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Working Paper 99-09

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Summary and Implications for Further Work

Descriptive data from the sample survey of households in the study communities enable us to profile the characteristics of: (1) farm households; (2) the maize populations they grow, based on their own descriptors and the perceptions of both men (production decision-makers) and women (consumption decision-makers);[1] and (3) farmers' seed selection and management practices.

Farm households

- Households average between 4 and 6 members, and the mean age for production decision-makers is about 50 years. All production and consumption decision-makers are Spanish-speaking. Indigenous languages are used more in Mazaltepec and Santa Ana.
- By some indicators of wealth (television, refrigerator, electricity, gas stoves), from a global perspective, survey households are not poor.
- Huitzo depends more on local nonfarm income than other survey sites; Huitzo and Valdeflores depend less on local agricultural production; Huitzo and Mazaltepec depend less on remittances. In San Lorenzo, Santa Ana, Valdeflores, and Amatengo, at least one-fourth of households reported that remittances are an important source of income.
- All sites except Huitzo reported average per capita maize requirements higher than the national mean. The average farm household in the survey communities is a net seller in some years and a net consumer in others. The market for maize appears to be local.
- The average farm size in 1996 was 3.5 ha with 3 ha of maize. The mean number of soil types per farm, as well as the extent of land fragmentation, was lower in Huitzo and Amatengo. Fragmentation seems to be highest in Santa Ana and Valdeflores. Tenure arrangements contrast sharply between communities.

Maize populations

- Maize populations grown by farm households have been classified based on farmer taxonomy into 5 classes of Blanco (white-grained) maize, 3 classes of Amarillo (yellow-grained) maize, 1 Negro (black or purple-grained) maize, 1 Belatove (pinkish-grained) maize, 1 Pinto (grain of mixed color), 1 Mejorado (improved) class and a Tepecentle variety. Tepecentle is a distinct maize race, and all other classes are found within the Bolita racial complex.
- Blanco types occupy over 80% of the area and representing two-thirds of the seed lots planted in 1997. Improved maize was grown almost exclusively in Huitzo, which has the most irrigated land. Even in Huitzo, it occupied only 7% of the area in the survey year.
- Subjective yield distributions suggest that: (1) improved maize dominates local types; (2) Blanco types dominate colored-grain types; and (3) consumption partners (women) are significantly more pessimistic than production partners (men). The yield distributions of Santa Ana are significantly different from those of Huitzo, Mazaltepec, and Amatengo.
- Farmers in the survey communities grow maize primarily for food or feed rather than grain sales, and they are interested in many characteristics in addition to yield. While they rate improved maize well in terms of grain yield and fodder, they rank it as a poor supplier relative to local varieties. Among the local varieties, Blanco types were rated superior to colored-grain types with respect to grain yield per hectare, suitability for sale and most consumption characteristics. Amarillo was highly rated for *tlayudas*, feed, and fodder, and Negro and Belatove have shorter growing seasons.

[1] See Methods section for definition of terms.

- Although men and women rank the importance of characteristics differently, four of the top five characteristics are the same for both sexes: (1) drought tolerance; (2) resistance to insects in storage; (3) produces "something" even in bad years; and (4) grain weight. Men added grain yield per hectare and women added the taste of *tortillas* to the set of most important characteristics.

Seed management

- Farmers know their varieties—they have grown them for an average of over 20 years. The concept of "own seed" is ambiguous, however, since a large proportion of farmers also combine and replace seed lots (see definition of terms in Methods section). The highest propensity to give, exchange, combine, or replace seed was found in Santa Ana, although these practices were also observed in San Lorenzo and Amatengo. Exchange is primarily local.
- As has been found elsewhere in Mexico, the seed selection criteria used by farmers are those related to grain and ear health, grain size, grain filling, and ear size. Less than half of survey farmers reported that they separated food or feed grain from seed at harvest time. The most frequent form of selection is the continual separation of good ears from those removed every few days for preparation of *nixtamal*. Perceptions differ between men and women regarding responsibilities for seed management and selection, but women's role is likely to be substantial in this separation activity.
- There is evidence that farmers are exerting strong indirect selection pressure for resistance to insect damage in storage, but no direct pressure on husk cover. Husk cover is important as a "first-line defense."

Maize diversity

- Farm-level diversity appears to be greatest in Santa Ana and San Lorenzo and least in Amatengo and Valdeflores, as measured by numbers of varieties per farm and by a Simpson index based on area shares.
- Community-level diversity bears no direct relationship to farm-level diversity because of differences in the scale of measurement. Diversity remains high at the community level in San Lorenzo and is relatively low in Santa Ana.
- There is no strong evidence that farmers in these communities recognize a loss of maize populations during the past two decades.

Implications for further work

Some implications for further work can be drawn from the descriptive data. The multivariate analyses that follow this baseline summary should provide additional insights.

- Given that markets are local, most households both consume and sell maize, and that a small proportion of the maize they produce passes through the market, enhancing characteristics based on current market valuation is not likely to affect farmer welfare appreciably. *A formal hedonic study is probably not warranted.*
- Like studies elsewhere in Mexico (Perales et al. 1998), this study confirms that in maize production farmers are not motivated strictly by yield per hectare or profitability but by a number of concerns. In the Central Valleys of Oaxaca, these include consumption-related characteristics. This does not imply that grain yield per hectare does not matter, but that (1) "yield" has many components on-farm (grain weight; post-harvest production; the lower tail of the yield distribution; drought tolerance), and (2) farmer welfare can be improved by

enhancing other characteristics. The large yield gap between farmers' expected yields and potential yields further suggests that addressing agronomic or other constraints may be more effective in improving on-farm yields than breeding. *Other characteristics may be easier to improve than grain yield per hectare under farmers' conditions through participatory breeding techniques, and they may also contribute to farmer welfare. Appropriate interventions may include development of and training in techniques designed to improve storability or agronomic practices.*

- Farmers rate their own varieties fairly low with respect to several of the agronomic characteristics they identify as most important, suggesting that their seed selection practices are not as effective as they would want them to be for these traits. They rate them high for consumption characteristics, suggesting that their selection practices for these traits are adequate to meet their needs. In other words, *the tools of professional breeders and farmer-breeders may be complementary*.

- While there are differences between men and women in the relative importance of certain maize characteristics, they agree on those that are most important. *There are no obvious gender implications associated with addressing any one the major characteristics identified by survey farmers through breeding or or other strategies.*

- There may be a means through simple management methods to increase farmers' selection pressures for resistance to insects in storage, including emphasis on husk cover. *The effects of direct selection, for husk cover need to be tested more fully.*

- There are likely to be strong gender implications related to the strategies designed to enhance seed selection and management practices. *Women who make decisions regarding seed management, selection, and storage must participate actively in any experiments or tests.*

- The propensity to exchange, combine, and replace seed lots for the same variety has implications for intra-varietal genetic diversity and for the genetic gains that can be achieved through improved methods of mass selection, which depend on retaining seed from the harvest over successive seasons. *Additional, focused research is required to understand farmers' seed management practices and their effects on genetic diversity.*

- Farmers are most likely to continue growing the Blanco types because these maize varieties supply more of the characteristics they demand than other local classes of maize. This implies that encouraging farmers to maintain the Blanco types would cost less in terms of additional economic incentives. There appears to be more than a difference in grain color between Blanco and the other local classes of maize, however. Grain color may "mark" other traits that are significant for maintaining diversity in the region. *More genetic work is necessary to identify populations within and among the classes identified by farmers that are key from a genetic diversity standpoint as well as a crop improvement perspective.*

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Introduction

The varietal and genetic diversity maintained by maize farmers in the Central Valleys of the state of Oaxaca reflects the way they have managed their landraces for thousands of years. Some of the economic and environmental changes now faced by these farmers, however, may make growing landraces and managing them as they have in the past less attractive. Because farmers have their own immediate concerns, the maize populations they choose to grow are not necessarily those considered most desirable for the conservation of genetic diversity.

The major underlying assumption in the project initiated by Mexico's Instituto Nacional de Investigaciones Forestales y Agropecuarias (INIFAP) and CIMMYT and funded by Canada's International Development Research Centre (IDRC) is that the maintenance of key maize landrace populations and the management practices that shape them are crucial for conserving maize diversity. Maize diversity serves farmers and consumers because it provides the basis for farmer improvement of varieties as well as improvement by professional plant breeding programs, both today and in the future.

On-farm conservation poses serious challenges unless the productivity or quality of the maize produced can be improved without eroding genetic diversity. The goal of this pilot study is to determine whether it is possible to identify collaborative plant breeding strategies that improve maize productivity while maintaining or enhancing genetic diversity. By "collaboration" we refer to a range of activities with differing levels of involvement by farmers and professional plant breeders. We define maize productivity broadly in terms of yield, stability, or other characteristics of interest to farmers. If maize diversity as well as productivity can be enhanced, both the individual welfare of farmers and social welfare will increase. This central idea is summarized using micro-economic concepts in Figure 1, and the conceptual basis of the project is explored more fully in Bellon and Smale (1998).

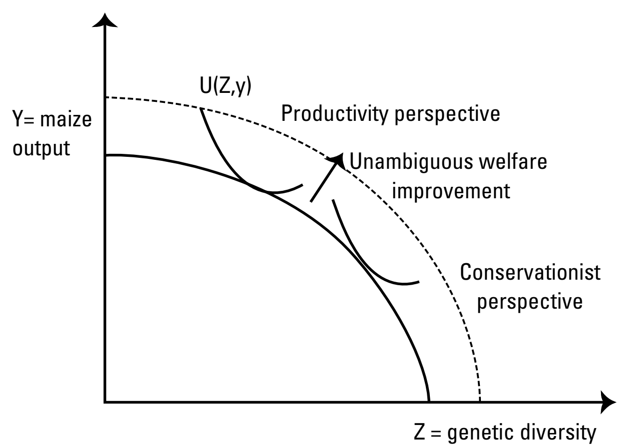


Figure 1. Social utility and aggregate production transformation curve for maize outputs and diversity.
Note: Maize output may represent a bundle of attributes rather than grain yield per hectare. Product transformation curve is for a fixed area allocated among varieties by farmers in a reference region.

To implement the project we need to: (1) identify the crop populations that should be conserved; (2) identify the types of farmers that are more likely to conserve them; (3) identify the participatory plant breeding (PPB) strategy to improve the crop populations. Addressing the first issue involves identifying the crop populations and characteristics with the most potential for genetic gains, the greatest importance to farmers, and which contribute the most to genetic diversity.

In the initial phase of the project we have conducted research that addresses the first two questions. Research consisted of four activities. The first, led by the INIFAP and CIMMYT maize breeders, included the collection, evaluation, and characterization of maize populations from 15 communities in the Central Valleys of Oaxaca. Farmers' preferences concerning these populations were elicited and related to key socioeconomic characteristics of the farmers (Bellon et al. 1998). The second effort, led by INIFAP and CIMMYT social scientists, involved a stratified random sample survey of maize-growing households in 6 of the 15 communities. The third, also implemented by the social scientists, was a detailed monitoring survey of the seed stock management practices of 24 households in the 6 communities (Mendoza, forthcoming). The fourth effort is a series of focus group discussions with male and female farmers in the six communities. The purpose of these discussions is to elicit the "rules of thumb" they use in variety choice and planting decisions, as well as their knowledge and perceptions of their own capacity to modify maize populations through management practices such as seed selection.

This report presents the descriptive data from the sample survey of households in the study communities. The data enable us to profile the characteristics of (1) farm households; (2) the maize populations they grow, based on their own descriptors and the perceptions of both farm men and farmer women; and (3) their seed selection and management practices. We employ the morpho-phenological characteristics farmers use to classify their varieties to construct Simpson indices of maize diversity at the farm and community level. These indices will be supplemented later by genetic data based on seed samples drawn from the maize populations of a smaller number of farmers. Since little maize is sold by survey households, hedonic pricing methods provide limited information regarding the economic valuation of traits. As proxies for the demand and supply of characteristics, we use farmers' assessments of the importance of characteristics and the extent to which their maize populations provide them. Combined with the results of the other research efforts of the initial phase, these data provide a statistical baseline for the project.

Methods

Site Selection

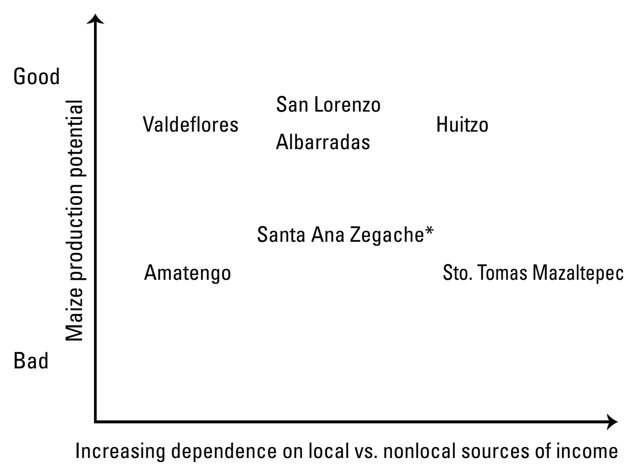
The region known as the Central Valleys of Oaxaca was chosen for this pilot project because of: (1) the importance of the major maize race grown in the region (the "Bolita complex"; (2) the negligible impact of modern varieties in the zone; (3) the ethnic diversity and agroecological heterogeneity in the zone; and (4), despite the economic importance of labor migration to the local economy, the recognizable emphasis placed by these communities on certain cultural traditions, including culinary practices for maize. Although the Bolita complex has served as the basis of several maize breeding programs in other parts of the country (Ortega-Pazcka 1995), its collection and study in this region has not been extensive.

In 1997-98, maize breeders on the project collected, evaluated, and characterized 170 samples of maize landraces in 15 communities of the Central Valleys of Oaxaca. All of the communities where they collected are located between 1,310 and 1,839 masl. The principal criteria in site selection were the variation in maize populations and the range of uses by farm families, known from past work in the region.

In order to select fewer communities among the sites for more detailed socioeconomic study and diagnostic work, data from INEGI (Instituto Nacional de Estadística, Geografía, e Informática, 1996) were consulted and local authorities were interviewed regarding the general socioeconomic features of each community. Local authorities provided their own estimates of the number of households, major sources of income in the community, supply of infrastructure and transportation, and types of markets. Little variation was apparent in distance to markets or basic physical infrastructure. More pronounced differences were apparent in the extent of reliance on nonfarm income and income from migrants. This information was combined with data on ethnicity (INEGI) and on maize yield potential derived from previous work by INIFAP. Six communities representing contrasts in these variables were selected from the 15, as shown in Figure 2. The horizontal axis represents decreasing dependence on nonlocal sources of income as compared to local agricultural or nonfarm income, including remittances from within and outside Mexico. The vertical axis represents location in zones of increasing maize yield potential.

Selection of Households

A stratified random sample of 240 farm households was drawn with a list frame. A subsample size of 40 was considered the minimum necessary for analysis within each community, or stratum. Lists were revised with the assistance of community authorities, excluding producers no longer cultivating, or respondents too old, handicapped, or sick to participate in interviews. Missing or excluded households were replaced in a few cases by sampling from the remaining list of active producers. The sampling fraction varies by community (from 9% to 27%) and statistics that are aggregated across strata are weighted by the inverse probability of selection (Table 1).



* >30 % indigenous population.

Figure 2. Conceptual representation of survey sites by source of income, ethicity, and maize yield potential.
Sources: INEGI, INIFAP, CIMMYT/INIFAP comunity diagnostic survey.

Table 1. Farm household sample, Central Valleys of Oaxaca, 1998

Community	Effective number of farm households	Sampling fraction	Weight
Huitzo	326	0.123	0.1665815
Mazalatepec	253	0.158	0.1292795
San Lorenzo	447	0.0895	0.2284108
Amatengo	146	0.274	0.0746085
Valdeflores	320	0.125	0.1635155
Santa Ana	465	0.086	0.2376085

Survey Content

In each household, a questionnaire was administered to both the individual who takes primary responsibility for maize production decision-making (PDM) and the household member who assumes primary responsibility for making decisions related to maize consumption (CDM). (Definitions are provided at the end of this section, and the questionnaire in Spanish is available from the authors.) In almost all cases, the PDM and CDM are husband and wife. The PDM questionnaire consists of 8 parts, covering general household characteristics, taxonomy of maize types grown in 1997, seed sources, production details by maize plot, seed selection and storage, importance of maize characteristics and rating of varieties, and perceptions of losses in maize varieties. Of these topics, the CDM questionnaire excludes plot details.

Survey Implementation

The survey was conducted in April-June of 1998, including training and call-backs. A brief pre-test of the questionnaire was conducted by supervisors. Enumerators were trained for 3 days including a field test in Santa María Coyotepec.

Production and consumption decision-makers were interviewed separately by teams of one male and one female maize technician. The survey was implemented with the endorsement of community authorities, who intervened when respondents needed clarification regarding the purpose of the interviews. Enumerators were supported by three supervisors and conducted an average of 2 household interviews (4 questionnaires) per day.

While reviewing the data in June, supervisors noted some confusion over the concepts in the section on seed sources. Few enumerators had used the cards designed to assist them in eliciting the importance of maize characteristics from farmers. During that month, teams revisited households and repeated the sections about seed sources and variety characteristics. Additional details on seed storage were also collected at that time.

Written questionnaires were edited manually by supervisors and by computer, using a program written to test ranges and consistency using SPSS. Supervisors developed classification systems for maize populations and soil types based on farmers' perceptions. Data coding and entry were completed in July. Key definitions are reported below.

Key Definitions

Production decision-maker (PDM). The household member who claims primary (but not exclusive) responsibility for decisions regarding maize production, such as the area planted, crops grown, and plot management. In survey households, the production decision-maker is typically but not always male.

Consumption decision-maker (CDM). The household member who claims primary (but not exclusive) responsibility for decisions within the home, including processing of the maize harvest for consumption. The CDM is typically but not always the wife of the production decision-maker.

Maize types or classes. The classification used in this study is based on the criteria farmers use to differentiate between their varieties: ear size, color, form and grain type, cob type, number of rows, and length of growing period. Farmers differentiated 13 types of maize: (1) Blanco (white); (2) Blanco delgado (white maize with narrow grain); (3) Blanco ancho (white maize with wide grain); (4) Blanco violento (early-maturing white maize); (5) Blanco tardío (late-maturing white maize); (5) Amarillo (yellow maize); (7) Amarillo delgado (yellow maize with narrow grain); (8) Amarillo ancho (yellow maize with wide grain; (9) Negro (black or purple maize); (10) Belatove (pinkish) (11) Pinto (mixed color); (12) Mejorado (improved); (13) Tepecentle (a different race from 1 through 12, which belong to the Bolita complex).

Soil types. The classification used in this study is based on the criteria farmers use to differentiate soils, including: moisture, nutrient content, color, depth, and texture. Eight soil types were identified among those described by farmers.

Seed flows refer to seed procurement or the strategies farmers use to save, combine, or replace the physical unit of seed they will use to produce the varieties grown in the next season. An *exchange (intercambio)* refers to the transfer of seed to another farmer in return for seed. A *partial change (cambio parcial)* refers to the combining of seed saved by the farmer from the previous harvest with seed obtained from another farmer, of the same or another variety. A *total change (cambio total)* refers to the replacement of the seed lot of a variety with (a) a new seed lot of the same variety or (b) with a new variety. Case (a) occurs when seed stocks are exhausted due to a poor harvest or when a farmer wants to "renew" the seed by substituting it entirely with seed of the same variety grown by another farmer. Case (b) occurs with "adoption" of either a traditional or improved variety.

A *seed lot* is the physical unit of seed used to reproduce a variety (Louette 1994).

Farm, Farmer, and Household Characteristics

Education, Language, and Experience

Few statistical differences are observable for household characteristics between survey communities. The average size of household is 4 to 6 persons across survey communities. Production decision-makers tend to be 50 years or older, having been responsible for maize farming decisions for a mean of 28 years (Table 2). Production decision-makers have more formal education in Huitzo and less in Mazaltepec, with an overall average of 3 years in school. Consumption decision-makers have the same overall age, but both decision-makers in Huitzo and Mazaltepec have more education than in the other survey communities. In Mazaltepec, consumption decision-makers have clearly spent more years in school than production decision-makers, while differences are less evident in other sites.

In all survey sites, both production and consumption decision-makers describe themselves unanimously as Spanish-speaking. In Mazaltepec and Santa Ana, a minority spoke Spanish with their parents, and fewer speak Spanish with their children than in other survey communities. These results are consistent with those reported by INEGI (Figure 2) except in the case of San Lorenzo.

Table 2. Household characteristics by survey community, Central Valleys of Oaxaca

	Huitzo	Mazaltepec	San Lorenzo	Santa Ana	Valdeflores	Amatengo	All
			—mean—				
Household size	4.85	4.85	5.15	6.07	5.13	4.82	5.25
Production decision-maker							
Age	51.9	48.5	57.3	55.6	54.7	57.5	54.4
Years as operator	24.7	22.0	27.6	33.6	29.3	30.3	28.3
Years education	5.18 *	1.95 +	2.70	2.20	3.18	2.60	3.36
			—percent—				
Spanish-speaking	100	100	100	100	100	100	100
With parents	95	10	100	5	100	100	65
With children	98	24	100	13	100	100	70
Consumption decision-maker			—mean—				
Age	46.03	39.73	53.13	49.68	50.83	49.43	48.74
Years education	5.85 *	4.92 *	2.50	1.48	2.30	1.97	3.06
			—percent—				
Spanish-speaking	100	100	100	100	100	100	100
With parents	95	18	100	36	100	100	74
With children	95	55	100	89	100	100	91
Services			—percent—				
Electricity	98	100	93	98	95	100	97
Gas stove *	98	45	48	23	68	20	51
Television *	95	75	65	68	88	53	75
Refrigerator *	85	28	15	25	40	15	35
Car or truck	23	10	13	5	13	10	12

Source: CIMMYT/INIFAP 1997 survey, 240 total households with 40 households by community.
Note: Estimates in “All” category are weighted by inverse probability of selection.
* Significantly higher mean (different percents) with one-tailed t-test (chi-squared test), .05 significance level.
+ Mean significantly lower using one-tailed t-test, .05 significance level.

Sources of Income

By some indicators of wealth, based on a global scale, typical farm households in the survey communities would not appear to be poor (Table 2). Almost all are served by electricity, and while those in Huitzo and Valdeflores are more likely to have televisions, gas stoves, and refrigerators, a large proportion of farmers have them in each community. Over all communities, only 12% have cars or trucks.

Huitzo, where both production and consumption decision-makers are more educated, has the lowest reported maize requirements per household and per capita of the survey communities (Table 3). In Huitzo, as compared to other sites, households are more likely to depend on local nonfarm employment and less likely to identify remittances and agricultural production as their most important source of income. Households in Mazaltepec, which is located in a poorer production zone than Huitzo, report significantly higher annual maize needs and depend more heavily on their own farm production or labor on nearby farms. They are also less likely to rely on remittances as a major source of income and to report nonfarm earnings as important.

For all of Mexico (including Mexico City), averaged over 1994-96, estimated per capita consumption of maize by the human and livestock population was 235 kg/yr (Calvo et al. 1998). Rural households would be expected to consume more maize for food and feed than urban households, both because of the composition of their diet and other social obligations. Stated consumption needs may also be higher than actual, since when reporting their requirements, household members may have overstated their needs or inadvertently included some production destined for sale rather than home consumption. On average over all survey sites, reported maize requirements were over 100 kg higher per annum than for Mexico at a national level. All sites except Huitzo averaged higher stated requirements

Table 3. Household maize needs and sources of income by survey community, Central Valleys of Oaxaca

	Yield potential / Community						
	Good	Poor	Poor	Good	Good	Poor	
	Huitzo	Mazaltepec	San Lorenzo	Santa Ana	Valdeflores	Amatengo	All
				—mean—			
Maize needs per year	1033+	2455*	1363	1909	1856	1417	1636
(kg per capita)	227+	596*	287	353	410	335	354
				—percent—			
Important income source							
Local agricultural production	70*	100	95	100	85*	98	91
Local nonfarm employment	40*	28	30	15*	25	25	27
Remittances	3*	13*	23	25	25	38	20

Source: CIMMYT/INIFAP 1997 survey, 240 total households with 40 households by community.
Note: Estimates in "All" category are weighted by inverse probability of selection.
* Mean (frequency) significantly higher (different) using one-tailed t-test (chi-squared test), .05 significance level.
+ Mean significantly lower using one-tailed t-test, .05 significance level.

for maize consumption than the estimated national mean. Most of the very high annual maize requirements were reported by farmers in Mazaltepec, the community which relies most on local agricultural production. In a number of these households, but not in all of them, higher figures appear to be associated with livestock production.

Excluding Huitzo and Mazaltepec, the few statistical differences among sites for annual maize requirements and distribution of income by source are not meaningful in magnitude. The vast majority of households in these communities, whether they are located in better or poorer maize production zones, confirm that local agricultural production (on their own farm or working on other farms) is a major source of income. In addition, about one-quarter of all survey households state that local nonfarm employment is an important source of income. For all communities taken together, however, remittances through migration seem nearly as important as local nonfarm employment.

Farm Production

Despite the emphasis these farmers place on agriculture as a source of income and maize as a daily need, they farm relatively small areas. Of the 32 states of Mexico, only Puebla, Tlaxcala, Mexico, and Hidalgo have both a larger proportion of farmers under 5 ha and a greater dependence on maize in agriculture, as measured by the percent of area planted to maize (Hernández Estrada 1998). The average farm size in 1996 was 3.5 ha, of which 3 ha were planted to maize (Table 4). Farm sizes and maize areas are smaller in Huitzo and Amatengo than in other communities. The percent of maize area planted to improved maize seed in the survey year was significantly different from zero only in Huitzo.

Farm-level soil and moisture conditions vary by site. Soil types were defined based on farmers' classification systems (see Methods section). The number of soil types per farm ranged from 1 to 6. The mean number of soil types per farm was lower in Huitzo and Amatengo than in the other survey communities, as well as the number of fragments. Here, we use the term "fragments" in referring to plots within parcels on which distinct maize varieties are grown. Farmers may plant several parcels, with several varieties per parcel. They may also grow the same variety in more than one parcel. The number of fragments on the farms surveyed ranges from 1 to 9. The highest degree of fragmentation of maize area was found in Santa Ana and Valdeflores, and the lowest in Huitzo and Amatengo. One factor affecting the degree of fragmentation may be access to irrigation: almost no irrigated maize area was found in Santa Ana, and Huitzo has the highest percent of farms (85) with some irrigated maize area. Including all survey communities, 30% of farms had some irrigated maize. The average percent of maize area irrigated per farm was higher in Huitzo and lower in Santa Ana and Valdeflores than in other sites.

Sharp contrasts in land tenure arrangements are evident among survey sites. While all farmland is privately owned in Santa Ana, almost none is privately owned in Valdeflores, Mazaltepec, or San Lorenzo. In Huitzo, privately owned land represents on average about half of the land farmed by survey households, and in Amatengo it represents about one-quarter. Overall, about 60% of farm households own a team of oxen, while only 2% own tractors. Variation in ownership of oxen among survey communities is considerable, while the percent of households owning tractors is negligible in all communities.

Differences are evident among communities in type and scale of livestock production. Large numbers of pigs and poultry are raised in Huitzo relative to other communities, and more sheep are raised and horses are used in San Lorenzo, which is located in the hills. More poultry and cattle are produced in Valdeflores, although the greatest average number of cattle per household is found in Mazaltepec. Amatengo has a smaller average farm size, less maize area, less pork and poultry production than the other communities, and lower average numbers of sheep than the overall average.

Subjective Yield Estimates and Subsistence Ratios

Do households meet their maize requirements through their own production? To generate estimates of yield based on farmers' perceptions, both production and consumption decision-makers were asked to report the minimum, maximum, and most frequent yields

Table 4 . Farm characteristics by survey community, Central Valleys of Oaxaca

	Yield potential						
	Community						
	Good	Poor	Poor	Good	Good	Poor	
	Huitzo	Mazaltepec	San Lorenzo	Santa Ana	Valdeflores	Amatengo	All
	—mean per farm—						
Farm size 1996 (ha)	2.44+	3.91	4.01	3.46	3.87	2.84+	3.49
Percent land privately owned	49.60*	0.00	1.00	100*	0.00	2 7.42*	34.30
Maize area 1997 (ha)	1.99+	3.65	3.02	3.22	3.55	2.76+	2.99
Number of soil types	1.98+	2.73	2.78	3.08	2.73	2.13+	2.65
Number of fragments[1]	2.23+	3.98	3.28	4.08*	4.73*	2.55+	3.56
Percent maize area irrigated	54.2*	15.7	8.10	0.17+	3.78+	11.90	14.00
Percent maize area in improved seed	0.14*	0.00	0.04	0.01	0.00	0.00	0.04
Bovines	1.30	2.80*	1.08	1.08	1.83*	0.95	1.45
Equines	0.93	1.70*	2.32*	1.20	1.13	1.33	1.47
Porcines	2.45*	1.87	0.77	1.95	2.05	0.38+	1.65
Poultry	16.88	6.15+	12.10	14.55	20.05*	8.98+	13.78
Ovines	3.90	2.42	5.75*	2.30	1.55+	2.07	3.23
	—percent of farms—						
Own a team of oxen*	43	75	55	43	63	80	60
Own tractor	5	0	0	5	0	3	2
With any irrigation*	85	40	18	3	20	35	30

Source: CIMMYT/INIFAP 1997 survey, 240 total households with 40 households by community.
Note: Estimates in "All" category are weighted by inverse probability of selection.
* Mean (frequency) significantly higher (different) using one-tailed t-test (chi-squared test), .05 significance level.
+ Mean significantly lower using one-tailed t-test, .05 significance level.
[1] Fragments are plots within parcels planted to distinct maize varieties.

for the maize varieties they grow.[2] Table 5 shows that the expected yields of Blanco maize types (including five classes identified by farmers) are higher than the yields of types with colored grain (including three Amarillo classes, Belatove, Negro, and Pinto), and improved maize has higher expected yields than Blanco types. The estimated variance is higher for these maize types as well, but coefficients of yield variation are lower for improved than for traditional maize types. This result probably reflects in part the fact that most of the improved maize in the survey sites is grown in Huitzo, which has more irrigation. Production decision-makers estimate higher mean yields and variances than consumption decision-makers.

Table 6 shows the average expected yield, variance of yield, and the coefficients of yield variation calculated from farmers' subjective yield distributions. Mean expected yields are significantly higher in Huitzo. Although they also appear higher in Amatengo and lower in Santa Ana, differences are not statistically significant assuming separate variances. Variance of yield is higher in both Huitzo and Amatengo. The coefficients of yield variation are similar across the sites and relatively high—they compare, for example, to some aggregate estimates of the coefficient of yield variation for rainfed maize in southern Africa (P. Heisey, pers. comm.).

A comparison of expected yields calculated from farmers' subjective yield distributions and mean yields obtained in 5 irrigated trials of a sample of varieties collected in each of the communities shows a large gap between expectations and yield potential (Taba et al. 1997). Breeding for higher yield may be of limited value to farmers if they are not able to attain the advances under their own farming conditions. Agronomic or economic constraints may influence on-farm yields more than genetic enhancements.

Table 5. Farmers' yield estimates, by maize type, Central Valleys of Oaxaca

Maize type	Expected yield	Variance of yield	Coefficient of yield variation
		—mean kg/ha—	
Blanco	705*	53,6 62*	0.297
Amarillo	475	31,618	
Negro	498	32,302	
Belatove	447	28,517	
Pinto 645	3,7547		
All colored types	507	32,438	0.341
Improved	2,238*	119,447*	0.135+
All maize types	671	48,401	0.310
Production partner	779*	61,659*	0.305
Consumption partner	540	32,312	0.311

Source: CIMMYT/INIFAP 1997 survey, 240 total households with 40 households by community.
Note: Blanco and improved types are compared to all colored types taken together.
* (+) significantly higher (lower) with one-tailed t-test at 5 % level.

2 Since the average number of years farming and growing maize types is about 20 years, these represent distributions over time for each farmer. The distributions reported in Figures 3-5 are cumulative mean yields calculated from the triangular distributions elicited from farmers, representing a cross-section.

Cumulative yield distributions by maize type, decision-maker, and site are shown in Figures 3-5. Improved maize varieties dominate all other maize varieties in the first-order stochastic sense; at any yield level, the probability of a yield below that level is less for improved maize (Figure 3). This implies that regardless of the farmers' attitudes toward risk, a farmer who chooses maize varieties on the basis of yield alone would always choose to grow an improved variety. The data show instead that very few grow improved varieties—suggesting that other maize characteristics play a role in variety choice. In addition, as shown in Figure 4, Santa Ana has the least favorable yield distribution; 100% of expected yields reported by its farmers, including all classes of maize, fell lower 1.2 t/ha. Although subjective yield distributions are not entirely consistent with the yield potential classification obtained from INIFAP, because they represent distinct underlying concepts

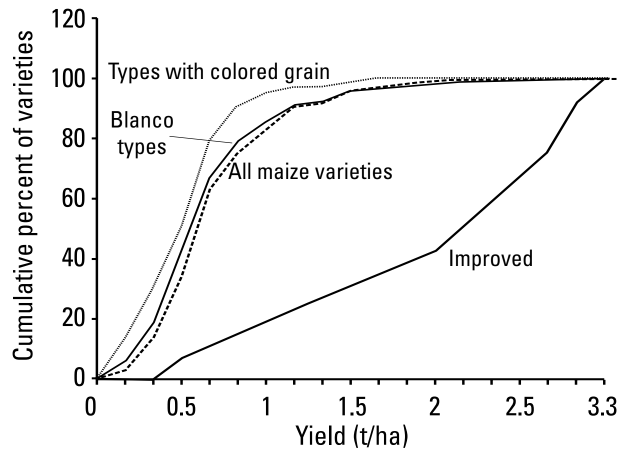


Figure 3. Cumulative expected yield distributions by maize type, Central Valleys of Oaxaca.

Note: Distributions for Blanco, colored-grain, and improved maize types are significantly different with Mann-Whitney test at P= .00.

Table 6. Yield estimates by survey community, Central Valleys of Oaxaca

	Good	Poor	Poor	Good	Good	Poor	
Yield potential / Community	**Huitzo**	**Mazaltepec**	**San Lorenzo**	**Santa Ana**	**Valdeflores**	**Amatengo**	**All**
	—mean kg/ha, all maize types —						
Farmers' estimates							
Expected yield	1,117*	681	677	472	645	818	671
Variance of yield	75,076*	54,006	47,766	32,401	38,781	92,287*	48,401
Coefficient of yield variation	0.244	0.308	0.306	0.348	0.259	0.318	0.31
On-farm trials							
Mean yield	2,189	2,044	2,016	2,743	2,448	2,773	2,359
Standard deviation	322	336	263	405	444	392	429
Maximum	2,774	2,530	2,618	3,395	3,266	3,237	3,400
Minimum	1,606	1,609	1,696	2,178	1,757	2,107	1,246

Source: CIMMYT/INIFAP 1997 survey, 240 total households with 40 households by community, and Taba et al. (1997).

Note: Estimates in "All" category for survey data are weighted by inverse probability of selection. Trial data are from samples of 8-13 maize populations per site and in "All" category, 152 populations collected in the Central Valleys. Trials were researcher-managed, with fertilizer and supplemental irrigation.

* Significantly higher with one-tailed t-test at 5%. Note that the average coefficient of variation is lower in Huitzo and Valdeflores than in Santa Ana, but not lower than in other sites.

they may not be comparable. The expected yield distributions between Santa Ana and Huitzo, Mazaltepec, and Amatengo are statistically significant. Production decision-makers are also significantly more optimistic than consumption decision-makers (Figure 5).

Including all maize varieties, farmers, and sites, the expected maize yield is 671 kg/ha. The farm family cultivating 3 ha of maize would expect to meet the average stated minimum maize requirement of 1636 kg/yr. The ratio of expected production to stated minimum requirements, at the mean for each site, would be more than 2 for Huitzo, 1 for Mazaltepec, 0.8 for Santa Ana, 1.5 for San Lorenzo, 1.2 for Valdeflores, and 1.6 for Amatengo. The ratio of the means implies nothing about the shape of the distribution, of the proportion of households that are self-sufficient, however. Many of these households are likely to be net consumers in one year and net sellers in other years. This means that the implicit price of grain lies somewhere between the producer and consumer prices. The location of the price within that band is unique to each household and is determined by its characteristics.

The price data reported by farmers reinforces the evidence that maize production is important primarily for on-farm consumption or local markets (Table 7). No significant differences were reported between mean consumer and producer prices for maize grain immediately before planting time, when maize stocks were already low or exhausted because of the drought experienced in the preceding season, and the price band between consumer and producer prices would be expected to be high. Response rates were higher for consumer than for producer prices—perhaps reflecting the fact that very few households had maize grain to sell and most were purchasing maize. Seed prices for unimproved maize varieties were generally higher than grain prices, and fodder prices were much more variable both within and among communities.

The valley communities of Oaxaca are well-served by an ancient, decentralized marketing system (Beals 1975; Malinowski and de la Fuente 1982; Waterbury 1968) and distances to markets do not differ appreciably among communities. Risopoulos (1998) 9conducted a

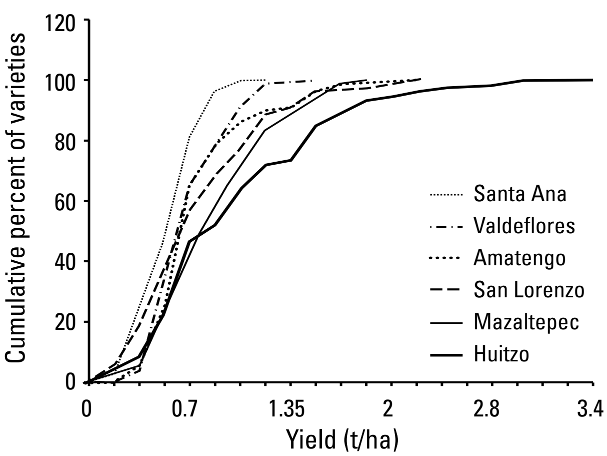


Figure 4. Cumulative expected yield distributions, by site, Central Valleys of Oaxaca.

Note: Distribution for Santa Ana is significantly different from distributions for Huitzo, Mazaltepec, and Amatengo with Mann-Whitney test at P=.00.

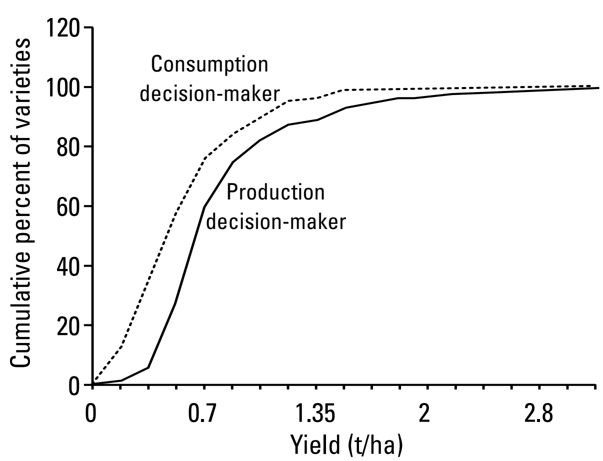


Figure 5. Cumulative expected yield distributions, by decision-maker, Central Valleys of Oaxaca

Note: Distributions are significantly different using Mann-Whitney test at P=00.

preliminary assessment of the market for grain of maize landraces in the Central Valleys to determine whether any characteristics are valued by the market. Grain shape and grain health seem to influence price, but only an estimated 5% of production of maize landraces enters the market (Risopoulos 1998).

There are at least two implications of these findings for maize breeding. First, enhancing characteristics based on current market valuation is not likely to affect farmer welfare appreciably, unless new niche markets are created. Second, in seeking to identify characteristics of importance to farmers in this setting, hedonic techniques using market prices offer scant information. Other methods must be used to elicit farmers' valuation of characteristics.

Table 7. Producer and consumer prices reported by survey households for maize seed, grain, and fodder, Central Valleys of Oaxaca, May 1998

	Huitzo	Mazaltepec	San Lorenzo	Santa Ana	Valdeflores	Amatengo	All*	n
Seed ($MX/kg)								
Buy	4.66	3.98	—	4.09	2.95	2.83	3.77	148
Sell	4.34	3.74	4.97	4.07	2.93	2.84	3.95	148
Grain ($MX/kg)								
Buy	2.20	2.45	1.54	2.61	2.01	2.01	2.18	193
Sell	2.17	2.40	2.06	2.60	2.00	2.03	2.27	151
Fodder ($MX/manojo)								
Buy	5.25	7.00	9.12	4.62	3.00	9.04	5.67	125
Sell	6.33	5.50	8.89	4.62	2.92	8.96	5.75	123

Source: CIMMYT/INIFAP 1997 survey, 240 total households with 40 households by community.
Notes: Estimates in "All" category are weighted by inverse probability of selection. The correlation between consumer and producer prices was high, particularly for seed and fodder. Many farmers were unable to report prices (see column "n").
* Paired t-tests show no significant differences between mean consumer and producer prices.

Farmer Management of Maize Diversity

Three features of farmers' management of their crop influence its diversity: (1) the choice of varieties to grow each season; (2) seed flows, or the means of procuring the seed for the season's crop; and (3) the selection and management of the seed stock from one crop season to another (Bellon, Pham, and Jackson 1997).[3] Indicators of each of these management practices in the study area are presented in this section.

Variety Choice

Farmer choice of variety determines the inter-varietal diversity, or the diversity among varieties, at the level of the individual farm. The second two management practices affect intra-varietal diversity, or diversity within varieties of the same crop. The definition of variety depends on the study and its purpose; here, as explained in the Methods section, we

[3] For an outcrossing crop like maize, in particular, management of sowing dates and plot location also influences the genetic structure of varieties according to the degree of cross-pollination that occurs between adjacent fields.

have based our classification of varieties on farmers' morpho-phenological descriptors. There is typically a strong relationship between classification based on these descriptors and the taxonomy developed by Wellhausen et al. (1952) for maize in Mexico, since this system was itself derived from farmers' descriptions. In the tables that follow, to conserve degrees of freedom, five subclasses of Blanco and three of the Amarillo classes have been grouped under the single categories "Blanco" and "Amarillo"(see Methods section). Although there are few of them, improved varieties have been categorized separately. We occasionally use the term "seed lot" to refer to the physical unit of seed of any variety that is planted to produce the next season's crop (Louette 1994). The aggregate of all farmers' seed lots constitutes a variety. The concept of a seed lot is useful for describing intra-varietal diversity. While many farmers may grow the same named variety (i.e., Blanco), management practices that shape the genetic structure of the seed lots that make up the variety are unique to each farmer.

Table 8 shows mean hectares planted per farm in 1997 by class of maize (Blanco, Amarillo, Negro, Belatove, Pinto, Improved), and the average percent of maize area represented by each maize class at the household and community levels. Blanco types are clearly dominant, occupying over 80% of area in the study areas. Of the 358 seed lots planted by farmers in 1997, 67% were blanco types, 11% were yellow types, 19% were other colored types, only 3% were improved, and one was a Tepecentle variety. Farmers in San Lorenzo and Santa Ana planted much higher proportions of colored maize types, and Huitzo was

Table 8. Maize areas and area shares by farmers' taxonomic class and community, Central Valleys of Oaxaca

	Huitzo	Mazaltepec	San Lorenzo	Santa Ana	Valdeflores	Amatengo	All
			—mean ha planted per household in 1997—				
Blanco	1.63+	3.50*	1.81+	2.63	3.49*	2.75	2.54
Amarillo	0.15	0.09	0.18	0.35	0.05	0	0.17
Negro	0.04	0.05	0.33	0.2	0	0.0175	0.14
Belatove	0.03	0	0.14	0.01	0	0	0.04
Pinto	0	0.01	0.52	0	0.01	0	0.12
All colored maize	0.213	0.152	1.16*	0.575*	0.0635	0.0175	0.47
Improved	0.14*	0	0	0.0125	0	0	0.04
			—percent of household maize area 1997—				
Blanco	90.3	95.6	61.57+	78.06+	97.4	99.2	83.3
All colored maize	4.24	4.44	36.93*	21.8*	2.64	0.77	15.40
Improved	5.5*	0.00	1.5	0.17	0	0	1.30
			—percent of total maize area planted per community in 1997—				
Blanco	82	96	60	82	98	99	83
All colored maize	11	4	39	18	2	1	15
Improved	7	0	1	0	0	0	1

Source: CIMMYT/INIFAP 1997 survey, 240 total households with 40 households by community.

Note: Estimates in "all' category have been weighted by inverse probability of selection. 240 households in 6 sites grew 358 total maize varieties, which have been grouped into classes based on farmers' criteria. Blanco and Amarillo contain other subclasses. All classes are Bolita race complex, except one case of Tepecentle.

* (+) significantly larger (smaller) with one-tailed t-tests at .05 level.

essentially the only community in which improved maize was grown. Even there, improved maize was planted to only 7% of the area in 1997. In all communities taken together, farmers planted on average of 2.5 ha of Blanco types, about one-sixth of a hectare each of Amarillo, Negro, and Pinto types, and very small amounts of Belatove and improved maize.[4]

Reflecting the long experience of the farmers in the survey communities, the number of years growing all maize classes averaged over 20 years. As would be expected based on its genetic characteristics, improved maize has been grown for only 3 years. Santa Ana farmers have grown each of their maize types the longest (Table 9).

Growing the variety for many years does not imply that the seed source for each successive season is exclusively the farmer's own harvest. Although we attempted to determine how many years the farmer had planted a seed lot derived exclusively from the preceding harvest, the distinction between seed lot and variety was difficult for both enumerators and farmers to grasp and results were not reliable. The concept of "own seed" is also ambiguous, as illustrated by the data in Table 10. The overwhelming majority of farmers stated that the seed they planted in 1997 was their "own," and they said that they frequently saved seed from the harvest to plant in the next season. At the same time, a third of them reported that they "sometimes" or "frequently" exchanged seed with other farmers in their community, combined their "own" seed of a variety with seed from other sources, or replaced it entirely. For example, 94% of Amatengo farmers saved their seed, but 28% also exchanged seed in Amatengo, 41% combined it with seed obtained from other farmers, and 22% replaced it at least sometimes. In Santa Ana and San Lorenzo, similar patterns appear.

Table 9. Mean number of years growing maize class, by community, Central Valleys of Oaxaca

	Huitzo	Mazaltepec	San Lorenzo	Santa Ana	Valdeflores	Amatengo	All
All classes	18.9	16.0	20.8	30.62*	24.3	26.2	23.7
Blanco	21.9	16.1*	21.7	30.6*	26.0	26.2	24.2
Amarillo	—	—	19.8	32.6	—	—	—
Negro	—	—	17.7	30.2	—	—	—
Belatove	—	—	19.5	25.3	—	—	—
Pinto	—	—	22.5	—	—	—	—
All colored	—	15.8	20.1	30.9	—	—	24.4
Improved	3.2	—	—	—	—	—	2.9

Source: CIMMYT/INIFAP 1997 survey, 240 total households with 40 households by community.

Note: Estimates in "all' category have been weighted by inverse probability of selection. 240 households in 6 sites grew 358 total maize varieties

* Mazaltepec is significantly lower with one-tailed t-test at .05 level; Santa Ana is significantly higher than Huitzo, Mazaltepec and San Lorenzo.

— Implies two few observations.

[4] It is worth noting that although production and consumption decision-makers did not always report the sample planting patterns for varieties, the differences between them were not statistically significant. Divergence may reflect difficulties in recalling what had been planted or differences in their taxonomic descriptions of the varieties.

In Huitzo, replacement is probably more related to the practice of growing improved maize, as indicated by the higher proportion of farmers purchasing their seed in 1997. In Huitzo, Mazaltepec, and Valdeflores, the practices of exchange and combination seem rarer, and in none of the survey communities did many farmers appear to be exchanging seed beyond the confines of their own community. Giving seed to other farmers was most frequently reported in Santa Ana, and less in Huitzo than in the other communities. Similar strategies of mixing, combining, and replacing the seed lots for traditional varieties have been reported in Mexico by Louette (1994) for the community of Cuzalapa in the state of Jalisco, and Aguirre (1999) for southeast Guanajuato.

Why do farmers in these communities pursue these strategies? Table 11 shows the most frequent explanations they offered. If the seed planted in 1997 was not their "own" seed, the source was typically a neighbor or family member in the same community. When seed is given to other farmers, it is generally given to family, friends, or neighbors in exchange for money or seed. Farmers usually exchange seed when they are looking for something new, given there is sufficient seed to exchange. They combine seed lots for experimentation or to complement inadequate seed supplies. Full replacement occurs when seed has been lost due to a poor harvest and/or storage problems.

Seed Selection and Storage Practices

As has been found in other studies of maize seed selection in Mexico, the most common seed selection criteria used by farmers are those related to grain and ear health, grain size, grain filling, and ear size (Table 12; e.g., SEP, 1982). The only significant difference of

Table 10. Seed sources, exchanges, and replacements, by community, Central Valleys of Oaxaca

	Huitzo	Mazaltepec	San Lorenzo	Santa Ana	Valdeflores	Amatengo	All
			—percent of all maize classes grown in 1997—				
Source of seed in 1997							
Own	80.2*	94.8	86.7	97.5	86.2	85.2	89.7
Bought	19.8*	3.1	0.6	1.9	12.6*	9.1*	
Exchanged	0	0	9.1	0.6	0	1.1	
Seed of variety has been given to other farmers	12.9*	28.9	30.6	56.1*	23.9	28.4	34.8
Save seed frequently	76.2	96.8*	76.7	98.1*	88.2	94.3*	87.1
Exchange seed							
In community	3	7.3	32.1*	77.1*	12.9	28.4*	36.9
Outside community	1	2.1	5.7	12.7*	1.2	5.7	6.3
Combine own seed with seed from other sources for same maize class	5	14.6	41.4*	61.1*	5.7	40.9*	35.6
Replace seed	27.5	13.5*	50.0*	75.8*	20.7	21.6	30.8

Source: CIMMYT/INIFAP 1997 survey, 240 total households with 40 households by community.
Note: Estimates in "all' category have been weighted by inverse probability of selection. 240 households in 6 sites grew 358 total maize varieties.
* Differences significant with pairwise chi-squared test at .05 level.

opinion between production and consumption decision-makers was found for the criterion of ear weight. The finding that consumption decision-makers are more likely to identify ear weight as an important selection criterion may be related to processing or to their perceptions of the relationship between ear weight and yield of *masa* (maize dough).

The criteria identified by farmers ensure healthy seed and germination, and are likely related as well to the maintenance of ideotypes (Louette and Smale 1998). Farmers exert direct selection pressure on ear characteristics but only indirect pressure on related plant characteristics, since only a minority mark plants for selection in the field (Table 13).

Less than half of farmers reported that they separated food or feed grain from seed at harvest time. The most common form of selection was the continual separation of good ears from those removed every few

Table 12. Maize selection criteria, production and consumption decision-makers, Central Valleys of Oaxaca

Criterion Consumption	Percent of decision-makers using criterion Production	
Ear size	93.9	90.9
Ear health	92.9	100
Ear weight	64.5	80.2
Well-filled ear	84.1	88.9
Number of rows	35.9	37.0
Good husk cover	17.1	9.1
Thick husk	6.7	3.4
Healthy husk	15.4	14.5
Grain size	94.0	91.8
Uniform grain	78.5	89.6
Healthy grain	96.6	98.4
Size of cob	57.2	43.7
Color of cob	15.2	19.2

Source: CIMMYT/INIFAP 1997 survey, 240 total households with 40 households by community.
* significant difference at 5 percent level, chi-squared test.

Table 11. Most frequent explanations for seed exchanges and replacements Central Valleys of Oaxaca

Practice	Most frequent explanation
Source of seed in 1997 "Own" Bought Exchanged	If not "own" seed, obtained from neighbor or family in same community
Seed of variety has been given to other farmers	Given to family, friend or neighbor in same community in exchange for money or seed
Exchange seed+ In community Outside community	When looking for seed and there is sufficient seed to exchange, generally in own community
Combine own seed with seed from other sources for same maize class+	To try new seed or because of seed loss
Replace seed+	Primarily because of seed loss

Source: CIMMYT/INIFAP 1997 survey, 240 total households with 40 households by community.
Note: Estimates in "all' category have been weighted by inverse probability of selection. 240 households in 6 sites grew 358 total maize varieties.
+ Practice sometimes or often.

days for the preparation of *nixtamal (*maize grain soaked in lime prior to grinding). This implies that no global selection occurs; at no point in time do farmers compare all of the plants in the field or all the ears from the harvest (D. Soleri, pers. comm.). The potential importance of the continual separation *(apartar)* activity in seed selection has been raised by Rice, Smale, and Blanco (1998) based on work in the Sierra de Santa Marta and was studied in greater detail during the monitoring survey conducted in these communities (Mendoza, forthcoming). Some revision of seed stocks occurs immediately before planting, and the majority of farmers try to avoid dipping into their seed supply for food as their grain stores run low.

Selection activities at harvest and immediately before planting appear to be accomplished by both production and consumption decision-makers, often in combination with other members of the household (Table 14). As might be expected, perceptions of responsibilities for setting aside seed ears as grain is consumed differ between production and consumption decision-makers. Consumption decision-makers claim greater responsibility for this seed selection activity, as well as for withdrawing seed from stocks when food stores are low.

Table 13. Maize seed selection practices, Central Valleys of Oaxaca

Practice	Percent of farmers reporting practice
Select plant in field	2.2
At harvest, separate seed from food or feed	41.7
Put aside good ears when removing for food or feed	66.7
Use seed set aside for food when food stocks are low	21.1
Make final selection at planting time	26.2

Source: CIMMYT/INIFAP 1997 survey, 240 total households with 40 households by community.

Most families store their seed, combined with or separated from food and feed, in a room, passage, or designated area of the house. Some store their seed in a crib (*troje*). Typically, the ears are piled loosely. Less often, they are shelled and the grain is stored in bags or sacks or metal drums.

Table 14. Perceptions of responsibilities for maize seed selection practices, production and consumption decision-makers, Central Valleys of Oaxaca

		Decision-maker responsible for practice		
Practice	Respondent	Production	Consumption	Other*
At harvest, separate seed from food or feed	Production decision-maker	11.9	4.4	83.7
	Consumption decision-maker	15.1	22.6	62.3
Put aside good ears when removing for food or feed	+ Production decision-maker	8.5	12.5	79.0
	Consumption decision-maker	8.7	69.2	22.1
Use seed set aside for food when food stocks are low	+ Production decision-maker	6.7	28.6	64.7
	Consumption decision-maker	3.7	93.8	2.6
Make final selection at planting time	Production decision-maker	23.8	13.2	63.0
	Consumption decision-maker	16.9	34.4	48.7

Source: CIMMYT/INIFAP 1997 survey, 240 total households with 40 households by community.
* Both or combinations of household members.
+ Significant difference between perceptions of decision-makers, at 5 % with chi-squared test.

Storing ears in sacks, bags, or baskets is another method. Slightly less than two-thirds of farmers reported that they protected their seed, and the majority of these used agrochemicals.[5]

This information, combined with the study conducted by Bergvinson and Savidan, suggests that farmers are exerting strong but indirect selection pressure for resistance to insect damage in storage. The two major components of this complex have contrasting husk characteristics. Zapalote Chico has a thick, tight husk, and Tabloncillo has a thin, long husk cover. From analysis of experimental data on 37 of the 170 materials collected from farmers, Bergvinson (1998) concluded that kernel resistance is not a trait for which farmers have selected directly. The negative correlation between kernel resistance and husk characteristics suggests that farmers are indirectly selecting for resistance by exposing ears to insect infestation. This finding is supported by the data in Tables 12 and 15.

None of the entries was as resistant as the farmers' variety that was used as the resistant check and several rivaled the susceptible check. Direct selection for husk cover, which is the "first line of defense" to insect damage, may have a role to play in improving the effectiveness of farmers' practices. Rather than advocate application of insecticide under most farmers' conditions, a promising route may be to arrest the development of the insect population at harvest by separating ears with damaged husk cover. Additional testing with farmers would be required to test this hypothesis and explore the implications for grain savings and labor time (Bergvinson, pers. comm.).

Table 15. Maize seed storage practices of survey households, Central Valleys of Oaxaca

	Most frequent practice	Percent practicing
Place of seed storage	Room	34.8
	Troje	22.5
	House	18.3
	Corridor	10.0
Method of seed storage	(Ears in husks) piled	43.3
	(Ears in husks) sacks,	
	Bags, baskets	18.1
	(Grain) bags, sacks	24.0
Protect seed		62.0
Form of protection	Agrochemicals	82.5

Source: CIMMYT/INIFAP 1997 survey, 240 total households with 40 households per community.

Measures of Diversity at the Farm and Community Levels

Without measurements on morpho-phenological descriptors or molecular data, the only indices of diversity that can be constructed for traditionally managed maize populations are those based on named varieties. Genealogical indices require known pedigrees. In the next phase of the project, we hope to develop morphological and molecular indices. These require the collection of seed samples from the maize populations grown by farmers.[6]

5 We did not ask them to specify the type of chemical.

6 For more on measurement of crop genetic diversity for use by social scientists, see Meng et al. (1998).

Table 16 shows several diversity indices based on the taxonomic classes used by survey farmers (see Methods section). Classes consist of five Blanco (white-grained) varieties, three Amarillo (yellow-grained) varieties, Negro (black- or purple-grained), Belatove (pinkish-grained), Pinto (mixed color), and Mejorado (improved). The mean number of these varieties grown simultaneously by farmers averaged 1.6 over all survey communities in 1997, and is greater in San Lorenzo and Santa Ana than in the other sites. The percent of farmers growing more than one variety varies greatly among the sites, from less than 10% in Amatengo to almost 70% in San Lorenzo.

Varietal diversity measured at the household level says little about diversity when assessed at the community level. The Simpson index, commonly used in the ecology literature (Magurran 1988), captures to some extent the "evenness" in the spatial distribution of populations as well as their "richness" (number).[7] When this index is constructed at the household level, San Lorenzo and Santa Ana stand out as more diverse than the other communities. The picture changes when the same index is measured at the community level. In Santa Ana, only one of the four Blanco types is grown by all farmers, although they also grow several colored types. All four are grown more uniformly across the farms of Mazaltepec and Valdeflores, despite the fewer number of varieties cultivated by individual farmers. The community-level index for Santa Ana is similar to that of Huitzo, where farmers generally grow one Blanco type and some improved maize, with very small amounts of the colored maize types. San Lorenzo, however, ranks relatively high on all the measures reported in Table 16. Almost all of the different maize classes identified among the survey sites can be found in San Lorenzo.

Table 16. Numbers of varieties per household and Simpson index of varietal diversity, by community, Central Valleys of Oaxaca

Maize class		Huitzo	Mazaltepec	San Lorenzo	Santa Ana	Valdeflores	Amatengo	All
Mean number of varieties planted per household in 1997		1.26	1.21	2.13*	1.98*	1.11	1.10	1.59
Percent households growing more than one variety	+	26.3	18.8	68.8	65.0	10.0	8.8	40.2
Household level Simpson index of varietal diversity		0.083	0.069	0.321*	0.27*	0.032	0.059	0.170
Community level Simpson index of varietal diversity		0.314	0.450	0.767	0.315	0.603	0.516	0.593

Source: CIMMYT/INIFAP 1997 survey, 240 total households with 40 households by community.

Note: Estimates in "all" category have been weighted by inverse probability of selection. 240 households in 6 sites grew 358 total maize varieties, which have been grouped into classes based on farmers' criteria. Blanco and Amarillo contain other subclasses. All classes grown by farmers belong to the Bolita complex, except for one case of Tepecentle.

* Significantly higher with one-tailed t-test at 5% level.

\+ Significant differences by community with chi-squared test at 5% level.

[7] The Simpson index used here is constructed as $1-\Sigma_i p_i^2$, where p_i is the proportion of maize area planted to a maize class. The index ranges between 0 and 1.

There is little evidence from direct questioning that farmers in these communities recognize loss of diversity over the past two decades (Table 17). The vast majority had no recollection of varieties grown before that have since been "lost" or "abandoned." Of those reported, all except 2 were found in Huitzo. They included a Blanco delgado, a Belatove, a Pinto, and in particular, a Negro variety. Farmers stated that the white-grained variety was abandoned because of bad agronomic characteristics, the black-grained variety because of its consumption characteristics, and the other two because there was no market for their grain.

Table 17. Varieties reported as lost or abandoned in the Central Valleys of Oaxaca

	Decision-maker		
Maize type	Production	Consumption	Both
Known losses			
Blanco delgado	0.4	0.4	0.4
Negro	12.5	5.5	8.7
Belatove	0.3	0.0	0.2
Pinto	1.2	0.6	0.9
No knowledge of losses	85.4	94.1	89.8

Source: CIMMYT/INIFAP 1997 survey, 240 total households with 40 households by community.

Demand for and Supply of Characteristics

The data shown in the section on farm and household characteristics, and the yield and price data, suggest that farmers in survey communities grow maize not for home consumption but rather for commercial purposes. This does not diminish the importance of maize as a source of real income, nor does it imply that farmers are not motivated by yield considerations. Other components or aspects of yield may be as or more important to them than mean grain yield per hectare.

We can interpret farmers' statements about the importance of maize characteristics as an expression of their demand for them, although we cannot infer any willingness to pay for these attributes, or substitutability among attributes, from their responses. Table 18 shows the percent of production decision-makers and/or consumption decision-makers who rate a characteristic as "very important" (versus "more or less" or "not" important). The rating provides an absolute rather than a relative measure of preferences. The list of characteristics was identified in farmer interviews when collections were made, and farmers were asked to rate each of them.

Several points emerge in examining Table 18. First, significant differences occur between production (mostly men) and consumption (mostly women) decision-makers, principally with respect to the importance of consumption characteristics. Of the other types of characteristics, only disease resistance and the capacity of a variety to produce "something" even in a bad year (disaster avoidance) were more likely to be very important to women than to men. The capacity of a variety to produce "something" even in a bad year can be interpreted as disaster avoidance, or avoiding yields in the lowest tail of the distribution. The emphasis on consumption-related characteristics and disaster avoidance makes sense given the definition of the consumption decision-maker. Second, the five most important characteristics were similar for production and consumption decision-makers, although men included grain yield per hectare and women included instead the taste of *tortillas*. For all respondents taken together, the most important five characteristics were, in decreasing order of importance: (1) drought tolerance; (2) resistance to insects in storage; (3) disaster avoidance; (4) grain weight; and (4) the taste of *tortillas*. Third, most of these are agronomic rather than consumption-related characteristics. Fourth, while only 6 characteristics were rated very important by over 50% of production decision-makers, the same percentage of women rated 14 characteristics as very important. In general, more characteristics seem to "matter" to women than to men. This same pattern was found in the voting results from the on-farm demonstrations (Bellon et al. 1998). Finally, feed, forage, and sales of grain or fodder are not ranked by the majority of farmers as very important. Nor are management considerations, or "costs" of production.

Table 18. Demand for variety characteristics, Central Valleys of Oaxaca

		Percent of decision-makers rating characteristic as "very important"			Top 5 characteristics		
Characteristic		**Production**	**Consumption**	**Both**	**Production**	**Consumption**	**Both**
Agronomic							
Grain weight (kg/*almud*)+		76.3	76.6	76.4	3	4	4
Grain yield (kg/ha)		52.8	66.1	59.4	5		
Length of growing period		46.5	46.9	45.7			
Produces "something" even in bad years	*	63.8	89.8	76.8	4	2	3
Drought tolerant		91.1	89.9	90.5	1	1	1
Resistant to lodging		25.1	51.4	38.2			
Weed tolerant		26.7	39.8	33.2			
Disease resistant	*	31.5	61.4	46.4			
Cold tolerant		22.9	34.7	28.8			
Resistant to insects in storage		79.7	75.5	77.6	2	5	2
Shells easily		16.4	31.4	23.9			
Consumption-related							
Number *tortillas/almud*	*	26.4	63.5	44.9			
Good for *nixtamal*		40.0	61.0	50.6			
Taste of *tortillas*	*	50.8	78.4	64.6		3	5
Good for *atole*	*	34.0	60.2	47.1			
Good for *nicuatole*		1.7	17.7	9.7			
Good for *tamales*	*	14.9	38.4	26.6			
Good for *tejate*		26.7	39.8	26.6			
Good for *pozol*	*	8.3	25.4	16.9			
Good for *tlayudas*		27.5	50.7	39.1			
Good for forage		30.9	51.4	41.2			
Good for feed		37.1	50.0	43.1			
Management							
Good for sale		32.4	53.6	43			
Produced with little labor		37.4	43.5	40.3			
Produced with few purchased inputs		48.2	57.5	52.9			

Source: CIMMYT/INIFAP 1997 survey, 240 total households with 40 households by community.
Note: An *almud* is a commonly used volume measurement used in marketing grain or seed.
* Significant difference between perceptions of decision-makers, with chi-squared test at 5% level.

How well do the varieties farmers grow supply the characteristics they demand? Table 19 shows farmers' quantitative estimates of yield components and cycle length as well as the percent rating the maize type as "very good" for the characteristic.[8] Although the small number of observations in the category of improved maize makes the numbers less reliable than for other categories, it is evident that except for expected grain yield per hectare and fodder, improved maize is a poor supplier of all characteristics relative to any of the

Table 19. Supply of variety characteristics, by maize type, Central Valleys of Oaxaca[1]

	Percent farmers rating maize type as "very good"				
Characteristic	**Blanco**	**Amarillo**	**Negro**	**Belatove**	**Improved**
	—Mean reported by farmers—-				
Agronomic					
Grain weight (kg/*almud*)+	3.96	3.96	3.94	3.87	4
Expected grain yield (kg/ha)	705 *	475	498	445	2238 *
Days from emergence to flowering	78	72	68	69	101
Days from emergence to harvest	126	121	111 +	115 +	149 *
	—Percent farmers rating maize type as "very good"—				
Produces "something" even in bad years	74	66	70	78	14
Drought tolerant	39	49	34	27	5
Resistant to lodging	40	53	47	32	33
Weed tolerant	30	20	13	18	19
Disease resistant	38	34	18	27	5
Cold tolerant	51	22	9	14	29
Resistant to insects in storage	19	22	9	14	29
Shells easily	74	77	84	86	52
Consumption-related	—Mean reported by farmers—-				
Number *tortillas*/*almud*	46	39	40	37	58
	—Percent farmers rating maize type as "very good"—				
Good for *nixtamal*	93	88	84	86	19
Taste of *tortillas*	95	90	95	91	19
Good for *atole*	94	63	43	44	14
Good for *nicuatole*	68	28	29	13	14
Good for *tamales*	93	88	65	78	14
Good for *tejate*	49	24	9	9	5
Good for *pozol*	81	70	40	51	24
Good for *tlayudas*	86	93	83	83	14
Good for forage	78	93	55	65	81
Good for feed	86	99	90	87	14
Management					
Good for sale	90	62	31	27	10
Produced with little labor	5	4	6	5	14
Produced with few purchased inputs	2	1	0	0	14

Source: CIMMYT/INIFAP 1997 survey, 240 total households with 40 households by community.

Note: An *almud* is a commonly used volume measurement used in marketing grain or seed. There are few observations for Belatove and improved maize.

* (+) Significantly higher (lower) with one-tailed t-test at 5% level.

[1] Includes both production and consumption partners.

8 Among the six major characteristics, there are no significant differences in the assessment of maize types between production and consumption decision-markers, except for expected yield per hectare.

traditional varieties. Improved maize has a longer growing cycle and is grown primarily in Huitzo, which has more irrigated maize. Among the traditional varieties, the five Blanco varieties (collapsed into one category, "Blanco") dominate the types with colored grain (Amarillo, Negro, Belatove) with respect to grain yield per hectare, suitability for sale, and most consumption characteristics. Of the major characteristics demanded, the traditional varieties supply *tortilla* flavor well. They produce similar grain weight. All are rated relatively low with respect to drought tolerance, very low with respect to insect resistance in storage, and relatively better in terms of disaster avoidance.

Why are the maize varieties with colored grain still grown? The dominance of Blanco types in maize area is consistent with its dominance in terms of characteristics of importance to farmers. Amarillo maize is rated high for the production of *tlayudas*, fodder, and feed—although these characteristics are not so important. Grain color seems to "mark" agronomic features such as duration of growing cycle; Negro and Belatove have significantly shorter growing cycles than Blanco or Amarillo. They may be grown as a means of coping with the risk of crop failure in growing seasons of variable length and grown in small quantities in order to assure a seed supply. As the area planted to Amarillo, Negro, Belatove, and Pinto types declines, the supply of local seed may also constrain demand.

References

Aguirre, J.A, 1999. Análisis regional de la diversidad del maíz en el sureste de Guanajuato. PhD thesis. Universidad Nacional Autónoma de Mexico, Facultad de Ciencias, Mexico, D.F., Mexico.

Beals, R. L. 1975 . *The Peasant Marketing System of Oaxaca, Mexico.* California: University of California Press.

Bellon, M. R. 1996. The dynamics of crop infraspecific diversity: A conceptual framework at the farmer level. *Economic Botany* 50, 26-39.

Bellon, M.R., J.L. Pham, and M.T. Jackson. 1997. Genetic conservation: A role for rice farmers. In N. Maxted, B.V. Ford-Lloyd and J.G. Hawkes (eds), *Plant Conservation: the* In Situ *Approach*. Chapman and Hall, London, pp. 263-289.

Bellon, M. R. and M. Smale. 1998. *A Conceptual Framework for Valuing On-Farm Genetic Resources*. CIMMYT Economics Working Paper, in press. Mexico, D. F.: CIMMYT.

Bellon, M.R., M. Smale, A. Aguirre, F. Aragón, and H. Castro. 1998. Identifying maize landraces for participatory breeding: Does gender make a difference? Paper presented at the workshop "*Strategic Research on Gender Issues in Rice-Based Household Economy*", IRRI, Los Baños, Laguna, Philippines, August 23-28, 1998.

Bergvinson, D. 1998. Annual Research Progress Report 1997. Maize Entomology. Mexico, D.F.: CIMMYT.

Calvo, R., P. Aquino, P. W. Heisey, and F. Carrion. 1998. Part II of *CIMMYT World Wheat Maize Facts and Trends*, 1998. Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT).

Hernández Estrada, M. I. 1998. Tipología de productores agropecuarios. Ponencia presentada en el Seminario "Los pequeños productores rurales: Las reformas y las opciones, Colegio de México, México, D.F., September 10.

INEGI. 1996. La agricultura en Oaxaca. *VII Censo Agropecuario* 1991.

Louette, D. 1994. Gestion traditionnelle de variétés de maïs dans la réserve de la Biosphère Sierra de Manantlán (RBSM, états de Jalisco et Colima, Mexique) et conservation in situ des ressources génétiques de plantes cultivées. Thèse de doctorat, Ecole Nationale Supérieure Agronomique de Montpellier, Montpellier, France.

Louette, D. and M. Smale. 1998. *Farmers' Seed Selection Practices and Maize Variety Characteristics in a Traditionally-Based Mexcian Community.* CIMMYT Economics Working Paper 98-04. Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT).

Magurran, A. 1988. Ecological diversity and its measurement. Princeton, Princeton University Press.

Malinowski, B., and J. de la Fuente. 1982. *The Economics of a Mexican Market System*. London: Routledge and Kegan.

Mendoza, J. Forthcoming. Participation of Farm Women in the Management and Selection of Maize Seed in the Central Valleys of Oaxaca. Tesis de licenciatura.

Meng, E. C. H., M. Smale, M. Bellon, and D. Grimanelli. 1998. Definition and measurement of crop diversity for economic analysis. In M. Smale, M. R. Bellon, and P. Pingali (eds), *Farmers, Gene Banks and Crop Breeding*. Norwell, MA, Kluwer Academic Publishers and CIMMYT, pp. 19-31.

Ortega-Paczka, R. 1995. Origen de la agricultura e importancia de los valles centrales de Oaxaca. In M. A. Vásquez Dávila (ed), *La Tecnología Agrícola Tradicional*. Oaxaca, México, Instituo Indigenísta Interamericano/CONACYT, pp. 189-200.

Perales R., H., S.B. Brush, and C.O. Qualset. 1999. Agronomic and economic competitiveness of maize landraces and *in situ* conservation in Mexico. In M. Smale (ed.), *Farmers, Gene Banks, and Crop Breeding: Economic Analysis of Diversity in Wheat, Maize, and Rice.* Norwell, Mass.: Kluwer Academic Publishers.

Rice, E., M. Smale, and J.-L. Blanco. 1998. Farmers' use of improved seed selection practices in Mexican maize: Evidence and Issues from the Sierre de Santa Marta. *World Development* (September).
Risopoulos, J. 1998. Assessment of the potential for conducting a hedonic pricing study for maize landraces produced and marketed in the Central Valleys, State of Oaxaca, Mexico. CIMMYT Internal document.
SEP (Secretaría de Educación Pública). 1982. Nuestro maíz—Treinta Monografías Populares. Consejo Nacional de Fomento Educativo, Secretaría de Educación Pública, Tomo 1 y 2, México.
Taba, S., F. Aragón, J.M. Hernandez, J. Díaz, H.C. Garcia, and A. Aguirre. 1997. *In situ* conservation of maize biodiversity in the Central Valleys of Oaxaca, Mexico: results and workplan. Internal document. Mexico, D.F.: CIMMYT and INIFAP.
Waterbury R.G. 1968. The traditional market in an urban setting: Oaxaca , Mexico. PhD thesis. Los Angeles: University of California..
Wellhausen, E.J., L.M. Roberts, and E. Hernandez X. 1952. *Races of Maize in Mexico: their Origin, Characteristics and Distribution*. The Bussey Institution. Cambridge: Harvard University.

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