluations of their role in campesino subsistence. This information was obtained during a second year of fieldwork. Details of these studies can be found in Casas et al. (1994) for the Mixtec region and Vázquez (1986) for the Nahua region.

Finally, in the third phase, particular studies were carried out with *Porophyllum ruderale* subsp. *macrocephalum* (A.DC.) R.R. Johnson, and *Leucaena esculenta* (Moc. et Sessé ex A.DC.) Benth., to analyze examples of phenotypic variation in wild, weedy, and cultivated plant populations managed in different ways. Studies of this phase were carried out within a period of 2 years of field and experimental work. Some results of these studies are summarized in different parts of this paper but details on methods and results can be found in Casas (1992), Casas and Caballero (in press) for the case of *L. esculenta*, and Vázquez (1991) for the case of *P. ruderale*.

RESULTS

In the two sites studied, a total of 180 species of edible plants was registered. Sometimes the same species was observed under different ecological and cultural conditions. Table II shows the total number of the edible plant species observed in each condition. Wild, weedy, and domesticated plants are managed in different ways, as it is described below.

Ways of Management of Wild Plants

Gathering. Wild plants are mostly gathered in natural vegetation areas. Many of them, mainly annual plants, are gathered without special prefer-

Table II. Number of Edible Plant Species Within Different Ecological and Cultural Status

Ecological status	Cultural status					
	Gathered	Tolerated	Enhanced	Protected	Sowed	Transplanted
Wild	67	37	2	10	16	5
Weed	48	41	7	15	14	3
Domesticated	—	—	—	—	83	—

ences among individuals. However, with some others, especially perennial plants, indigenous gatherers usually distinguish individuals that are different in features related to qualities of food, such as flavor, texture, size, color, presence, or absence of toxic substances, etc. Gatherers choose the best plants to use. For example, within populations of the "guamúchil" (*Pithecollobium dulce* (Roxb.) Benth.), people differentiate between trees with sweet and bitter fruits and they collect the sweet ones.

A similar situation was found in the case of the "guaje" (*Leucaena esculenta*). The Mixtec distinguish, through trial and error and through the association of morphological characters, three types of trees: (1) the "guaje de vasca" ("vomitory guaje"), a toxic variety; (2) the "guaje amargo" ("bitter guaje"), with bitter seeds that are edible only after being roasted; and (3) the "guaje dulce" ("sweet guaje"), whose seeds are edible raw. People selectively gather the "sweet guajes," taking the "bitter guajes" only when the sweet are scarce (Casas, 1992; Casas and Caballero, in press).

The Nahua and the Mixtec also selectively gather fruit from trees such as *Psidium* spp., *Spondias mombin* L., *Byrsonima crassifolia* (L) H.B.K., and other species mentioned in Table III.

Toleranced or Sparing. Edible wild plant species and especially the preferred varieties, are tolerated when they are found during the opening of forest areas to cultivate corn. Those individuals whose edible parts are not preferred by people are eliminated. Table III indicates species of wild plants tolerated selectively by people in this manner. This form of management may have consequences on the phenotypic structure of populations, because some phenotypes are increased in frequency and others are eliminated. For example, in the case of *Leucaena esculenta*, Casas and Caballero (in press) found that this process has produced significant morphological differences between wild and tolerated populations. Thus, in tolerated populations, trees producing larger seeds and pods were observed to be more frequent than in wild populations.

Enhancement. The management of the palm *Brahea dulcis* (H.B.K.) Mart. by the Mixtec is an example of enhancement of wild plants. In this case, fruits (called "capulines") and "palmetto" are edible, although the main use of the plant is the manufacturing of handicrafts such as hats and traditional mats called "petates." This palm has a vegetative reproductive system and its young ramets are resistant to fire. People use these characteristics to increase the numbers of this palm. They fell trees and shrubs and burn the area in order to eliminate competitors. A similar form of management is practiced to create artificial grasslands in order to increase the availability of some species used as forage for animals.

Protection. Campesinos occasionally prune and take actions against pests of the "sweet" phenotypes of *Pithecollobium dulce* (Roxb.) Benth.

Table III. Wild Edible Plants

Family	Species	Site[a]	Gathered	Tolerated	Enhanced	Protected	Sowed	Transplanted
Agavaceae	*Agave* sp.	A	X					
	Agave cupreata Trel. et Berger	A	X	X	X	X		X
Anacardiaceae	*Comocladia mollisima* H.B.K.	A	X					
	Cyrtocarpa procera H.B.K.	A,J	X	X				
	Spondias mombin L.	A,J	X	X			X	
Annonaceae	*Annona cherimola* Mill.	A	X	X		X	X	
	Annona purpurea Moc. et Sessé	J	X	X			X	
	Annona reticulata L.	J	X	X			X	
Asclepiadaceae	*Cynanchum jaliscanum*	A	X					
	Matelea crenata (Vail) Woodson	A	X					
Bignoniaceae	*Parementiera edulis* DC.	A	X	X			X	
Bombacaceae	*Ceiba parvifolia* Rose	A	X					
	Ceiba aesculifolia (Kunth) Britton and Baker	J	X					
Boraginaceae	*Cordia cylindrostachya* (Ruiz and Pav.) Roem and Shult	A	X					
	Cordia dentata Poiret	A	X					
Cactaceae	*Opuntia* sp.	A	X					
	Stenocereus stellatus (Pfeiffer) Riccob.	A	X	X				X
Compositae	*Porophyllum ruderale* (Jacq) Cass.	A,J	X	X				
	Porophyllum nutans Rob. and Greenm.	A,J	X	X				
	Tagetes filifolia Lag	A	X					
	Tridax mexicana A. Powell	A	X	X				
Convolvulaceae	*Operculina* sp.	A	X					
	Exogonium bracteatum (Cav.) Choisy	J	X					
Euphorbiaceae	*Euphorbia graminea* Jacq.	A,J	X	X			X	
	Euphorbia macropus (Klotz and Gaerke) Boiss.	A	X					

Fagaceae	*Quercus glaucoides* Mart and Gal.	A	X	X		
	Quercus obtusata Humb. et Bonpl.	A	X	X		
	Quercus urbanii Trel.	A	X	X		
Gramineae	*Zea mays* L. subsp. mexicana (Schrad.) Iltis	A	X			
Juglandaceae	*Juglans mollis* Engelm.	A	X	X		
Lauraceae	*Litsez glaucescens* H.B.K.	A	X			
	Persea americana Mill.	A	X	X		X
Leguminosae	*Acacia angustissima* (Mill) Kuntze	A	X			
	Canavalia villosa Benth.	A	X			
	Desmodium sericophyllum Schldl.	A	X	X		
	Desmanthus virgatus (L.) Willd.	A	X	X		
	Eysenhardtia sp.	A	X	X		X
	Gliricidia saepium (Jack.) Steud.	A	X	X		X
	Leucaena esculenta (Moc et Sessé ex A.DC.) Benth. subsp. *esculenta*	A,J	X	X	X	X
	Leucaena esculenta (Moc. et Sessé ex A.DC.) Benth. subsp. *paniculata* (Zárate)	A	X	X		
	Leucaena macrophylla Benth.	A,J	X	X		
	Pachyrrhyzus erosus (L.) Urban.	A	X			
	Phaseolus coccineus L. subsp. *formosus* (Kunth) Mare., Masch. and Stain.	A	X	X		
	Phaseolus vulgaris L. var. *mexicanus* A. Delgado	A	X	X		
	Nissolia sp.	J	X			
	Pithecollobium dulce (Roxb.) Benth.	A,J	X	X	X	X

Table III. Continued

Family	Species	Site[a]	Gathered	Tolerated	Enhanced	Protected	Sowed	Transplanted
	Prosopis laevigata (Humb. and Bompl. ex Willd.) M.C. Johnston	A	X	X		X		
	Sena occidentalis (L.) Link	A	X					
Liliaceae	*Allium glandulosum* Link. and Otto.	A	X	X				X
Malpighiaceae	*Bunchosia palmerii* Wats.	A,J	X					
	Byrsonima crassifolia (L.) H.B.K.	A,J	X	X		X	X	
	Malpighia glabra L.	J	X					
Malvaceae	*Malva parviflora* L.	A	X					
Moraceae	*Ficus cotinifolia* H.B.K.	A,J	X					
Myrtaceae	*Psidium guajava* L.	A,J	X	X		X	X	X
	Psidium sp.	A	X	X		X	X	X
	Psidium sartorianum (Berg.) Nied.	A	X	X		X	X	X
Palmae	*Brahea nitida* André	A	X					
	Brahea dulcis (H.B.K.) Mart.	A,J	X	X	X	X		
	Pseudophoenix sargentii Wend.	J	X	X		X		
Passifloraceae	*Passiflora* sp.	A	X					
Phytolaccaceae	*Phytolacca icosandra* L.	A	X	X				
	Phtyolacca octandra L	A	X	X				
Rutaceae	*Casimiroa edulis* Llave and Lex.	A	X	X				
Sapotaceae	*Sideroxylon capiri* (DC.) Pittier	J	X					
Sterculiaceae	*Guazuma ulmifolia* Lam.	A	X					
Verbenaceae	*Vitex mollis* H.B.K.	A	X					

[a]A = Alcozauca, Guerrero; J = Jolalpan, Puebla.

Psidium spp., *Leucaena esculenta*, and other species in wild or tolerated populations. These protected wild species are also shown in Table III.

Sowing or Planting. Some wild plants are also cultivated. Their seeds are sowed mainly in home gardens. Most of them are woody plants such as *Leucaena esculenta*, wild avocado (*Persea americana* Mill.), and several fruit trees. Nevertheless, *Euphorbia graminea* Jacq. and *Allium glandulosum* Link. and Otto can also be mentioned as two relevant examples of cultivated herbaceous wild plants. The wild plants cultivated by sowing or planting observed in this research are listed in Table III.

Transplantation. Examples of transplantation of wild plants were found in the agave "maguey mezcalero" (*Agave cupreata* Trel. et Berger) and in the guava "guayaba tlahuanca" (*Psidium guajava*). In the first case, seedlings of agave are transplanted by people from natural populations to corn fields, where they grow as living fences or as soil barriers in traditional terraces. In the latter case, young ramets of guavas are usually transplanted from wild individuals to home gardens. Peasants occasionally transplant seedlings of pine, oak, and *Bursera* species to the fences of corn fields.

MANAGEMENT OF WEEDS

Forty-eight species of edible weeds were found growing within and around the crop fields (Table IV). Among them, there are some plants traditionally used as edible greens. These plants are the "quelites" that have been characterized by Bye (1981). The "quelites" are called *quilitl* among the Nahua, and *yiwa* among the Mixtec. Table IV indicates the 24 "quelite" weedy species registered in this study. All of them are important for the diet of indigenous people. Thus, Viveros et al. (1993) report that the "quelites" constitute around 10% of the total annual food consumption in the municipality of Alcozauca.

Gathering and Tolerance or Sparing. All edible weeds reported in this study are gathered in agricultural fields and disturbed areas. However, 27 of them were plants that peasants tolerated during the weeding of cornfields. Table V shows the relative abundance of "quelite" species registered during a sampling of corn fields in Alcozauca after the weeding.

A certain selection is carried out on intraspecific forms during the gathering and weeding. For example, with *Anoda cristata* (L.) Schl. (Malvaceae), a herb called "alache," people distinguish between two main variants: (1) the "alache macho" ("male alache"), which have slender and pubescent leaves, with a high fiber content, and which is not palatable; and (2) the "alache hembra" ("female alache") which has broader and nonpubescent leaves, a lower fiber content and a good flavor. People gather young

Table IV. Weeds and Ruderal Edible Plants

Family	Species	Site[a]	Gathered	Tolerated	Enhanced	Protected	Sowed	Transplanted
Amaranthaceae	*Amaranthus hybridus* L. (*)	A,J	X	X	X			
Asclepiadaceae	*Asclepias* sp. (*)	A	X	X				
Bignoniaceae	*Parmentiera edulis* DC.	A	X	X			X	
Boraginaceae	*Cordia cylindrostachya* (Ruiz and Pav.) Roem and Shult	A	X					
Chenopodiaceae	*Chenopodium ambrosioides* L. (*)	A	X	X	X	X		
	Chenopodium berlandieri Moq. (*)	A	X	X	X	X	X	
Compositae	*Galinsoga parviflora* Cav. (*)	A	X	X				
	Porophyllum ruderale (Jacq) Cass. (*)	A,J	X	X		X	X	
	Porophyllum nutans Rob. and Greenm. (*)	A,J	X	X				
	Porophyllum tagetoides D.C. (*)	A,J	X	X				
	Tagetes filifolia Lag.	A	X					
	Tridax mexicana (*)	A	X	X				
Cruciferae	*Brassica campestris* L. (*)	A	X	X				
Cucurbitaceae	*Melothria pendula* L.	A	X	X				
	Sicius sp. (*)	A	X					
Labiatae	*Hyptis suaveolens* (L.) Poir	A	X	X				
	Lippia palmeri S. Watson	J	X					
Leguminosae	*Crotalaria pumila* Ortega (*)	A	X	X	X		X	
	Crotalaria longirostrata Hook. and Arn. (*)	J	X	X			X	
	Desmodium sericophyllum Schldl.	A	X	X				
	Desmanthus virgatus (L.) Wild.	A	X	X				
	Eysenhardtia sp. (*)	A	X	X				
	Gliricidia saepium (Jack.) Steud.	A	X	X			X	
	Leucaena esculenta (Moc. et Sessé ex A.DC.) Benth. subsp. *esculenta* (*)	A,J	X	X	X	X	X	
	Phaseolus coccineus L. subsp. *formosus* (Kunth) Marc., Masch. and Stain.	A	X	X				

	Phaseolus vulgaris L. var. *mexicanus* A. Delgado	A	X	X				
	Pithecollobium dulce (Roxb.) Benth.	A,J	X	X		X	X	
	Prosopis laevigata (Humb. and Bonpl. ex Wild.) M.C. Johnston	A	X	X		X		
	Sena occidentalis (L.) Link	A	X					
Malpighiaceae	*Byrsonima crassifolia* (L.) H.B.K.	A,J	X	X		X	X	
Malvaceae	*Anoda cristata* (L.) Schl. (*)	A,J	X	X			X	
	Malva parviflora L. (*)	A	X					
Martyniaceae	*Martynia annua* L.	A	X					
Myrtaceae	*Psidium* guajava L.	A,J	X	X		X	X	X
	Psidium sp.	A	X	X		X	X	X
	Psidium sartorianum (Berg.) Nied.	A	X	X		X	X	X
Nyctaginaceae	*Salpianthus purpurascens* (Cav. ex Lag) Hook & Arn. (*)	A	X	X				
Oxalidaceae	*Oxalis* sp. (*)	A	X	X				
Phytolaccaceae	*Phytolacca icosandra* L. (*)	A	X	X				
	Phtyolacca octandra L. (*)	A	X	X				
Polygonaceae	*Rumex* sp. (*)	A	X	X				
Portulacaceae	*Portulaca oleracea* L. (*)	A,J	X	X	X			
Solanaceae	*Capsicum frutescens L. var. baccatum* Irish.	A	X	X	X	X		
	Lycopersicon esculentum Mill.	A	X	X		X		
	Physalis philadelphica Lam.	A,J	X	X	X	X	X	
	Solanum mitlense Dunal (*)	J	X	X		X		
	Solanum nigrum L. (*)	A,J	X	X		X		
Verbenaceae	*Vitex mollis* H.B.K.	A	X	X				

[a]A = Alcozauca, Guerrero; J = Jolalpan, Puebla; (*) Quelites.

Table V. Relative Abundance of Edible Weeds in Agricultural Systems of Alcozauca, Gro., Mexico (I = Individuals; B = Biomass)

	Agricultural systems							
	Sh		S		I		Hg	
Species	I/m2	B/ha	I/m2	B/ha	I/m2	B/ha	I/m2	B/ha
Amaranthus hybridus	0.42	39.48	0.03	2.82	0.17	15.98	3.01	282.94
Anoda cristata	0.02	2.38	0.07	8.33	0.8	95.2	0.07	8.33
Crotalaria pumila	—	—	0.91	74.22	0.01	0.816	0.02	1.14
Oxalis sp.	0.42	0.42	0.93	0.93	0.06	0.06	—	—
Physalis philadelphica	0.015	13.095	0.04	34.92	0.12	104.76	0.57	497.61
Phytolaca icosandra	0.03	9.15	0.11	33.55	—	—	—	—
Porophyllum nutans	—	—	0.01	0.157	—	—	—	—
Porophyllum ruderale	—	—	0.01	0.163	—	—	—	—
Porophyllum tagetoides	—	—	0.03	0.426	—	—	0.01	0.142
Portulaca oleracea	—	—	0.02	0.46	0.09	2.07	0.2	4.6
Solanum nigrum	0.11	9.57	0.03	2.61	0.07	6.09	—	—

[a]Sh = shifting agriculture sowing with the indigenous traditional stick; S = seasonal agriculture sowing with plow; I = irrigated agriculture sowing with plow; Hg = home gardens.

individuals or stems and leaves of the "female alache." When individuals are removed, the populations are directly thinned, and with such an action it could be expected that populations of this variety might be easily displaced by those of the "male alache" and eventually disappear. However, this does not occur because not all individuals of the "female alache" populations are removed and, in addition, many individuals of the "male alache" populations are eliminated during weedings.

A similar situation occurs with *Crotalaria pumila* Ortega (Leguminosae), which is called "chipile," in which people distinguish the "chiple macho" ("male chipile") which have small leaves and a bad taste, and the "chipile hembra" ("female chipile") with bigger leaves and good taste. Also in the case of *Porophyllum ruderale* subsp. *macrocephalum* (Asteracea), the "papaloquelite" or "quelite de mariposa" ("butterfly quelite"), two main variants are distinguished: (1) the "papaloquelite hediondo" ("stinking papaloquelite"), which have a stronger flavor and bad odor, and (2) the common "papaloquelite," which have good flavor and odor. In these cases, the desirable variants are gathered and the nondesirable variants are eliminated during weedings (Vázquez, 1991).

Enhancement. Peasants disperse seeds of the desirable weeds in order to increase their population density. These practices are ways of enhancement of weedy plants. Examples of these interactions were observed in seven species in Alcozauca (Table IV), being especially important in *Porophyllum ruderale* subsp. *macrocephallum*, *Amaranthus hybridus* L., *Anoda cristata*, *Crotalaria pumila*, and *Physalis philadelphica* Lam. Also, in Table

V it can be observed that *Amaranthus hybridus* shows a particularly high relative abundance in home gardens because people intentionally disperse seeds of this plant in the field.

Protection. Physalis philadelphica and the weedy form of *Lycopersicon esculentum* Mill. are not only tolerated and enhanced; they are also fertilized, and protected against frost and pests. It is important to note that these practices usually occur on cultivated plants and only rarely on weeds and wild plants.

Sowing or Planting. Seeds of some weeds are collected to cultivate them in the crop fields. This occurs, for instance, with the species *Anoda cristata, Crotalaria pumila, Brassica campestris* L., *Amaranthus hybridus*, and *Porophyllum ruderale* subsp. *macrocephallum*. All these species are sold commercially in the traditional markets, mainly during the dry season.

WAYS OF MANAGEMENT OF DOMESTICATED PLANTS

The Mixtec and the Nahua know, use, and manage many native or introduced plants in advanced degree of domestication (Table VI). These species are cultivated and receive attention from sowing to harvest. Based on variation generated by crossing between domesticated and wild, weeds and other domesticated plants, people carry out consecutive selection, generation after generation. This selection directs the enhancement of phenotypic features that are favorable to the changing cultural and environmental conditions. Such processes exemplify domestication as a continuous process occurring even on already domesticated plants.

For example, in the municipality of Alcozauca there are 12 local variants of corn, each with some specific characteristics selected according to different utilitarian purposes (Casas et al., 1994). Variants with the sweetest flavor are consumed as "elotes" (green corn). Red colored corns are used to make "tortillas," "atole" (corn beverage), and "pinole" (roasted corn flour with sugar and cinnamon) for ceremonial practices, while black and white varieties are valued for the appearance given to the "tortillas." Seed size is selected also as a characteristic associated with higher yields. In a similar way, cob size and number of seed rows are selected to improve productivity. Furthermore, seed size is associated with specific uses; for example the biggest seeds are destined to prepare "pozole" (corn grains and meat soup). Seed hardness is selected to improve resistance to storage losses. However, there are also some soft variants selected for their faster cooking and easiness to mill, that are consumed soon after harvesting. Easiness to shell is also selected. Length of life cycle, phenology, drought re-

Table VI. Domesticated Edible Plants

Family	Species	Site[a]	Native species	Exotic species
Amaranthaceae	*Amaranthus hypocondriacus* L.	A		X
Anacardiaceae	*Mangifera indica* L.	A,J		X
	Spondias mombin L.	A,J	X	
	Spondias purpurea L.	A		X
	Spondias sp.	A		X
Annonaceae	*Annona squamosa* L.	A		X
	Annona cherimola Mill.	A	X	
	Annona diversifolia Saff.	A		X
	Annona muricata L.	A		X
	Annona purpurea Moc. et Sessé	J		X
	Annona reticulata L.	J		X
Cactaceae	*Opuntia ficus-indica* (L.) Mill.	A		X
	Opuntia sp.	A		X
	Stenocereus stellatus (Pfeiffer) Riccobono	A	X	
Caricaceae	*Carica papaya*	A		X
Chenopodiaceae	*Chenopodium berlandieri* Moq.	A		X
Combretaceae	*Terminalia catappa* L.	A		X
Compositae	*Porophyllum ruderale* (Jacq) Cass.	A,J	X	
Convolvulaceae	*Ipomoea batatas* Lam.	A		X
Cruciferae	*Brassica oleracea* L.	A		X
	Raphanus sativus L.	A		X
Cucurbitaceae	*Cucumis melo* L.	A		X
	Cucumis sativus L.	A		X
	Cucurbita ficifolia Bouche	A		X
	Cucurbita mixta Pang.	A		X
	Cucurbita moschata Duch.	A		X
	Cucurbita pepo L.	A		X
	Citrullus vulgaris Sch.	A		X
	Sechium edule Sw.	A		X
Ebenaceae	*Dyospiros digyna* Jacq.	A		X
Gramineae	*Saccharum officinarum* L.	A		X
	Sorghum vulgare Pers.	A		X
	Zea mays L.	A,J	X	X
Juglandaceae	*Juglans regia* L.	A		X
Labiatae	*Hyptis suaveolens* (L.) Poir	A	X	X
Lauraceae	*Persea americana* Mill.	A	X	X
Leguminosae	*Arachis hypogaea* L.	A		X
	Erythrina americana Mill.	A		X
	Leucaena esculenta (Moc. et Sessé ex A.DC.) Benth. subsp. *esculenta*	A,J	X	X
	Leucaena leucocephala (Lam.) de Wit. subsp. *leucocephala*	A,J		X
	Leucaena leucocephala (Lam.) de Wit. subsp. *glabrata* Zárate	A		X
	Pachyrrhyzus erosus (L.) Urban.	A	X	X
	Phaseolus coccineus L.	A	X	X
	Phaseolus vulgaris L.	A,J	X	X
	Pithecollobium dulce (Roxb.) Benth.	A,J	X	
	Tamarindus indica L.	A,J		X

Table VI. Continued

Family	Species	Site[a]	Native species	Exotic species
Liliaceae	*Allium cepa* L.	A		X
	Allium sativum L.	A		X
Malpighiaceae	*Byrsonima crassifolia* (L.) H.B.K.	A,J	X	
Moraceae	*Ficus carica* L.	A		X
	Morus sp.	A		X
Musaceae	*Musa paradisiaca* L.	A		X
Myrtaceae	*Psidium guajava* L.	A,J	X	X
	Psidium sp.	A	X	
	Psidium sartorianum (Berg.) Nied.	A	X	X
Oleaceae	*Olea europaea* L.	A		X
Palmae	*Phoenix datylifera* L.	A		X
Passifloraceae	*Passiflora choconiana* Wats.	A,J		X
Piperaceae	*Piper auritum* H.B.K.	A,J		X
Punicaceae	*Punica granatum* L.	A		X
Rosaceae	*Crategus pubescens* (H.B.K.) Steud.	A		X
	Cydonia oblonga Mill.	A		X
	Eriobotrya japonica Lind.	A		X
	Malus pumila Mill.	A		X
	Prenus persica L.	A		X
Rubiaceae	*Coffea arabica* L.	A		X
Rutaceae	*Casimiroa edulis* Llave and Lex.	A	X	
	Citrus aurantifolia (Chirst) Swingle	A		X
	Citrus limetta Risso	A		X
	Citrus maxima (Brum) Merr.	A		X
	Citrus novilis Lour.	A		X
	Citrus auriantum L.	A,J		X
	Citrus sinensis Osbeck.	A		X
Sapotaceae	*Pouteria sapota (Jacq.)* H.B. Moore and Stearn	A,J		X
Solanaceae	*Capsicum annum* L. var. *acuminatum* Fring.	A	X	
	Capsicum annum L. var. *grossum* Sendt.	A		X
	Capsicum annum L. var. *longum* Sendt.	A		X
	Capsicum frutescens L. var. *baccatum* Irish.	A	X	X
	Lycopersicon esculentum Mill.	A		X
	Lycopersicon esculentum Mill. var *piriforme* Hort.	A		X
	Physalis philadelphica Lam.	A,J	X	X
Umbelliferae	*Apium leptophyllum* (Pers.) F. Muell.	A		X
Vitaceae	*Vitis vinifera* L.	A		X

[a]A = Alcozauca, Guerrero; J = Jolalpan, Puebla.

sistance, and pest and disease resistance are selected according to different environmental conditions.

Year after year, successive generations of corn crops are submitted to artificial selection pressures. Such a process is modulated by social and cultural changes, for example, changes in customs, in patterns of diet, etc. Social and cultural changes are determined strongly by seasonal migration of people to other parts of Mexico and the U.S. for employment. Also, the increasing of marketing and the introduction of mass media of communication such as T.V. and radio are important (Viveros et al. (1993). In addition, artificial selection pressures are also modulated by technological and environmental changes such as changes in agricultural systems and the impoverishing of soils. A good example of this interaction can be found in the changes brought about with the use of chemical fertilizers to produce corn in Alcozauca. In this municipality, the campesinos began to use chemical fertilizers in 1974. Since then, they have selected seeds of corn variants that grow better and produce more under such technological innovation. As a consequence, many peasants today agree that corn production is impossible without chemical fertilizers.

Beans also present different routes of selection by people. For example, in Alcozauca there are 14 variants of *Phaseolus vulgaris* L. and four of *P. coccineus* L. (Casas et al., 1994). Peasants select on length of life cycle to ensure availability of immature and mature beans at different times. Vine growing beans (the "frijoles enredadores") are selected to be cultivated together with corn in the traditional corn fields called "milpas," while the bushy beans (the "frijoles mateados") are selected to be cultivated in monospecific fields. These two characteristics, as well as drought, pest, and disease resistance, are selected to exploit different environmental conditions. A reduced content of fiber in pods is selected in those variants that are eaten as green beans (the "ejoteros" beans). As with corn, peasants select beans with hard seeds to resist storage pests, but they also select beans with soft seeds that are easily cooked.

It is important to mention that in the two study areas, there are wild and weedy plant populations of *Phaseolus coccineus* subsp. *formosus* that are usually close to agricultural fields located between 1700 and 2500 meters above sea level. In theory, this situation makes possible a continuous exchange of genes between wild, weed, and cultivated varieties, which are outbreeders. This is an extraordinary source of variation which has not yet been evaluated. However, according to information from peasants, these crosses may occur frequently, because it is common to find "frijoles quemados" ("burned beans"), which are possibly hybrids between cultivated and wild beans.

A similar situation may be occurring between wild and cultivated trees such as *Psidium guajava, Byrosonima crassifolia* (L.) H.B.K., *Annona cherimola* Mill., *Spondias mombin* L., *Persea americana*, and *Leucaena esculenta* and between other weedy or wild plants and cultivated plants such as *Lycopersicon esculentum, Pachyrrhyzus erosus*, and *Physalis philadelphica*. In all these cases, the exchange of alleles might make possible, at least hypothetically, the existence of a wide morphologica and genetic variation providing a rich raw material for the operation of artificial selection.

DISCUSSION

Cases of plant management analyzed in the present study reveal the existence of different forms and intensities in which the Mixtec and Nahua campesinos manage and select their plant resources. Gathering and other ways of management of weeds and wild plants are practices that have developed along with agriculture, and that at present are integrated in subsistence patterns based on strategies of diversified ways of use and management of natural resources. These subsistence patterns are common among Mexican indigenous peoples (Viveros et al., 1993).

Changes determined by artificial selection on already domesticated plants are examples of domestication as a continuous process. This process occurs not only on plants such as corn and beans, which traditionally have been the food products for the indigenous subsistence, but also on plants introduced from the Old World after the conquest.

It has been mentioned that artificial selection is the crucial evolutionary force in domestication. This kind of selection basically implies that human beings enhance desirable phenotypes and eliminate the undesirable ones in a plant population. Artificial selection has usually been associated with cultivation. Under cultivation, manipulation of successive generations of plants makes evident both artificial selection and its results. Equally, plant domestication has been considered a process intimately associated with sowing or planting. For example, De Wet (1992) and Harlan (1992), from studies on evolution of cereals, state that domestication is a natural evolutionary process resulting from selection pressures associated with sowing and harvesting occurring in successive generations. However, in cases presented here, mechanisms of artificial selection seem to be present in wild and weedy plant populations under the described *in situ* and *ex situ* forms of plant management, although results are not so evident as in true cultivation. This observation suggests that evolution of plants, as directed by human being, may be a consequence of not only sequences of planting and selection, but also of a wide spectrum of human–plant interactions.

In Tables III, IV, and VI, it is possible to appreciate that in some species different forms of management are acting at the same time. This situation suggests that domestication is not a linear sequence of forms of management but may take different routes, as indicated in Fig. 2.

Characteristics of interactions between humans and plants are determined by biological features of plants and their ecological conditions (wild,

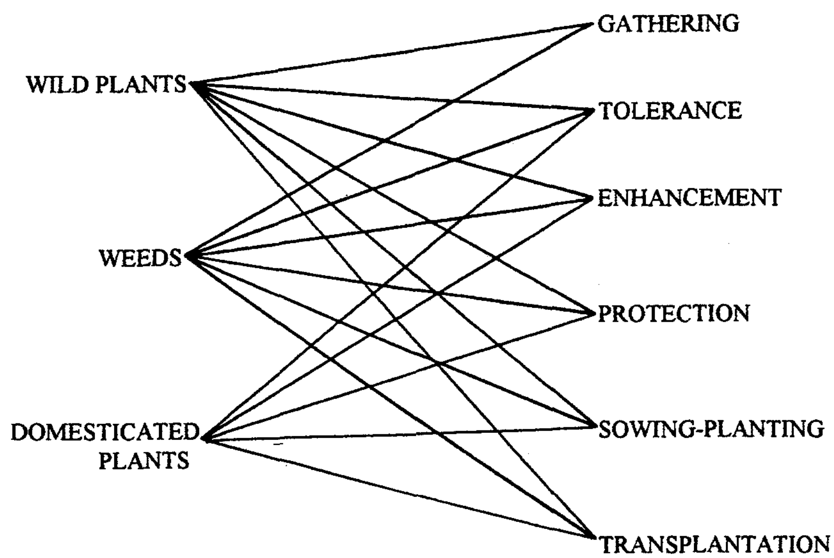

Fig. 2. Forms of management of edible wild, weedy, and domesticated plants among the Nahua and the Mixtec. Possible routes of plant domestication.

weedy, or domesticated plant). However, the cultural context also plays a determinant role. According to Hernández-X. & Ramos (1977), "Ethnic groups have maintained much plant species in different domestication levels according to the uses and achievements of the desired features. . . ." The types of plants managed and the ease of management, the requirements satisfied by those plants, the morphologic features of plants used by humans and the ease of artificial selection, as well the preferences for particular colors, flavors, odors, shapes, or textures, are all aspects modulated by culture and therefore influence the degree of intensity of the human-plant interaction. Changes affecting human culture may also influence domestication trends through time.

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