KEEPERS OF MAIZE IN CHIAPAS, MEXICO[1]

MAURICIO R. BELLON AND STEPHEN B. BRUSH[2]

Bellon, M. R. *(Centro de Ecología, Universidad Nacional Autónoma de México, Apartado Postal 70-275. México, D.F. 04510, México) and* **S. B. Brush** *(Applied Behavioral Sciences, University of California, Davis. Davis, CA, 95616).* KEEPERS OF MAIZE IN CHIAPAS, MEXICO. *Economic Botany 48(2):196–209. 1994. This study concerns the knowledge and selection of biological diversity of maize* (Zea mays) *within its center of domestication in Mesoamerica. Maize farmers in central Chiapas of Southern México keep local varieties (landraces) belonging to six races and four race mixtures. Fifteen local varieties are recognized. In spite of widespread adoption of a modern, high yielding variety, maize farmers continue to select local varieties for specific soils and because of agronomic and use criteria. Farmers maintain maize varieties primarily through seed selection. Spatial and temporal separation do not seem sufficient to maintain varieties. The management of improved varieties can lead from a uniform population to a heterogeneous one as hybridization with local maize populations occurs.*

Custodios de maiz en Chiapas, México. *Este estudio trata sobre el conocimiento y la selección de la diversidad biológica de maíz* (Zea mays) *en su centro de domesticación en Mesoamerica. Pequeños productores de maíz en la parte central del Estado de Chiapas en el sureste de México mantienen variedades pertenecientes a seis razas y cuatro mezclas raciales. Se reconocen quince variedades locales. A pesar de la adopción de variedades mejoradas de alto rendimiento, estos agricultores continúan seleccionando variedades locales para suelos particulares y debido a criterios agronómicos y de uso. Estos agricultores mantienen sus variedades de maíz através the la selección de la semilla. La separación espacial y temporal no parecen ser suficientes para mantener estas variedades. El manejo de las variedades mejoradas puede conducir de una población uniforme a una heterogénea en la medida que occurre una hibridazación con las poblaciones locales de maíz.*

Key Words: maiz; races of maize; biological diversity; human selection; Chiapas.

Despite the general acceptance of the Darwinian model of crop evolution and extensive research on the cultural ecology of agriculture, we still know relatively little about the current management of the plant genome in farming systems that are found in regions of crop domestication and evolution. There is the widespread notion that the development and release of improved varieties and changing socioeconomic and technological conditions in areas of crop domestication lead to the extirpation of landraces and native varieties (Hawkes 1983:109). However, studies in different regions indicate that farmers who adopt modern varieties have not totally abandoned their local varieties (landraces) (Brush, Taylor and Bellon 1992), and modern varieties may be transformed from uniform populations into highly heterogeneous ones by the farmers' management. These patterns are important not only for understanding agricultural evolution in general but also for developing methods to conserve crop genetic resources. The purpose of this paper is to describe farmer management of the plant genome of maize (*Zea mays* L.) within its Mesoamerican region of domestication. Our topics are how farmers in Chiapas, México manage their maize fields so as to control variability and how they acquire new genotypes and yet maintain known types of maize. Three factors will be analyzed for an agroecosystem that has undergone modernization: (a) the number of maize varieties and races present; (b) the seed management practices of the farmers; and (c) the role of land holding fragmentation on creating oppor-

[1] Received 17 November 1993; accepted 2 February 1994.

[2] To whom inquiries should be sent.

tunities for hybridization among maize races and varieties.

As Rindos (1989:29) notes, crop evolution takes place in the context of two interdependent spheres, the plant genome and the learned behavior of cultivators toward their crop. All farmers are faced with two problems in managing the plant genome: how to acquire new genotypes and how to maintain existing ones. New genotypes are required to meet the random events of evolutionary and environmental change, the appearance of new pests, pathogens and competitors, climatic instability, and edaphic change in soil and water resources. Moreover, they are required to meet evolutionary changes in human society itself, such as decreased fallow land arising from increased sedentism and population density. New genotypes are also needed as the agricultural frontier expands.

Maize in Mexico

México is within the primary region of maize diversity. A long history of coevolution connects maize and human populations in Mesoamerica (Hernández X. 1985; Wellhausen et al. 1952). The overall influence of domestication on the genetic architecture of maize is rather clear (Wilkes 1989), but the role of the farmer in the evolution of maize has been difficult to specify. Several descriptions and analyses of maize farming systems in México give evidence of linkage between certain human groups and maize races (Hérnandez X. 1985; Mapes 1987; Nigh 1976). Mesoamerican Indian and *mestizo* cultures have developed fine grained knowledge systems associated with maize farming systems (Bellon 1991). We have long recognized the association between the biogeography of maize and the cultures which grow it (e.g., Anderson and Cutler 1942), yet little effort has been expended on understanding how farmers actually identify, select and maintain varieties or how social factors actually influence maize populations. Wellhausen, Fuentes, and Hernández-Corzo (1957:29) note that there is little evidence that "man . . . in the early stages of culture" consciously added to the natural forces of evolution of maize under domestication, mutation, random genetic drift, natural selection and hybridization. Lamentably, nearly fifty years of research on Mesoamerican agriculture has not provided a clear picture of the knowledge and role of farmers as they might affect maize evolution.

Study Site and Methods

Fieldwork was carried out in the *ejido* Vicente Guerrero in the central part of Chiapas from June 1988 to February 1989. Vicente Guerrero was selected for two reasons. First, it is an area where local and improved maizes compete with each other in farmers' selection. In the higher zones of Chiapas, local varieties predominate; and in the Pacific lowlands, improved maize predominates. By choosing a study site in the intermediate region, we could examine the balance between these two types. Second, farmers in the intermediate zone grow maize both for subsistence and commercial purposes, allowing us to understand the effects of farm strategy on maize variety choice. The people of central Chiapas are descendants of Zoque speaking people, but they are now Spanish speaking.

The *ejido* Vicente Guerrero is the largest and most populated *ejido* in the municipality of Ocozocoautla. The *ejido* covers approximately 5125 ha and has a population of approximately 2300, consisting of about 380 households. Vicente Guerrero is located 25 km from the city of Tuxtla Gutiérrez, the state capital, and 18 km from the city of Ocozocoautla, the administrative center of the municipality. The community is linked with both cities by unpaved roads, and there is a regular bus service to Tuxtla Gutiérrez.

Vicente Guerrero is located in the Grijalva River watershed between 800 and 900 meters above sea level. The climate according to Koeppen's classification system modified by García (1979) is $Aw_O''(w)(i')g$, warm sub-humid with summer rains. The average annual temperature is 23.8°C. The average annual rainfall is 864 mm, 91% of which is concentrated between May and October. As in most of México, there is a drought period of variable length during the months of July and August known as the *canícula* (Hernández-Díaz 1986). Rainfall and temperature are homogeneous throughout the *ejido* and favorable for maize production.

Ethnographic research in 1988–1989 involved structured and unstructured interviews and detailed observations on maize fields (*milpas*). Maize ears of all varieties declared by the farmers were collected and also taken to the Colegio de Postgraduados in Chapingo for botanical identification and classification into races. A questionnaire was applied to a sample of 97 farmers. This questionnaire was designed to elicit infor-

TABLE 1. USE OF PURCHASED INPUTS IN THE *EJIDO* VICENTE GUERRERO.

Input	Arado (%)	Pedregal (%)
Fertilizer (farmers)	100.0	98.7
Herbicide (farmers)	94.8	98.7
Hired labor (farmers)	60.2	55.3
Use tractor (farmers)	50.5	na
Improved variety (area)	51.0	21.2

Source: Bellon 1991.

mation on household and field characteristics. Farmers provided information on each of the fields they managed, its location and soil types, the maize variety or varieties planted in each of them, and the source of the seed they planted. In the case of the improved seed, we asked how many years had elapsed since it was bought. We inquired about the reasons for planting two varieties in the same field.

Maize is the main crop and it is produced for home-consumption and for the market. This *ejido* produces a maize surplus and has benefited from the development policies of the Mexican government. The national grain marketing board, Compañia Nacional de Subsistencias Populares S. A. (CONASUPO), maintains a grain storehouse in the town and purchases maize surplus. Members of the community have access to official credit and insurance through the Banco de Crédito Rural del Itsmo S. A. (BANCRISA) and Aseguradora Nacional S. A. (ANAGSA).

The *ejido* is divided by the farmers into 31 different "*trabajaderos*" (work sites), each with a name, a specific location and well defined boundaries. Vicente Guerrero farmers practice two distinct tillage systems, plow agriculture and swidden agriculture, known as *arado* and *pedregal* respectively. Plow agriculture, using animal or mechanical traction, is characterized by a continuous use of the land, the use of higher rates of fertilizers, flatter fields with a low content of stones, and plots permanently assigned as household property. On the other hand, swidden agriculture (*pedregal*) with digging sticks is practiced in forested and rocky areas. In *pedregal*, fields are farmed for one to five years and then are left fallow for a mean seven years. *Pedregal* land is collectively owned and parceled out on request. A farmer has rights to this field up to one year after it is abandoned.

The use of modern technologies is widespread, as summarized in Table 1. Farmers have used commercial fertilizers and improved maize varieties since the early 1960s. More recently (ca. 1970) herbicides and pesticides have also been introduced. Fertilizers, herbicides, insecticides and an improved maize variety are used in both *arado* and *pedregal*, although at different rates. The first improved maize varieties were originally introduced in the early 1960s, and these are currently used along with newer introductions.

MAIZE VARIETIES AND RACES

The units of analysis in this study are the farmer-named maize variety and race. These units are used here as proxies for genetic diversity that might be measured in other ways (Doebley, Goodman, and Stuber 1985). Farms with a larger number of farmer varieties and races are assumed to have greater genetic diversity in their maize populations than farms with smaller numbers of the same. Maize is a highly outcrossing species, hybridizing with both cultivated and uncultivated *Zea* plants, and maintaining discrete varieties or even races requires active human intervention. One of the great achievements of Mesoamerican farming is to have developed the knowledge of how to maintain races and varieties of maize keyed to specific cultural or agronomic criteria.

Farmer variety (hereafter variety) is important because it is the actual unit of human selection in the general maize population. Maize varieties are naturally variable because of the outcrossing nature of the crop and because of the informal and non-standardized nature of farmer classification. This variability is, however, controlled to a certain extent by seed selection and the sharing of knowledge. For farmers in our study area, a variety is identified primarily by its kernel and cob characteristics. Characteristics of particular importance are kernel color, size, shape, hardness (crystallinity), and density, number of seed rows, and cob length. While varieties are identified according to these morphological characteristics, they are also associated with agronomic characteristics (e.g., plant height, flowering date, performance on different soils) and use characteristics (e.g., storage, tortilla or feed). The selection of varieties is done according to agronomic and use criteria. The analysis by Sanchez and Goodman (1992) suggests that several characteristics known and used by farmers in our

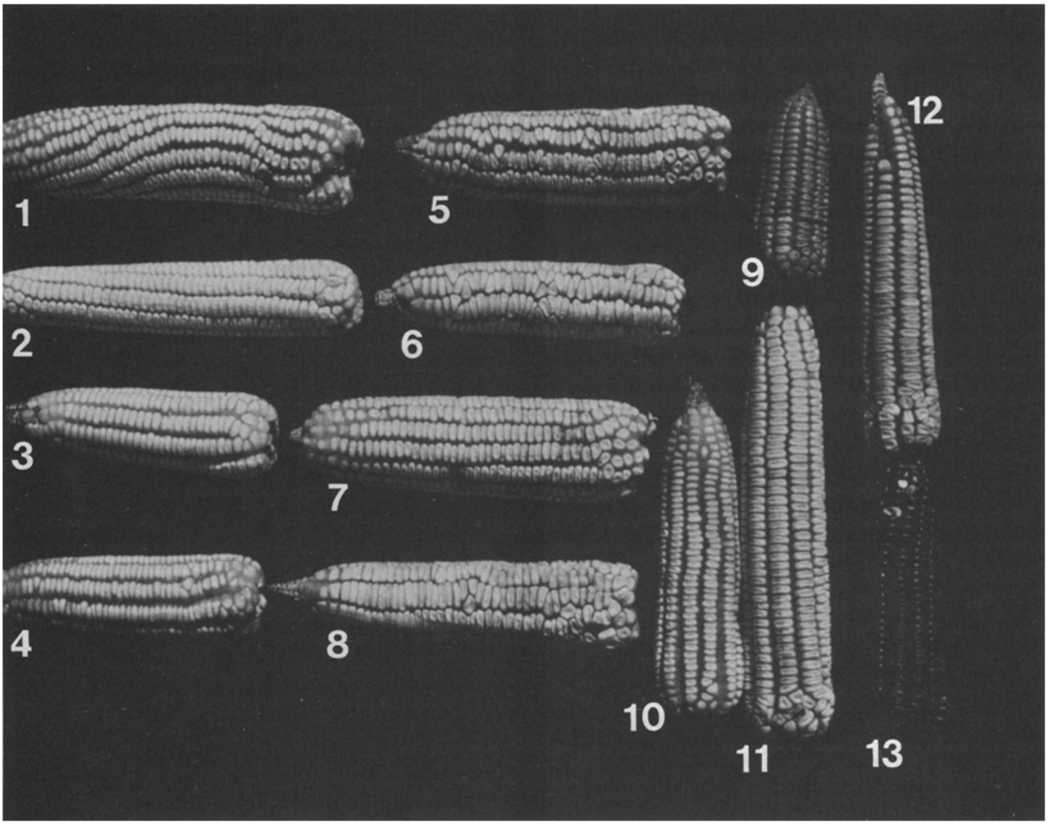

Fig. 1. Thirteen local maize varieties from Vicente Guerrero. 1. V-524; 2. Olotillo Blanco; 3. Chimbo Blanco; 4. Crema; 5. Hibrido Amarillo; 6. Crema Olotillo; 7. Rocamex; 8. Napalú; 9. Chimbo Amarillo; 10. Canelo; 11. Jilguero; 12. Olotillo Amarillo; 13. Negro.

study area have clear biological meaning for racial groupings, for instance number of rows of kernels, kernel width, kernel width/length, kernel volume, ear length.

The number of varieties alone may overestimate genetic diversity if these varieties belong to the same race. Race remains an important concept for understanding the crop in spite of the development of more powerful taxonomic tools (Benz 1987; Bretting and Goodman 1989; Doebley, Goodman, and Stuber 1985; Sanchez and Goodman 1992). Anderson and Cutler 1942: 71) provided a definition of maize race that still stands:

> A maize race is a group of related maize plants with enough characteristics in common to permit their recognition as a group . . . From the standpoint of genetics a race is a group of individuals with a significant number of genes in common, major races having a smaller number in common than do subraces.

More than forty maize races are reported for Mesoamerica, thirty-one are found in México (Bretting and Goodman 1989). Maize races are distributed geographically (by latitude and longitude) (Wellhausen et al. 1952) and regionally along altitudinal and rainfall gradients (Hérnandez X. 1985). Within communities and microregions, they are associated with different soil qualities (Bellon and Taylor 1993; Nigh 1976). Both isozyme analysis (Doebley, Goodman, and Stuber 1985) and analysis of morphological characteristics (Sanchez and Goodman 1992) indicate that variability between races is significant. For races grown in the same locality, farmer selection and management is important in maintaining this between-race variability.

Fifteen variety names were recorded in Vicente Guerrero (Table 2). Of those, thirteen referred to varieties planted in the fields and two to varieties planted in home gardens (*sitio*). Maize varieties in Vicente Guerrero belonged to six dif-

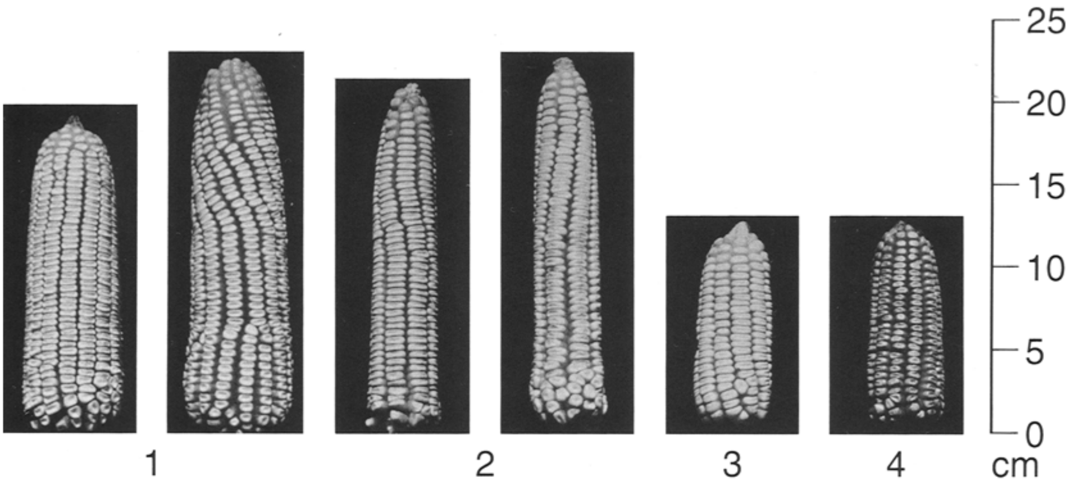

Fig. 2. Maize races and race mixture in Vicente Guerrero. Tuxpeño (1–2), Olotillo (3-4), and Nal-tel/Zapalote (5-6). Tuxpeño and Olotillo are isolated by flowering times (60 and 90 days, respectively).

ferent races: (1) Olotillo; (2) Tuxpeño; (3) Argentino; (4) Tepecintle; (5) Zapalote Grande; and (6) Nal-tel. Several of the varieties were a mixture of two of these races. Figure 1 shows 13 maize varieties found in Vicente Guerrero. Figure 2 shows two races (Tuxpeño, Olatillo) and one race mixture (Nal-tel/Zapalote).

Olotillo is the most important local race in the Central Depression of Chiapas (Benz 1987), and probably is the race with the most variation in this state (Ortega-Paczka 1973). Two varieties of this race are cultivated, according to the color of the kernel, *Olotillo Amarillo* and *Olotillo Blanco,* with yellow and white kernels respectively. Farmers consider them the local landraces (*criollos*) especially suited to poor or unfertilized soils.

The Tuxpeño race is one of the most productive maizes in the world (Mangelsdorf 1974). Tuxpeño appears to have been domesticated in the Oaxaca-Chiapas region (Kato 1988); its germplasm is widespread throughout the tropics and is an important constituent of many improved varieties and hybrids (Goodman and Brown 1988). Ortega-Paczka (1973) noted the coexistence of this race in the western part of the Central Depression of Chiapas. Tuxpeño is suited to fertile soils and dominates commercial maize production in Chiapas. In Vicente Guerrero several Tuxpeño varieties are cultivated. The most important is the *V-524,* an open-pollinated improved variety, locally referred only as *Tuxpeño* (hereafter cv. V-524). It has been widely adopted throughout tropical Chiapas since its introduction in 1976 (Coutiño pers. comm.). This variety is the result of the eleventh cycle of selection for short plant height from a tropical maize population named *Tuxpeño Crema 1.* It has white kernels, relatively late maturity, excellent stalk strength, relatively short plant stature and good tolerance to tropical foliar diseases (CIMMYT 1979, 1988).

Three other varieties belong to the Tuxpeño race: *Rocamex* or *Rocamey* (hereafter cv. Rocamex), *Canelo* and *V-424.* Cultivar Rocamex is the advanced generation of the varieties *V-520* (local variety collected in Temuin, San Luis Potosí) or *V-520* (collected in San Rafael, Veracruz), that were improved during the 1940s by the Oficina de Estudios Especiales (Ortega-Paczka 1973). These varieties have not been commercially distributed since the late 1960s and early 1970s (Ortega-Paczka 1973). Nevertheless, farmers continue to preserve and exchange this type of seed. Little information about cv. Canelo is available. It was reported by Hernández X. in his collection in the 1940s in the area of Ocozocoautla, but it was not found by Ortega-Paczka in 1971 (Ortega-Paczka 1973). V-424 is an improved open-pollinated variety, derived from further selection on the same population from which cv. V-524 originated, with a shorter stature and growing cycle (CIMMYT 1988). V-424 was first distributed in Chiapas in 1983 (Coutiño pers. comm.).

Three varieties found in Vicente Guerrero are intermediate between the Olotillo and Tuxpeño races in terms of racial characteristics. In two (*Jilguero* and *Napalú*), Tuxpeño is dominant. In the other (*Crema Olotillo*), Olotillo is dominant. The phenomenon of varieties being intermediate between Olotillo and Tuxpeño was reported by Ortega-Paczka (1973). Of these three, Ortega-Paczka reported only *Napalú*. Apparently it has been planted since the 1960s.

Híbrido Amarillo is a widely planted creole cultivar, and seems to be the advanced generation of the improved variety *Poey T-66* (Ortega-Paczka 1973). It belongs to the race Argentino, introduced to Chiapas from Cuba by the Poey Seed Company (Ortega-Paczka 1973). The race Argentino was described by Hatheway (1957). Creole cultivars are originally improved varieties which have been mixing with landraces, and they appear to have acquired many characteristics of local maize varieties.

One variety planted in Vicente Guerrero belongs to the race Tepecintle. It is the only black maize and it is planted only by a few farmers on a very small area. Wellhausen et al. (1952:112) note that Tepecintle is of ancient origin, widely distributed and influential on other modern races and varieties. In fact Tuxpeño is considered to be the result of the hybridization of the Tepecintle and Olotillo races.

Nal-tel is a widely distributed race in Chiapas and is particularly characterized by a short growing cycle, which makes it desirable to subsistence farmers (Ortega-Paczka 1973). *Crema* is a variety intermediate between the Tuxpeño and the Nal-tel races. It was reported by Ortega-Paczka (1973) as an advanced generation of the hybrid H-507. This variety was developed from Tuxpeño populations by the Mexican National Maize Program.

The race Zapalote Grande has only one variety in Vicente Guerrero, locally known as *Zapalote.* Although common to low elevations, floury texture varieties of this race can be found in Chiapas at elevations up to 900 meters (Wellhausen et al. 1952). The variety *Chimbo* is a mixture of Nal-tel and Zapalote Grande races. Two variants of Chimbo (*Chimbo Blanco* and *Chimbo Amarillo*) are planted only in home gardens (*sitios*) and are usually eaten fresh (*elote*). Chimbo is the only variety used exclusively for home-consumption. It is characterized by a short growing cycle, and it provides maize when the reserves are exhausted and before the new crop is harvested.

Almost twenty years after Ortega-Paczka's (1973) study of maize races in Chiapas, all races reported by him for tropical Chiapas, except for Zapalote Chico, are still present in Vicente Guerrero. Finding all this diversity in just one *ejido* may seem surprising. Roads and previous migrations may have favored the influx of different maize varieties. Several farmers reported that they obtained varieties from other communities. Others reported testing varieties collected on trips away from the town, not all of which grew well in Vicente Guerrero.

TABLE 2. MAIZE RACES AND VARIETIES IN VICENTE GUERRERO.

Race	Cultivated variety
Olotillo	Olotillo Amarillo
	Olotillo Blanco
Tuxpeño	Tuxpeño (V-524)
	Rocamex
	Canelo
	V-424
Argentino	Híbrido Amarillo
Zapalote Grande	Zapalote
Tepecintle	Negro
Tuxpeño/Olotillo	Jilguero
	Napalú
Olotillo/Tuxpeño	Olotillo Crema
Tuxpeño/Tepecintle	Crema
Zapalote Grande/Nal-tel	Chimbo Amarillo
	Chimbo Blanco

Source: Bellon 1991.

SELECTION CRITERIA

Farmers in Vicente Guerrero have a thorough knowledge of the ecological, technological and culinary features of their maize varieties (Bellon 1991), perceiving advantages and disadvantages and trade-offs among varieties. Planting and management decisions are individual but follow a common set of selection criteria: performance on different soils, labor demands (especially weeding), tolerance of weeds, fertilizer requirements, and environmental risk such as wind lodging. Varieties are valued for different soil types and different levels of risk; some require high quantities of inputs and strict timing, while others only need small amounts of inputs and flexible timing (Bellon and Taylor 1993).

Because this is a subsistence economy with maize tortillas as the staple food, certain differences among varieties are based on use criteria. Most important is storability, determined by how well the husk covers the ear and the crystallinity

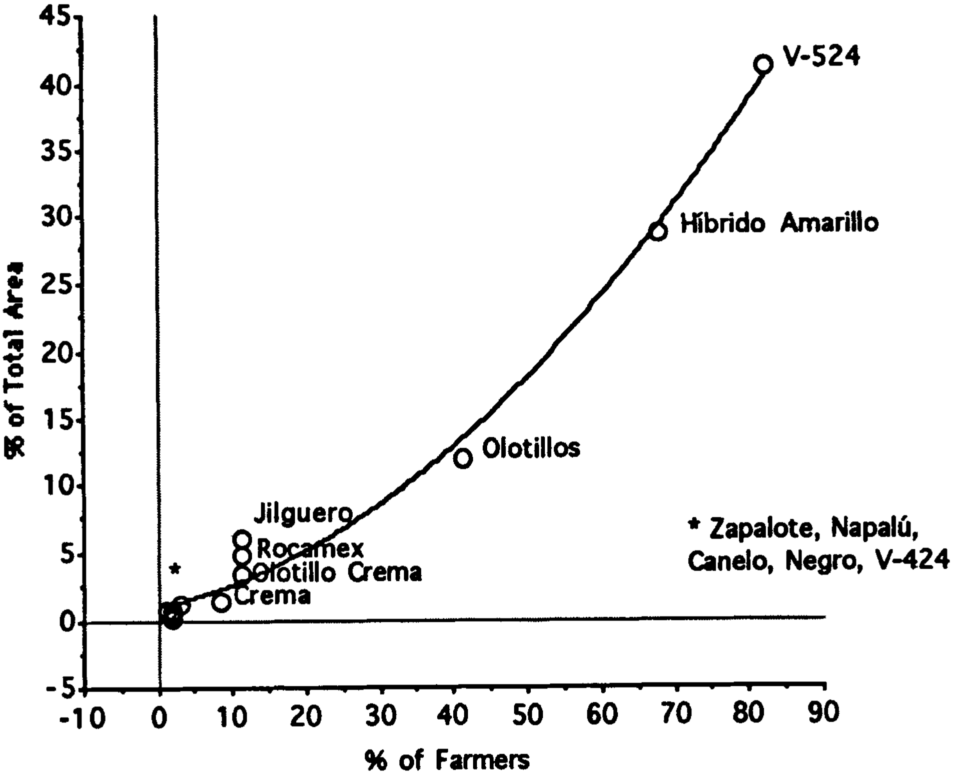

Fig. 3. Relative importance of maize varieties by percentage of area and farmers.

(hardness) of the kernels. The improved variety, cv. V-524 is inferior to other varieties for home use, because of its small husk and relatively soft kernels. Cultivar Hibrido Amarillo, the most crystalline and best storing variety, is the most widely kept for home-consumption. Tortillas made from cv. Olotillo flour (*masa*) are considered as slightly better tasting, but taste differences were not weighted heavily by our informants. The women of this *ejido* do not perceive significant differences between maize varieties in terms of grinding or texture, perhaps because of the ubiquity of mechanical mills.

No variety alone satisfies all of the farmers' concerns. The heterogeneous environment and differences among households require that farmers keep distinct maize varieties with known characteristics such as tolerance of poor soil conditions. Evidence of this is the fact that on average each farmer planted three varieties. For example, 64% of the farmers who planted the improved variety cv. V-524 also planted the creole variety cv. Híbrido Amarillo and 34% the traditional variety cv. Olotillo at the same time. Only a relatively small proportion (21.6%) of farmers specialized in one variety, and even among these, the improved variety only accounted for 47.6% of them. Figure 3 compares the relative number of farmers who plant twelve varieties with the relative area occupied by each of them. The more farmers who plant a variety, the more area it covers, but the relationship is not linear. Four varieties, cv. V-524, cv. Híbrido Amarillo, cv. Olotillo Amarillo and cv. Olotillo Blanco, accounted for 81.7% of the total area sampled. The remaining eight are planted by only a few farmers and occupy a small area.

Table 3 summarizes the principal criteria for selecting maize varieties and farmers' consensus about the three primary maize varieties. The key agronomic criteria used by farmers are performance on different soil types, ability to withstand wind, drought resistance, and tolerance for poorly timed inputs such as fertilizer or labor to weed (Bellon and Taylor 1993). Tight scheduling of inputs is often beyond the control of the household. In general, the local varieties are believed to be better for marginal soils and more tolerant

TABLE 3. SELECTION CRITERIA AND QUALITIES OF PRINCIPAL MAIZE VARIETIES.

Critera	Cultivated variety		
	Olotillo	Hibrido Amarillo	Tuxpeño
Background	landrace	creole	improved
Storability	medium	good	poor
Performance on poor soils	good	medium	poor
Performance on good soils	poor	medium	good
Fertilizer response	low	medium	high
Input schedule demand (fertilizer & weeding)	low	medium	high
Wind resistance	poor	medium	good
Drought tolerance	good	medium	poor
Yield by weight	poor	good	good
Yield by volume	good	medium	poor

Source: Bellon 1991; Bellon & Taylor 1993.

of late inputs such as weeding. Since local varieties are tall, they are susceptible to being knocked down by strong winds. The popularity of cv. V-524 reflects the farmers' ability to improve many soils with fertilizer and the variety's resistance to wind lodging. Cultivar V-524 is planted on the best soils, richer farmers plant it more, and farmers performing off-farm labor plant it less. Olotillo is planted on the poorest soil, and there is a positive association between the number of male children in the household and the area planted to Olotillo (Bellon and Taylor 1993).

The biology of maize requires that specific methods be employed to maintain varieties. Purchasing new seed from state or commercial sources is uncommon. Like cultivators elsewhere who plant open-pollinated maize, farmers in Vicente Guerrero can use three production methods to maintain varieties with desired characteristics: spatial separation through field dispersal, temporal isolation, and seed selection.

SPATIAL SEPARATION THROUGH FIELD DISPERSAL

Maize is open-pollinated, and wind is the main pollination agent. Approximately 200 meters separation is necessary to keep maize in different fields from cross-pollinating (Villena pers. comm.). Intensive cultivation in peasant farming systems such as in Vicente Guerrero does not permit each farmer to isolate his/her fields so as to maintain varietal purity. However, effective isolation is perhaps possible because of land fragmentation, a management pattern where a single farm consists of numerous discrete parcels often scattered over a wide area (Bentley 1987; Binns 1950). Land fragmentation is a common feature of the agricultural systems of small farmers in the tropics (Bentley 1987; Kirkby 1973). It has been linked with risk reduction by giving farmers a variety of soils and growing conditions. It may help to spread agricultural work and avoid labor bottlenecks, particularly in areas with different altitudes where crops ripen at different times. It may allow the use of multiple ecozones, and let farmers grow a wide mix of crops (Bentley 1987).

Farmers in Vicente Guerrero have an average of four fields scattered around the *ejido,* and some own as many as eleven fields. Residents of the *ejido* point out that field dispersion is practiced to encourage an equitable distribution of the different soil qualities present in the *ejido* (Bellon 1990). Different soils are found and recognized within areas farmed by the two general tillage systems, *arado* and *pedregal,* and maize varieties are specifically selected for different soils (Bellon and Taylor 1993). Besides the existence of two

TABLE 4. CHARACTERISTICS OF *TRABAJADEROS* OF VICENTE GUERRERO (N = 31).

	Mean	Range
No. of different soils	2.8	1–5
No. of different farmers*	8.8	3–28
No. of races	2.7	1–4
No. of races & race mixtures	2.9	1–5
No. of races & race mixtures**	3.2	1–6
No. of varieties	4.2	2–9
Average *trabajadero* size (ha)	21.1	7–69.2
Average field size (ha)	2.0	1–3.1

* There was no *trabajadero* where farmers belonging to a single socioeconomic group controlled all of the fields. In most of the *trabajadero,* farmers of the three socioeconomic groups were present.

** cv. Tuxpeño (V-524) treated as a separate category due to its improved status.

TABLE 5. RACE AND RACE MIXTURE BY *TRABAJADERO*.

Trabajadero	Area (ha)	No. farmers	No. fields	Percentage of area by race and race mixture					
				Tuxpeño	Argentino	Olotillo	Zapalote Grande	Tuxpeño/ Olotillo	Tuxpeño/ Nal-tel
Aguachinadero	7.3	3	4	34	34			14	18
Amatillo	19.0	8	9	55	32	13			
Barranco Seco	32.4	9	18	45	20	25		10	
Calzada Larga	34.0	12	15	72	25	3			
Caoa	34.4	21	22	69	24	2	6		
Carretilla	64.9	28	29	35	29	11		22	3
Cebollinal	15.2	5	5		26	8		66	
Chilar	33.3	12	18	20	72	3		6	
Chipilinar	17.4	7	8	37		29		35	
Divisadero	11.0	6	4	1			00		
Eden	9.1	4	4	88					12
Guayabitos	10.7	5	5		63			37	
Hojaral	12.0	7	7	33	29	38			
Huerto	12.5	4	4	64	36				
Llano Bonito	7.0	3	4	29	71				
Llano Copal	69.2	20	26	24	62	12		2	
Monte Redondo	20.7	10	10	100					
Malpaspo	13	5	5	8	38	38		16	
Montanita	24.2	10	12	29	42	9		20	
Morrito	20.0	9	10	63	20	18			
Otatal	25.0	8	15	30	62				8
Rincon Novillo	16.3	5	6	69	31				
Rejoya	8.3	5	6	24	36	33		6	
San Sebastian	8.5	3	4	88				12	
Sur	33.9	14	15	55	37	8			
Tepeguajal	24.5	13	18	18	34	45		4	
Tranca	9.5	6	8	100					
Tunas	9	4	4	78				22	
Vuelta del Cacho	9.6	6	6	48	26			26	
Zacatonal	11.3	4	4	56	44				
Zona	30.1	16	18	49	36	15			

tillage systems in this *ejido,* fields are also separated by the practice of dispersing them among different work sites, or *trabajaderos,* of the same tillage system. Most farmers plant fields in more than one work site, and several farmers own fields in each work site.

Fields located in the same work site are more likely to be in closer proximity than fields located in different work sites. Maize fields within a work site form a continuum; sometimes a small path divides fields belonging to different owners, although in most cases, there are no formal divisions between them. The proximity of fields within each work site presents a stronger likelihood for cross-pollination among varieties within work sites than between them. Farmers choose what variety to plant for particular fields, but they have no control over what variety their neighbors may plant.

In a single work site many soil types may be present, and consequently several maize races and varieties are present in each, as indicated in Table 4. Furthermore, the average field size in each work site is small, increasing the chance that pollen from maize in one field could reach other fields. In Vicente Guerrero, we found a statistically significant association between the number of races and race mixtures, and the number of farmers per work site (Kendall tau = 0.35, $P \leq 0.01$). The same positive association is true for the number of varieties and the number of farmers per work site (Kendall tau = 0.47, $P \leq 0.01$). These positive correlations suggest that work sites do not isolate varieties or races. The lack of spa-

TABLE 6. DAYS TO FLOWERING AFTER PLANTING.

Cultivated variety	Farmers	Literature*
Tuxpeño (V-524)	60	61[a]
Hibrido Amarillo	75	62[b]
Olotillo	90	58–78[b]
Rocamex	75	59[c]
Crema Olotillo	75	nd
Jilguero	75	nd
Crema	90	nd

* Based on experimental fields in different ecological area from Vicente Guerrero.
[a] CAECEH 1984:21.
[b] Ortega Paczka 1973:126.
[c] Ortega Paczka 1973:153

TABLE 7. MEAN DIFFERENCES IN DAYS SEPARATING FLOWERING TIME.

Cultivated varieties	Days separating flowering time
Tuxpeño (V-524)—Hibrido Amarillo	18
Tuxpeño (V-524)—Olotillo	33
Tuxpeño (V-524)—Others[a]	12
Hibrido Amarillo—Olotillo	15
Hibrido Amarillo—Others[a]	6
Olotillo—Others[a]	21

[a] Others include Jilguero, Crema Olotillo, and Rocamex, all with similar flowering dates according to farmers.

tial isolation is also evident in Table 5, showing the distribution of maize races and race mixtures among work sites. Except for the exclusive presence of Tuxpeño in three work sites, races are not generally segregated by work site, and the overlap of races among them provides ample opportunity for hybridization among races over time.

TEMPORAL ISOLATION

The fact that varieties have different growing cycles, especially flowering times, potentially decreases cross-pollination. Nevertheless, growing cycles may overlap because different planting dates may cause flowering to coincide. In order to achieve temporal isolation, it is necessary to plant two varieties with similar growing cycles (flowering time) 21 days apart (Villena, pers. comm.).

Planting is timed according to the onset of summer rains, and two distinct planting cycles are followed: *en seco* (dry) and *en húmedo* (wet). In the former, the maize is planted before the rains start, and germination takes place as soon as rains come. In the latter, planting takes place after rains have started. The latest planting date recorded in 1988 was July 20th, and the rains started June 7th. Therefore, the planting window for *en húmedo* was from June 7th to July 20th. Planting date was an individual decision, and we did not find evidence that farmers made a joint effort to schedule planting. In terms of total area, 53.8% was planted *en seco,* while 46.2% was *en húmedo.* All fields in *pedregal* were planted *en seco*; while in *arado,* 67.4% of the area was planted *en húmedo* and 32.6% *en seco.* The predominance of planting *en seco* points out the extent to which varieties can be separated by their different flowering times.

The dry and wet planting patterns suggest that temporal isolation among varieties may occur because of their different flowering times. Table 6 gives information on flowering cycles from the farmers as well as from the literature. According to the farmers, there is a difference of fifteen days between cv. Tuxpeño and cv. Hibrido Amarillo, and one month between cv. Tuxpeño and cv. Olotillo. Cultivated varieties Rocamex, Jilguero, and Crema Olotillo are considered to flower about the same time as cv. Hibrido Amarillo, and cv. Crema is considered equal to cv. Olotillo.

Table 7 shows the mean difference among varieties for flowering days. If 21 days between flowering times are needed for isolation, according to these data cv. Tuxpeño was isolated from cv. Olotillo (Fig. 2). Likewise, cv. Olotillo was isolated from cv. Rocamex, cv. Crema Olotillo and cv. Jilguero. All other combinations were less than 21 days, therefore there was a good chance that they could mix.

Some temporal isolation might result from varieties with different flowering times, but most maize varieties in Vicente Guerrero flower within 21 days of each other. Since they are planted in close proximity, they may have a good chance to hybridize and open a route of gene-transfer among varieties, with certain varieties acting as bridges (cv. Hibrido Amarillo between cv. V-524 and cv. Olotillo). The pattern in Vicente Guerrero contradicts Johannessen's (1982) observation for Guatemala that different maize maturation times maintain varietal purity without farmer cognizance.

Seed Selection

The preceding sections suggest that neither spatial separation nor temporal isolation are practiced by farmers to maintain distinct maize varieties. The final means to achieve this is through seed selection. Seed selection has been emphasized by observers of traditional maize agriculture in Mesoamerica (Anderson 1947; Nigh 1976; Wellhausen et al. 1952). Except for the small percentage of farmers who bought certified seed, all maize varieties in Vicente Guerrero are subject to the same traditional seed management practices. Contrary to the recommendation of the local agricultural experiment station, which advises farmers to select the seed for the next planting from healthier and shorter plants located at the center of the field and surrounded by other plants, farmers in Vicente Guerrero do not select their seed in the field but once the ears have been harvested and are at home. This does not allow them to directly take plant morphological traits (e.g., stalk strength) into consideration when selecting seed. Farmer knowledge, however, associates plant morphology with seed type.

Seed selection is a process carried out year after year, by each farmer. Although some farmers are more careful than others, a four stage process is common: (1) harvested ears are brought home and piled in the patio, to be segregated by maize variety; (2) the farmer selects and separates the largest ears, well covered by the husk; (3) the selected ears are opened and examined, selecting those that fit the ideal type for the variety, based on kernel color and size, density and shape, cob length, and number of seed rows; (4) selected ears are shelled, and larger, undamaged grains from the middle part of the ear are saved for seed. Kernels at the bottom and at the tip are not used, since farmers believe that they yield weak plants, a common practice in Mesoamerica (Johannessen 1982; Nigh 1976). In the past, the seed was preserved by smoking the ears and keeping them in the kitchen; currently the shelled grains are kept in a sturdy plastic bag with insecticide to prevent pest attack. Respect for seed is shown in the practice of discarding the cobs of seed ears in "fresh" areas such as river bottoms, rather than the usual burning accorded to other cobs. Farmers in Vicente Guerrero believe that burning seed cobs may translate into burning their maize plants in the next planting cycle.

Expansion and Contraction of Local Genetic Diversity

The preceding sections have shown that farmer seed selection is the primary way of maintaining purity of maize varieties in this *ejido* of central Chiapas. Seed selection is also a critical factor in maintaining the level of genetic diversity in the local farming system. Increased genetic diversity may be accomplished in two ways: 1) maintaining naturally occurring hybrids of maize-maize or maize-teosinte crosses and 2) adding seeds from distant places through purchase or exchange. Decreased diversity may result from natural or human selection against existing varieties, with human selection acting as the primary agent.

As noted above, naturally occurring maize-maize hybrids are encouraged by spatial and temporal factors. The fact that six of the maize varieties found in Vicente Guerrero are intermediate between two different races (Table 2), supports the idea that hybridization among the races and varieties is an on-going process. Evidence of these crosses is also seen in the short-statured, improved variety cv. V-524. Farmers note that cv. V-524 gains additional height each year after seed purchase, looking more and more like local varieties. Additional evidence is the fact that once improved varieties, cv. Rocamex and cv. Hibrido Amarillo, are now thoroughly mixed with local ones and considered to be local maize varieties. Maize's wild relative teosinte (*Zea mexicana*) is not present in Vicente Guerrero. In fact, scientists from the local experimental station familiar with teosinte have never seen it in the areas they have worked in Chiapas (Coutiño, Zamarripa pers. comm.).

The loss of genetic diversity is more problematic than its increase. As human populations have increased, as markets have expanded, and as purchased inputs of fertilizer and pesticides have become widely available, farmers in ancient farming areas such as Chiapas are faced with the possibility of replacing local varieties with purchased seed of varieties that are higher yielding or more responsive to fertilizer. The possibility of genetic erosion or the loss of crop biological diversity, is considered a serious threat in México and elsewhere (Hawkes 1983). The dominance of two races, Tuxpeño and Argentino (a race exotic to Chiapas), is troubling evidence of genetic erosion caused by the swamping of local maize populations by exotic races and varieties. Improved varieties are considered to have a narrow genetic base (Hawkes 1983), while native varieties or landraces are considered to have considerable genetic variation (Frankel and Soule 1981). However, careful farmer selection, the heterogeneous farming conditions of central Chiapas, and the outcrossing nature of maize are counterbalances to genetic erosion from crop introduction. Ortega-Paczka (1973) compared maize varieties found in Chiapas in 1942 and 1971, concluding that the introduction of new varieties may actually serve to increase diversity. The practice of cultivating several varieties of maize simultaneously in Vicente Guerrero supports this conclusion (Bellon 1991). Furthermore, almost twenty years after the study of Ortega-Paczka (1973), all races except for one reported by him for tropical Chiapas are present in this *ejido.*

Frequent purchase of seed can be expected to decrease the diversity at the subrace level by replacing local varieties (Brush, Bellon-Corrales, and Schmidt 1988). In Vincente Guerrero, most varieties are kept by the farmers from one agricultural cycle to the next. Farmers exchange varieties because they want to try a new variety or because they have lost their seed of a desired variety. Loss may happen because a farmer stops planting a variety, miscalculates the amount of seed to be saved, or is forced to sell all of his maize, including his seed. Maize varieties are rarely sold among farmers. The improved variety cv. V-524 is the only one that is commercially available. Most of the cv. V-524 seed used is several years old, and only 3.7% of those planting cv. V-524 in 1988 purchased new seed that year, even though farmers receive credit to purchase seed. Although cv. V-524 is planted by most farmers and occupies 41.1% of the area planted to maize, most of the seed is several years old and thus contains germplasm from local maize populations. However, the adoption of the improved maize variety has lowered the area in the principal landrace. A high proportion (94.6%) of farmers declared that they used to plant cv. Olotillo, but only 41% were still planting it. While no one planted cv. V-524 in 1978, approximately 80% sowed it in 1988.

Nevertheless, displacement of landraces by improved varieties has limits. Our study revealed that there is no strong trend of abandoning of landraces in association with social or economic differences among households (Bellon 1990; Bellon and Taylor 1993). Micro-environmental differences, especially marginal soil conditions, are associated with landrace conservation. Farm size and fragmentation are positively associated with an increase in the area planted to the landrace as well as the improved variety (Bellon and Taylor 1993). Family wealth is negatively associated with area in landrace, but only when land quality is considered in the equation. Off-farm employment, however, is negatively associated with the area in improved varieties, suggesting that increased income allows farmers to keep landraces as a luxury.

A great deal of cultivar diversity can be maintained in small areas, giving importance to land fragmentation for landrace conservation. Although cv. V-524 and cv. Híbrido Amarillo are very important overall, other varieties can be very important in specific work sites (Table 5). Cultivated varieties of Olotillos cover only 12% of the overall area, but in three work sites they are the most widely planted varieties (Hojaral, Malpaso, Tepeguajal). The same is true for varieties belonging to racial mixtures of Olotillo and Tuxpeño, dominant in two work sites (Cebollinal, Chipilinar).

There is ample opportunity for the improved maize variety cv. V-524 to hybridize with the other varieties. In fact, farmers talk of cv. V-524 as becoming a localized creole ("acriollado") by losing some of its traits such as short stature. They consider the creole version to be better adapted to the conditions of the *ejido.* The process by which farmers in Chiapas transform improved varieties from uniform populations into a more heterogeneous one was pointed out by Ortega-Paczka (1973). We also found this process to be taking place with cv. V-524 in Vicente Guerrero.

CONCLUSION

Vicente Guerrero exhibits a pattern observed elsewhere in cradle areas of crop domestication that are undergoing technological change (Brush 1992). Islands of diverse, local crop varieties (landraces) persist in a more intensive, commercialized, and biologically simplified agricultural landscape. There can be little doubt that reducing local and diverse varieties to islands has reduced biological diversity in peasant agriculture. Nevertheless, the existence of these islands shows the will of peasants to maintain diversity wherever possible.

The maintenance of several maize races and varieties, seed management practices and opportunities for hybridization due to fragmented land holdings suggest that genetic diversity is maintained in Vincente Guerrero in spite of the adoption of improved varieties and a wider integration into the market. Furthermore, these farmers may be transforming the improved variety cv. V-524 into a local, creole one, such as they did with cv. Híbrido Amarillo and cv. Rocamex in the past.

Farmers act both directly (seed selection and keeping specific varieties for different soils) and indirectly (planting patterns) upon the genetic variability of their maize crop. Social organization creates a condition, land fragmentation, that is influential on biological diversity. The social factors at play here are an *ejido* rule favoring nonpartible inheritance of land, prohibitions against selling or renting land, and an expressed value on equity. The distribution of land in different work sites so as to achieve equity among households is critical to maintaining crop diversity since it increases the number of households which keep local varieties. Outside the community, factors such as the availability of credit for the purchase of new seed, the promptness of input suppliers, and regional labor markets have influence.

An important assumption of agricultural development planning is that improved varieties are superior to native ones in the environment created by new technology, rapid population growth, and rapid economic and cultural change (Brush 1989). A corollary of this assumption is that improved crop varieties will displace local ones so as to cause genetic erosion. However, this is not always true. In Vicente Guerrero several maize varieties, belonging to six maize races coexist, and local varieties persist in spite of technological and socioeconomic changes. The process of varietal adoption is more complex than a simple dichotomous decision to adopt/not adopt, even in the face of these rapid changes (Bellon 1991). While new maize varieties have displaced local ones in Vicente Guerrero, this has not occurred in a simple linear fashion. This work supports the contention that the mechanism of "simple replacement," i.e., a direct substitution of one technology by another, posited in the genetic erosion hypothesis, is too simplistic. Farmer knowledge of the environment, different cultivation regimes, and the social context of land distribution and emphasis on equity act together to modify the intrusion of a new technology and to preserve tradition. These elements connect past and present agricultural evolution in this Mesoamerican region of crop domestication.

Acknowledgments

The Fieldwork for this project was carried out with support of fellowships from the Consejo Nacional de Ciencia y Tecnología (CONACYT-México) and the InterAmerican Foundation, as well as an NSF Dissertation Improvement Grant (BNS-8815002). Additional fieldwork was funded by the Centro de Ecología, Universidad Nacional Autónoma de México. We wish to thank the late Efraím. Hernández X. for the identification of the maize ears, Willy Villena of CIMMYT for information on maize pollination, standards to produce improved maize seed and improved varieties of Tuxpeño, as well as Colleen K. Kelly for discussion and comments. Also, we wish to acknowledge the advice for assistance provided by Alcides Zambrano, Esteban Betanzos, Ausencio Zamarripa, and Bulmaro Coutiño of the Ministry of Agriculture in Chiapas, and Rafael Ortega-Paczka of the Universidad Autónoma de Chapingo. Thanks also to H. Garrison Wilkes, Lawrence Kaplan, Hugo Perales Rivera and an anonymous reviewer for very helpful comments on an earlier draft.

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