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A maize landscape: Ethnicity and agro-biodiversity in Chiapas Mexico

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Abstract

The ecology of maize (*Zea mays* L.) in Mexico, its center of domestication and diversity, has been researched for several decades. While the broad outlines of diversity and dynamics of native maize populations are known at the farm and national levels, these topics are less well known at the landscape level. Although environmental factors are the principal forces behind the overall diversity of the species in Mexico, recent research suggests that social origin, for instance community of residence or ethno-linguistic group, influences maize population structure at more local levels. A landscape perspective can help to determine whether these social factors operate in a consistent fashion across different environments. Case study data from Chiapas are presented and used to illustrate the role of ethnicity in understanding the ecology of maize diversity in Mexico. The paper contrasts the maize populations and management practices of Spanish speaking mestizos and Mayan language speaking indigenous people across four altitude zones in Chiapas. Environmental differences are primary in determining the overall pattern of maize diversity across the Chiapan landscape, but social origin has a significant effect on maize populations in all environments.

Keywords: Crop diversity; Agriculture; Indigenous people; Mestizos

1. Introduction

The purpose of this paper is to examine the effect of social origin on patterns of maize (*Zea mays* L.) diversity at a landscape level between the extremes of the national and community levels. Among other aspects, analysis of Mexican maize diversity at the national and community levels has focused on the overall structure of the species (e.g., Sánchez et al., 2000), the distribution of diversity across different environments (Perales et al., 2003a), and competition between landraces and modern varieties (Bellon and Brush, 1994). Early research (e.g., Anderson, 1947) established that maize diversity is not randomly distributed but rather is a function of environmental factors. Systematic collection and analysis has confirmed that ecology, determined by altitude and geographic location, explains the distribution of the 59 races of maize in Mexico (Sánchez and Goodman, 1992). In this, Mexican maize follows a familiar pattern to the biogeography of other organisms (Rosenzweig, 1995) and crops (Frankel et al., 1995) in which spatial distribution across bio-physical environments accounts for diversity. Although Mexico has undergone modernization in many regards, its maize crop is primarily sown with local seed. The use of improved varieties from public and commercial breeding is confined to a relatively small percentage of Mexican maize area, primarily in the intensive cropping systems below 1200 m above sea level (m a.s.l.) (Aquino et al., 2001).

Research on the diversity and dynamics of Mexican maize has focused primarily at two levels at different spatial extremes. The overall diversity of the species has been studied from national collections and material from relatively few farmers obtained without social context (Wellhausen et al., 1952). At the other extreme, the selection and maintenance of maize has been examined at the local or micro-regional level and reliant on relatively intensive collecting and surveying of farm households (e.g., Bellon and Brush, 1994; Perales et al., 2003a). One important study that is focused between the national and local levels is

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Aguirre et al. (2000) analysis of maize diversity in southeastern Guanajuato. Aguirre et al. (2000) examed such landscape variables as economic infrastructure and agronomic potential in relation to maize types. Other landscape variables that are important elsewhere in Mexico, such as contrasting, altitude related environments and the ethnic composition of different towns and villages, were not considered as they are in this study.

Good theoretical grounds exist for studying crop ecology at the landscape level (Veldkamp et al., 2001). Arguably, crop evolution needs to be understood at different spatial scales. Larger scales, such as the nation and its major eco-geographic regions, are useful when natural selection is the objective of research. When artificial selection is the object, a smaller scale is useful. Conscious selection is ultimately the product of individual actors, although individuals act in concert with shared knowledge systems and markets that extend beyond the community. Moreover sharing of seed among farmers results in the pooling of individual actions and locations. The combination of social factors above the individual level and pooling through seed networks bids us to work at higher levels than the individual or single village. Because contrasts among crops, environments, and social groups are most discernable at the landscape level, the impact of artificial selection on crop diversity can most readily be identified and triangulated at that level.

While ecological factors play a dominant role in the distribution and structure of maize diversity, several research findings suggest that social factors contribute to maize diversity at the landscape level. Location specific research (e.g., Bellon and Brush, 1994) suggests that maize diversity is found primarily between communities rather than within them. Hernández (1985) emphasizes the association between maize diversity and uses by different ethnic groups across various regions. Maize landraces are partly the product of seed exchange beyond the community (Louette et al., 1997). Pressoir and Berthaud (2004b) and Perales et al. (2005) find that population structure measured by morphological and agronomic traits is a function of different communities and ethno-linguistic groups in relatively small regions. Finally, several researchers have found that different regions are more or less dynamic in terms of the number of landraces present, farmer activities directed at changing landraces, and the replacement of local populations with modern varieties (e.g., Aguirre et al., 2000; Perales et al., 2003b). This paper builds on previous research by expanding the scale for understanding maize diversity in relation to human components.

2. Distribution and structure of maize diversity in Mexico

2.1. Races of maize

The historic unit of analysis of maize diversity has been race, defined by Anderson and Cutler (1942) as ‘‘a group of individuals with a significant number of genes in common, major races have a smaller number in common than do sub-races.’’ Using plant, ear and tassel characteristics as well as physiological, genetic, and cytological characteristics Wellhausen et al. (1952) analyzed their countrywide collection to described 25 Mexican maize races. Continued collection and new methodologies, such as isozyme analysis, have increased that number to 59 (Sánchez et al., 2000). Variation within races is evident when measured by quantitative and agronomic measures (Herrera-Cabrera et al., 2004; Pressoir and Berthaud, 2004b). Although the use of molecular markers to study population structure of Mexican maize is limited to the study of single races (Pressoir and Berthaud, 2004a), research with these tools on the background of U.S. maize suggests that racial complexes are distinguishable at the molecular level (Ho et al., 2005). Race remains the unit of classification for analysis of maize populations in Mexico.

2.2. Maize biogeography and ecology

Work of Anderson (1947), Wellhausen et al. (1952), Mangelsdorf (1974) and Hernández (1985) in Mexico and Guatemala laid the foundations of our contemporary understanding of maize biogeography in Mesoamerica. This research describes continuous variation among domesticated maize, although regional clusters or complexes are apparent, each comprising several races that are more closely allied with one another and genetically more distant from races in other clusters. Geographical and environmental determinants of the structure and distribution of maize races and groups of races are unambiguous. It is especially clear that altitude plays an important role in racial grouping. This is illustrated by the long recognized Mexican Pyramidal (*Cónico*) group from the central highlands and the Mexican Narrow Ear complex at or below 1800 m a.s.l. (Anderson and Cutler, 1942; Benz, 1986) and by weak differentiation among races from the highlands of southern Mexico and Guatemala (Bretting et al., 1990).

The strength of environment in determining racial distribution of maize is so large that a human role in maize evolution and distribution has been difficult to identify or weigh. Indeed, some maize researchers would dismiss a significant human role; as reflected in Wellhausen et al.'s (1957) observation that there is little evidence to define a human contribution to maize evolution. Nevertheless, research in ethnobotany and cultural ecology have begun to elucidate a role of social factors in shaping maize evolution, for instance in explaining the existence of sympatric races in single farming systems. Two lines of research have contributed here. One line is the general ethnobotany of maize, especially the work Hernández (1985) and his students (e.g. Ortega-Paczka, 1973). The second line is the cultural ecology of maize selection and management (e.g., Bellon and Brush, 1994; Louette et al., 1997). Review of these case studies reveals several common features of management:

- Persistence of local maize despite the introduction of improved types.
- Relative dominance of one type at both the household and community levels.
- Cultivation of minor varieties, which contribute minimally to overall production.
- High substitutability of different maize types for *tortillas*, the basic staple.
- Selection of seed from harvested ears, based on an ideotype of local maize.
- Relatively frequent acquisition of new seed from neighbors and more distant markets.
- Maintenance of landraces in highland regions.

Mesoamerican maize agriculture is thought to be a relatively stable biological system (Hernández, 1985), withstanding the extensive biological and technological transformation that maize has experienced in industrial regions, such as the U.S., and in other underdeveloped regions, such as southern and eastern Africa. Hybrid maize seed is restricted to a few geographic regions and farm types in Mexico, and improved, open pollinated varieties have been adopted by only a small percent of farmers (Aquino et al., 2001).

2.3. Maize in Chiapas

Chiapan maize has been collected over the past 60 years, including three state-wide collections done at 25 and 29 year intervals: 1946 (Wellhausen et al., 1952), 1971 (Ortega-Paczka, 1973) and our collection in 2000. Apart from these collections, Chiapan maize agriculture has been studied by ecologists (Bellon, 1991; Perales et al., 2005) and anthropologists (Collier, 1975).

Maize from southern Mexico and Guatemala comprises a major sub-group, defined by late maturity (Sánchez et al., 2000). This group was examined in detail by Bretting et al. (1990), who distinguish high- and low-elevation clusters. Chiapan maize constitutes a distinct regional cluster with 11 races (Perales and Hernández, 2005) characterized by late maturity, tall plants, 23–28 leaves per plant, many tassel branches, long ears, and extreme sensitivity to photoperiod and temperature (Bretting et al., 1990). Above 1800 m above sea level (m a.s.l.), the two most common races are *Olotón* and *Comiteco*. In Mexico, *Olotón* is only present in Chiapas in the highlands. *Comiteco* probably originated in Chiapas and is not common elsewhere in Mexico. Ortega-Paczka (1973) reports an inverse relationship in Chiapas between the number of maize races and altitude, although Bretting et al. (1990) report that maize from highland Guatemala is more heterogeneous than those from lower elevations.

Following Anderson (1947), the biogeography of maize has been described as a function of geographic and environmental factors such as latitude and altitude. The relevance of these factors is unambiguous and demonstrated through the gene by environment interaction analysis by Sánchez and Goodman (1992). Although ecological factors dominate the biogeography of Mexican maize at the national level, three research findings point to the possibility that other factors may play a role in the nature of maize diversity at different geographic scales. First, biogeographic analysis at the national level reveals the presence of regional complexes involving several races. Using morphological and isozyme data, Sánchez et al. (2000) identify four principal groups and several subgroups within these. For instance, Group 2 includes 12 races of eight-rowed maize from western and northwestern Mexico. Multiple races occupy single gene by environment interaction zones and persist in the presence of a small but regular and potentially significant exchange of seed between farmers, villages, and geographic areas such as watersheds and valleys. Moreover, farmers are known to experiment and to move material between agroclimatic zones. One might ponder, therefore, why seed movement and hybridization do not reduce racial diversity in the general environments and racial complexes described by Sánchez and Goodman (1992) and Sánchez et al. (2000).

Second, maize researchers have recognized that farmer selection for special purposes can greatly affect the diversity within races. Herrera-Cabrera et al. (2004) report a very wide range of morphological and agronomic traits for the widely grown *Chalqueño* race of the central highlands of Mexico. In contrast, geneticists (Sánchez et al., 2000) report that selection for special use greatly reduces the genetic diversity within certain populations, and ethnobotanists (e.g., Hernández, 1985) note that this selection is often associated with particular ethno-linguistic groups.

Third, intensive research at small regional levels reveals that the structure of maize populations reflects social structure of maize farmers. Pressoir and Berthaud (2004a,b) analyzed the population structure of *Bolita* maize among communities in the central valleys of Oaxaca using molecular marker and quantitative methods. While the molecular markers revealed a lack of structure according to the origin of seed in different communities (Pressoir and Berthaud, 2004a), quantitative and agronomic measures showed that maize population structure of the region was determined by the community where samples were collected (Pressoir and Berthaud, 2004b). A study in the highlands of Chiapas (Perales et al., 2005), revealed that the presence of two races, *Olotón* and *Comiteco*, corresponded to two Mayan ethno-linguistic groups, the Tzotzil and Tzeltal. Although adaptation to the local environment was found for each group, the maize of one group was competitive in both environments. Similarly to the Oaxaca study of Pressoir and Berthaud (2004a,b), the Chiapas research showed that population structure based on morphological and agronomic traits was a function of the origin of the sample in different social groups, but that the use of neutral markers (isozymes) revealed no underlying structure to the maize from the different communities. The studies from Oaxaca and Chiapas thus suggest that the social origin of maize, whether by community or ethno-linguistic group, affects the crop's population structure when measured by traits that are under conscious selection. The lack of population structure measured by neutral traits suggests the significance of seed flow among communities in erasing structure.

Contrasting highland and mid-low elevation farming systems have been identified in Chiapas (Collier, 1975; Brush et al., 1988). In the highlands above 1400 m a.s.l., maize is primarily a subsistence crop, produced on small plots in mixed cropping (*milpa*) systems, receiving low amounts of purchased inputs, and having yields below 1500 kg/ha. In contrast, in the lowland and mid-elevations (<1400 m a.s.l.) maize is commonly a commercial crop, although subsistence-oriented production is also found. Commercial production is associated with large plots, monocropping, purchased inputs, and yields above 2000 kg/ha. Because of the productivity of the mid-low elevation farms, Chiapas is one of Mexico's prime maize producing states and exports maize to other parts of the nation. In contrast, highland farms struggle for self-sufficiency in this basic subsistence food and often rely on purchased grain (Perales et al., 2005).

2.4. The social landscape of Chiapas

Mestizos are Spanish speaking people who identify with Mexico's national culture (Wolf, 1959). The term that comes closest to marking their identity is ''Mexicano,'' a term that lacks racial connotation but marks affinity to the national culture rather than to a regional, indigenous culture (Chance, 1979). In Chiapas, they represent 69% of the population (INEGI, 2002). Indigenous people are primarily speakers of one of several Mayan languages and represent 31% of Chiapas' population (INEGI, 2002). The largest Mayan language groups in Chiapas are the Tzotzil (291,555 persons in the 2000 general census) and the Tzeltal (278,577 persons). Chiapas has 111 municipalities, and in 99 of these, there is a significant indigenous population. Thirteen municipalities are comprised of 98% indigenous language speakers, 22 are comprised of 90% indigenous inhabitants, and 36% are above 50% indigenous language speakers (INEGI, 2002). The presence of indigenous people is strongly associated with altitude. Above 1400 m a.s.l., over 50% of the communities have a majority of indigenous language speakers, while below 900 m a.s.l., less than 20% of the communities have an indigenous majority.

The divide between mestizo and indigenous people has been a prominent feature of the social landscape of Mexico since the European conquest 500 years ago (Wasserstrom, 1983). Within a few generations after the conquest, mestizos emerged as a new ethnic group from the combination of indigenous and European cultures. The division is culturally salient and recognized in Mexican Constitution and law, for instance in the establishment of Indigenous Communities as collective land holding entities with some administrative autonomy (Speed and Collier, 2000). The boundary between mestizo and indigenous is fluid and cultural identity is changeable and self-ascribed. Nevertheless, the cultural distance between Spanish speaking mestizos and indigenous peoples who speak one of several Mayan languages is perceived as real and greater than the distance separating Mayan ethno-linguistic groups.

3. Research on the social origin of maize

3.1. Objectives

The objectives of our research were (1) to provide a preliminary analysis of data on maize diversity and management gathered at the landscape level and (2) to inquire whether the importance of the social origin of maize can be seen at a larger geographic scale that includes different agroclimatic environments, numerous maize races, and different ethnic groups.

Social origin has been shown to affect maize population structure and diversity at smaller regional scales and within single maize environments in Oaxaca (Pressoir and Berthaud, 2004b) and highland Chiapas (Perales et al., 2005). The diversity studied here is the richness of maize landraces rather than diversity measured in other ways such as by evenness or the Shannon–Weaver index. The landscape examined is the state of Chiapas in southern Mexico. Its territory encompasses different environments, social groups, and organizing frameworks such as communities, municipalities, ethnic groups, and markets. Our focus is on four maize growing environments defined by altitude and two social groups defined by ethnicity and language. Chiapas is heterogeneous in terms of agricultural environments, level of intensification, maize races, and the organization of production. Finally, Chiapas is one of the most socially and culturally heterogeneous areas of Mexico, offering sharp contrasts between ethno-linguistic groups and production systems that run the gamut from household, subsistence-oriented to large scale, commercial ones. To look for possible impact of social origin on maize populations and diversity, we concentrate on the sharpest ethnic division in Chiapas, between mestizo and indigenous producers.

3.2. Methods

Two fieldwork periods collected data on maize in Chiapas. In 1999–2000, research was concentrated in highland municipalities around the city of San Cristobal de la Casas (Perales et al., 2005). The second, state-wide field work period was 2002–2004 using the same approach as in 1999–2000. During both periods, 119 communities were sampled, and surveys and maize samples were taken from 2073 households. Fig. 1 is a map of the sites included in the 1999–2000 and 2002–2004 survey and collection. Six ears of seed quality maize were sought for each type sown by

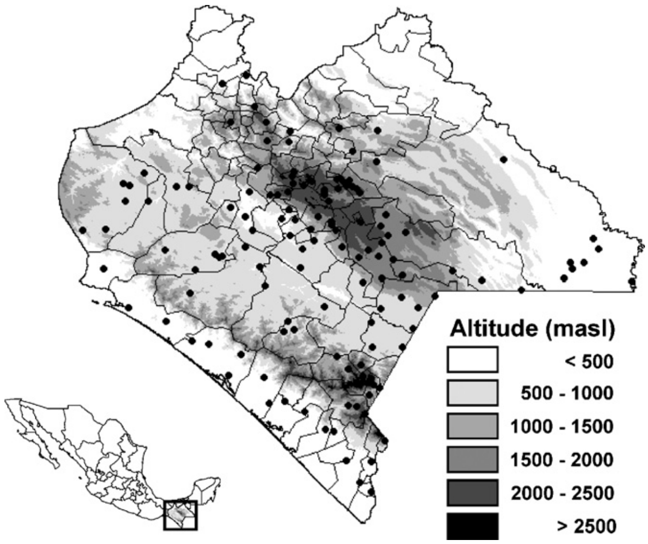

Fig. 1. Chiapas: topography and community sample, 2002–2004.

the farm household in both seasons. In all 2941 maize samples were obtained. Ear measurements (length, diameter, cob diameter, seed length, width and thickness) were done for the sample and a small representative subsample was planted in common garden plots for agronomic and phenological data.

Racial classification of the maize sample was done following Wellhausen et al. (1952), Benz (1986) and Sánchez (1989). Altitude classes were determined inspecting the sample for classes at 100 m intervals; racial composition within altitude class is very consistent throughout the sample. Chisquare analysis was performed within each altitude class to test for independence of ethnicity and variables considered.

3.3. Results

Our study of maize growing farms uses data from 119 communities, 2073 households and 2941 maize samples from both indigenous and mestizo farmers in all four altitude zones (<900, 900–1400, 1400–2000, and >2000 m a.s.l.). Table 1 summarizes the 2002–2004 state-wide survey of Chiapas maize production. As the figures on percent of households which sell maize indicate, mestizo farmers are more commercially oriented than indigenous farmers. Nevertheless, throughout most of the altitude ranges, farm size between the two groups is not significantly different.

3.3.1. Maize races in Chiapas

As shown in Table 2, eight maize races account for almost all of the maize grown in the state. Two of these, *Cubano amarillo* and *Tuxpeño* are introductions to Chiapas, and the remaining six are native to the state or introduced before 1950 (Wellhausen et al., 1952). Maize diversity, measured by the presence of different races, is inversely related to altitude, with the lowest altitudes showing the highest number of races and the highest altitudes the fewest. Three of the eight races are dominant, and their dominance depends on altitude: *Tuxpeño* below 900 m a.s.l., *Comiteco* in the intermediate altitudes (900–2000 m a.s.l.) and *Olotón* above 2000 m a.s.l. The altitude zone where a race is dominant may be considered to be its primary agricultural habitat where it has a natural advantage.

Table 1
General attributes of households surveyed in Chiapas, 2002–2004

	Altitude class (m a.s.l.)			
	0–900	900–1400	1400–2000	2000–2500
No. of communities surveyed	69	10	28	12
Household sample	1040	218	514	301
Mestizo	876	116	193	87
Indigenous	164	102	321	214
% communities > 50% indigenous	14.5	40.0	53.6	58.3
No. of maize samples collected	1258	288	836	559
Average No. of maize types per household	1.21	1.32	1.63	1.90
Average maize area (ha)				
Mestizo	2.26	2.02	1.76	1.14
Indigenous	2.07	1.19	1.61	1.16
t^{a}	0.97 n.s.	3.07**	0.71 n.s.	0.88 n.s.
Average reported maize yield (tones/ha)	1.8	1.4	1.3	1.5
% households selling maize				
Mestizo	56.5	64.7	27.5	18.4
Indigenous	37.8	36.3	29.0	7.2
Chisq[b]	19.45**	17.50**	0.13 ns	8.67**

n.s. non-significant, $^{*}P < 0.05$, $^{**}P < 0.01$.

[a] *t*-Test comparison of average maize area between mestizos and indigenous people by altitude class.

[b] Chisquare test for frequency of mestizos and indigenous households selling maize by altitude class.

Table 2
Principal maize races of Chiapas (relative frequency)

Race	Altitude (m a.s.l.)[a]			
	0–900	900–1400	1400–2000	2000–2500
No. of seed lots	959	241	786	559
Olotón	0.0	0.0	8.7	65.8
Comiteco	8.2	62.2	79.5	33.3
Tuxpeño	81.2	18.7	2.7	0.2
Olotillo	2.7	9.1	8.0	0.0
Tepecintle	1.8	3.3	0.9	0.7
Tehua	0.0	5.8	0.0	0.0
Zapalotes	1.4	0.0	0.1	0.0
Cubano amarillo	4.7	0.8	0.1	0.0

Chisq = 2743.2 for Olotón, Comiteco, Tuxpeño and "other races" vs. altitude class; $P_{Chisq} < 0.0001$.
[a] Average frequencies of seed lots by community.

Our inquiry about the role of social differences on maize diversity and maize management begins with the proportions of the three major maize races that are kept by mestizo and indigenous farmers in the four altitude classes. Fig. 2 shows that the maize types grown by the two social groups reflect the dominance pattern revealed in Table 2. However, it is also evident that the proportions of the different races cultivated by the two groups differ at each altitude, and the differences are significant at each altitude. *Tuxpeño* was introduced from Mexico's Gulf Coast and the Caribbean to the lower elevations of Chiapas and elsewhere in Mexico, and it has been the most important source for maize improvement by public breeding programs since the 1950s (Bellon, 1991; Ortega-Paczka, 1999). A significant proportion of the *Tuxpeños* present in Chiapas are landraces introduced decades ago, most probably from the Gulf Coast area of Veracruz. The race produces white grain and has been bred for short stature and high yields on favorable soils (Bellon and Taylor, 1993). It is the maize of choice for commercial production in Chiapas's major maize producing areas, such as the Grijalva River Valley and the coast near Soconusco. Although mestizo and indigenous farmers produce *Tuxpeño* in similar proportions below 900 m a.s.l., mestizos give it more emphasis between 900 and 2000 m a.s.l. In contrast, indigenous and mestizo farmers grown comparable proportions of *Comiteco* between 1400 and 2000 m a.s.l., but indigenous farmers grow it at a higher rate at lower altitudes than mestizo farmers. *Olotón* exhibits a mirror-like pattern to *Comiteco*: comparable cultivation by the two social groups in the main altitude zone (>2000 m a.s.l.) but higher rates on indigenous farms at lower altitudes. In sum, *Tuxpeño* is pushed into marginal altitudes of its adaptation by mestizo farmers, while *Olotón* and *Comiteco* are pushed into marginal altitudes by indigenous farmers. While all three races are marketed, several characteristics make *Tuxpeño* the most important commercial race in Chiapas: its consistently white grain, relatively high yields, dominance in the intensively cultivated lower altitudes, and the investment of breeding effort that it has received. In contrast, *Olotón* and *Comiteco* are more associated with household consumption and have not received the attention from breeders that *Tuxpeño* has. The differences in the percent of households that sell maize (Table 1) indicate that mestizo producers are more commercially oriented. Their practice of pushing *Tuxpeño* beyond its primary habitat is likely to derive from this orientation. In contrast, indigenous producers appear to be more subsistence-oriented and push the native races, *Olotón* and *Comiteco*, beyond their primary habitats.

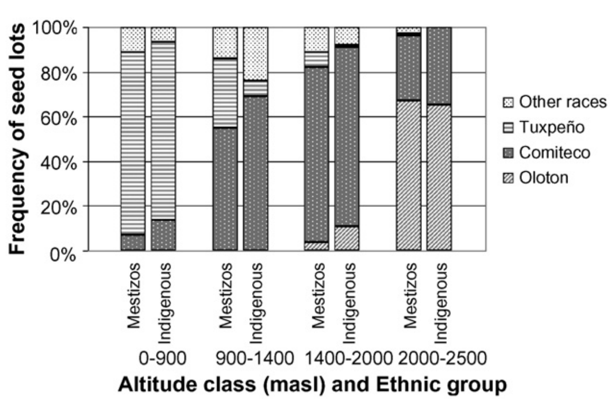

Fig. 2. Dominant maize races by altitude and ethnic group.

3.3.2. Seed types and seed lots

Agronomists and social scientists studying the maintenance of maize populations and the changing maize production system of Mexico distinguish three types of seed: traditional varieties, modern varieties, and advanced generations of modern varieties. Traditional varieties are landraces and local variants of maize races and interracial hybrids that are maintained by farmers and planted from farmer seed stocks. At the other extreme are modern varieties that are released from public and private maize breeding programs as either open-pollinated varieties or commercial hybrids. A third category, advanced generations of improved varieties, stands between these two extremes. These are comprised of the progeny of modern varieties that have been re-planted in successive years and allowed to hybridize with other populations. In this process, the advanced generations loose some of the distinctive characters of the original modern variety, such as short stature, but they are considered by farmers to retain some of the advantages of the original modern variety while achieving greater adaptation to local conditions. This process, referred to "creolization" by farmers (Bellon and Risopoulos, 2001), allows them to capture advantageous traits of modern varieties without radically changing their seed system by shifting to purchased seed. Many seed lots of *Tuxpeño* have been subject to creolization in Chiapas.

Following Louette et al. (1997), maize researchers in Mexico recognize that landraces in a particular locality are open systems with small but regular infusion of seed from other communities or regions. Perales et al. (2003b) point

Table 3
Maize seed type by altitude and ethnic group (relative frequency)

Altitude (m a.s.l.)	Ethnic group	No. of seed lots	Maize seed type			Chisq[a]
			Traditional variety	Modern variety	Advanced generation	
0–900	Mestizo	1057	57.1	15.8	27.2	19.5***
	Indigenous	200	70.5	5.0	24.5	
900–1400	Mestizo	149	85.9	0.0	14.1	8.1**
	Indigenous	139	95.7	0.0	4.3	
1400–2000	Mestizo	271	93.7	0.0	6.3	15.0***
	Indigenous	565	98.5	0.2	1.4	
2000–2500	Mestizo	148	96.6	0.0	3.4	15.6***
	Indigenous	409	100.00	0.0	0.0	

n.s. non-significant, *$P < 0.05$, **$P < 0.01$ and ***$P < 0.001$.

[a] Chisquare test by altitude class for ethnic group vs. maize seed type. Modern varieties were excluded from test in altitude classes above 900 m a.s.l.

out that some landraces are relatively stable while others are more dynamic and more often infused with material from exotic varieties. In central Mexico, the general pattern was that maize in the higher elevations exhibits stability while lower elevation maize undergoes greater directional selection, hybridization, and change by farmer management (Perales et al., 2003b). The same pattern holds in Chiapas. Table 3 shows that traditional maize is strongly dominant at all altitudes; modern varieties are only found at the lower altitudes, and advanced generations are most important there but found in small amounts at higher elevations. Again, a contrasting pattern between indigenous and mestizo farmers is evident. Mestizos grow modern varieties and their advanced generations at a higher rate at all altitudes than indigenous farmers, and only mestizos plant advanced generations in the upper altitude area. In other words, the mestizo and indigenous practices of planting different types of seed follow similar patterns across the four altitude classes, but mestizo farmers are more dynamic in changing their maize seed and in promoting gene flow from improved varieties into local populations. The age of the seed lot, shown in Table 4, is another indication of the same phenomena. The seed lots of both ethnic groups become older with altitude, but the seed lots of mestizos are on average younger than those of indigenous farmers at all altitudes. Analysis of variance for age of seed lot by altitude class showed that altitude and ethnicity were significant variables ($p \leq 0.0001$ and $p \leq 0.01$, respectively) when data across the four environments were pooled, and the interaction of these was non-significant. When examined by altitude class, however, ethnicity was only significant in the lowest altitude class (<900 m a.s.l.) ($p \leq 0.05$).

3.3.3. Color preference

A similar pattern emerges in the distribution of color and seed type by altitude and ethnic group. Maize geneticists have found that color is not strongly linked to agronomic and phenological characteristics. In Chiapas and elsewhere in Mexico, and for mestizo and indigenous farmers alike, color is the most important criteria in identifying and classifying maize (Soleri and Cleveland, 2001; Benz et al., 2007). As shown in Table 5, white and yellow maize are the most common types in our maize collection, but red, pinto, and/or blue/black maize is found at all altitudes. White is dominant at the lowest elevation, while yellow maize becomes dominant for both ethnic groups above 1400 m a.s.l. Although both white and yellow maize is grown at all altitudes by mestizo and indigenous farmers alike, mestizos

Table 4
Maize seed lot age by altitude and ethnic group (relative frequency) and average seed lot age

Altitude (m a.s.l.)	Ethnic group	No. of seed lots	Age of seed lot (years)				Chisq[a]	Average number of years with seed lot
			1	2–5	6–20	>20		
0–900	Mestizo	1058	19.6	36.5	27.2	16.8	12.0**	10.1
	Indigenous	199	11.5	32.5	34.0	22.0		12.2
900–1400	Mestizo	149	7.4	19.5	33.6	39.6	10.3*	19.6
	Indigenous	139	3.6	21.6	21.1	54.7		22.7
1400–2000	Mestizo	271	5.5	24.4	29.5	40.6	7.9*	22.3
	Indigenous	565	4.8	19.8	24.4	51.0		24.3
2000–2500	Mestizo	148	6.1	15.5	19.6	58.8	6.1 n.s.	25.8
	Indigenous	409	3.1	13.5	15.0	68.4		28.5

n.s. non-significant, *$P < 0.05$, **$P < 0.01$ and ***$P < 0.001$.

[a] Chisquare test by altitude class for ethnic group vs. age of seed lot.

Table 5
Maize color of seed lots by altitude and ethnic group (relative frequency)

Altitude (m a.s.l.)	Ethnic group	No. of seed lots	Maize color					Chisq[a]
			White	Yellow	Blue or black	Pinto	Red	
0–900	Mestizo	1057	83.9	14.7	0.8	0.1	0.6	19.15***
	Indigenous	200	74.0	21.0	3.5	0.5	1.0	
900–1400	Mestizo	149	60.4	34.9	4.0	0.7	0.0	24.82***
	Indigenous	139	35.3	46.8	10.1	6.5	1.4	
1400–2000	Mestizo	269	36.8	57.6	3.0	1.5	1.1	30.32***
	Indigenous	552	33.5	46.4	11.8	5.8	2.5	
2000–2500	Mestizo	148	35.1	43.9	7.4	9.5	4.1	15.67**
	Indigenous	458	22.5	43.2	16.2	10.0	8.1	

*$P < 0.05$, **$P < 0.01$ and ***$P < 0.001$.
[a] Chisquare test by altitude class for ethnic group vs. maize color.

grow white maize at higher rates than indigenous farmers at all altitudes, and the reverse is true for yellow maize. Moreover, indigenous farmers grow minor colors more often and at higher rates than mestizo farmers. Analysis of variance in the color of seed lots showed significance at the 0.05% level for both altitude class and ethnicity and for their interaction. Commercial buyers of maize, such as millers, tortilla manufacturers, and wholesalers, strongly prefer white maize. Yellow and colored maize, in contrast, is used for home-use. Minor colors, especially red maize, are associated with indigenous agricultural rituals throughout Mexico (e.g., Sandstrom, 1991). The distribution of color thus shows that while both ethnic groups engage in production for both home-use and sales, mestizos, especially in lower elevations, are more likely to reduce color variation in their maize in order to satisfy the market.

3.3.4. Origin of new seed lots

The final contrast in management of maize by indigenous and mestizo farmers in Chiapas is their practice of acquiring seed, shown in Tables 6 and 7. No matter what the maize type, Mexican farmers have been shown to replenish seed regularly (Louette et al., 1997). While this process may introduce new varieties to a locality (Louette et al., 1997), the most common practice is to seek seed of the same type (e.g., race) both within the community and beyond. Because maize is an allogamous crop, even a small amount of new seed from the outside opens local maize populations and makes it difficult to discern population structure based on where maize samples are collected (Pressoir and Berthaud, 2004a; Perales et al., 2005). Nevertheless, farmer selection for morphological traits is able to create distinct populations based on location (Pressoir and Berthaud, 2004b; Perales et al., 2005). Table 6 shows that maize at all altitudes is normally replenished by acquiring seed within the community, although outside sources are more important at lower altitudes. Table 7 shows that family and acquaintances are the most common donors of seed lots, although commercial sources are used at the lower altitudes. At the higher altitudes, two thirds or more of the seed is from parents and family members, in particular for indigenous people. While the patterns of seed source by indigenous and mestizo farmer show overall similarity, significant differences also exist. Mestizo farmers at the lowest altitude area are more likely to use commercial seed than indigenous farmers. On the other hand, indigenous farmers in this area show a slightly higher use of seed from outside of Chiapas, perhaps reflecting connections between indigenous people in Chiapas and in

Table 6
Place of origin of seed lot by altitude and ethnicity (relative frequency)

Altitude (m a.s.l.)	Ethnic group	No. of seed lots	Origin of seed lot				Chisq[a]
			Community	Other community	Commercial source	Out of state	
0–900	Mestizo	1040	64.0	11.6	22.2	2.1	21.5***
	Indigenous	198	77.9	8.0	10.1	4.0	
900–1400	Mestizo	146	78.1	19.2	2.1	0.7	2.8 n.s.
	Indigenous	139	84.9	13.7	1.4	0.0	
1400–2000	Mestizo	269	80.3	16.4	2.2	1.1	12.4**
	Indigenous	557	86.7	12.6	0.7	0.0	
2000–2500	Mestizo	144	93.1	5.6	0.7	0.7	4.7 n.s.
	Indigenous	409	95.8	3.9	0.0	0.2	

n.s. non-significant, *$P < 0.05$, **$P < 0.01$ and ***$P < 0.001$.
[a] Chisquare test by altitude class for ethnic group vs. origin of seed lot.

Table 7
Relation of seed lot donor by altitude and ethnicity (relative frequency)

Altitude (masl)	Ethnic group	No of seed lots	Relation of seed lot donor					Chisq[a]
			Father	Family	Acquaintance	Seed company	Market	
0–900	Mestizo	1003	16.1	17.4	41.3	24.5	0.8	22.7***
	Indigenous	198	22.6	14.1	51.3	11.1	1.0	
900–1400	Mestizo	146	37.7	20.6	37.0	2.7	2.1	15.6**
	Indigenous	138	60.9	13.8	23.2	1.5	0.7	
1400–2000	Mestizo	267	41.2	20.2	34.5	2.6	1.5	55.5***
	Indigenous	557	68.2	10.6	19.6	1.1	0.5	
2000–2500	Mestizo	140	54.3	17.9	26.4	0.7	0.7	57.5***
	Indigenous	409	83.9	5.3	10.8	0.0	0.0	

*$P < 0.05$, **$P < 0.01$ and ***$P < 0.001$.
[a] Chisquare test by altitude class for ethnic group vs. relation of seed donor.

neighboring Oaxaca and Guatemala. In contrast, mestizos acquire seed from non-family members at higher rates than indigenous farmers at all altitudes.

3.4. Discussion

Our state-wide farm survey and maize collection in Chiapas shows that environment, defined by altitude, is a clear and dominant factor in the distribution of races, seed types, colors, and seed source. Lower altitudes are more diverse in the number of races and seed types present, while the higher elevation is more diverse in the number of colors. Moreover, the management of maize populations in lower altitude areas is more dynamic in terms of the age of the seed lot, its age, and source outside of the community and kinship group. The maize of mestizo and indigenous farmers share these differences across the four altitude classes. Both mestizo and indigenous people use management practices that promote diversity—the maintenance by many households of different maize (race, type, color) and the replenishment of seed from outside sources. Nevertheless, significant differences exist between the two ethnic groups in the distribution of maize races, types, colors, and seed systems, and the ethnic differences are significant regardless of environment. Mestizo farmers appear to be more active than their indigenous counterparts in commercial production, as evidenced by their higher rate of planting white maize, reliance on commercial seed, and somewhat younger seed lots acquired beyond parents and family. The maize populations managed by mestizo producers are likely to be more heterogeneous because of a higher rate of planting modern varieties, more rapid turnover of their seed, and a wider base from which to acquire new seed. The maize populations of indigenous producers, on the other hand, are more heterogeneous in the number of races and colors that they manage.

The mestizo and indigenous social groups studied here represent historic and still-salient divisions in Chiapas and elsewhere in Mexico. Both historic research (e.g., Chance, 1979) and contemporary studies (e.g., Collier, 1975) document that these are not closed groups and that there is movement of ideas, cultural practices, and people between them. In spite of this openness and the simultaneous occupation of the same landscape, we can detect differences between the agricultural management practices of two groups. Similar findings about cultural differences in relation to knowledge and management of biological resources are reported elsewhere in Mexico (Benz et al., 2000) and Guatemala (Atran et al., 1999).

Three explanations for the differences in managing maize reported above might be cited: (1) environmental attributes of the two groups' agricultural lands within the four general altitude classes, (2) socio-economic attributes of the two groups, and (3) cultural knowledge attributes of the two groups. While it is beyond the scope of our current data set and this paper to test these explanations, some assessment of their relative merit is possible.

3.4.1. Environmental attributes

An environmental attribute explanation for the differences in maize management between mestizo and indigenous people would rest on showing that the two groups occupy ecologically dissimilar areas within the four altitude zones and that management differences, such as the proportion of different races or maize types, is a response to these environmental differences. It is possible that indigenous and mesitzo people live in villages whose agricultural assets differ or that mestizo and indigenous farmers who live in the same village occupy different agricultural niches within the village. A history of domination of indigenous people by non-indigenous people in Chiapas is well documented, including expropriation of indigenous people's land and indigenous retreat to more marginal areas (e.g., Collier, 1975; Wasserstrom, 1983). Except for the highest altitude area (2000–2500 m a.s.l.), the villages sampled in our study include mixed, mestizo/indigenous populations as well as villages that are wholly indigenous or mestizo. Mixed villages are the most common type (43.7%) followed by mestizo villages (40%) and indigenous villages (19.3%). The similarity of the maize types found mestizo and indigenous farms across the four altitude zones suggests that they occupy similar environments in each zone. Moreover, because the most notable differences are behavioral, such as source and frequency of seed exchange and preference for white or colored maize, environmental differences between the two ethnic groups appear minor.

3.4.2. Socio-economic attributes

A socio-economic attribute explanation would emphasize the assets, such as farm size, education, participation in the off-farm labor market, and access to information and credit, of mestizo and indigenous producers. The higher percentage of mestizo households that sell maize in all but one of the altitude zones (Table 1), is indicative of attitudes and behavior associated with fuller economic integration that is linked with other maize management characteristics. These include more rapid technological turnover shown in the shorter age of maize seed lots reported by mestizo households (Table 4) and greater reliance on non-family and commercial sources for seed (Tables 6 and 7). The history of class and ethnic relations in Chiapas (Wasserstrom, 1983), suggest that socio-economic differences between the mestizo and indigenous people are significant and logically related to the behavioral differences noted above. Nevertheless, a sharp dichotomy in these characteristics between the two groups is unlikely. The average age of head of household among mestizos is 48.8 and among indigenous households 43.9. Participation in the labor market by the two groups is virtually the same. Among mestizos, the rates of off farm labor engagement are 39% for household heads and 33% for other family member. Among indigenous households, the rates are 38% and 23%, respectively. The average area planted to maize by mestizo households is 2.1 ha while for indigenous households it is 1.8 ha. Although both ethnic groups engage in commercial production, especially below 1400 m a.s.l., mestizo farmers are more active in this than indigenous ones, and this important difference may reflect socio-economic differences, such as education, that influence access to the market.

3.4.3. Cultural attributes

Finally, a cultural explanation would refer to the nature of understandings, values, and orientation and the flow of information within the two ethnic groups. Again, the similarities between the two groups, as well as the history of highly permeable boundaries between mestizo and indigenous cultures, suggest that no sharp and definitive contrast between them exists or can account for the behavioral differences observed by us. Nevertheless, the important difference between households that are primarily oriented toward commercial production versus those that are primarily oriented toward subsistence production is likely to have a cultural basis in that indigenous communities experience centripetal cultural pressure that is absent in mestizo communities (Wolf, 1959). The cultural knowledge systems relative to maize, defined by nomenclature, cultivation practices, and maize use in cuisine, cannot be sharply distinguished between indigenous and mestizo producers. Community and culture may affect maize population structure (Pressoir and Berthaud, 2004b; Perales et al., 2005), but this effect appears to work through the organization of social networks rather than differences in the content of knowledge systems. The higher percent of seed lots that are obtained within the community and from family members by indigenous households (Tables 6 and 7) appears to support the idea that their knowledge and social networks are more closely tied to locality than among mestizo farmers.

4. Conclusion

Environmental differences are the driving force behind the overall pattern of maize diversity that is observed at the landscape level in Chiapas. Nevertheless, the state's two most prominent cultural groups are found across the landscape and have a significant effect on maize populations in all environments. The influence of ethnic diversity appears in the finer grain ecological analysis, such as the distribution of maize races beyond their primary habitats and the nature of seed movement among farmers. Mestizo producers push maize populations toward the more commercial types and are more active and far reaching in changing seed. Indigenous producers maintain local races and a greater mixture of minor maize races and colors. Although socio-economic attributes and cultural knowledge affect the management and distribution of maize, behavioral differences between the two groups are ones of degree rather than kind. Both mestizo and indigenous producers are active in producing and maintaining the diversity of maize that is a legacy of their ancestors.

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