E C O N O M I C S

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* Elizabeth Rice is a graduate student at Cornell University, Ithaca, New York; Melinda Smale is an economist at CIMMYT, Mexico; and José-Luis Blanco is a sociologist with the Proyecto Sierra de Santa Marta, Jalapa, Mexico. The views presented in this paper are the authors' and do not necessarily represent policies of their respective institutions.

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Abstract

The principal advantage of *in situ* conservation is that it allows adaptive evolutionary processes to continue in the species that are being conserved. For a cultivated crop species, *in situ* conservation involves farmers' management of their own genetic resources even as the farmers themselves adapt to a changing environment. Improved seed selection practices and other on-farm breeding strategies have been proposed as a means of providing economic incentives for farmers to continue growing traditional varieties or landraces identified as important for conservation. This paper describes a pilot study among a group of indigenous farmers in the Sierra de Santa Marta, Veracruz, Mexico, who have collaborated in such efforts. The findings raise key issues about the potential impact of such an approach, as well as some useful methodological points for applied economists.

In the study area, there is a high frequency of experimentation, exchange, loss, and replacement of seed over time – *seed of the same varieties, including both modern and traditional varieties*. This poses a challenge for economists' models of varietal choice, which tend to be based on static perceptions of a "variety" as well as simplistic distinctions between "modern" and "traditional" varieties. Seed selection in the study area is not a single event but an iterative, continuous process. Women may be more involved in seed selection than previously thought, which may have implications for the welfare impact of new seed selection practices. Other implications of the study are that (1) the impact of introducing practices to enhance farmers' varieties is likely to be diffuse and difficult to observe, predict, or measure, and (2) in developing analytical models of farmer decision-making as it affects the diversity of genetic resources on the farm, the most appropriate unit of analysis for predicting the effects of some policy interventions is not likely to be the individual farmer or the individual farm household. A better understanding of the "social infrastructure" shaping seed and information flows is needed, since in the diffusion of innovations of this type, the seed system is based entirely on farmers and their interactions.

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Research Context and Purpose

Ex situ and *in situ* strategies for genetic resource conservation are increasingly viewed as complementary rather than substitutable. In theory, while *ex situ* conservation is geared toward a relatively small number of known plants and "fixes" the genetic material of the plant at the time that it enters the germplasm bank, *in situ* conservation allows adaptive, evolutionary processes to continue and natural pre-breeding processes to occur. Since the risk of extinction due to some natural or man-made process is greater *in situ*, *ex situ* collections serve an insurance purpose (Dempsey 1996; Maxted, Ford-Lloyd, and Hawkes 1997).

The classical *in situ* model for wild species is based on geographical isolation of the target species in a protected reserve. By contrast, *in situ* conservation of cultivated species necessarily involves farmer management of their own crop populations in the farming systems (Bellon, Pham, and Jackson 1997). Given the way that Mexican farmers manage their maize genetic resources, for example, a model of *in situ* conservation based on geographical isolation is likely to be inappropriate, even for farmers in traditional communities. In Mexico, Louette, Charrier, and Berthaud (1997) and Aguirre (1997) have shown that the structure of genetic diversity in farmers' varieties depends on the flow of varieties and seeds among households and communities.

If the classical model for *in situ* conservation is inadequate for crop species, what other models do we have to assist us in defining what to conserve and how? Although the historical role of farmers in shaping the evolution of crops and their diversity has long been recognized, rigorous investigations of the complex socioeconomic and scientific issues involved in such farmer-managed conservation efforts have only just begun.[1] Unless these issues are investigated with care, it will be difficult to develop strategies for, and assess the impact of, conservation initiatives.

Among the socioeconomic issues that must be examined in regard to *in situ* conservation, the economic issue of farmers' incentives is fundamental. On-farm crop improvement through breeding and/or seed selection practices has been proposed as a means of encouraging the continued cultivation and adaptation of farmers' varieties while providing

[1] At the International Rice Research Institute, the project, "Safeguarding and Preservation of the Biodiversity of the Rice Genepool, Component II: On-Farm Conservation"; in Mexico, the McKnight Foundation project, "Conservation of Genetic Diversity and Improvement of Crop Production in Mexico: A Farmer-Based Approach"; and at CIMMYT, the project, "Maize Diversity Management and Utilization—A Farmer-Scientist Collaborative Approach"; in Turkey, the project, "Ecology and Ethnobiology of Wheat Landrace Conservation in Central Turkey"; a longitudinal study undertaken by the Institut National de la Recherche Agronomique (INRA) in France; see other initiatives for Ethiopia and Andean crops described in Maxted, Ford-Lloyd, and Hawkes (1997).

them welfare benefits. Although the strategy for on-farm crop improvement will depend on the maize variety or race, as well as the social, economic, and environmental characteristics of the community, such strategies typically include the recommendation that farmers select their seed in their fields from desirable plants. The traditional method of selecting maize seed used by Mexico's farmers does not include plant selection.

There are two major — and questionable — assumptions behind the notion that on-farm improvement of farmers' varieties will contribute to conserving maize diversity, even though many such efforts have already been undertaken by various nongovernmental and public organizations. The first assumption is that improving the characteristics of any given landrace will help to prevent the loss of diversity through slowing the replacement of landraces by improved varieties. In fact, improving a landrace by a criterion that farmers identify as economically important may reduce diversity just as readily as it enhances it. Furthermore, whether improved varieties actually "replace" landraces or coexist with landraces in a given geographical area is an empirical issue.

A second major assumption of on-farm improvement strategies is that they can produce a perceptible impact on the crop's value to the farmer, leading to their adoption and diffusion among farmers. The purpose of the pilot study whose results are summarized here was to record, in detail, the use of recommended seed selection practices (from the plant) by a group of farmers participating in the initiatives of the Proyecto Sierra de Santa Marta, a nongovernmental organization (NGO) in the state of Veracruz, Mexico. The study is part of a growing body of research undertaken to analyze the prospects for on-farm improvement as a strategy for assisting farmers to manage and conserve their own genetic resources.

Before discussing specific issues of adoption and impact, we summarize key information about the study site and the methods used in the study, and we define terms used in this paper. We then proceed to describe farmers' management of maize genetic resources in the study area. The seed selection technique that was introduced to the farmers is described, and its hypothesized effects are outlined. Next, we examine the evidence on farmers' use of the technique. Implications for the impact of similar techniques and for economic methods are discussed in the final section of the paper.

Site Description, Methods, and Definitions

Site Description[2]

Soteapan and Ocotal Chico, the two sites where this study was conducted, are small, indigenous communities on the flanks of a rain-forested volcano in the Sierra de Santa Marta, in the State of Veracruz, Mexico. The people of both communities are indigenous Popoluca for whom Spanish is a second language. Literacy rates are low. Around 40% of the population over the age of 15 in the municipality where the communities are located is literate (Paré, Argüero, and Blanco 1994). The area is different from many other areas in

[2] See also Appendix A, Table A1.

Mexico in that off-farm work and migration are fairly uncommon (Rice, Godínez, and Erenstein, forthcoming), a situation not necessarily true of bordering municipalities (Buckles and Perales 1995).

The farming system of the area consists of shifting, slash and burn agriculture, with a strong emphasis on subsistence maize production. A sextupling of the population of the Sierra from about 8,000 inhabitants in the early 1900s to nearly 53,000 in 1990 has caused strong land pressure and high rates of deforestation in recent years (Paré, Argüero, and Blanco 1994). Declining fallow periods and low productivity are indicators that the system is under stress (Buckles and Erenstein 1996). Words such as "poverty" and the "hungry months" of June and September appear in current descriptions of the area (Blanco 1995), in contrast to the 1940s, when Foster (1942) described the shame of a man having to buy maize to support his family. Estimates suggest that now more than half of the households must supplement their own maize with store purchases (Rice, Godínez, and Erenstein, forthcoming).

Maize production in the study area is entirely manual, partly because of the steep, rocky terrain. Input use is very low and only small amounts of inputs are used. Herbicides are used more commonly than fertilizer (Paré, Argüero, and Blanco 1994; Perales 1992; Rice, Godínez, and Erenstein, forthcoming). The climate in the area is warm and humid, with 2,000-3,500 mm of annual rainfall. Most of the rainfall occurs between June and January. Wet-season maize, the primary crop, is planted in late May or early June at the onset of the rainy season. Yields are quite low. They were 640-840 kg/ha for neighboring communities over the wet seasons of 1992-93 to 1994-95 (Rice, Godínez, and Erenstein, forthcoming). The dry season lasts from February to May and typically increases in severity with each month that passes; late April and May are very dry (Stuart 1978.)

Farmers in the lower areas of the Sierra traditionally plant a second maize crop during the dry season. This crop, known as the *tapachole* maize crop, is usually planted between the rows of wet-season maize in November. The labor costs associated with such a crop are lower because the clearing and weeding requirements are lower, but the risks are much higher. The *tapachole* crop is threatened by winds at the beginning of the cycle, drought at the end of the cycle, and by hungry mountain animals throughout (Buckles and Perales 1995).

Methods

Both of the study sites benefit from the work of the PSSM. From its inception in the early 1990s, the PSSM has used various tools of participatory research to diagnose pressing issues and problems in Sierra communities. The maize production problems identified through this work are associated with the late maturity and tall stature of traditional maize varieties, especially in Ocotal Chico, the upland community of the two study sites described here.[3]

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[3] Traditional varieties often stand 3-4 m high, with ears placed at 1.5-2.0 m. The top-heavy, slow-to-mature maize is vulnerable to the hurricanes and high winds that buffet the area. The expansion of cultivated area into the forest also appears to have exacerbated problems of lodging because there is less protection from wind (Blanco, Buckles, and Perales 1994). Oral histories from the study area tell of fewer problems with winds in the past, despite the tall stature and long growing cycle of traditional maize varieties (Perales 1992).

In 1993, with technical support from CIMMYT, the PSSM initiated a program to address the maize production issues that farmers had raised. The program had two parts. First, farmers themselves were to screen modern, open-pollinated maize varieties under their own conditions, selecting the best performers for distribution and promotion by the PSSM (Blanco 1996). Next, the PSSM planned to enable farmers to improve their own traditional maize by selecting seed from plants with the characteristics they desired, such as shorter plant height and early maturity. The PSSM began a series of workshops during the wet season of 1994 to teach farmers how to improve their own maize through seed selection and management practices. Approximately 50 farmer-promoters participated in the workshop. These farmers were encouraged to hold their own workshops in their experimental fields. Of the total number of farmers included in the initial work, a group of approximately 100 in four communities (Soteapan, Ocotal Chico, Santa Marta, and Mazuniapan) received new seed and learned about the new seed selection and management practices.

The 16 farmers whose practices are described in this paper were the last members of the original group of farmers who still showed any interest in the introduced seed and practices at the time of the study.[4] These farmers come from two of the four communities (Soteapan and Ocotal Chico) that participated in the initial work. The findings emerging from this study are the result of repeated household and field visits to these 16 farmers over five maize growing seasons to monitor their use of seed and recommended selection practices, by variety, from the wet season in 1994 through the wet season of 1996.

Because of his close relationship to the farmers and his previous research in the area, the principal investigator was able to supplement a standard set of data collected in each cycle with information from a field diary and informal discussions with farmers. As the study evolved and issues such as those related to women's role in seed selection emerged, informal discussions were augmented by more structured interviews.

In the tables that follow we report quantitative data, but when the farmer or farm household is the unit of observation, readers should bear in mind that the number of farmers is small. Since the original purpose of the study was to document the use of seed and selection practices for each of the varieties planted in each cycle, and since these few farmers grow a large number of varieties and use many seed lots over five growing cycles, the numbers of observations are not so restricted for variables describing maize varieties and seed.

A pilot study of this type is not intended to be representative of farmers' practices in the study zone or other study zones. Instead, the detailed information obtained in multiple visits with cooperating farmers is useful for raising issues and formulating hypotheses for further research. Where it is possible and directly relevant to do so, we have drawn on related research.

[4] These numbers do not represent adoption rates, however, for two reasons. First, incomplete records were kept of the total number of farmers involved in each stage of the research, although there is some evidence that a large number discontinued use voluntarily or involuntarily. Second, we have not documented the diffusion of seed or practices from farmer to farmer.

Definitions of Terms

A *race of maize* is a subdivision of a species that typically contains numerous varieties grouped according to similarities in morphological and genetic characteristics. Of the 40 maize races reported for Mesoamerica, 31 are found in Mexico (Bretting and Goodman 1989). In this study, races have been identified principally by their ear characteristics, as defined in Wellhausen et al. (1952).

Here, a *variety* of maize refers to a maize population as it is recognized and named by farmers. Whether the population is the product of a national or international breeding program, or the product of the seed selection and management practices of a farmer and farm family, we refer to it interchangeably as a *variety* or *farmers' variety. Modern varieties* are varieties that have been developed by a national or international plant breeding program, and they include the first generation and advanced generations that have been grown for many years by farmers. *Traditional varieties,* whether they originate in the survey communities or have been introduced from other communities, are selected and developed by farmers.

To analyze the intravarietal flow of seed among farmers, we have adopted the term *seed lot* as originally used by Louette (1994). A seed lot consists of all kernels of a specific type of maize or variety selected by a farmer and sown during a cropping season to reproduce that particular maize type or variety. A variety then comprises all of the seed lots bearing the same name. A seed lot can be thought of as a physical unit; a variety is associated with a name.

Seed selection, as we refer to it, is the choice of seed for the next season's maize crop. Seed may be selected in several different places at different times and may assume different forms. Plants in the field may be marked for seed, "good" ears may be set aside when grain is processed for food, and a "selection event" may occur when many ears are selected at once from a stock of maize grain or seed. All of these seed selection procedures are considered here. *Seed management* refers to the treatment and storage of seed.

Farmers' Management of Genetic Resources in the Sierra de Santa Marta

Choice Variables in Farmers' Management of Genetic Resources

Bellon, Pham, and Jackson (1997) have described farmers' management of genetic resources as not only the varieties they maintain, but as the management processes that the varieties are subject to, and the knowledge that guides these processes. They identify several components of farmers' management of genetic resources, including: (1) the choice of variety, (2) seed flows, and (3) seed selection and management. These components can be conceptualized as the dependent variables that one may want to explain in a study of the bases of on-farm conservation, or as behavioral variables one may want to influence in a project whose goal is to foster it (such as an on-farm breeding project). Here, we use this structure primarily as a means of describing the setting in which recommended seed selection practices were introduced. This enables us to identify some major issues that are relevant to the adoption of seed selection practices and their potential impact.

Choice of Variety

Like other farmers in Mexico, farmers in the Sierra de Santa Marta have traditionally grown many varieties of maize, distinguished primarily by the color and form of the grain, the thickness of the cob, and by consumption preferences in the communities where the farmers live (Herrera 1996). Over the years since they began cultivating their own fields, survey farmers have grown 34 named varieties. The full list of maize varieties (modern and traditional) grown by farmers in the survey zone from the year they began cultivating their own fields, as well as the racial classification of the variety, is shown in Appendix A, Tables A2 and A3.

Here and in the Appendices, varieties have been categorized as: (1) modern maize (including both white and yellow maize); (2) traditional white maize; (3) traditional yellow maize; and (4) traditional black maize. These categories reflect the fact that survey farmers themselves refer to their maize by its color and whether or not it is improved (*mejorado*). Modern yellow maize has been grouped with modern white maize.[5]

Farmers participating in the PSSM initiative grew 30 varieties over the five survey seasons, although the number of races in the ancestry of these varieties is relatively small and most of the modern and traditional white varieties that dominate the maize area are based on Tuxpeño populations. In the dry season, as compared to the wet season, fewer farmers grow maize, fewer varieties are grown, and the modern maize varieties introduced through the PSSM and CIMMYT are more important as a percentage of the maize area (Table 1; see also details in Appendix A, Tables A4-A10).

Table 1. Number of maize varieties, races in ancestry, and percent area planted, wet and dry seasons, 1994-96

	Average total number				Percent of total maize area	
Maize category	Wet season	Dry season	Cumulative total, all seasons	Number of races in ancestry	Wet season	Dry season
Modern white and yellow	11	7	13	(*)	22	73
Traditional white	7	1	8	5	49	13
Yellow	3	1	6	3	20	14
Black	3	0	3	3	9	0
All categories	24	9	30	5	100	100

Source: PSSM/CIMMYT monitoring survey, 1994-96, Soteapan and Ocotal Chico, Veracruz, Mexico.
Note: (*) indicates numerous populations. See Appendix Table A3.

[5] Although few farmers grow it, as will be seen later in this paper, modern yellow maize occupies areas similar in magnitude to those of modern white maize (when it is grown), and its processing characteristics are also comparable.

This planting pattern was unforeseen but is easily explained by the agronomic characteristics of the varieties. The modern maize varieties distributed through the PSSM mature more rapidly and are shorter than traditional varieties, which enables them to escape or resist the strong northern winds and hurricanes which blow through the area. The materials from CIMMYT's drought-stress program tolerate dry spells, and all varieties yield as well as, or better than, traditional varieties.[6]

In general, no single variety fits all of the production conditions (rainfall, temperature, altitude, growing period, slope of field) and meets all of the end uses of maize (*tortillas*, cash grain sales, feed, specialty foods) for farm families in the survey communities. Yellow maize (either traditional or modern), according to the farmers surveyed, "grows well on the mountain." Its relatively short growing period (compared to traditional white maize) and its heavy, crystalline grain make it attractive to producers because of its resistance to wind and insects; it also yields well (farmers' statements; Perales 1992; Stuart 1978). Black maize is grown especially for the production of *pozol*.[7] Households clearly prefer black maize as the basis of *pozol*, and there is some disagreement about the extent to which other categories of maize can also be used. Details on production and consumption characteristics of varieties grown by farmers are found in Appendix B.

Cultivation patterns and the discussions of varietal characteristics among participating farmers illustrate a point that recurs in the literature on varietal choice in developing countries. Farmers in these indigenous communities typically grow more than one variety per season (they also grow a different mix of varieties in dry and wet seasons). Several approaches from microeconomic theory can explain this essential feature of their farming system, including risk management, transactions costs, fixity of related production inputs, and learning behavior or experimentation (Meng 1997; Smale, Just, and Leathers 1994). The detailed information that was collected from the survey farmers also suggests a slightly different way of thinking about a farmers' choice of varieties. A variety can be considered a bundle of characteristics or a multidimensional vector of traits (Bellon 1996). Usually no single variety contains all of the characteristics a farmer seeks. In some sense, to a maize producer, characteristics are "fixed" in the short term, meaning that they are specific to varieties or types of maize. To satisfy all the requisites of their soils and climate as well as the types of products they seek, farmers plant combinations of varieties.[8]

These findings raise another important point regarding the relationship of modern varieties to the diversity of varieties grown in farmers' fields. In communities where varieties must

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6 The major disadvantages of the modern varieties are their thinner husks and poorer husk cover, which can result in ear rot and insect damage during field and home storage. Modern white varieties are typically considered by farmers to have heavier weight per unit of volume than traditional white varieties and to possess whiter grain, and thus they are preferred for cash sale. Modern white maize is usually sold soon after harvest to avoid storage problems with these relatively thin-husked varieties.

7 In these communities, *pozol* is a lightly fermented drink.

8 Maize breeding can be thought of as a way of relaxing the "fixity" of traits in varieties. A potential contribution of professional maize breeders to the work of Mexico's maize farmers includes methods to increase the speed and efficiency with which farmers can re-bundle the characteristics they value. Some characteristics are more easily changed by farmers than others. In this project, farmers were attempting to move the traits of short stature and early maturity ("fixed" in modern varieties) to their own traditional varieties.

satisfy multiple concerns related to production and consumption needs, the equilibrium adoption state may be one in which modern varieties coexist with, rather than replace, traditional varieties. This point is supported by previous research in the survey area (Perales 1992) and generalized in related research by Bellon (1990) and Brush (1995).

Seed Flows and Sources

A grasp of how seed flows from farmer to farmer is essential to understand the potential adoption, diffusion, and impact of strategies aimed at improving germplasm on the farm. Detailed field research by Aguirre (1997), Louette (1994), Louette, Charrier, and Berthaud (1997), and Louette and Smale (forthcoming), using different analytical tools and conducted in different regions in Mexico, has documented the significance of seed exchange among farmers in the genetic composition of maize races and traditional varieties.

In their research on beans, Sperling, Scheidegger, and Buruchara (1996) have emphasized that in adoption studies it is important to understand the mechanisms and social institutions through which farmers obtain their seed from other farmers. In addition to the biological characteristics of the crop, the agroecological and socioeconomic environment in which the crop is grown shapes farmer-to-farmer seed transfer systems and affects the success of proposed systems. Sperling, Scheidegger, and Buruchara (1996) found that the "circle of diffusion" among farmers is "socially narrow." Not everyone who asks for seed obtains it. Seed targeted for stressful environments moves more slowly than "highly productive" seed. Some desirable seed can disappear altogether when socioeconomic or environmental disruptions end the season's production.

Figures 1-2 and Tables 2- 3 are constructed from the recollections of farmers participating in the PSSM initiative (see Appendix C for additional figures). In detailed interviews conducted over several visits, farmers recalled their seed sources and seed use over the full span of years in which they cultivated maize. Figures 1 and 2 demonstrate how the story of a Mexican farmer's maize seed is interwoven with his or her own life. In Figures 1 and 2, cycles of seed introduction, loss, and replacement for the maize varieties grown by survey farmers are plotted, along with major junctures in farmers' lives. Each farmer's lifecycle, and thus his or her maize seed cycle, begins in the family home and continues to the present. Varieties that farmers continue to plant are indicated with an arrow. For varieties that farmers cease to plant, we distinguish between varieties that were abandoned (an intentional end to planting) or lost (an unintentional end). We also record the reasons for abandonment or loss. The source of seed for later varietal introductions or seed changes, or infusions of new genetic material into varieties under cultivation, is also recorded. The lifecycles and seed cycles range from 8 to 38 years in length, depending on the number of years each farmer has been cultivating his or her own fields.

Figure 1 presents an example of how farmers experiment with their local maize: the first yellow maize that this farmer grew was something he picked up along the road. After a few years, he decided that he no longer liked that particular yellow variety, but he still liked that class of maize and changed to another yellow variety. In 1976, this farmer changed his black maize variety, not because of unsatisfactory yield or plant height, but because he preferred the color of the *pozol* that the new variety produced.

In the case of white maize, which occupies most of the maize area in the study sites, the first farmer keeps two varieties. Although both varieties have been continuously cultivated, neither of the seed "lifelines" is unbroken. At different points, both varieties have been lost and recovered — from the farmer's father in the early years and from his son in later years. In this case, the unit of seed conservation appears to be the immediate family, although the father and son do not reside together. In other seed cycles, the source of seed is neither the immediate nor the extended family.

The seed cycles reveal the high frequency of changes in farmers' seed, among both modern and traditional varieties. Recently many modern maize varieties have been introduced into the study area, and major social changes, such as land reform, have occurred as well. Figures 1 and 2 show especially high rates of experimentation and turnover in both modern and traditional varieties during this period. Figure 2 presents the example of a producer who grows predominantly modern white varieties and traditional black varieties. Over the past few years, this farmer has experimented with up to five modern varieties at the same time, eventually deciding not to continue cultivating most of them.

Some of the information in the seed lifecycles is also summarized numerically in Tables 2 and 3. Table 2 shows that, on average, farmers have grown three varieties each of modern maize and traditional white maize, although most of the modern varieties have been cultivated in the seasons since their introduction by the PSSM. Fewer traditional yellow and black varieties have been grown by farmers over time, but a traditional black variety tends to be grown for longer than other categories of varieties. Traditional white and black maize varieties have been cultivated by survey farmers in about 20 out of the 25 years since they began growing them, while farmers began growing yellow and modern varieties only about a decade ago. For all categories of maize, however, the cultivation of varieties is

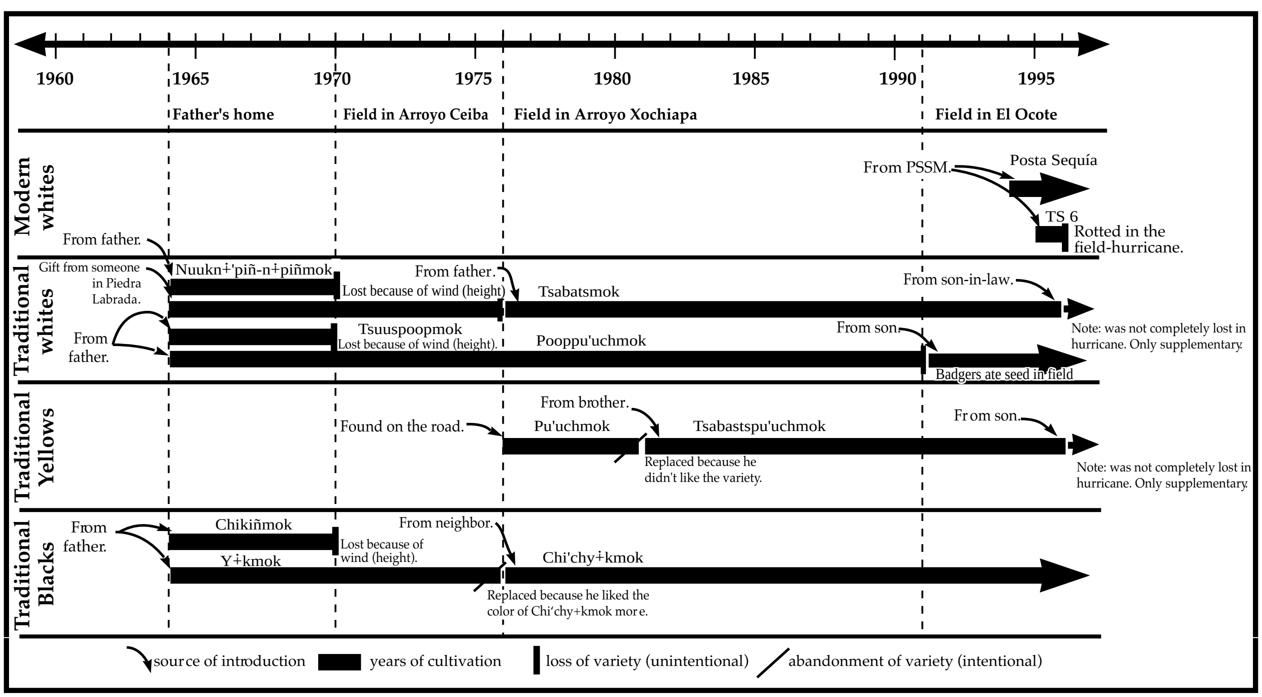

Figure 1. Example 1: Lifecycles of farmers and their maize seed.

discontinuous. The average number of years in cultivation is less than the average number of years since each type was cultivated from beginning to end.

In Table 2, changes in varieties are categorized as introductions, substitutions, and abandonments. Changes in seed are categorized as losses or infusions. An *introduction* means new cultivation of a variety that has not been grown by the farmer for more than a year. The same variety can be introduced more than once if the introductions are separated by more than one year. A *substitution* of one variety for another must occur within one year of the end of cultivating the previous variety, and it is not applicable to the category of modern maize, which was introduced so recently. *Abandonment* is the intentional end to cultivation of a

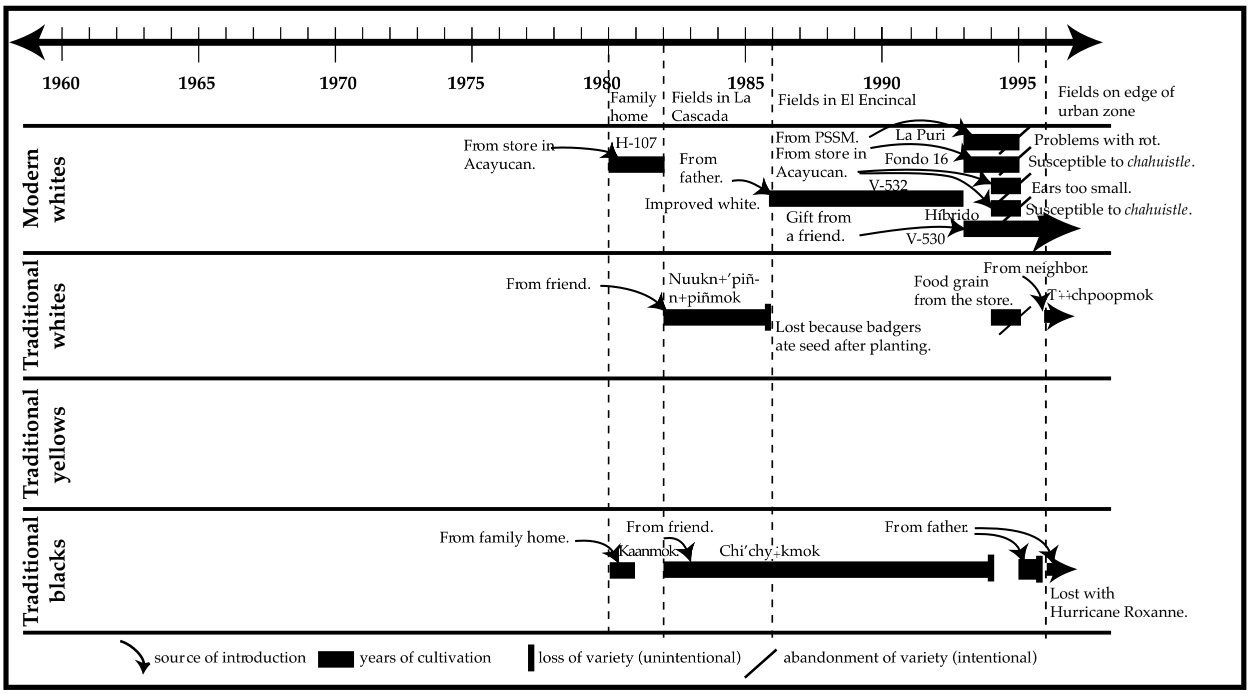

Figure 2. Example 2: Lifecycles of farmers and their maize seed.

Table 2. Seed cycles and maize varieties grown over years farming

	Modern maize	Traditional maize		
		White	Yellow	Black
	Average number of varieties/farmer			
Years cultivating maize category	5.7	20.1	12	19.5
Varieties grown since began farming	3.1	2.9	2	1.7
Varieties grown per year	1.6	1.6	1.2	1.4
Varietal introductions	3.2	0.8	0.4	0.5
Varietal substitutions		0.8	0.1	0.4
Varietal abandonments	0.6	0.6	0.4	0.5
Seed losses	1.3	0.8	0.2	0.4
Seed infusions	0.2	0.5	0.3	0.4

Source: PSSM/CIMMYT monitoring survey,1994-96, Soteapan and Ocotal Chico, Veracruz, Mexico.

variety. *Loss* is the unintentional end to cultivation of a variety when seed is lost (for example, because of a poor harvest or insect infestation). Whether or not it has been lost, seed can also be *infused* when the farmer receives or obtains new seed for the same variety.

Survey farmers introduce modern varieties into their planting patterns more than other types of maize, but they also abandon them and lose seed for them more frequently. Some survey farmers grew modern varieties as early as 1960 and 1967, but the cultivation of modern varieties is patchy (not continuous over time), because the varieties tend to lose their distinctive characteristics and are not replaced. Seed losses among modern varieties have occurred rapidly within the past few seasons. Difficult weather conditions have undoubtedly influenced this pattern, although it is not clear how atypical the past seasons have been. Seed infusions of modern varieties — including replacements for seed losses — are lower than infusions of traditional maize varieties. In many ways, the patterns of cultivation for modern varieties look like the patterns of cultivation for traditional white maize, compressed from 30 years to 5.

Farmers also introduce traditional maize varieties and frequently substitute one traditional maize variety for another. Among the categories of traditional maize, white maize varieties are introduced, substituted, and lost most often. Like traditional white maize, black maize has high rates of infusion of new seed to supplement or replenish continuing cultivation of the same variety. High rates of infusion suggest that the varieties are highly valued by the farmers and that seed sources are available. When the number of varieties grown by farmers is considered, the rate of introduction and substitution is similar for traditional white and black maize.

The distribution of varietal introductions, substitutions, and seed infusions by source of seed is shown in Table 3. Among categories of traditional maize, the most important seed source is the family, both when the farmer begins cultivating his or her own fields and later, as a source of seed infusions for varieties in cultivation. In survey households, seed has typically been passed from parent to child (or grandparent to grandchild).

Table 3. Sources of seed for varietal introductions, substitutions, and seed infusions over years farming

			Traditional maize					
	Modern maize		White		Yellow		Black	
Seed source	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Family, at time farm established	1	2	26	47	9	47	20	50
Family, since farm established	4	7	19	33	8	42	14	35
Friends or neighbors	6	11	10	18	0	0	6	15
Store	12	22	2	2	0	0	0	0
Proyecto Sierra Santa de Marta	31	58	0	0	0	0	0	0
"Found" on the road or in a field	0	0	0	0	0	11	0	0
All sources, all participating farmers	54	100	57	100	17	100	40	100

Source: PSSM/CIMMYT monitoring survey, 1994-96, Soteapan and Ocotal Chico, Veracruz, Mexico.

Friends or neighbors outside the extended family are a significant source of seed for traditional varieties, however. Two survey farmers "found" yellow maize (in a tree after a hurricane, and picked up on the side of a path) and began to grow it as their own traditional maize. In each case, it was the first yellow maize the farmer had ever grown. One of the farmers is still growing the variety. The primary sources of seed for modern maize are, as expected, the PSSM or the store. The data also reveal some movement through the traditional channels of family and friends, which begins to appear several years after the introduction of a modern variety.

Seed Selection and Management Practices

By *historical* seed selection and management practices, we mean "the ways of the ancestors," as represented in literature sources. There is no unique set of historical seed selection practices because they were undoubtedly community-specific, although some practices may have been fairly common and others may have spread more widely through intermarriage between communities. Some seed selection practices are described in Stuart (1978) for the study area. Historical ways of storing seed included thatched granaries raised above the ground. These were filled with maize and fires lit beneath them (the fires were maintained for months and up to a year) so the smoke would drift through the loosely woven floor and preserve the maize (Perales 1992; Stuart 1978). The loft (*tapanco)* system operates in much the same way: maize is stacked in the loft above the kitchen and smoke from the cooking fire drifts up and protects the maize. No granary structures can be found in the study area, but the *tapanco* system, although rare, is still in use.

In this paper, the "traditional" seed selection practices described by survey farmers are those used in recent history or before the selection techniques were introduced and recommended by the PSSM. No detailed, systematic baseline study on seed selection practices was conducted prior to introducing the new techniques. Our view of "traditional" practices is derived from descriptions in the literature and interviews with farm households.

Traditionally, maize was harvested and carried home, where it was used to make a raised platform (*estiba)* stacked high with maize ears, still in their husks. Most of the literature states clearly that maize is selected soon after the harvest, either at home or in the field. The selection was either done or supervised by the male head of the household (Stuart 1978; Baez-Jorge 1973). The farmers we spoke to added that every few days, as a farm woman removed maize ears from the *estiba* to prepare *nixtamal* (the mixture of maize grain and lime that is made to prepare the maize grain for grinding), she would set aside the "best" ears for seed. She would remove all but three leaves of the husks, knot them with the remaining leaves of another ear, and hang the pair over a beam in the kitchen, a rafter, a hook, or a tree. As it accumulated, the seed she selected came to resemble and was called "the pineapple" (*piña*). Before planting, the farm woman, her husband, or both together, would select seed maize from these ears. Ears with rotted grain or grain eaten by insects would be discarded, and the good ears shelled, bagged, and planted. There was, of course, variation in this system among households and between years.

Introduced Seed Selection Technique and Hypothesized Effects

Elements of the Seed Selection Technique

Both Stuart (1978) and Perales (1992) noted that when farmers in the study area selected seed, they did not appear to select for desirable characteristics such as reduced height and rapid maturity. Farmers did not select from maize plants, but from harvested ears. Nor did they differentiate between seed for the wet and dry seasons, although the planting conditions are markedly different for each cycle. In 1994, the PSSM introduced a set of recommended seed selection and management practices, which consisted of the following:

1. Marking desirable plants, with chalk or a tie, in the field.
2. Selecting plants in the center of the field (within five rows from its boundaries) to reduce "contamination" from other varieties.
3. Selecting plants under good competition (from one plant in a group of ten plants, every 5 m or every fifth lot of 3 or 4 m^2), and with large ears, to ensure healthy, robust plants.
4. After harvest, in the home, selecting seed ears from the ears of marked plants based on other ear characteristics (size, healthy and dry kernels, well-filled ears, ears with more rows, ears with straight rows, relevant type and color of grain).
5. Using seed from the center of the cob only.
6. Dusting the seed with insecticide or ash and storing it separately in a dry place.

Plants were to be marked at a time consistent with the farmer's objective. For example, a farmer wanting to select for early maturity would mark the plants that flowered first (which implies selecting during the flowering period). The PSSM recommended that farmers mark the number of plants that would yield twice their seed requirements, to allow for subsequent losses from rotting or insect damage. No particular storage container was recommended, although farmers were encouraged to take care by separating seed maize from food grain, dusting it with ash or insecticide, and storing it in a dry place.

Hypothesized Diversity and Welfare Benefits

The recommended seed selection and management practices were introduced in conjunction with modern seed, but they were explained as a way to control for desirable characteristics in traditional maize. The assumption behind the introduction of the technique was that by encouraging farmers to improve their own traditional varieties by using recommended seed selection practices, the PSSM and participating farmers would help maintain the diversity of the maize grown in the study area by enhancing farmers' welfare. The recommended practices were, in some sense, meant to counterbalance the introduction of improved seed which occurred as the other part of the research plan (Buckles, pers. comm).

The effect of using these practices to improve maize yield or other characteristics is not known conclusively. Points (1), (2), (3), and (6) are deduced from the theory and practice followed by plant breeding programs. Points (4) and (5), however, reflect farmers' "traditional" practices in Mexico. Farmers believe there is a relationship between the size of the seed and the vigor of the plant (Aguilar 1982:74-75). Louette and Smale (forthcoming) have analyzed the effects of selection based on ear characteristics and the relationship of ear characteristics and varietal ideotype. Unpublished results of germination tests indicate that the top kernels had a lower germination rate than the base and center kernels. Furthermore, kernels at the top of the ear are often damaged by birds, insects, and fungi. No justification is apparent for excluding the base kernels, however (Louette and Smale, forthcoming).

Adoption of the Technique

Use of the Technique

Table 4 shows how participating farmers used the recommended practices during the study period, by percentage of seed lots, for modern and traditional varieties. In general, farmers who adopted the practice made few modifications. Almost all of the seed they selected was from the center of the field from plants in good competition. Seed lots contained an average of 100-150 ears. Whether farmers chose to select seed in the field or not, most of them shelled their seed maize from the center of the cob and dusted stored seed with insecticide to minimize storage losses.[9]

These practices were followed for both modern and traditional varieties but used with greater frequency on modern varieties, even though in introducing the practices the PSSM emphasized their suitability for traditional varieties. Farmers often describe modern

Table 4. Use of recommended selection and management practices, 1994-96

	Percent of seed lots on which practice was used				
Practice	**Wet season 1994**	**Dry season 1994**	**Wet season 1995**	**Dry season 1995**	**Wet season 1996**
Modern varieties					
From plant marked in field	40	36	20	0	15
In center of field	95	100	83	..	80
In competition	100	100	100	..	100
Seed from center of cob	84	75	53	..	100
Dusted with insecticide	68	..	77	..	100
Traditional varieties					
From plant marked in field	17	0	15	0	0
In center of field	80	..	100	..	..
In competition	100	..	100	..	..
Seed from center of cob	77	..	43	..	..
Dusted with insecticide	52	..	78	..	..
Number of seed lots	78	11	67	5	59

Source: PSSM/CIMMYT monitoring survey, 1994-96, Soteapan and Ocotal Chico, Veracruz, Mexico.

[9] No particular storage practice was recommended for seed, and the recorded information on shelling and bagging is not as complete as other information. Most seed maize seems to have been bagged, and less of it was shelled. The high frequency of bagging may reflect only the fact that with the small harvests it was a good way to separate seed maize from maize to be used for food.

varieties as needing more "care" than traditional varieties, which may (or may not) reflect modern varieties' relative adaptability to the specific growing environment. Farmers may also have associated "new" techniques and "new" seed because they were introduced at the same time and are often associated either deliberately or unconsciously in promotional campaigns.

The percentage of seed lots selected from plants in the field declined in each season, however. For traditional varieties, the practice appears to have been discontinued entirely in 1996, despite several farmers' statements that they had achieved desired changes in plant height through selecting seed from shorter plants. These statements are hard to support, given the small number of seasons in which farmers selected for plant height. The practice was not used in either dry season on traditional varieties, since few traditional varieties are planted in the dry season (see Table 1). The large decrease in the percentage of seed lots selected from the plant between 1994 and 1995 is also difficult to explain with the information we have. We do know that much of the 1995 crop was lost long before the plants reached flowering (because of hurricane damage), reducing the chances for applying the practice. We also know that, following the reorganization of land use rights that accompanied the recent land reform, some of the survey farmers began cultivating plots in different, more distant areas, which would have increased the time required to apply the practice.

Labor is likely to influence the attractiveness of selection techniques for farmers. Although marking plants should not be particularly time-consuming, farmers' fields in Ocotal Chico are far from their homes and located on steep slopes. The timing of labor requirements is also critical, since a major source of cash income — coffee — competes with maize for labor in certain periods. By the close of the study period, none of the participating farmers in Ocotal Chico, the coffee-growing community, was selecting plants in the field.

Referring to a labor-intensive, on-farm selection program to improve seed quality and resistance to disease in beans, Sperling, Scheidegger, and Buruchara (1996) reported that the yield advantage of 14% was "not very convincing for those who had to do the extra maintenance." They concluded that opportunities for improving the quality of bean seed proved less attractive to farmers than access to new genetic material and varietal diversity for a range of environments.

Zimmerer (1991) has argued that acute labor shortages resulting from seasonal migration have undermined the management of multiple crops and varieties in a traditionally complex cropping system in Peru. In the two survey communities described here, migration is not as great and therefore the opportunity cost of farm labor is not as high as it is in many other Mexican communities. In a Oaxacan community in Mexico, García-Barrios and García-Barrios (1990) identified "diversity management" as first in a list of three agronomic characteristics of pre-Hispanic maize systems that labor migration seriously threatens.[10]

[10] In their study, less than 30% of those born in the area who are between the ages of 20 and 45 currently reside in their community of birth.

On the other hand, there is anecdotal evidence that farmers other than those surveyed have adopted the practice or the improved seed that resulted from surveys farmers' use of the practice. A few producers went on to sell the seed they had selected in the field. More modern maize was sold than traditional, and less and less maize was sold over time. (Furthermore, seed from marked ears was stolen from the fields of some farmer-promoters.)

Finally, the adoption patterns for the improved maize seed introduced at the same time as the recommended seed selection practices bear mention. From the year of introduction in 1993, in each season, the percentage of producers growing each of the 27 varieties jointly tested by PSSM and CIMMYT has declined. This is true even for the two varieties released by the Mexican national research program, INIFAP (Instituto Nacional de Investigaciones Forestales y Agropecuarias), which were grown in the area prior to the project. Although the percentage of farmers growing each variety may have declined, there is no clear pattern among varieties in total areas planted. These data represent a small number of farmers and a brief time period. Furthermore, Hurricane Roxanne caused large losses of seed after the wet season in 1995, although losses of that type may not be atypical in the Sierra de Santa Marta. The difficulty that participating farmers have had in using the seed and the recommended practices in each cycle has implications for research impact, even if it is too early to conclude that neither the seed nor the practices have been "adopted." [11]

Current Seed Selection and Management Practices

"Current" practices are those used by survey farmers since the introduction of the new technique. These practices are a mixture of traditional practices and those recommended by the PSSM. In Tables 5 and 6, we have structured the detailed information obtained through formal and informal interviews to depict current seed selection practices in five phases. The phases may occur simultaneously, and some phases may be practiced to the exclusion of others.

Four of the phases are discrete events:

1. Selection of superior plants in the maize field around flowering time and separation of ears from marked plants at harvest time.
2. Selection of a bulk of maize ears when the harvest is brought to the house.
3. A second selection of a bulk of maize ears from the stored maize at some time between harvest and the next season's planting.
4. Selection close to planting time. Preplanting seed selection occurs an average of ten days before planting among those who practice it.

Among the five phases, the fifth — selection of seed when maize is prepared for food — is unique in that it is a continuous process in which a few ears of maize are set aside each day, and these accumulate over a longer period. We hypothesize that ignoring this phase when recommending new seed selection practices may have implications for selection criteria and for the success of the proposed innovation. These implications are related to whether men

[11] With the seed trials, the PSSM also introduced double-density planting. Although double-density planting increased yields for modern varieties compared to regular planting densities for traditional varieties, farmers did not adopt the practice, in large part because of the labor it required (Blanco 1996).

or women or both assume responsibility for seed selection, in which phase, and for which characteristics they select.

Traditionally and currently, selection of maize seed in these communities is an iterative and continuous process. For the 1995 wet season, members of survey households selected seed of traditional and modern varieties two to three times, in distinct phases and ways. The most common phase of seed selection practiced by survey households was selection immediately before planting. As expected, differences emerge in the selection practices for modern and traditional varieties.

Seed selection practices are less iterative for modern maize varieties than for traditional maize (Table 5). Seed for modern maize varieties tends to be selected in the earlier phases, with more selection occurring in the field and immediately after harvest. Most often, modern maize is shelled, bagged, and treated with insecticide at that point. Before planting, this same seed may be subjected to the "water test" in which good kernels with the endosperm intact sink to the bottom of a bucket of water, and bad kernels (rotten or insect-infested) float and are strained off the top to be discarded.

By contrast, seed for traditional maize varieties tends to be selected in the phases that occur later in the season (Table 6). More of the seed for traditional varieties is selected from stored seed, particularly during food preparation. This finding reflects the fact that modern maize has less husk cover and is known to be vulnerable to insect damage in storage.[12] Traditional

Table 5. Timing and characteristics of maize seed selection for modern varieties, wet season, 1995

	Phase of seed selection				
Timing and practice	From plant, in field	In bulk, from harvested maize in house	In bulk, from stored maize, in house	When stored maize removed to prepare food	Pre-planting, from selected seed
	pecentage of seed lots				
Time selected	35	57	19	29	67
Storage method					
Shelled and bagged	..	83	0	0	100
Unshelled and bagged	..	17	50	0	0
Selected by:					
Hung	..	0	50	100	0
Men only	71	75	25	17	86
Women only	0	8	50	83	0
Both men and women	29	17	25	0	14
Insecticide applied	100	58	0	0	86
Time of final selection	40	83	0	0	..

Source: PSSM/CIMMYT monitoring survey, 1994-96, Soteapan and Ocotal Chico, Veracruz, Mexico.
Note: Number of seed lots (56) is fewer than those reported in Table 4. These refer to varieties harvested, while those in Table 4 refer to varieties planted.

[12] Some farmers complain that the insects arrive because of the more vulnerable modern maize but stay to eat the traditional maize. This is also why the seed of modern varieties is more often shelled, bagged, treated with insecticide, and in many cases stored separately.

maize varieties that are more vulnerable to insects, such as the variety Nuukn+̇'piñ-n+piñmok, are treated more like modern varieties than traditional ones in this respect.

For both modern and traditional varieties, bulk selection from stored maize later in the season is not very common (about one-fifth of the households) and is generally provoked by a problem, such as insect infestation or an apparent shortage of food maize putting pressure on seed supplies. In other cases, the second, bulk selection takes the form of a more complete selection, done by the women of the household, almost immediately after the men have completed a rapid initial selection of the harvested ears. Often this second phase of bulk selection replaces the more traditional continuous selection that occurs as ears are removed for food preparation.

Although the selection of seed immediately before planting is more common for traditional than for modern maize varieties, in either case, most of the selection is a revision of the existing seed collection. When households separate new maize seed, it is usually because the amount they have already set aside is not enough (because of insect problems, a change in planting plans, and so on). For both modern and traditional varieties, the majority of households use insecticides on their shelled maize before planting, with the intention of protecting it in the ground. Hanging seed from a beam in the kitchen is typically associated with setting aside good ears during food preparation but also occurs after the first and second bulk selections.

Table 6. Timing and characteristics of maize seed selection for traditional varieties, wet season, 1995

	Phase of seed selection				
Timing and practice	From plant, in field	In bulk, from harvested maize in house	In bulk, from stored maize, in house	When stored maize removed to prepare food	Pre-planting, from selected seed
	pecentage of seed lots				
Time selected	14	50	31	59	97
Storage method					
Shelled and bagged	..	28	9	0	100
Unshelled and bagged	..	61	64	0	0
Hung	..	11	27	100	0
Selected by:					
Men only	60	39	18	12	53
Women only	0	22	64	88	21
Both men and women	40	39	18	0	27
Insecticide applied	100	33	0	0	82
Time of final selection	..	33	9	0	..

Source: PSSM/CIMMYT monitoring survey, 1994-96, Soteapan and Ocotal Chico, Veracruz, Mexico.
Note: Number of seed lots (56) is fewer than those reported in Table 4. These refer to varieties harvested, while those in Table 4 refer to varieties planted.

In years of low production, such as 1995, some households do not have enough maize to make an *estiba,* and they store their maize in bags instead. Selecting unshelled maize for seed and putting it into bags is usually just a way to separate seed maize from other maize. Bags of *shelled* maize, however, seem to be associated with modern maize, introduced methods, and powdered insecticides.

Despite the fact that modern varieties are considered more vulnerable to insects than traditional varieties, insecticides are used almost as frequently on traditional maize. Perhaps survey households regard the use of the insecticides on traditional varieties as insurance or a way of cutting potential losses. Since they produce little surplus above subsistence needs, the value of losses below subsistence levels could be great. However, the increased use of insecticide on traditional maize may have implications for genetic resistance to insects in storage, since farmers are no longer directly selecting for that trait by using ears that have resisted insects throughout the season. The use of insecticide (typically Graneril) on maize grain also appears to be "contagious": the insecticide is not only used on grain for seed, but also on grain that is used for food. Frequently, in both cases, the insecticide is "painted" on the outside of unhusked ears.

The data in Tables 5 and 6 also strongly suggest that men and women have different roles in seed selection. Selection of superior plants in the field is almost exclusively accomplished by men, and setting aside of good ears during food preparation is almost exclusively the domain of women. The selection of seed in bulk from harvested maize, and the later bulk selection from stored maize, appear to be the responsibility of either men, women, or both. Men tend to select the seed immediately before planting. In these households, men generally plant the seed.

Although women in the survey households participate substantially in nearly all phases of selection, when asked directly whether they "select" seed (*seleccionar)*, they typically answer "no." They answer "yes" when asked if they "set aside" (*apartar)* maize for seed. The term "selection" seems to have a very specific definition and appears to be related to the practice of selecting superior plants or to the selection of seed immediately before planting. These are primarily the tasks of men.

Modern varieties in general also appear to be more the domain of farm men than of farm women. There are several cases in which women are responsible for all levels of seed selection of the local varieties, whereas men take responsibility for all the seed selection among the modern varieties. The most obvious explanation for this finding is probably similar to that generally cited for other agricultural innovations. Farm men more frequently attend and speak at group meetings held to introduce new farming practices, unless the meetings are specifically arranged for women or to include both men and women in the learning process. The farmers in the sample are those who presented themselves voluntarily to participate in the PSSM initiatives. Only one participant is a woman, although both men and women in participants' households were interviewed in the monitoring survey.

In some sense, however, once the harvested maize enters the house, it becomes the domain of the women of the household. For example, even among farm households that are using the practice of selecting plants in the field, a discordance often remains: while the men select plants and select seed immediately after harvest, and consider their seed finished and ready for planting, the women continue to set aside "good" ears as they remove them from the *estiba* during food preparation. They may then sell or barter their seed maize locally. However, if the men have insufficient seed for the next planting, they may select from the seed the women have set aside.

In 1942, Foster noted that "division of labor along gender lines is found to be less marked in Popolucan culture than in many other communities. Women engage at times in even the heaviest field work, and there is no social stigma attached to a man's doing housework if forced to by personal circumstance." The participation of women in seed selection through setting aside "good" ears during daily food preparation may have implications for on-farm maize improvement and the introduction of seed selection and management practices, and women's participation in seed selection seems likely to occur in other indigenous communities of Mexico.

Implications for Research Impact and Economic Methods

Understanding the process of selecting, storing, and caring for the maize kernels that will become the seed of the next season's maize crop is critical, both for the farmers and for the researchers whose objective is to recommend complementary or improved practices. From the farmer's viewpoint, this process casts the genetic die for future generations of maize, determining which varietal characteristics are conserved or lost. The process is so intuitive, customary, and natural to farmers that often they do not volunteer information because they consider it obvious. To enable farmers to better manage their genetic resources or enhance their own varieties through selection strategies, researchers need to understand current practices before recommending new ones.

Our experience leads us to one overriding conclusion: selection practices in indigenous communities are likely to be more complex than has been assumed in the literature or described through casual observation. More specifically, we have found that (1) seed selection does not appear to be a single event but an iterative, continuous process, and (2) in indigenous communities such as these, women may be more involved in seed selection than previously thought.

These findings may have implications for the welfare impact of the innovation. The extent to which women are involved in seed selection in other communities, and whether the exclusion of women's seed selection practices would have a neutral, positive, or negative effect on the household or farm women's well-being, remains to be studied. In general, we cannot assume *a priori* that the introduction of plant selection in the field will make farmers' selection practices more "efficient," if other selection criteria or pressures are eliminated in the process of adopting that practice.

The pictorial representation of the seed cycles overlaid on the farmers' lifecycles not only generates hypotheses about the potential effects of introducing germplasm and recommended seed selection practices but raises a methodological point. Economists' models of varietal choice tend to be based on static perceptions of a "variety" as well as simplistic distinctions between "modern" and "traditional" varieties. These approaches are challenged by data on the high frequency of experimentation, exchange, loss, and replacement of seed for the same variety over time, including both modern and traditional varieties. Traditional black and white maize are the mainstay of maize production in the study area, both in terms of numbers of varieties and of the planted area they cover. Yet farmers frequently introduce traditional black or white varieties or infuse new seed for varieties currently in cultivation. They also abandon them intentionally and lose them unintentionally — but less often than modern varieties. Farmers exchange not only varieties but seed lots for the same varieties. This finding is fundamental to understanding the genetic composition of maize varieties grown by farmers, and it is essential in understanding the diffusion and impact of techniques to improve maize on the farm. Although the conclusions economists draw are more sensitive to some simplifying assumptions than others, perhaps these warrant closer attention in research related to adoption of on-farm strategies for crop improvement and crop diversity.

The seed cycles and lifecycles also demonstrate that the unit of seed conservation is larger than the household unit of production and consumption. Certainly the nuclear and extended family are important sources of seed (especially for traditional white and black maize), both in the initial years of farming and over a farmer's cultivating life, but the role of the community, represented by friends and neighbors, is also significant. In the case of traditional white maize, friends and neighbors have provided almost one-fifth of the introductions, substitutions, and seed infusions for the traditional maize varieties grown by survey farmers over their years of farming.

The findings presented here conflict with the popular (as opposed to scientific) stereotype that, especially in centers of crop origin, each farm family retains and hands down its maize seed from generation to generation.[13] The economic implications are essentially that (1) the impact of introducing practices to enhance farmers' varieties is likely to be diffuse and difficult to observe, predict, or measure, and (2) in developing analytical models of farmer decision-making as it affects the diversity of genetic resources on the farm, the most appropriate unit of analysis for predicting the effects of some policy interventions is not likely to be the individual farmer or the individual farm household. Certainly a better understanding of the "social infrastructure" that shapes seed and information flows will be needed, since in the diffusion of innovations of this type, the seed system is based entirely on farmers and their interactions.

Our limited understanding of diffusion mechanisms also renders inconclusive our evidence regarding the prospects for the adoption and impact of improved seed selection practices

[13] This stereotype is well represented by a description in Franzen et al. (1996:20): "In many developing countries . . . smallholders produce, in the traditional cropping systems, their own seed by saving part of the harvest for sowing the next crop. In this way, the seed is handed down from generation to generation. . . ."

and the seed that results from those practices. Although use of the practices appears to have declined among the survey farmers, the survey farmers are few, and the extent to which other farmers have adopted the practices through the activities of survey farmers is not known. The PSSM is now doing more follow-up among farmers who had participated in the workshops to encourage them to continue with the practices and to identify particular problems imposed by the practices, such as time conflicts and competing demands for labor. Such subtle innovations are also vulnerable to abrupt seasonal disruptions, such as those caused by Hurricane Roxanne, or to social changes such as the recent land reform, as well as to genetic drift caused by the use of small populations and seed lots, which is characteristic of crop production in more marginal environments. One-third of the survey farmers who marked plants in the field in 1995 harvested nothing after the hurricane, yet hurricanes are not infrequent in the study area. The likelihood that farmers might adopt labor-intensive innovations is also diminished by current migration patterns and the high opportunity cost of labor in much of rural Mexico. In terms of time and human capital, the costs of developing the social relationships that support the diffusion of such innovations is often high, and it is borne by NGOs such as the Proyecto Sierra de Santa Marta and the participating farmers themselves.

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Appendix A

Additional Descriptive Tables

Appendix Table A1. Study site characteristics (Soteapan and Ocotal Chico, Veracruz, Mexico)

Characteristic	Soteapan	Ocotal Chico
Population	4,500	770
Elevation (masl)	120-560 masl	490-1,110 masl
Physical landscape	Low hillsides	High, middle, and low hillsides
Agricultural zone	Maize	Maize-coffee
Climate	Subhumid, warm	Humid, warm
Rainfall (mm/yr)	2,000	2,000-3,500
Average temperature (ºC)	24	22-24
Average *milpa*[a] size (ha/family)	1.12	1.88
Total area (ha)	3,600	1,354
Maize area (ha)	770	270

Source: Blanco (1995).
[a] A *milpa* is a maize field.

Appendix Table A2. Maize races and farmer's varieties grown by survey households

Maize category and variety	Maize race(s)
Modern maize	
VS-536	
VS-532	
V-530	
V-527	
Posta Sequía	Tuxpeño cross
La Puri	Tuxpeño, ETO, US hybrids
Texcoco	Tuxpeño, Cuban flints, ETO
PR-90	Tuxpeño, ETO, US hybrids
PR-91	Tuxpeño, ETO, US hybrids
Fondo 16	Tropical early maturing flints and dents, Tuxpeño
TS 6	Tuxpeño cross
H 507	Tuxpeño cross
TL 90 A (yellow)	Tuxpeño, Corn belt, Coastal Tropical Flints, yellow ETO
PR 90 A (yellow)	Tuxpeño, Caribbean and Brazilian Flints and Dents, yellow ETO
"Hibrido" Acayucan	
"Conasupo"	
"Blanco Mejorado"	
Improved Yellow	
Traditional white maize	
Poopmok	Olotillo x Tepecintle
T++chpoopmok	Olotillo x Tuxpeño
Tsuuspoopmok	Tuxpeño
Nuukn+'piñ-n+piñmok	Tuxpeño x Tepecintle
Saiimok	Tuxpeño
Tsabatsmok	Tuxpeño x Olotón
Juchiteco	Nal-tel
"Foodgrain from store"	
Pooppu'uchmok	Tuxpeño
Traditional yellow maize	
T++chpu'uchmok	Tepecintle x Tuxpeño
Tsbastspu'uchmok	Olotillo
Pu'uchmok	Tepecintle x Tuxpeño
Traditional black maize	
Y+kmok	Tepecintle x Tuxpeño
Chi'chy+kmok	Olotillo
Kaanmok	Olotillo x Tepecintle
Chikiñmok	Tuxpeño x Tepecintle

Note: Information about modern varieties from S. Taba and G. Srinivasan (pers. comm.), CIMMYT (1995), and Perales (1992). Information for traditional varieties from Herrera (1996).

Appendix Table A3. Farmer's names for modern maize varieties and CIMMYT germplasm identification

Farmer's name	Germplasm
La Posta Sequía	Across 8843
La Puri	Across S-9022
Texcoco	Across S-8929
PR-90	Population 22 TSR (white)
PR-91	Synthetic White TSR
Fondo 16	Pool 16 Syn 1, F2
TL 90 A (yellow)	Synthetic Yellow TSR
PR 90 A (yellow)	Population 28 TSR (white)

Appendix Table A4. Number of maize varieties planted by survey households, Soteapan and Ocotal Chico, 1994-96

	Wet season				Dry season			Cumulative, all seasons
	1994	1995	1996	Average	1994	1995	Average	
Average number								
All categories	4.75	4.19	3.88	4.27	1.13	1.83	1.48	6.00
Modern whites and yellows	2.13	1.75	1.25	1.71	1.00	1.33	1.17	2.81
Traditional whites	1.31	1.19	1.31	1.27	0.06	0.50	0.28	1.63
Yellows	0.50	0.44	0.38	0.44	0.06	0.00	0.03	0.50
Blacks	0.88	0.88	1.00	0.92	0.00	0.00	0.00	1.13
Total number								
All categories	25	25	20	24	9	9	9	30
Modern whites and yellows	11	12	9	11	7	7	7	13
Traditional whites	8	7	6	7	1	2	1	8
Yellows	3	3	3	3	1	0	1	6
Blacks	3	3	2	3	0	0	0	3

Appendix Table A5. Maize area planted, by category, average for wet season, Soteapan and Ocotal Chico, 1994-96

Category of maize	Mean ha per household	Mean percent of household maize area	Total maize area in survey (ha)	Percent of total maize area in survey
All categories	..	..	35.58	100
Modern white maize	0.52	22	7.84	22
Traditional white maize	1.09	54	17.27	49
Traditional yellow maize	0.85	33	7.21	20
Traditional black maize	0.20	9	3.26	9

Note: Areas measured by combination of pacing and farmers' estimates.

Appendix Table A6. Maize area planted, by category, average for dry season, Soteapan and Ocotal Chico, 1994-95

Category of maize	Mean ha per household	Mean percent of household maize area	Total maize area in survey (ha)	Percent of total maize area in survey
All categories	..	..	6.94	100
Modern white maize	0.34	52	5.05	73
Traditional white maize	0.30	26	0.89	13
Traditional yellow maize	1.00	50	1.00	14
Traditional black maize	..	..	..	0

Note: Area measured by combination of pacing and farmers' estimates.

Appendix Table A7. Percent of total planted area, by ancestry of variety, Soteapan and Ocotal Chico, 1994-96

Maize category and ancestry	Average, wet season	Average, dry season	Cumulative, all seasons
All categories			
Tuxpeño	9	5	8
Tuxpeño mixture	78	95	81
Tepecintle mixture	36	11	33
Olotillo	4	0	4
Olotillo mixture	20	13	18
Olotón mixture	13	0	12
Nal Tel	0	0	0
Modern white maize			
Tuxpeño mixture	23	71	29
Traditional white maize			
Tuxpeño	9	5	8
Tuxpeño mixture	31	13	29
Tepecintle mixture	12	0	10
Olotillo mixture	20	13	18
Olotón mixture	13	0	12
Nal Tel	0	0	0
Traditional yellow maize			
Tuxpeño mixture	18	11	18
Tepecintle mixture	18	11	18
Olotillo	1	0	0
Traditional black maize			
Tuxpeño mixture	5	0	5
Tepecintle mixture	5	0	5
Olotillo	3	0	3
Olotillo mixture	0	0	0

Note: Racial classification of varieties from Herrera (1996) and S. Taba, CIMMYT (pers. comm.). Base area measured for varieties by combination of pacing and farmers' estimates. "Mixture" refers to a racial mixture of the race reported and another race.

Appendix Table A8. Percent of farmers growing and total area planted to introduced varieties, Soteapan and Ocotal Chico, 1994-96

Variety	Wet season, 1994	Dry season, 1994	Wet season, 1995	Dry season, 1995	Wet season, 1996
	Percent of farmers growing				
VS-536	31	19	19	6	13
V-530	31	6	13	6	19
Posta Sequía	31	13	19	6	19
La Puri	31	25	31	6	25
Texcoco	31	25	25	6	19
Fondo 16	13	6	6	0	0
TS 6	13	0	19	0	13
PR-90	..	..	6	0	6
PR-91	..	..	0	6	0
TL 90 A	..	..	6	0	6
PR 90 A	..	..	6	0	13
	Total area planted (ha)				
VS-536	2.6	1.9	1.3	0.9	1.7
V-530	1.5	0.8	2.2	0.1	1.7
Posta Sequía	0.8	0.3	0.7	0.5	0.6
La Puri	0.6	1.4	0.8	0.5	0.5
Texcoco	0.5	2.3	2.7	0.5	0.3
Fondo 16	0.4	0.1	0.0	0.0	0.0
TS 6	0.2	0.2	1.2	0.0	2.1
PR-90	..	..	0.1	0.0	0.1
PR-91	..	..	0.0	0.1	0.0
TL 90 A	..	..	0.1	0.0	0.3
PR 90 A	..	..	0.3	0.0	0.4

Note: PR-90, PR-91, TL 90 A, and PR 90 A were introduced in the wet season, 1995. Area measured by a combination of pacing and farmers' estimates.

Appendix Table A9. Maize area planted, by category and variety, average for wet season, Soteapan and Ocotal Chico, 1994-96

Maize category and variety	Mean ha per household	Mean percent of household maize area	Total area in survey (ha)	Percent of total maize area in survey	Percent of farmers growing
All categories	..	..	35.58	100	100
Modern white maize	0.52	22	7.84	22	88
VS-536	0.37	15	1.85	5	21
VS-532	0.13	4	0.13	0	2
V-530	0.36	18	1.79	5	21
V-527	0.08	3	0.08	0	4
Posta Sequía	0.12	5	0.70	2	23
La Puri	0.11	6	0.63	2	29
Texcoco	0.19	8	1.17	3	25
PR-90	0.02	1	0.02	0	4
Fondo 16	0.08	3	0.16	0	6
PR 91	..	..	..	..	0
TS 6	0.39	10	1.16	3	15
Improved Yellow	0.08	5	0.08	0	2
TL 90 A	0.10	7	0.10	0	4
PR 90 A	0.11	4	0.23	1	6
"Hibrido" Acayucan	0.06	2	0.06	0	2
"Conasupo"	0.07	4	0.15	0	4
Traditional white maize	1.09	54	17.27	49	88
Poopmok	0.57	17	2.29	6	17
T++chpoopmok	0.76	43	4.58	13	33
Tsuuspoopmok	0.40	31	1.21	3	17
Nuukn+'piñ-n+piñmok	0.92	47	1.83	5	13
Tsbatsmok	0.67	28	4.67	13	31
Juchiteco	0.06	6	0.06	0	4
"Foodgrain from store"	0.46	14	0.46	1	2
Pooppu'uchmok	0.72	39	2.17	6	19
Traditional yellow maize	0.85	33	7.21	20	48
T++chpu'uchmok	0.82	33	2.45	7	19
Tsbastspu'uchmok	0.20	10	0.20	1	6
Pu'uchmok	1.04	40	4.15	12	19
Traditional black maize	0.20	9	3.26	9	85
Y+kmok	0.20	8	1.97	6	50
Chi'chy+kmok	0.20	9	1.23	3	33
Kaanmok	0.03	3	0.06	0	4

Appendix Table A10. Maize area planted, by category and variety, average for dry season, Soteapan and Ocotal Chico,1994-95

Maize category and variety	Mean ha per household	Mean percent of household maize area	Total area in survey (ha)	Percent of total maize area in survey	Percent of farmers growing
All categories	..	..	6.94	100	56
Modern white maize	0.34	52	5.05	73	53
VS-536	0.36	34	1.42	20	13
VS-532	..	..	..	..	0
V-530	0.23	38	0.47	7	6
V-527	..	..	..	..	0
Posta Sequía	0.14	23	0.41	6	9
La Puri	0.19	42	0.94	14	19
Texcoco	0.35	44	1.41	20	16
PR-90	..	.	..	..	0
Fondo 16	0.03	5	0.03	0	3
PR 91	0.03	2	0.03	..	3
TS 6	0.09	50	0.09	1	3
Improved Yellow	..	..	..	..	0
TL 90 A	..	..	..	..	0
PR 90 A	..	..	..	..	0
“Hibrido” Acayucan	..	..	..	..	0
“Conasupo”	0.25	50	0.25	..	3
Traditional white maize	0.30	26	0.89	13	9
Poopmok	..	..	..	..	0
Tɨɨchpoopmok	0.32	32	0.64	9	9
Tsuuspoopmok	..	..	..	..	0
Nuuknɨ’piñ-nɨpiñmok	..	..	..	..	0
Tsbatsmok	0.25	13	0.25	..	3
Juchiteco	..	..	..	..	0
“Foodgrain from store”	..	..	..	..	0
Pooppu’uchmok	..	..	..	..	0
Traditional yellow maize	1.00	50	1.00	14	3
Tɨɨchpu’uchmok	..	..	..	..	0
Tsbastspu’uchmok	..	..	..	..	0
Pu’uchmok	1.00	50	1.00	14	3
Traditional black maize	..	..	..	..	0
Yɨkmok	..	..	..	..	0
Chi’chyɨkmok	..	..	..	..	0
Kaanmok	..	..	..	..	0

Appendix B

Production and Consumption Characteristics of Varieties Grown by Survey Farmers

Production Characteristics

Among survey farmers, the primary production concerns for the wet season maize crop are yield, resistance to insects and to rot in the field, plant height, days to maturity, and resistance to insects in storage. The dry season brings some similar and some different concerns: resistance to insects remains important, as does early maturity, but the need for drought tolerance is specific to the dry season. The categories of maize are distinct with respect to these production characteristics. Differences also appear among varieties, but in this small sample, the patterns are most evident among categories of maize.

The modern maize varieties distributed through the PSSM have several advantages. First, although there is variation among them, they generally mature rapidly and are short in stature, which enables them to escape or resist the strong northern winds and hurricanes which blow through the area. The materials from CIMMYT's drought-stress program tolerate dry spells, and all varieties yield as well as or better than traditional varieties. The major disadvantage of the modern varieties is their thinner husk and poorer husk cover, which can result in rot and insect damage during field and home storage.[14] Traditional white maize varieties tend to mature later and grow taller, but they are highly resistant to insects and rot. Black maize varieties mature more rapidly than the other categories of local maize but share their resistance to insects and rot. Yellow maize varieties (either traditional or modern), according to the farmers surveyed, are best suited to growing in the upland slopes; their relatively short growing period (compared to traditional white maize) and heavy, crystalline grain make them attractive to producers because of resistance to wind and insects, as well as good yield. The literature (Perales 1992; Stuart 1978) and farmers' statements offer no explanation other than "yellow maize grows well on the mountain"; among the survey farmers, only those in Ocotal Chico grew yellow maize.

Consumption Characteristics

In the two survey communities, farmers almost unanimously reported their uses of maize in terms of only five major products. Ranked in terms of their economic importance to the household, survey households use their maize for: (1) *tortillas*, (2) grain sales, (3) animal feed, and (4) specialty food items (*tamales* and *pozol*).[15] Most household maize production is destined for the home preparation of *tortillas*, which may be either consumed by the household, traded, or very occasionally sold. Cash sales of maize are generally in the form of shelled grain sold by weight. Animal feed typically consists of ears that are less desirable

[14] Farmers in the survey area "double" their maize, or store it on the stalk, with the stalk bent and ear hanging downwards, for a long period after maturity.

[15] As noted previously, in these communities, *pozol* refers to a lightly fermented drink.

for other purposes. Specialty food items are consumed on particular occasions throughout the year, and they may also be traded or occasionally sold. When a market for specialty products exists and they can be sold, they may be of relatively high value per unit, although this issue was not explored in the survey. Other secondary uses of maize, such as using cobs for fuel or husks for compost, were mentioned but not accorded any particular importance by farmers.

Tortillas are the most economically important use of maize in survey households and all categories of maize (white, yellow, black; modern or traditional) are used to prepare them. Frequently, household members noted a preference for white maize because it makes "soft," "very white," and "smooth" *tortillas*. Many farmers prefer their traditional maize varieties to the modern varieties for *tortillas*, but most are willing to use either type. Several farmers mentioned a particular variety (traditional yellow or modern white) as a good *tortilla*-making variety because it was "heavy" and each kernel gave more flour. In some communities in the Sierra, and more so in Soteapan than in Ocotal Chico, yellow *tortillas* are not desirable: yellow maize is seen as food for animals and not for humans. In other communities, yellow *tortillas* are as desirable as white ones. A preference for black *tortillas* appears to vary among individuals within a community: some prefer them, and others avoid them.

Some categories of maize are more specifically suited to certain uses. For example, traditional black maize is grown especially for the production of *pozol*. Households clearly prefer black maize as the basis of *pozol*, and there is some disagreement about the extent to which other categories of maize can also be used. Producing *tamales* is less important than making *pozol*, and any type of maize appears to be suitable, although maize ears in the milky stage of development (*elotes*) are preferred.

For cash grain sales through official markets or to market intermediaries, white varieties are the most suitable. Farmers typically consider modern white varieties to have heavier weight per unit of volume than traditional white varieties, and whiter grain, and thus they are preferred for cash sale. Modern white maize is usually sold soon after the harvest to avoid storage problems with these relatively thin-husked varieties. In the informal trade and barter markets, however, sales are more commonly made by volume rather than by weight, and grain of any color may be sold.

All categories of maize are also considered suitable for animal feed except for black maize; several producers reported that farm animals simply will not eat it. In many cases, traditional yellow maize is preferred as feed because the grain of these varieties seems to be "heavier" and the animals "get full faster." In general, spoiled maize grain (usually damaged by insects or rot in storage) is fed to household animals.

Since such a large proportion of the maize produced in these communities is processed by farm women for household consumption, we hypothesized that differences in processing characteristics would be important to them. Each farm household was asked to rank all the maize varieties they grew by the processing characteristics they identified in informal interviews. The responses again reveal stronger comparisons among categories than between varieties.

The maize processing characteristics recorded below are related to the daily production of *nixtamal* by rural women. To prepare *nixtamal*, the maize is husked, shelled, and boiled with lime (calcium carbonate) to rehydrate the kernels, remove the pericarp (*cascara*), and soften the grain for grinding. After cooking, the mixture of water, lime, and maize grain is washed and then ground by hand or commercial mill into *masa*, the dough from which *tortillas* and other maize dishes are prepared.

Among survey households, there is a general consensus that modern varieties have fewer husks and that their husks are the least tightly closed (Table B1). These characteristics make modern varieties easiest to husk but contribute to significant losses from insects and other pests while the maize is drying in the field or stored in the house. Similarly, the pericarp around the kernel is thinnest in modern varieties. This means that less lime is needed to process modern varieties or that the varieties require less time in the water with lime (complementary characteristics). It also means that it is easiest to wash away the pericarp of modern varieties compared to others.

Traditional white and black maize varieties, with their long, thin cobs and nearly rectangular, tooth-shaped kernels, are the easiest to shell. Modern white varieties are somewhat more difficult to shell, and yellow varieties are often so difficult to shell that two farmers cited this as their reason for abandoning their traditional yellow varieties. Ease of grinding is related to the hardness of the grain, although many farmers felt that after processing all maize types were equally easy to grind. Those who saw differences reported that traditional white maize is the easiest to grind and traditional yellow maize is the most difficult. The ranking of categories appears similar for fermentation of the *masa*, the ease of grinding, and the softness of *tortillas*: traditional white maize ferments the fastest, creates the smoothest *tortillas* (which stay softest the longest), and is the easiest to grind. Traditional black maize, on the other hand, is the slowest to ferment, a characteristic which makes it desirable for making *pozol*.

Appendix Table B1. Processing characteristics of categories of maize

	Rank of categories of maize			
Characteristic	**Highest**			**Lowest**
Husk quantity/cover	Traditional white	Traditional yellow	Traditional black	Modern
Ease of shelling	Traditional white	Traditional black	Modern	Traditional yellow
Pericarp thinness	Modern	Traditional white	Traditional yellow	Traditional black
Ease of washing	Modern	Traditional white	Traditional black	Traditional yellow
Ease of grinding	Traditional white	Traditional black	Modern	Traditional yellow
Softness of *tortilla*	Traditional white	Modern	Traditional black	Traditional yellow
Masa ferments (or rots) quickly	Traditional white	Modern	Traditional yellow	Traditional black

Note: Maize is ground by hand mill or using a traditional mortar (*metate*). "Modern" refers to modern white or modern yellow maize. *Masa* is the dough from which *tortillas* are made.

Appendix C

Lifecycles of Farmers and Their Maize Seed

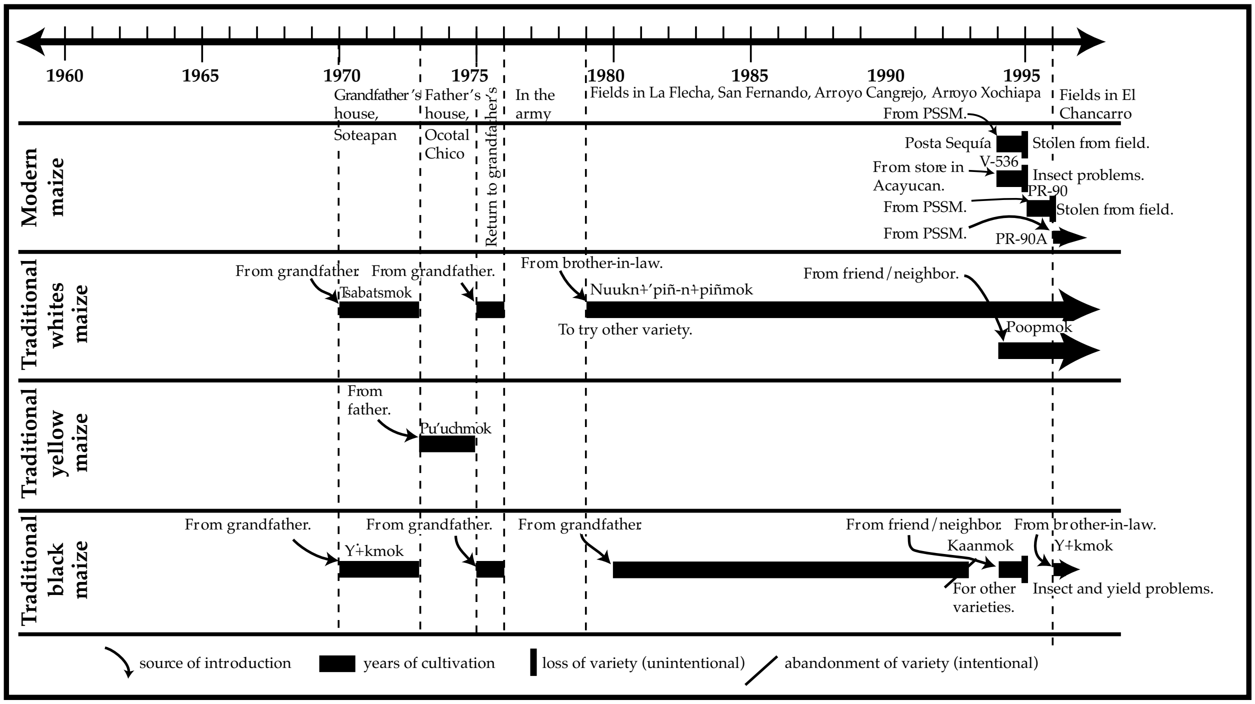

Figure C1. Lifecycle of farmer and maize seed, Soteapan 1.

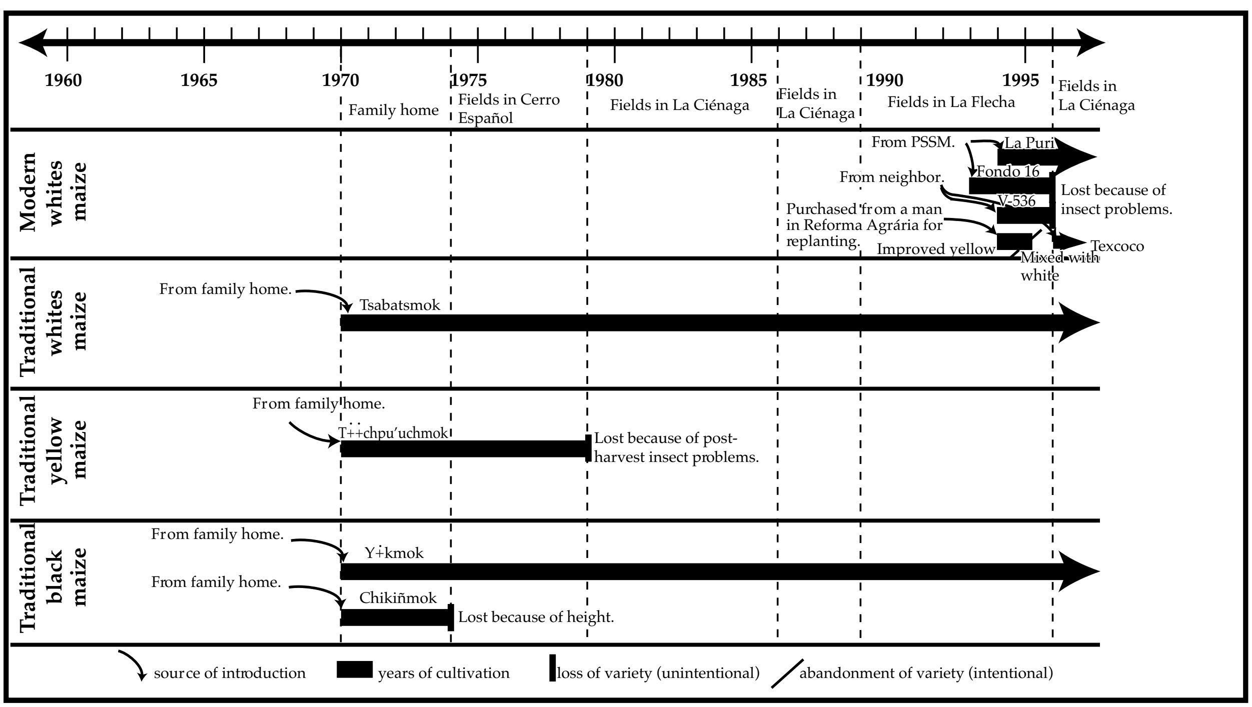

Figure C2. Lifecycle of farmer and maize seed, Soteapan 2.

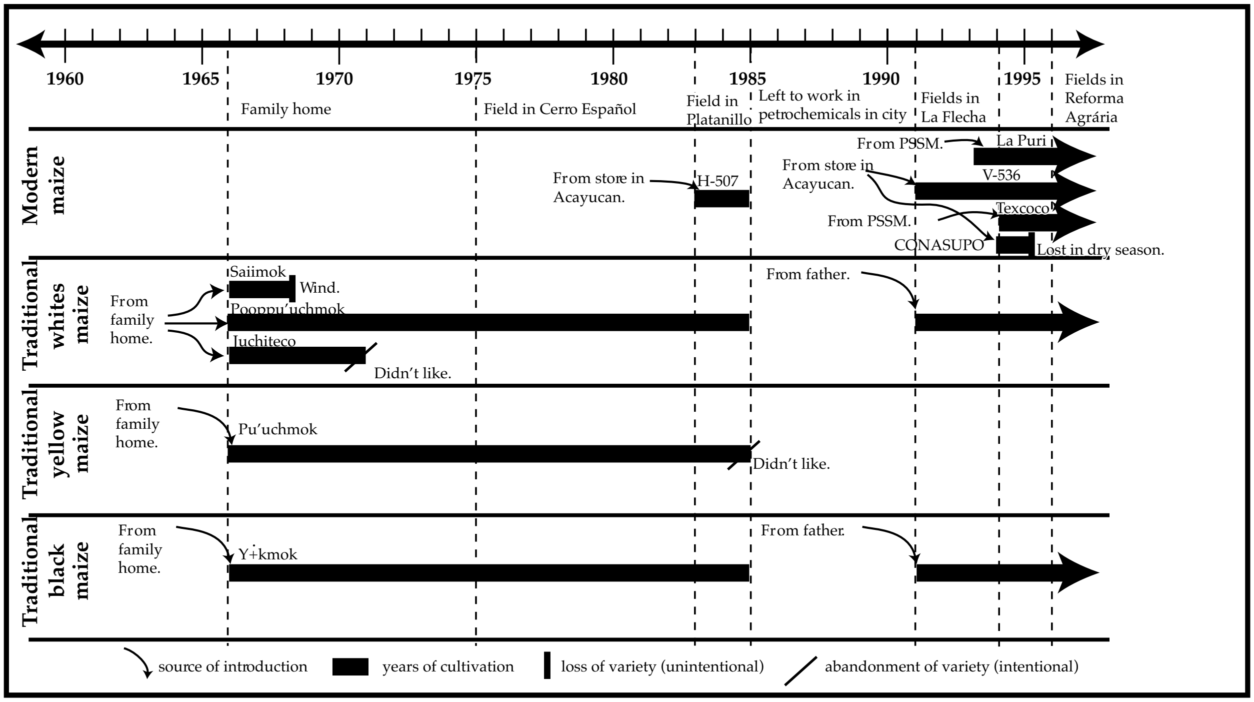

Figure C3. Lifecycle of farmer and maize seed, Soteapan 4.

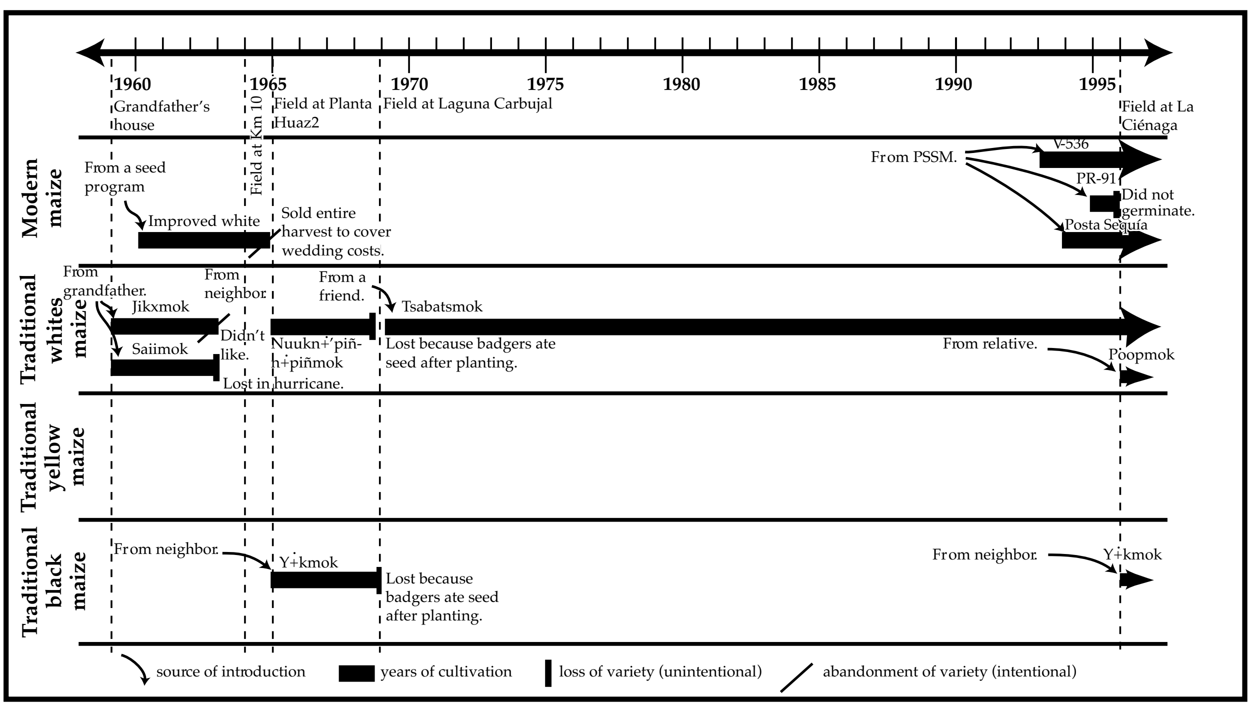

Figure C4. Lifecycle of farmer and maize seed, Soteapan 5.

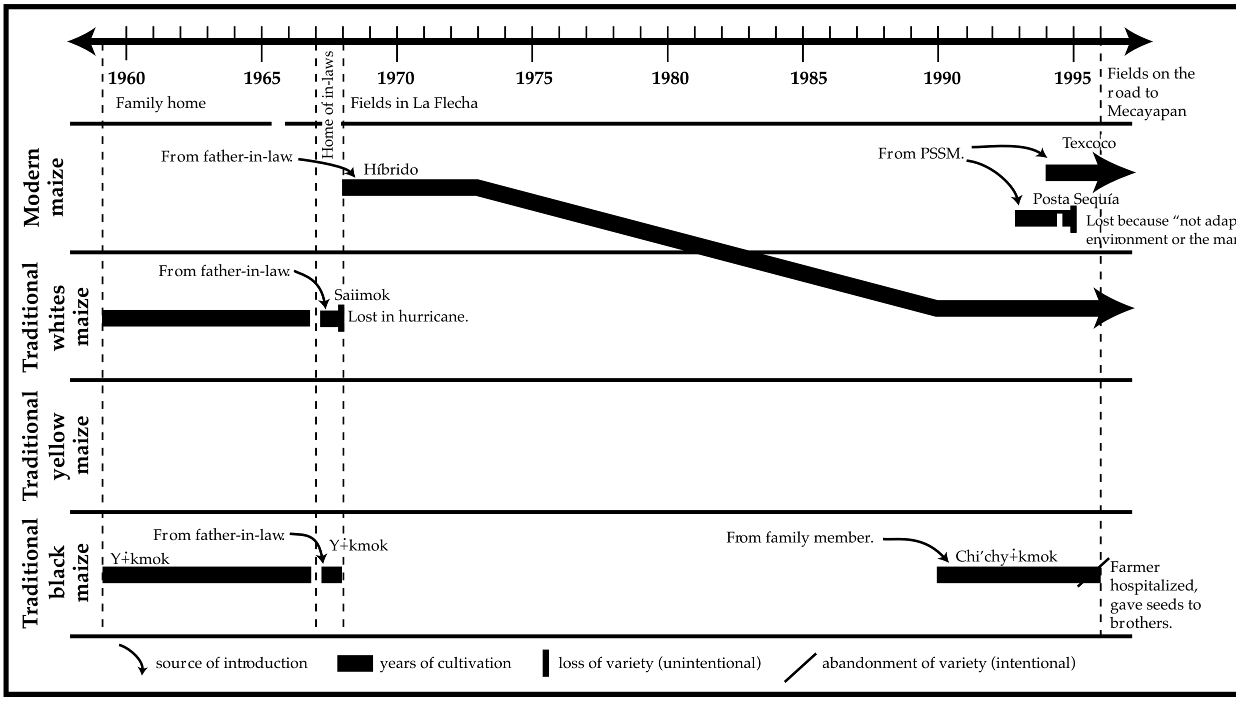

Figure C5. Lifecycle of farmer and maize seed, Soteapan 6.

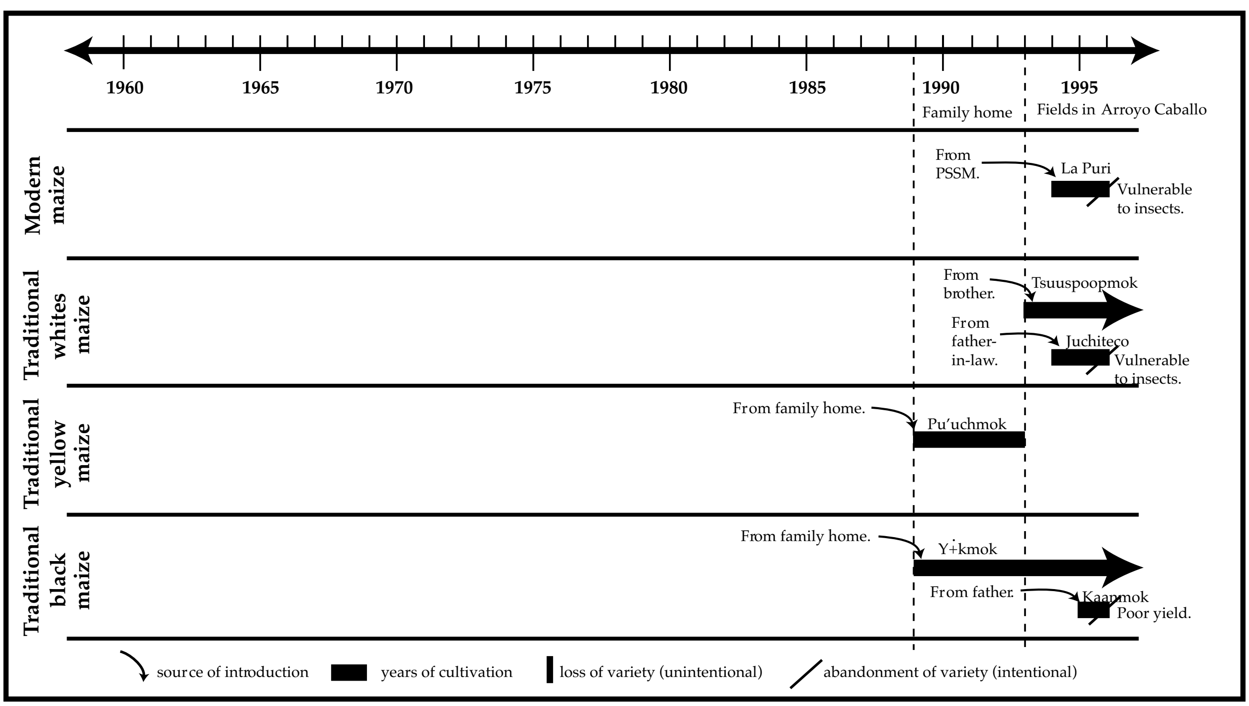

Figure C6. Lifecycle of farmer and maize seed, Ocotal Chico 1.

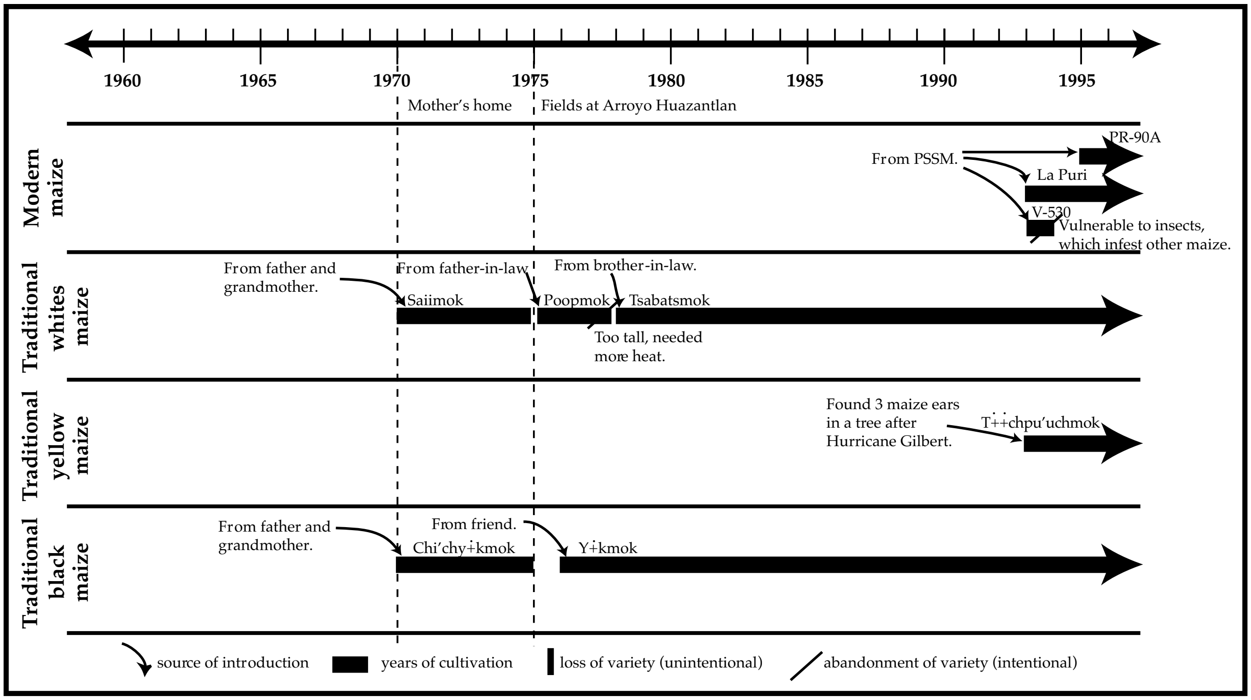

Figure C7. Lifecycle of farmer and maize seed, Ocotal Chico 2.

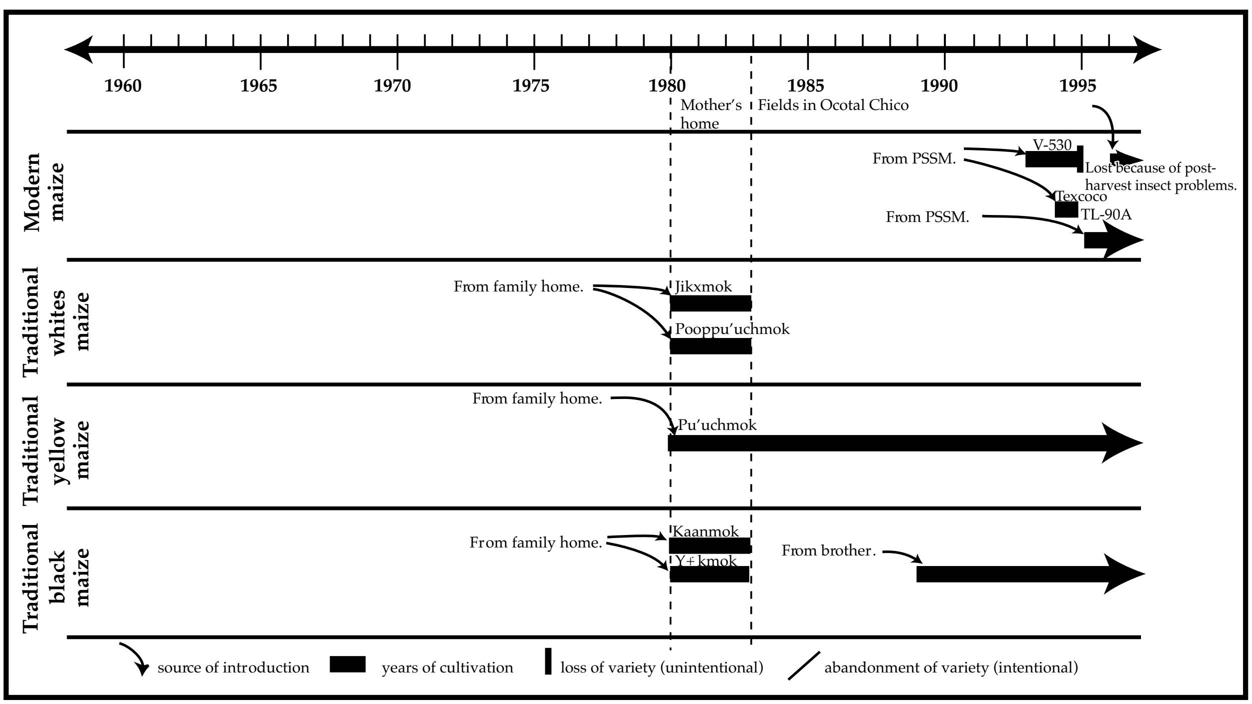

Figure C8. Lifecycle of farmer and maize seed, Ocotal Chico 3.

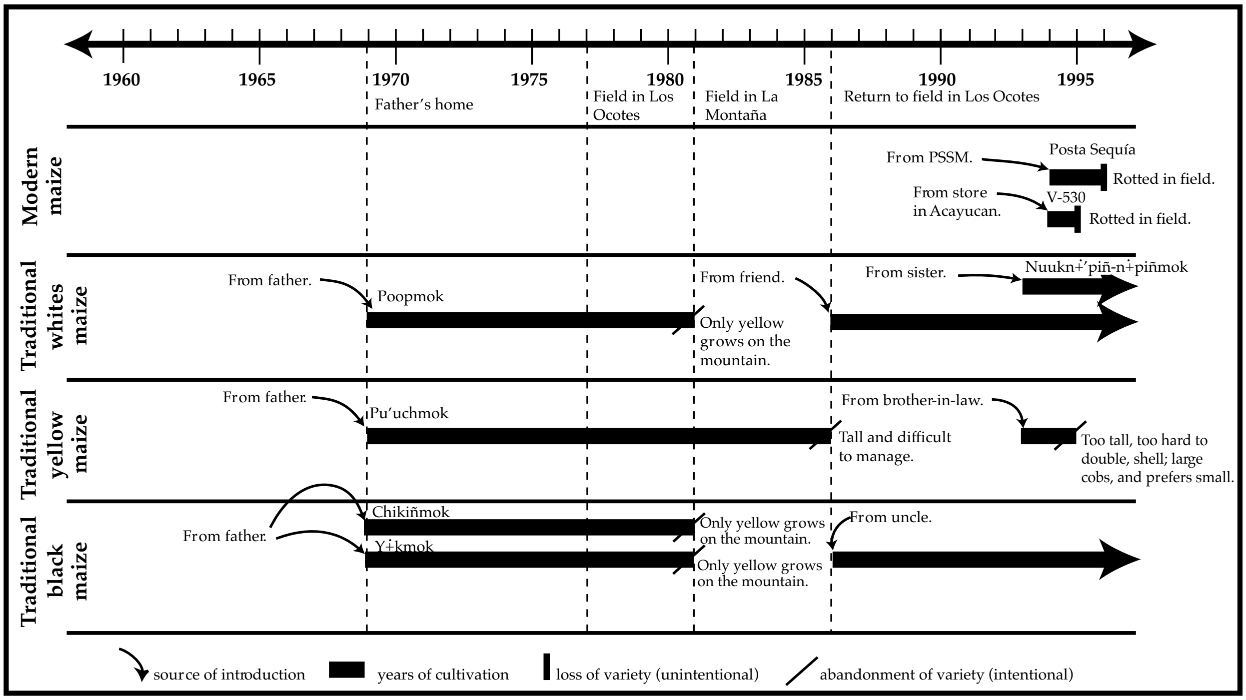

Figure C9. Lifecycle of farmer and maize seed, Ocotal Chico 4.

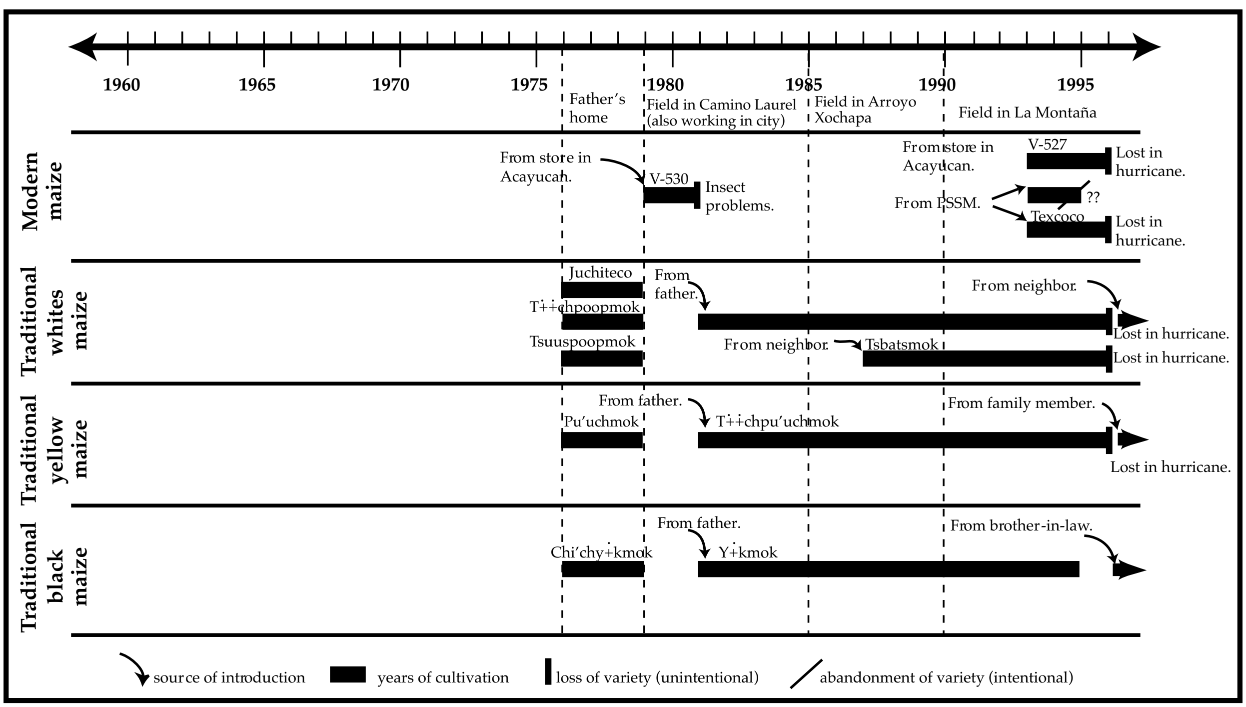

Figure C10. Lifecycle of farmer and maize seed, Ocotal Chico 5.

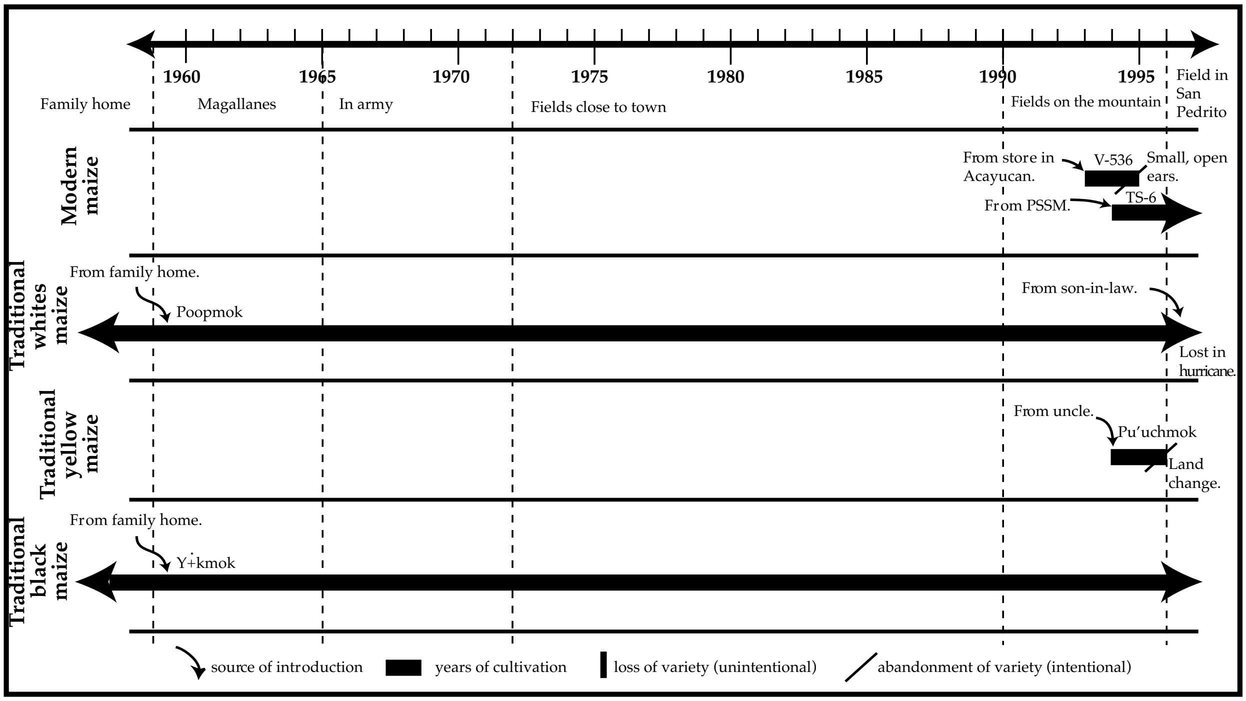

Figure C11. Lifecycle of farmer and maize seed, Ocotal Chico 6.

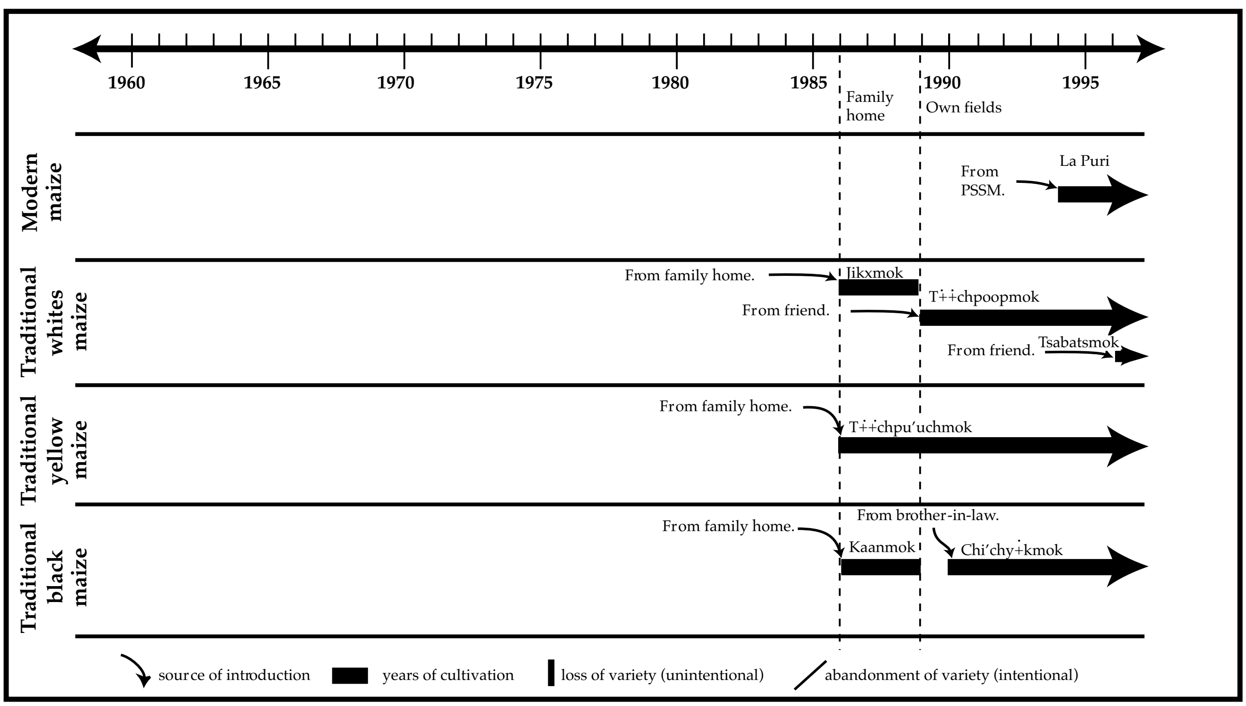

Figure C12. Lifecycle of farmer and maize seed, Ocotal Chico 8.

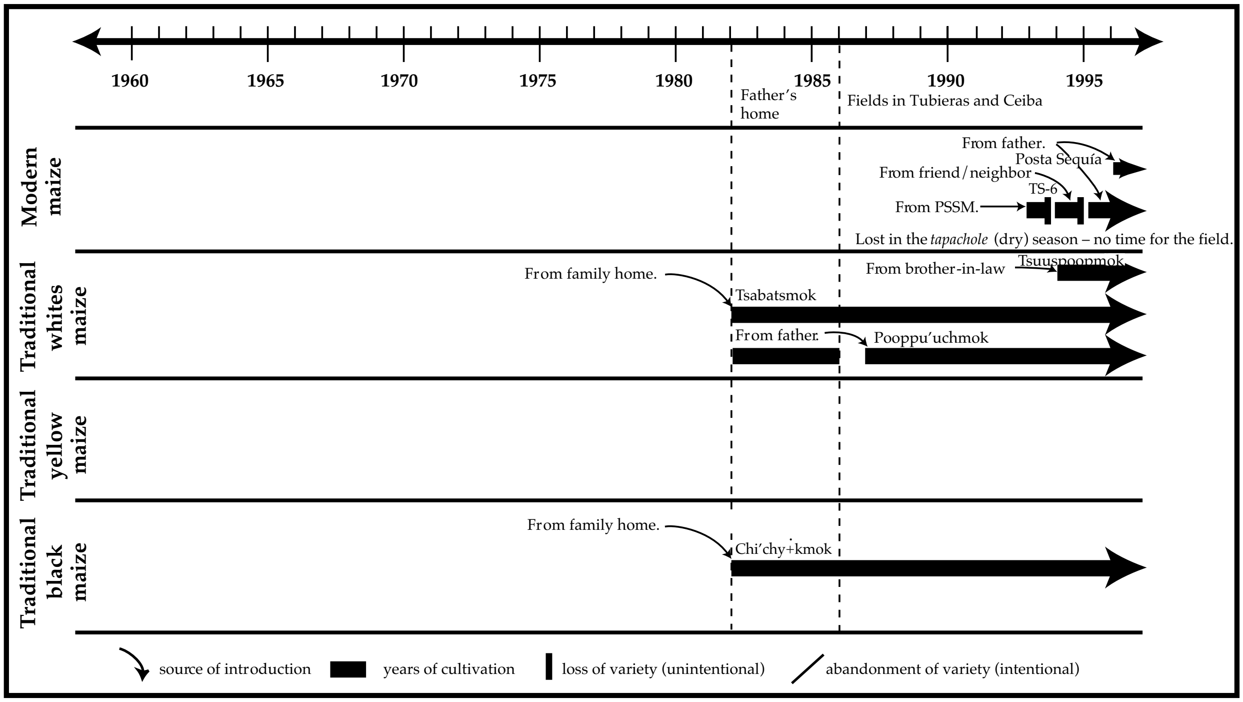

Figure C13. Lifecycle of farmer and maize seed, Ocotal Chico 9.

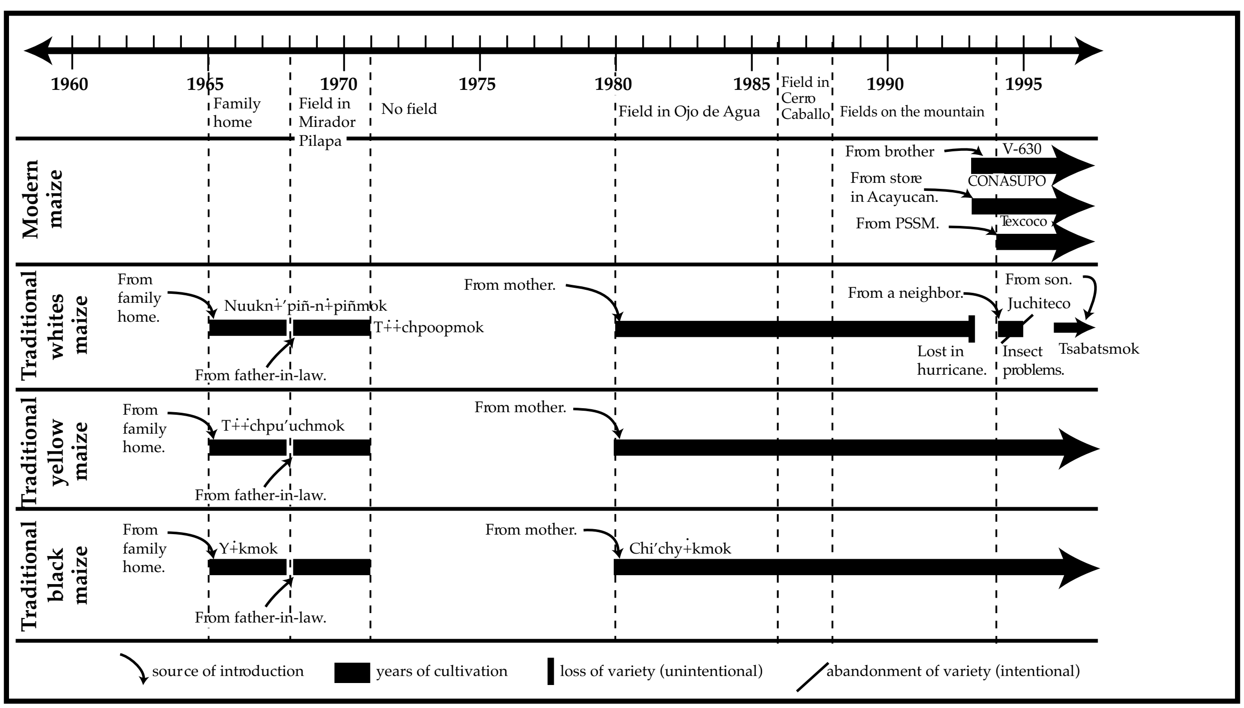

Figure C14. Lifecycle of farmer and maize seed, Ocotal Chico 10.

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International Maize and Wheat Improvement Center
Centro Internacional de Mejoramiento de Maíz y Trigo
Lisboa 27, Apartado Postal 6-641, 06600 México, D.F., México