

Reports

Tzeltal and Tzotzil Farmer Knowledge and Maize Diversity in Chiapas, Mexico

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Different maize races dominate the highland communities of the Tzotzil and the Tzeltal of highland Chiapas, Mexico. When Tzeltal and Tzotzil informants from four communities were asked to sort photographs of maize varieties from the two municipalities according to ear similarity and the pictured variety's ability to produce on their communities' lands, their responses revealed that they have a common system of maize classification based on color and that unnamed but culturally specific categories discriminate maize types according to ethno-linguistic group. The significance of these findings is that while color, a perceptually distinct but nonadaptive trait, dominates maize classification by these farmers, intermediate but unlabeled categories help to explain the geographic distribution of maize in the regional environment. Thus, ethno-linguistic diversity contributes to maize diversity.

When we compare the individuals of the same variety . . . of our cultivated plants . . . , one of the first points which strikes us is, that they generally differ more from each other than do the individuals of any one species or variety in the state of nature.

—C. Darwin, *On the Origin of Species*

Darwin's reference to the great variation in cultivated varieties suggests that human manipulation leads to broader phenotypic variation. Recent studies of cultivated plants in traditional agriculture illustrate the importance of color in local knowledge systems (e.g., Brush, Carney, and Huaman 1981; Boster 1985). Berlin (1992) identifies color as the most common attribute for naming crops of considerable agricultural importance. The importance of cultivar variation to the traditional agriculturalist is manifest, but we are still working

out its etic basis. Boster's (1985) study of Aguaruna manioc testifies to the importance of seemingly nonutilitarian morphological variation of folk varieties. Boster argues that perceptual distinctiveness is unrelated to use or survival of the cultivar and that cultivators focus on phenotypic variation that has no adaptive value because these characteristics have no impact on the cultivar's productivity or utility.

Boster's (1985) distinction between taxonomic and biologically meaningful variation is not conclusive because (1) he could not examine the morphological basis of perceptual distinctiveness on a regional basis to test whether local taxonomic variation did not also describe regional morphological variation and (2) there was no documentation of the genetic basis for the distinctions his informants described. His (1986) demonstration that greater informant cultural competence is due to greater shared knowledge suggests one reason for taxonomic variation: to provide convenient lexical handles for communicating about important agricultural species. Though Boster surmised that sexually reproducing cultivated plants would not necessarily fit the model of perceptual distinctiveness, our analyses of Tzeltal and Tzotzil maize categories and cultivated populations suggest that his model applies equally to maize.

Berlin's (1992) analysis of ethnobiological terminology reiterates the focus of cultivators on subtle morphological characteristics including color that leads to nomenclatural proliferation for taxa with great importance in subsistence. The emic focus of folk biology leads us to question whether these cultural practices have biological repercussions—whether evolutionary change based on differentiation of adaptive phenotypic traits (etic characters) follows logically from disruptive selection based on perceptual distinctiveness (emic characters).

This paper reports on experiments to examine the relation between the etic and emic aspects of maize diversity in the Mayan highlands of Chiapas, Mexico, and the region's ethno-linguistic diversity. It complements results published elsewhere that documented the biological (etic) basis of landrace differences between these two ethno-linguistic groups (Perales, Benz, and Brush 2005). Here we examine the emic classification and identification of maize of two Maya-speaking groups in the highlands, the Tzotzil and the Tzeltal.

Maize in Mexico: Background

Maize (*Zea mays*) was domesticated in central Mexico (Matsuoka et al. 2002) between 9,000 and 6,000 years ago (Benz 2000). Its evolution in Mesoamerica led to diversification into approximately 55 races (Sánchez G., Goodman, and Stuber 2000) Maize was the keystone of pre-Hispanic societies in the region, and it continues to occupy a uniquely important place in Mesoamerican civilization (Staller, Tykot, and Benz 2006). It is the most important crop plant for indigenous people of

Mexico, and the Tzotzil and Tzeltal are no exception (Breedlove and Laughlin 1993).

While environmental heterogeneity contributes to the crop's diversity (Sánchez G., Goodman, and Stuber 2000), other factors, including cultural diversity, must also contribute. One puzzle is why distinct landraces occur in geographic proximity and in seemingly similar environments. The mid-elevations, > 1,700 m a.s.l., that encompass our study site constitute a single maize environment with two races (Sánchez G., Goodman, and Stuber 2000). An extensive literature on maize in Mexico documents the skill of Mexican farmers in identifying and selecting maize for their local environments (e.g., Soleri and Cleveland 2001). The interaction of adaptation to environment and farmer selection for yield (Perales, Brush, and Qualset 2003a), seed flow (Louette 1999), and substitutability of different types of maize for its principal uses (Bellon and Brush 1994) should act to homogenize maize populations in similar environments, but in fact we find diversity of both principal and specialized (colored) maize in relatively small regions. Attachment to local maize is attested to by the fact that 75% of Mexican maize farmers still plant local varieties (landraces) (Aquino et al. 2001).

Maize Knowledge Systems

We expect that knowledge about and classification of maize landraces will differ among groups such as maize producers, breeders, and consumers (Romney, Weller, and Batchelder 1986; Medin et al 1997). The historical and still useful basis for maize classification by biologists and crop scientists is the race (Anderson and Cutler 1942), an eco-geographically and morphologically distinct maize population. Other terms used to describe maize ecology include "landrace" and "variety." Here we use "landraces" to refer to local or regional maize populations that show greater similarity to each other than to other maize populations. "Variety" or "cultivar" refers to a specific phenotype recognized and named by farmers. "Farmer variety" contrasts with "breeder variety" or "modern variety," and the three describe similar but biologically diverse populations that contrast in terms of their histories and agricultural habitats (Brush 2004). Maize farmers in Mexico use *criollo* to refer to local or "traditional" maize and *híbrido* to denote improved maize.

Tzeltal and Tzotzil farmers organize their knowledge by means of a taxonomic system that has been described by ethnobiologists (Berlin, Breedlove, and Raven 1974; Breedlove and Laughlin 1993). The Mayan term for maize is *?išim* (Berlin, Breedlove, and Raven 1974, 33; Breedlove and Laughlin 1993, 230), a folk generic referring to a larger set of cereals which includes barley, wheat, and sorghum. Several folk specifics of maize are recognized and distinguished by such traits as grain color and ear size (Berlin, Breedlove, and Raven 1974; Breedlove and Laughlin 1993). Tzotzil farmers recognize maize that is suitable for different habitats; for instance, they use *vitztikal* for temperate maize (Breedlove and Laughlin

1993, 236). The published nomenclature for maize of indigenous people does not reveal named categories that distinguish one ethno-linguistic group's maize from that of other groups.

Terms such as *criollo* and *vitztikal* are intermediate categories in that they rank small numbers of other taxa "on the basis of their perceived affinities in overall morphology (and behavior)" (Berlin 1992, 33). The difference between our usage of the intermediate rank for these maize types and Berlin's (1992) usage is that his refers to taxa above the generic level rather than below it. The intermediate rank has been found in the folk taxonomy of other crops in reference to groups below the species level (Brush 2004) and combines potentially numerous emic characters that are perceptually distinct (Boster 1985).

In the maize terminology described above, both maize breeders and farmers utilize regular and intermediate named ranks to describe different types of maize. The question we pose here is whether Mayan farmers of highland Chiapas recognize an unnamed but intermediate rank that refers to the maize grown by one's own ethno-linguistic group as opposed to maize grown by other groups. This rank would be different from other intermediate ranks that are shared across ethnic groups, such as *criollo* maize versus hybrid maize. If Tzeltal and Tzotzil farmers recognize their maize in contrast to maize grown outside of their group, then group members should be able to distinguish their own maize. These expectations, of course, depend on observable morphological differences between the crop samples from each ethno-linguistic group.

Documenting that Tzotzil and Tzeltal farmers distinguish their respective maize populations could suggest that culture plays a role in promoting racial variation. Moreover, documenting this source of artificial selection in a single production environment might help explain the coexistence of distinct races (Perales, Benz, and Brush 2005).

Tzeltal and Tzotzil Maize

The highlands of Chiapas (fig. 1) are approximately 220 km in length (northwest–southwest) and 50–100 km wide, with elevations from 1,000 m to a gently rolling summit at 1,800–2,500 m a.s.l. Climate is temperate above 1,800 m, with ample rainfall in summer and fall (ca. 1,000–1,200 mm/year), the east side being slightly wetter.

Tzotzils and Tzeltals are Mayan ethno-linguistic groups distinguished by similar but mutually unintelligible languages. Each language is the other's closest relative, both being descended from an ancestral language ca. 900 years ago (B. Stross, personal communication). Tzotzils and Tzeltals lived in the region at the time of the Spanish conquest, although in small numbers and with marginal interregional communication and trade (Vogt 1969). The Tzotzil communities studied are from the Chamula municipality northwest of San Cristóbal. They engage in the production of

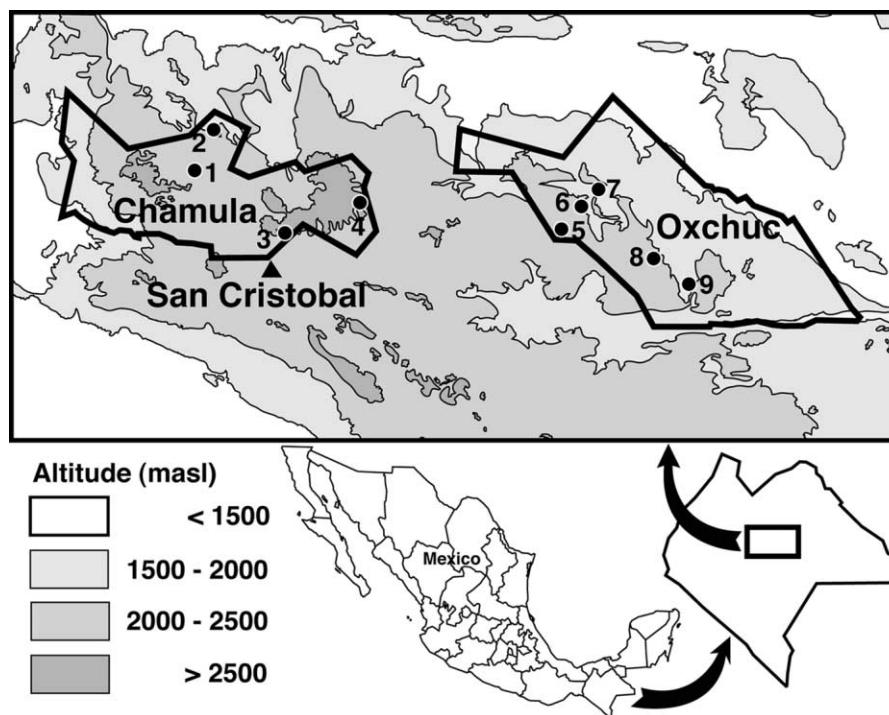


Figure 1. Study area in Chiapas, Mexico, 1, Los Ranchos; 2, Tentik; 3, Pozuelos; 4, El Crucero; 5, Pacbilna; 6, El Retiro; 7, Piedra Escrita; 8, Tuxaquilja; 9, Rancho del Cura.

maize, commerce, salaried work, and limited plantings of vegetables. The Tzeltal communities studied are from the municipality of Oxchuc, located northeast of San Cristóbal and some 20–30 km from Chamula. Oxchuc households rely on maize production, coffee plantations below 1,400 m a.s.l., and salaried work.

Detailed ethnobotanics of the Tzeltal and Tzotzil suggest that these groups maintain distinct populations of maize. With names used by Paul Mangelsdorf to identify collections of a few ears, Berlin, Breedlove, and Raven (1974, 429) report finding five native color varieties representing 11 distinct races and 4 hybrids among the Tzeltal. Again using Mangelsdorf's determinations, Breedlove and Laughlin (1993) report a higher number of specific taxa (26) for the Tzotzil, representing 15 distinct races and 11 hybrid mixtures, with several specifics referring to various races (and admixtures). According to Mangelsdorf, the Tzotzil collections made by Breedlove and Laughlin (1993) contain 7 (out of 15) distinct races that are not found as distinct races in the Tzeltal collections made by Berlin, Breedlove, and Raven (1974), and only 1 of these is found in a Tzeltal mixture; the Tzeltal collections contain 4 (out of 11) distinct races that are not found in the Tzotzil collections, with 1 of these found in a Tzotzil mixture. [The biological similarities and differences between Tzeltal and Tzotzil maize are discussed

in terms of morphological, agronomic, and isozyme data in the electronic edition of this issue on the journal's web site.]

The traditional maize landraces that dominate the highlands of Chiapas are managed and conserved by Tzotzil and Tzeltal farmers without any observable external intervention (Gómez S. 1982; Hernández J. 1982). The absence of modern varieties in the Chiapas highlands mirrors the situation in other regions of Mexico (Perales, Brush, and Qualset 2003a). Seed selection and management are largely carried out at the community level, although there is a small but consistent seed flow from outside the community (Perales, Benz, and Brush 2005). This seed flow appears to be serendipitous rather than based on social networks organized for the specific purpose of securing access to seed (Badstue et al. 2006).

Local essays and monographs about maize recognize the importance of grain color. Gómez S. (1982) discusses land preparation, maize as medicine, seed storage, and seed selection among the Tzeltal, indicating that clean, large ears and disease-free seed are obtained during harvest. No other considerations are listed for seed selection. Gómez S. identifies the three maize colors—yellow, purple, and blue—used by Tzeltal to prepare *pozol agrío* as a remedy for illness and indicates that white maize is best planted in canyons while yellow, which is more nutritious and slower-growing, is best

Table 1. Communities Sampled for Maize in Chamula and Oxchuc, Chiapas, 2000

Ethno-linguistic Group and Community	Altitude (m a.s.l.)	Number of Households	Households		Average Maize Planting (ha)
			Sampled for Maize	Maize Samples	
Tzotzil, Chamula					
Los Ranchos	2,400	66	24	65	1.2
Tentik	1,860	168	26	56	0.7
E1 Crucero	2,580	80	26	52	1.5
Pozuelos	2,460	79	36	80	0.8
All			112	253	1.1
Tzeltal, Oxchuc					
Pacbilna	2,180	117	32	78	1.1
E1 Retiro	2,100	72	35	59	1.2
Piedra Escrita	1,860	26	24	45	1.1
Tuxaquilja	2,160	165	32	59	1.9
Rancho del Cura	2,000	137	33	72	1.9
All			156	313	1.5

Note: Number of households in community from INEGI (1996).

planted in terrain that faces east or west. In the terminology outlined above, Gómez S.'s knowledge about maize is made up of named generic and specific ranks, with the latter based primarily on color.

Methods

Four Tzotzil communities in Chamula and five Tzeltal communities in Oxchuc located above 1,800 m a.s.l. were sampled for maize (see fig. 1 and table 1). In each household, we paid for six ears of seed-quality maize of each type sown during the 1999 season. A survey instrument documented maize names, characteristics, origin, and management. In all, 253 samples of maize were obtained from 112 households in Chamula, while in Oxchuc 313 samples came from 156 households. Maize ears were characterized morphometrically, 239 and 260 samples from Chamula and Oxchuc respectively, and internal cob characters were measured on 40 Chamula and 49 Oxchuc samples. We also analyzed isozyme variation in maize populations from an average of 42 plants from each community by examining 28 putative isozyme loci (Stuber et al. 1988). Finally, we carried out common garden experiments to explore the local adaptation of the maize to its municipality of origin. In these experiments, we planted blocks of maize from both municipalities in parcels in four communities, two in Chamula and two in Oxchuc. Grain yield and other agronomic performance indicators were used to judge adaptation. These studies, discussed elsewhere (Perales, Benz, and Brush 2005), provide support for the findings reported here.

To test for the existence of unnamed categories that identify the ethno-linguistic origin of maize in Chamula and Oxchuc, we used photographs of representative maize types from nine communities. The entire collection (566 household accessions of six ears each) was examined to ensure representative sample selection of the most common types from both municipalities. Five ears of a single household sample that we and our Maya field assistant judged to be representative of a particular

farmer variety from each municipality were photographed with a size reference (fig. 2). A scale and a hand were also used to aid informants in judging ear size. The purpose of these measures was explained to informants who asked. Thirty-two samples of maize were represented photographically. Pile-sorts (Borgatti 1999) of photographs were carried out with 20 informants in each of two communities in Chamula and two in Oxchuc in 2001. The pile-sort was explained to participants in their native languages. Randomly chosen individuals were asked to sort the maize photographs in two separate exercises with different criteria. Roughly ten men and ten women (average age 33.8 ± 14.2) in each of the four communities participated.

Numbered photographs were arranged randomly on a table, a flat surface, or the ground. For the first pile-sort each respondent was asked to place all photographs of maize representing the same type in a pile. Two restrictions were imposed on the respondents: they could not place all photographs in one pile, nor could they place each photo in its own pile. The numbers assigned to each photograph were then recorded for each pile of photos created by each respondent. After the first pile-sort was completed and the order of the photographs randomized, individuals were asked to sort photos according to the depicted variety's ability to produce if planted in their community. We chose this question because four-fifths of the Tzotzil and two-thirds of the Tzeltal respondents had previously replied to an open-ended question that they preferred the maize varieties they planted because they "yield well" (*da bién*), and "yielding well" is one indicator of good adaptation. We requested respondents to create only two categories (piles) for the question about a variety's ability to produce on their land: "yield poorly" and "yield well." Photographs that were not placed on either pile were assumed to be between those two in yield, and this was confirmed with each respondent. In general, people responded readily to the pile-sort activity, although individuals responded more

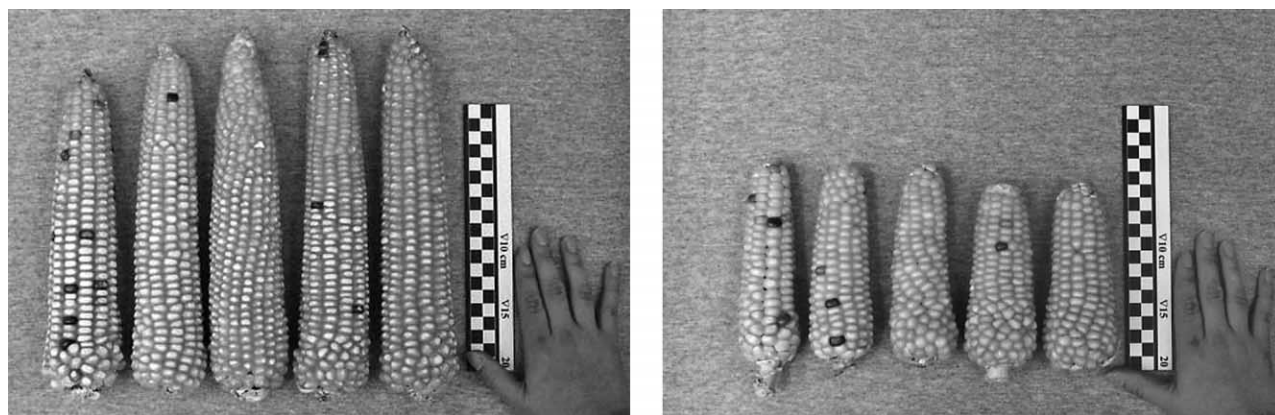


Figure 2. Yellow maize from highland Mayan communities used in interviews. *Left*, Tzeltal varieties; *right*, Tzotzil varieties.

quickly when interviewed alone than when interviewed in group settings.

Analysis with ANTHROPAC (Borgatti 1996a, b) was performed for the entire sample of respondents and according to origin of the respondent and gender. The pile-sort procedure produces results that can be used in consensus analysis and scaling programs. The aggregate proximity matrix made up of pairwise distances between photographs indicates the proportion of respondents that placed those photographs in the same pile. The individual proximity matrix is a collection of respondent proximity matrices, each describing which photographs were sorted into the same pile by that respondent. Metric multidimensional scaling reduces the aggregate matrix of pairwise distances between all sorted items for display in two dimensions. Scaling results were resolved in two to six dimensions to minimize stress in the final solution. The goal is to detect patterns in maize classification by Tzeltal and Tzotzil respondents in these two-dimensional plots. Consensus analysis (Borgatti 1999; Romney, Weller, and Batchelder 1986; Romney 1999) examines the individual proximity matrices to determine whether one underlying factor best explains their variation. It also allows determination of cultural competency, which indicates relative knowledge and provides an “answer key,” a matrix identifying the photographs which belong together on the basis of consensus. The pile-sort proximity matrices were also used to examine whether communities and ethno-linguistic groups classified maize photographs in similar ways. Aggregate proximity matrices for ethno-linguistic groups and communities were compared using the QAP correlation method (Borgatti 1996a, b), and individual proximity matrices and multidimensional scaling coordinates were compared using the multiresponse permutation procedure in Blossom (Cade and Richards 2001). These methods tested the hypothesis that ethno-linguistic groups and communities have culturally spe-

cific but unnamed categories that lead them to sort maize photographs differently.

Results

Ninety-five percent of seed lots planted in the 1999 season originated within the community. A small (ca. 5%) but consistent proportion of introduced seed lots was recorded in all communities (Perales, Benz, and Brush 2005). Tzotzil and Tzeltal people are very similar in their use of maize in terms of cuisine and ritual (see, e.g., Breedlove and Laughlin 1993; Berlin, Breedlove, and Raven 1974). On average, Tzotzil and Tzeltal communities had the same number of landraces/household, 2.3 and 2.0, respectively. White and yellow maize types were the most common, although the Tzotzil had a significantly greater amount of white maize and the Tzeltal more yellow maize (table 2). Blue, red, and pinto types were present in all communities (0.4 and 0.3/household), but red types were more common in Tzotzil (0.2/household) than in Tzeltal (0.05/household) communities. Different colors within a community were of the same race. Maize samples collected in Tzotzil and Tzeltal communities were statistically

Table 2. Color Distribution of Tzotzil and Tzeltal Maize

Characteristic	Mean (s.e.) Reported Proportion of Maize Area		
	Tzotzil, Chamula (4 Villages, 112 Households)	Tzeltal, Oxchuc (5 Villages, 156 Households)	Probability of Difference
White	0.43 (0.06)	0.22 (0.06)	0.0487
Yellow	0.35 (0.09)	0.94 (0.07)	0.0014
Blue-black	0.17 (0.05)	0.20 (0.05)	0.6773
Red	0.05 (0.01)	0.04 (0.02)	0.8937
Pinto	0.10 (0.04)	0.05 (0.03)	0.3061

Table 3. Maize Names Recorded, Listed According to Relative Frequency in Chamula and Oxchuc, 2000

Folk Term	English Gloss	No. of Respondents	% of Respondents	Average Rank ^a	Smith's Varietal Saliency ^b
Tzotzil (Average per household = 2.2)		64			
<i>C'anal Pišim</i>	Yellow	42	66	1.714	0.489
<i>Saquil Pišim</i>	White	40	63	1.225	0.576
<i>Ihc'al Pišim</i>	Black/Blue	25	39	2.320	0.224
<i>Pinto Pišim</i>	Pinto	13	20	2.380	0.111
<i>Tsajal Pišim</i>	Red	8	13	2.750	0.069
<i>Sac'ua Pišim</i>	White	2	3	1.000	0.031
<i>Bic'tal c'anal Pišim</i>	Little Yellow	2	3	2.500	0.020
<i>Tsoj c'anal Pišim</i>	Red Yellow	1	2	1.000	0.016
<i>Pinto ihc'al Pišim</i>	Pinto Blue	1	2	3.000	0.005
<i>Pinto saquil Pišim</i>	Pinto White	1	2	1.000	0.016
<i>Sac c'anal Pišim</i>	White Yellow	1	2	4.000	0.004
<i>Ba'i saquil Pišim</i>	First White	1	2	2.000	0.010
<i>Tsajal saquil Pišim</i>	Red White	1	2	3.000	0.005
<i>Bic'tal c'anal Pišim</i>	Small Yellow	1	2	2.000	0.010
Tzeltal (Average per household = 1.7)		70			
<i>C'anal Pišim</i>	Yellow	63	90	1.175	0.836
<i>Ihc'ua Pišim</i>	Black/Blue	17	24	2.118	0.140
<i>Sac'ua Pišim</i>	White	17	24	1.941	0.140
<i>Tsajal Pišim</i>	Red	3	4	2.667	0.023
<i>Burun</i>	Pinto	3	4	2.333	0.026
<i>C'anal Pišim</i>	Yellow	3	4	2.667	0.017
<i>Comiteco</i>	Yellow	3	4	1.667	0.031
<i>Niwac</i>	Big Yellow	2	3	1.000	0.029
<i>Ihc'al Pišim</i>	Black/Blue	1	1	2.000	0.011
<i>Biquit c'anal Pišim</i>	Small Yellow	1	1	1.000	0.014
<i>C'anal muc' Pišim</i>	Big Yellow	1	1	1.000	0.014
<i>Pinto</i>	Pinto	1	1	1.000	0.014
<i>Saquil Pišim</i>	White	1	1	2.000	0.010
<i>Niwac (2)</i>	Big Yellow	1	1	2.000	0.007
<i>C'anal patil Pišim</i>	Late Yellow	1	1	2.000	0.007
<i>Sac'ua Pišim (2)</i>	White	1	1	2.000	0.010
<i>Ihc'ua neel Pišim</i>	Early Blue	1	1	1.000	0.014
<i>Burun ihc'al sac'ua</i>	Pinto Blue White	1	1	1.000	0.014
<i>Niwac c'anal Pišim</i>	Big Yellow	1	1	1.000	0.014

^aAverage location of that name in all informants' lists.

^bA weighted average of the (inverse) rank of an item across informant freelists in which each list is weighted by the number of items it contains (Borgatti 1996a, b).

different for characteristics that are familiar to farmers and visible in the photographs: ear length and ratio of ear diameter/length.

Maize Classification in Oxchuc and Chamula: First Pile-Sort

Varieties were classified first in terms of color, a pattern that is consistent with other areas in Mexico (table 3; Perales, Brush, and Qualset 2003a; Soleri and Cleveland 2001). Yellow maize had the highest salience among the Tzeltal while the distribution of named varieties was more equitable among the Tzotzil. Ninety percent of the dominant white and yellow types were named only for their color, although some farmers took into account other characteristics such as planting dates or size of ear or grain. Only in one community of the nine did we find farmers who had two types of yellow maize based on long and short cycles. In all other cases, when farmers had

two or more types of maize they were different colors. There were more names for yellow landraces in the Tzeltal communities and more names for white types in Tzotzil communities, where they were more prominent. While color is the leading characteristic in our informants' maize classification, we found a very weak or nonexistent association between color and other morphological and agronomic characteristics.

Pile-sorting photographs based on similarity of maize produced a consistent pattern across groups (figs. 3 and 4) and gender (not shown), indicating that Tzeltal and Tzotzil classify maize by color. Independent of origin, maize photographs of one color had higher similarity indices than those of several colors, indicated by their clustering in the multidimensional scaling plots. Permutation (QAP) tests of aggregate proximity matrices comparing all four communities individually and each ethno-linguistic group collectively indicated a high correlation ($r \geq 0.93; p < 0.001$) among communities and ethno-

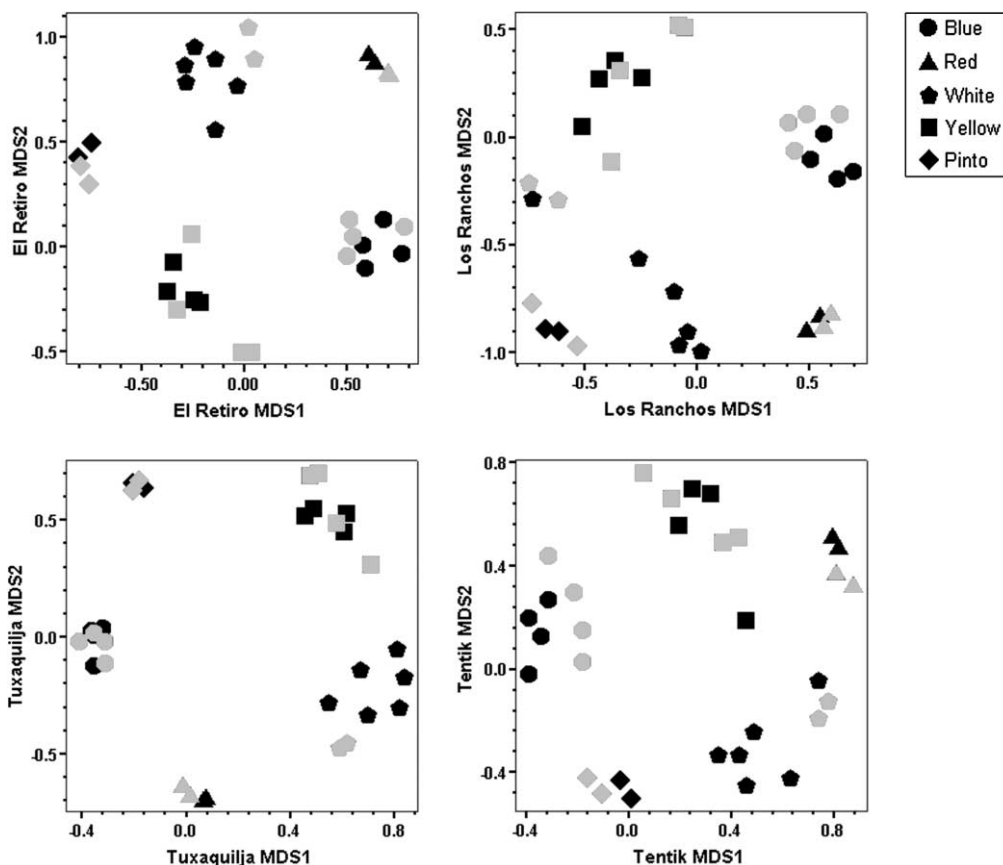


Figure 3. Multidimensional scaling plot of first pile-sort matrices showing respondent consensus in sorting photographs on the basis of color of the grain. *Black*, collections from Tzeltal-speaking communities; *gray*, collections from Tzotzil-speaking communities. El Retiro (*upper left*) and Tuxaquilja (*lower left*) are Tzeltal-speaking communities, Los Ranchos (*upper right*) and Tentik (*lower right*) Tzotzil-speaking communities.

linguistic groups in classification of maize variety photos according to color (table 4).

Consensus analysis for the first pile-sort indicated that knowledge was equally variable across both groups and genders (average respondent cultural competency 0.9 ± 0.05 ; the eigenvalue of the first dimension explained $> 93\%$ of variation). Cultural competency scores showed no significant difference between ethno-linguistic groups, between communities within ethno-linguistic groups, or between males and females within communities. Some respondents showed competency scores as high as 96%, and only two had less than 85% “knowledge.”

Culturally Specific Categories: Second Pile-Sort

The second pile-sort asked informants to sort photos into groups according to the depicted variety’s ability to produce if planted in their community. At first glance there appears

to be no obvious order in this sorting (fig. 5), but closer scrutiny indicates that the Tzotzil respondents separated varieties from their own communities from those of Tzeltal origin (fig. 6; see also table 4, $r = 0.45$; $p < 0.00$; $\delta = -1.45$; $p < 0.08$ over two dimensions). In figure 6, Tzotzil varieties occur to the left and Tzeltal varieties to the right. Recognition of the ethno-linguistic origin of landraces is also suggested by a slightly closer position within a color type (figs. 3, 4, and 6), and permutation tests sensitive to slight differences in group assignment (table 4) indicated that informants from communities in both ethno-linguistic groups discriminated even while relying on color as a selection criterion. The one place where maize types were sorted according to ethno-linguistic groups was the Tzotzil community of Los Ranchos, where respondents (fig. 7) consistently separated Tzotzil and Tzeltal landraces. This was corroborated by permutation tests (table 4).

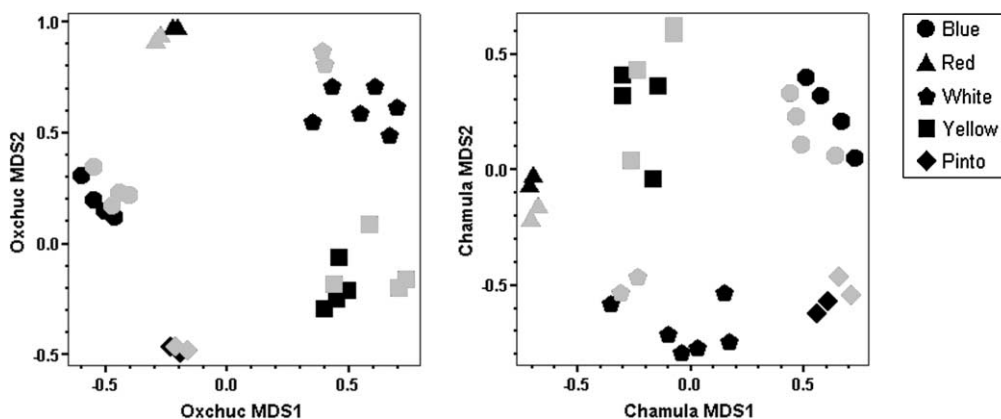


Figure 4. Multidimensional scaling plot of first pile-sort matrices of two communities combined from each ethnolinguistic group. *Black*, collections from Tzeltal-speaking communities; *gray*, collections from Tzotzil-speaking communities. *Left*, Tzeltal; *right*, Tzotzil.

Interethnic comparisons based on aggregate proximity matrices indicated that the two groups made similar distinctions about which depicted varieties could be productive on their lands. Three of four interethnic group comparisons of communities suggested that Tzeltal and Tzotzil identified the same photographs as productive varieties (table 4). In both ethnolinguistic groups, color of maize was apparently not a criterion used to classify landraces that potentially yield well in their respective environments. Permutation tests comparing individual proximity matrices suggested that ethno-linguistic groups made subtle yet significant distinctions, with half of the interethnic-group community comparisons showing statistically significant differences. Consensus analysis demonstrated widely shared opinions regarding which maize might be productively planted in their own fields (the first eigenvalue explained 85% of the total variation), yet respondent com-

petency varied widely (0.66 ± 0.12). No differences in cultural competency were observed between ethno-linguistic groups (competency scores of Tzeltal and Tzotzil together, K-S $Z = 0.83, p < 0.5$).

Discussion

Morphological and agronomic differences distinguish the maize planted by Tzotzil farmers of Chamula and Tzeltal farmers of Oxchuc, although all respondents classified maize types by color, irrespective of morphological differences between Tzotzil and Tzeltal varieties. Few respondents sorted maize solely according to morphological type or included more than one color in groups that maize biologists would recognize. However, our analysis of morphological, isozyme, and agronomic characteristics suggest that color is not a sig-

Table 4. Quadratic Assignment (r) (Borgatti 1996a, b) and Multiple Response Permutation (δ) Tests (Cade and Richards 2001) of Pile-Sort Aggregate Proximity and Individual Proximity Matrices Respectively Derived from Four Mayan Communities' Sorts of Maize Photos

Comparison	First Sort		Second Sort		First Sort		Second Sort	
	r	p	r	p	δ	p	δ	p
Within ethno-linguistic group								
El Retiro ^a vs. Tuxaquilja ^a	0.94	0.00	0.50	0.00	-0.49	0.60	-0.60	0.22
Los Ranchos ^b vs. Tentik ^b	0.95	0.00	0.37	0.00	-2.33	0.04	-5.56	0.00
Between ethno-linguistic groups								
Chamula ^b vs. Oxchuc ^a	0.96	0.00	0.45	0.00	-6.68	0.00	-1.45	0.08
Los Ranchos ^b vs. Tuxaquilja ^a	0.94	0.00	0.27	0.00	-1.93	0.05	-1.09	0.14
Tentik ^b vs. Tuxaquilja ^a	0.93	0.00	0.43	0.00	-6.88	0.00	-1.68	0.06
El Retiro ^a vs. Los Ranchos ^b	0.94	0.00	0.12	0.17	-0.51	0.23	-1.95	0.04
El Retiro ^a vs. Tentik ^b	0.94	0.00	0.42	0.01	-4.83	0.00	-4.46	0.00

^aTzeltal.

^bTzotzil.

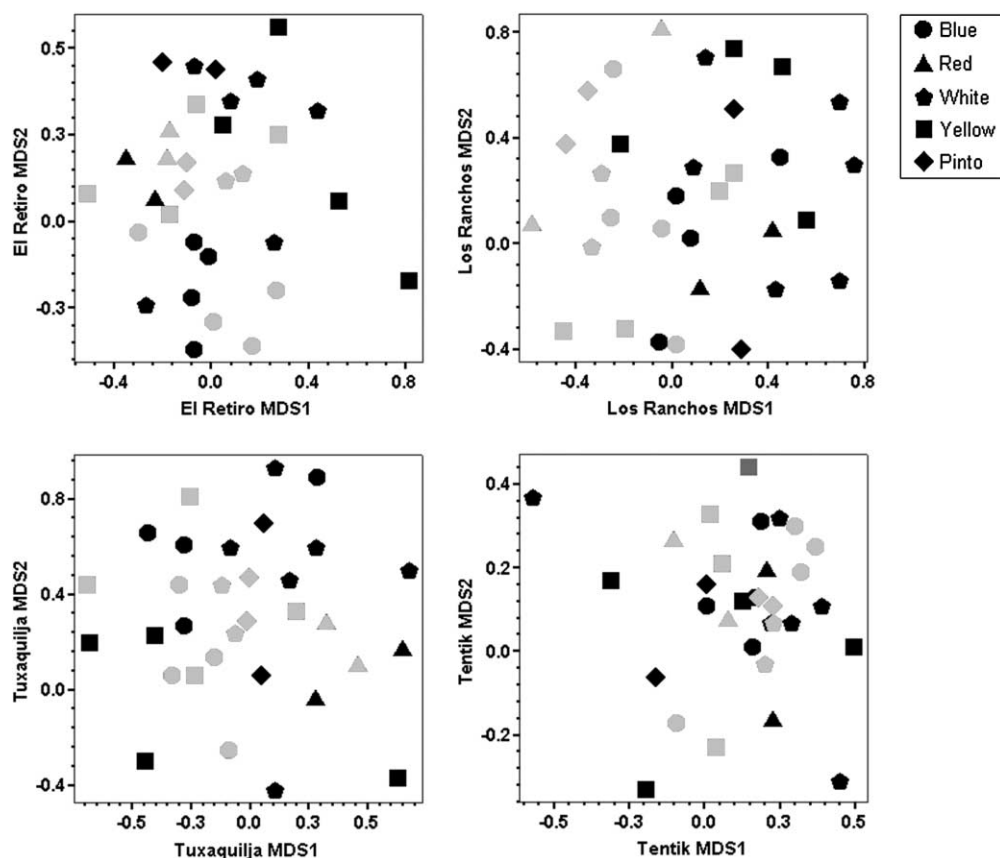


Figure 5. Multidimensional scaling plot of second pile-sort matrices, showing that grain color is not a criterion on which respondents rely to identify productive collections. *Black*, collections from Tzeltal-speaking communities; *gray*, collections from Tzotzil-speaking communities. El Retiro (*upper left*) and Tuxaquilja (*lower left*) are Tzeltal-speaking communities, Los Ranchos (*upper right*) and Tentik (*lower right*) Tzotzil-speaking communities.

nificant trait for distinguishing among different maize races, a finding that has been corroborated by other researchers (Sánchez G., Goodman, and Rawlings 1993). The fact that color is not a helpful referent in determining the geographic origin of maize may explain in part why many respondents had difficulty in identifying maize adapted to their community's environment. Although the race that dominates Oxchuc has a noticeably longer and more slender ear than the one that dominates Chamula, differences in the gross morphology of the ear were not used consistently by Tzotzil and Tzeltal informants to distinguish their local maize.

Nevertheless, when the results of the second pile-sort are aggregated by ethno-linguistic group (fig. 6), we see that the Tzotzil identify their maize as opposed to that of the Tzeltal, and this ability is especially strong in one community, Los Ranchos. These results suggest that an unnamed but culturally specific category is recognized by Tzotzil informants that dis-

tinguishes Tzotzil maize. The Tzotzil may distinguish their maize because it consistently produces smaller ears. The Tzeltal, in contrast, may not consistently distinguish their maize from that of the Tzotzil because the race that dominates Oxchuc is more variable than the maize of Chamula.

The fact that these farmers rarely plant more than one variety of the same color (tables 1 and 3) could point to a low discriminating power of color when dealing with more than one variety within a single color. This is not to say that farmers do not recognize variation within a color class; rather, such variation is less significant. Most of the families interviewed have used seed inherited from their parents for their entire productive lives (Perales, Benz, and Brush 2005), and strong adherence to local seed may limit familiarity with non-local seed.

The salience of color variation among the Tzeltal and Tzotzil mirrors that found among Aguaruna manioc culti-

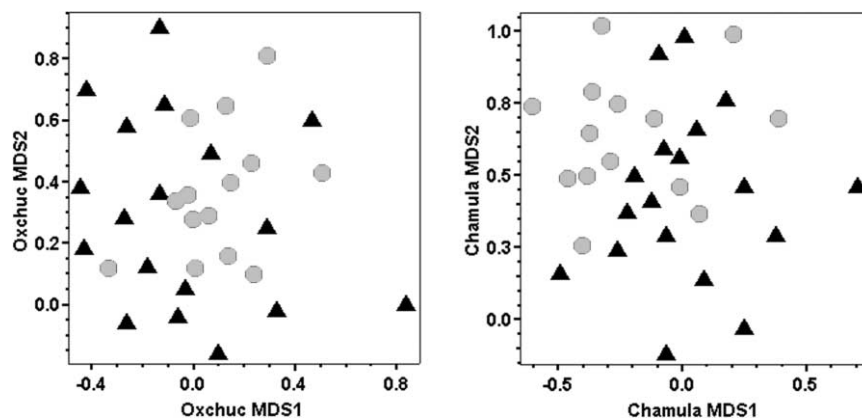


Figure 6. Multidimensional scaling plot of second pile-sort matrices of two communities combined from each ethnolinguistic group, suggesting cultural differences in ability to distinguish maize from their own community. *Left*, Tzeltal (triangles); *right*, Tzotzil (circles).

vators (Boster 1985). While there is no apparent difference in yield or agronomic performance between maize of different colors, the local taxonomy of maize is nevertheless based on color. Reflection on the genetic basis of kernel color may identify its underlying importance. Grain color in maize is multifactorial and results from the combined action of at least four gene loci (*C1*, *Pr1*, *R1*, and *Y1*). Both white and yellow kernel color result from the homozygous condition at three of four loci. Repeated self-pollination would produce the distinctive phenotypes of homozygous genotypes. Thus, the distinctive color phenotypes probably result as much from inbreeding as from farmer selection. The results of isozyme analyses indicate that there is a paucity of heterozygotes, and F_{is} values suggest that this may be due to nonrandom mating within these populations. The distinctive kernel phenotypes could be propagated relatively easily by planting the seeds of a single uniformly colored ear in an isolated plot and selecting for ears that show uniform phenotype during the harvest. Maize management and selection practices explain such high levels of inbreeding and the resulting color focus.

Conclusions

The phenotypic diversity of maize found here and elsewhere is a result of farmer management (Hernández X. 1985; Presoir and Berthaud 2004). While maize biology has greatly advanced our understanding of the role of natural selection in the distribution of maize diversity in Mexico and human ecologists have described individual farmer selection and management, little research has been done to link cultural diversity and maize diversity in Mexico.

An important research step is to probe the knowledge base that influences the collective process of maize evolution. Understanding consensus among farmers about identifying dif-

ferent maize types, as well as the distribution of this knowledge, allows us to estimate whether the diversity associated with ethno-linguistic differences is a product of “conscious” or “unconscious” selection (Darwin 1896 [1868]). This research shows that there are two maize populations in highland Chiapas that correspond to ethno-linguistic divisions. Working in tandem, inbreeding, selection for color, and preference for local seed would tend to push Tzeltal and Tzotzil maize populations apart, but the named categories that can be elicited from Chiapas farmers do not distinguish morphological and agronomic characteristics that separate the maize populations of Chamula and Oxchuc. Nevertheless, the presence of unnamed categories that separate these maize populations can be demonstrated in one of the two ethno-linguistic groups

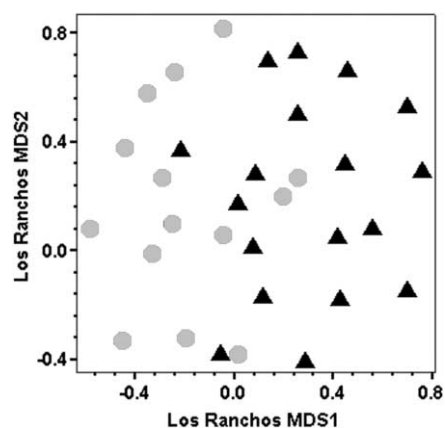


Figure 7. Multidimensional scaling plot of second pile-sort matrix of 20 informants from the Tzotzil community of Los Ranchos. Symbols as in figure 6.

and specifically in one study site. Our inability to identify the same phenomenon in the other ethno-linguistic group may be a product of the greater variability of their maize or the ephemeral nature of unnamed categories.

Ethno-linguistic diversity may produce bottlenecks by limiting the flow and natural competition of maize populations within what is otherwise a single maize environment. Repeated and prolonged genetic bottlenecks typify maize domestication (Wright et al. 2005 and references therein). That similar bottlenecks arise among traditional agriculturalists is not surprising. One result of the process is perhaps unanticipated: perceptual distinctiveness. Phenotypic variants result from repeated generations of inbreeding as homozygotes become more common. The genes responsible for color variation in plants become subject to selection as humans manipulate growing conditions and save seeds of peculiar variants from year to year. Therefore we should not be surprised that color variation is the most common referent used to describe cultivated plant varieties (Berlin 1992) or that color variation is not an adaptive characteristic but a by-product of cultivated plant management.

This research suggests that unconscious selection structured by social factors is a key element of maize diversity in our study region. Farmer maintenance of separate populations according to ethno-linguistic group is not conscious, although we can detect recognition of its maize by one group. A consequence of unconscious selection is the repetition of genetic bottlenecks that further distinguish local populations. The mechanisms of unconscious selection linked to ethno-linguistic identity may be explained by such factors as the relatively high cost of information from outside a language group or a community of neighbors and kinsmen whose experience is part of everyday observation. In this small-scale, subsistence farming, the struggle for self-sufficiency is often problematic, and precious economic resources are spent on purchasing grain. As a consequence, the judgment whether to plant a variety is critically important. Because farmers may change seed periodically or supplement existing stocks with new seed, it is essential that they trust the information about the variety that they obtain from another source. The importance of social learning in individual decision making (McElreath 2004) predicts that ethno-linguistic differentiation should thus contribute to evolving maize diversity.

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