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THE IMPACT OF IMPROVED MAIZE GERMPLASM ON POVERTY ALLEVIATION: THE CASE OF TUXPEÑO-DERIVED MATERIAL IN MEXICO

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Abstract

This study documents how poor small-scale farmers in lowland tropical Mexico use improved maize germplasm and how this contributes to their well-being. It does this by assessing both the direct adoption of improved varieties and examining the process of their "creolization." By exposing improved varieties to their conditions and management, continually selecting seed of these varieties for replanting, and in some cases promoting their hybridization with landraces, either by design or by accident, farmers produce what they recognize as "creolized" varieties. Our key hypothesis is that poor farmers benefit from improved germplasm through creolization. Creolization provides farmers with new options, as they deliberately modify an improved technology generated by the formal research system to suit their own circumstances and needs. Different methodologies such as participatory methods, ethnography, household case studies, a household sample survey, and a collection and agronomic evaluation of maize samples were used. This study was carried out in two regions: the coast of Oaxaca and the Frailesca in the states of Oaxaca and Chiapas, two of the poorest in Mexico. While one study area is subsistence-oriented and the other commercial, in both, extreme poverty is pervasive. Maize continues to play a key role in the livelihoods of the poor in both study areas. The results show that different types of maize germplasm are planted. Modern varieties, and particularly creolized varieties, are planted in both study areas. The impacts of the use of improved maize germplasm are defined and analyzed in terms of the extent to which they supply farmers with traits they consider important and the trade-offs they entail. The results support the hypothesis, and the implications of the findings are discussed.

Keywords: poverty, agricultural research, sustainable livelihoods, vulnerability, agricultural extension, maize germplasm, creolization, Mexico

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1. Introduction

Improved maize varieties have been available in Mexico for more than 40 years but diffusion of these varieties has been limited. Despite repeated government campaigns to encourage use of improved seed, today only about one-fourth of the total maize area in the country is planted to improved varieties; most of this area is located in the commercial production zones of central and northwestern Mexico (Morris and Lopez-Pereira 1999). The relatively low rate of diffusion may provide a misleading impression, however, of the true impacts of improved germplasm on the welfare of rural households. A growing body of evidence suggests that many small-scale subsistence-oriented farmers have taken up improved varieties and planted them alongside local varieties. Through exposing improved varieties to their conditions and management, continually selecting seed of these varieties for replanting, and in some cases promoting their hybridization with landraces, either by design or by accident, farmers produce what they recognize as "creolized" varieties (*variedades acriolladas*) (Bellon and Risopoulos 2001).[1]

Conventional germplasm impact studies usually focus on areas planted to improved varieties. To date, few attempts have been made to document the use of creolized varieties. The lack of studies in this area constitutes a major gap: if creolization is ignored, the benefits generated by formal plant breeding programs may be significantly underestimated. This study attempts to document how poor farmers in lowland tropical Mexico use improved maize germplasm both directly (by adopting improved varieties) and indirectly (by creating creolized varieties). In addition, the study attempts to determine how the use of improved germplasm contributes to the well-being of poor small-scale farmers. Our key hypothesis is that poor farmers benefit from improved germplasm through creolization. The reason is that while improved varieties provide desirable traits not found in landraces, they also may lack traits found in landraces. As a distinguishing feature of landraces is their local adaptation, choosing between them and

[1] Wood and Lenné (1997) use the term "rustication" to describe the process through which materials produced by formal plant breeding programs change in the hands of farmers.

improved varieties presents trade-offs for farmers. Creolization lessens these trade-offs by adapting improved varieties to local conditions most relevant to these farmers. Creolized varieties provide traits or a combination of traits not supplied by landraces, while they entail fewer trade-offs than improved varieties. Creolization thus provides farmers with new options, as they deliberately modify an improved technology generated by the formal research system to suit local circumstances and needs. The study involves three separate but related activities: (1) measuring and explaining diffusion, local adaptation, and use of improved maize germplasm; (2) understanding how adaptation choices are linked to livelihood strategies and vulnerability context of rural households; and (3) assessing the impacts of adoption on the welfare of rural households. The specific focus of the study is the Tuxpeño germplasm complex. Tuxpeño is one of approximately 250 maize landraces found in the New World. This maize race has been subjected to intensive breeding efforts, first by the Rockefeller Foundation and the Mexican Ministry of Agriculture and later by their successors, CIMMYT and Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias (INIFAP), respectively. Tuxpeño germplasm has been used by these and other institutions, including private companies, to breed both hybrids and improved open-pollinated varieties.[2] This study was carried out in two regions: the coast of Oaxaca and the Frailesca in Chiapas. Oaxaca and Chiapas are two of the poorest states in Mexico.

The rest of the paper is divided into six sections. Section 2 describes the methods used in the study, particularly how the study was designed and conducted. Section 3 describes the two study areas, especially how they contrast in terms of development, degree of commercialization, and maize production. Section 4 defines the different types of maize germplasm studied and presents a history of their diffusion, including the origin

[2] There are two types of improved maize varieties: hybrids and open-pollinated varieties (OPVs). A hybrid can be defined as the combination of two inbred lines—exhibiting hybrid vigor—while improved OPVs are populations that have been subject to selection by breeders. If seed from a hybrid is replanted it will not be as productive as the original seed. Therefore, seed has to be purchased every season to maintain high productivity. On the other hand, seed from an OPV can be replanted without major drops in yield—usually up to three years. Hence OPV seed needs to be purchased once every three years.

of seed used and its management. It shows that farmers plant many different types of maize germplasm, with different origins and management histories that affect their current choices. Section 5 presents results of adoption of different germplasm types. It shows that adaptation, management intensity, cultural factors, risk, and integration into the regional and national economies play a key role in the adoption process, although the process is dissimilar for each germplasm type. Section 6 presents the impacts of the different germplasm types on farmers' well-being. The impacts are defined and analyzed in terms of the extent to which different types of germplasm supply farmers with traits they consider important and the trade-offs they entail. It shows that farmers in both study areas—both male and female—value multiple traits in their maize, that the different maize types provide these traits in different degrees, that this in turn translates into trade-offs among these maize types. There is no "perfect" maize type; nevertheless, as hypothesized, creolized varieties present a compromise between improved varieties and landraces for certain traits. Section 7 presents conclusions.

2. Methods

The overall design of the research of this mixed-methods study used the sustainable livelihoods framework as a guide, sharing a common conceptual framework with four other studies of the impact of agricultural research on poverty (Adato and Meinzen-Dick 2003). Twelve communities were selected in areas of medium, high, and very-high marginality, defined according to an index used by the Mexican government to target its poverty alleviation program PROGRESA (CONAPO-PROGRESA 2000). They also included communities with indigenous populations. Site selection further considered agroecological conditions, since the study focused on a tropical maize germplasm, and government programs to diffuse seed of improved varieties.

The qualitative research began with two sets of focus group discussions. The first was on local perceptions of poverty, livelihood strategies, and vulnerability; the second was on perceptions of maize traits and how they respond to these conditions. These were

followed by household case studies conducted in four of the 12 communities. The case studies were carried out by anthropologists, who spent several months living in the villages and interacting with farmers in the household, field, markets, and other activities. Ten case studies were conducted per village, with households selected to roughly represent "extreme poor," "average poor," and "less poor" farmers. The quantitative research involved a representative sample survey of 325 farming households covering all 12 communities. Finally, the project included a collection of all maize types grown in the communities and an agronomic evaluation of maize samples.[3]

3. The Study Area

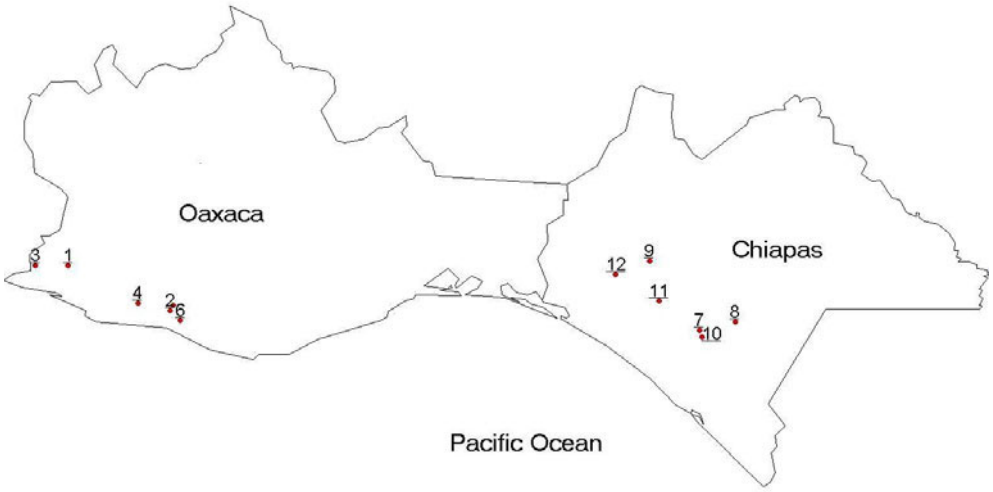
The 12 communities included in this study are located in two highly contrasting regions: the coast of Oaxaca and the Frailesca, Chiapas (see Figure 1). For simplicity these are referred to in the rest of the paper as Oaxaca and Chiapas. The communities were selected systematically so as to sample the range of marginality levels, levels of improved germplasm diffusion, and ethnicity present in both regions. We believe that these communities represent the range of conditions present in these two regions. It should be stressed however, that since we have adopted a case study approach, we consider that the results presented in this paper are valid only for the 12 communities studied.

Communities in Chiapas have better access to government-provided services and infrastructure, even for a similar marginality level than those in Oaxaca. Productive activities are more oriented to the market, and the region has received strong support from state and national governments, particularly for agricultural development. This region produces important maize surpluses that are exported to other parts of Mexico; however, agriculture is still dominated by small-scale farmers that produce both for the market and own consumption. There is an important dairy industry, and farmers can add

[3] For a complete description of the methodology see Bellon et al. 2003.

value to their maize by using it as animal feed. The use of inputs and improved seed has been promoted through several government projects throughout the years.

Figure 1—Map of the communities included in this study, Oaxaca and Chiapas



Coast of Oaxaca:
1. Santa Maria Cortijos
2. San Pedro Jicayan
3. Santiago Jocotepec
4. Santa María MagdalenaTiltepec*
5. Santos Reyes Nopala*
6. San Pedro Mixtepec

La Frailesca, Chiapas:
7. Libertad Melchor Ocampo
8. Primero de Mayo
9. Roblada Grande
10. Dolores Jaltenango*
11. Querétaro*
12. Rizo de Oro

* Communities included in the case studies

In contrast, Oaxaca has been more isolated and has not received much government support for agricultural development. The state imports substantial amounts of maize from other parts of Mexico and from outside. Although the coast has a better climate for maize and agricultural production than other regions of the state, it is not an important producer of this staple. Commercial agricultural activities are biased toward extensive cattle ranching and maize production toward home consumption. Development

has been more related to tourism, particularly in the southern part of the study area, where there are resorts such as Puerto Escondido, Puerto Angel, and Bahías de Huatulco.

As an example of these differences, Table 1 compares key characteristics related to population, farming, maize production, income sources, and poverty between the two study areas. There is a much larger population in Oaxaca than in Chiapas. However, the farming area is much smaller; hence, there is stronger population pressure on the land in Oaxaca. Farming households in Oaxaca produce maize mainly for self-consumption, with a low level of use of hired labor and fertilizers, and most do not sell or have to

Table 1—Comparison of key characteristics of the two study areas

	Oaxaca	Chiapas
Total farming population	21,471	10,507
Number of households	3,539	1,994
Households that only speak Spanish (percent)	34.5	94.3
Maize production		
Production objective (households)		
Self-consumption exclusively (percent)	82.6	2.9
Market and self-consumption (percent)	17	95.4
Agricultural land holdings (average/household in hectares)	1.9	5.3
Use of hired labor (percent)	27.1	60.5
Use of chemical fertilizers (percent)[a]	45.3	99.4
Average rate (kg N/hectare) [1]	52.9	202.6
Households that sell maize (percent)	27	98.8
Households that purchase maize (percent)	64.5	8.4
Animal holdings		
Households that who own cattle (percent)	36.4	27.4
Number of cattle/household (average)	10.9	8.5
Income sources		
Performance of off-farm labor	63.5	45
Performance of nonfarm farm labor	17.6	19.8
Temporal migration	16.7	14.1
Remittances	10.6	13.6
Poverty indicators		
Number of farming households		
Extreme poor	2,645	1,261
Poor	666	521
FTG poverty indices		
Headcount index	0.80	0.72
Poverty gap	0.34	0.27
Severity of poverty index	0.17	0.13

[a] These data are based on one plot per household.

purchase additional maize for consumption. Cattle ownership is not very high, although those who own cattle have a fair number of cattle. Many farmers work outside their farms as hired laborers, and other sources of income are not very common, with less than a fifth engaging in them. Farming households in Chiapas, on the other hand, mainly produce maize for the market, although they also consume what they produce, use a much higher level of hired labor and certainly of fertilizers (the average rate of use for those that use fertilizers is almost four times as high as in Oaxaca), and almost no farmer needs to purchase additional maize for consumption. Cattle ownership is lower than in Oaxaca, both in terms of number of households who own and the average number of heads owned. A much lower percentage of farmers work as farm hands compared to Oaxaca, although a similar proportion have other sources of income outside their own farm. The next section discusses the differences in poverty between the two study areas.

Poverty

Poverty is pervasive in both study areas, even in the more commercialized and developed Chiapas. Poverty rates were calculated with data on household consumption obtained from the survey. These data included both purchased and self-produced items to which local prices for similar goods and services were imputed.[4] Two poverty lines were constructed: extreme poverty and poverty.[5] Based on these lines, three groups were defined: the extreme poor (expenditure below the extreme poverty line), the poor (expenditure between the extreme poverty and the poverty line), and the nonpoor (expenditure above the poverty line).

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[4] Per capita expenditure was calculated and adjusted to adult equivalents with the weights used by Skoufias et al. (1999). Furthermore, household expenditure in Oaxaca was adjusted to make it equivalent to purchasing power in Chiapas, because prices for similar goods were higher in the former than in the latter.

[5] The poverty lines were developed according to the methodology of Sanginés et al. (2000). The extreme poverty line was defined as the expenditure necessary to purchase the COPLAMAR standard food basket plus 27 percent more for basic nonfood items (MX$415/capita month in 2001). The poverty line differed from the extreme poverty line in that it increased the amount of nonfood items to 125 percent of the cost of the food basket (MX$754.82/capita month in 2001).

Most farming households are under the extreme poverty line in Oaxaca and Chiapas, 74.7 and 63.2 percent, respectively. On a population basis, however, the rates of extreme poverty increased substantially. Table 1 shows that extreme poor farming households have on average more members than the others. This table presents the FTG poverty measures (Foster et al. 1984) using the extreme poverty line as reference. The headcount index, poverty gap, and severity of poverty index show that there are more poor in Oaxaca with a larger poverty gap and more extreme poverty than in Chiapas.

Poverty has multiple dimensions, and consumption is only one. The qualitative work provided important insights into other dimensions. Local indicators of poverty and wealth fall into several categories: material resources, culture, beliefs, and behavior. Resources are given the heaviest emphasis, with access to and uses of land being most significant; others include access to money, planting of other crops (e.g., coffee), performance of other activities besides agriculture, ownership of animals and implements, amount of family labor that can be mobilized, ability to speak Spanish, whether one receives remittances or not, and type of off-farm labor.

Another aspect of local perceptions of poverty is cultural: indigenous roots indicate poverty. Indigenous people live on the margins of the community with little land or money; illiteracy and lack of Spanish fluency keep people in poverty by limiting their ability to find work outside the area. Finally, poverty is also related to beliefs, practices, and behavior. Wealthier families are said to represent the best morals and practices: they are hard workers and frugal. They are also described as snobbish, untrusting, and stingy. Families of average wealth are described as hard workers, although they are held back by a lack of access to some vital resource. The poorest have great difficulties. They have no money and no one to help them. Additionally, they are perceived to hurt themselves by wasting money from government programs on vices, and to be perpetrators of domestic violence. Women cannot provide good homes since they have to work. Similarly, their children cannot study for lack of money. In some communities, religious affiliation seems to matter; in particular, evangelical Protestants are said to be wealthy because they are hard working and do not drink.

A number of factors related to agriculture and maize production make people vulnerable to falling into, or deeper into, poverty: These include the following:

1. *Population growth* that provokes land pressure.
2. *Resource pressures: cash* for investment in agriculture, "tired," hilly, and eroded land.
3. The *local economic system:* restricted access to markets, lack of stable wage work, little education, illiteracy, and monolinguism hinder employment prospects; falling coffee prices, low maize prices. The institutional environment surrounding maize markets in Chiapas reveals and exacerbates social differences. Warehouses require a minimum quantity and quality, which the poorest farmers cannot meet. They thus must sell it to intermediaries, better known as "coyotes." Coyotes are less demanding about quality and quantity, but they pay considerably less than the warehouses. Despite this coyotes, are seen as at least a necessary evil—they pay cash up front, pick up the maize, and do not charge for transportation. Coyotes also provide loans, and many farmers must go into debt in order to plant.
4. *Shocks:* Rapid *and* severe climatic, human, and animal health changes; delayed or excessive rainfall; and strong winds adversely affect agriculture. Pests and diseases affect larger animals.
5. *Seasonal changes*: Mainly, people run out of maize, and they have to buy seed and invest in their fields precisely when they have the least money or food. The poor must leave their fields to work elsewhere during the planting season, and as a consequence do not tend their fields, thus lowering yields. Colds and flu make work more difficult. Finally, the religious festival season requires the poor to harvest maize too early, before the ears are ready, and sell the grain before the price reaches its maximum as noted above.

Role of Maize in Farmers' Livelihoods

Households in these two study areas have diversified livelihoods: they grow several crops, keep different types of animals and participate in diverse off- and nonfarm-farm activities. The crops include, besides maize, beans, squash, fruit trees, coffee, tomatoes, red peppers, sesame seed, hibiscus, groundnuts, and cacao. All households grow maize, and this crop is an important component of farmers' livelihoods in both study areas. There are, however, differences between them. More than three-quarters of farmers in Oaxaca grow maize for home consumption exclusively, while in Chiapas almost all farmers grow maize for both home and market. Few farmers in both study areas produce entirely for the market. More than half of farmers in Oaxaca did not produce enough to meet their maize needs in the last five years. Only about a third of farmers frequently sell maize, and most sell less than half of their production. Maize is sold mainly to families in communities and, to a much lesser extent, local traders. On the other hand, farmers are very commercialized in Chiapas. More than 90 percent produced surpluses in the last five years, and almost all sold more than half of what they produced. They sold mainly to the government, private business, and local traders, or a combination of them. Almost none sold to other families in the community.

The price of maize varies between study areas. Maize is much more expensive (60 percent on average) in Oaxaca than in Chiapas. There are also differences between the purchasing and selling prices within the two study areas. While maize is more expensive in Oaxaca, there is almost no difference between the selling and purchasing price. However, there are important differences in Chiapas, where the price to buy maize is about 30 percent higher than the selling price.[6] Hence, it is significantly cheaper for a household in Chiapas to produce its own maize than to sell and buy it. This may explain, to a certain extent, why in a commercialized system such as the one in Chiapas, production for home consumption remains an important objective of maize production.

[6] The reasons for this difference are not clear. It may be that the local markets are thin and traders incur high storage costs as well as risks (not only the physical storage costs, but also the money tied to the product in the absence of efficient financial markets) and hence they demand a high premium.

The qualitative work supports many of these findings. In Oaxaca, people were found to mainly be growing maize for personal consumption. The poorest farmers depend on it for their food security ("it is the only thing that we cannot do without in the house"). Growing it enables them to use their little money on other items ("I plant so as not to buy, and when I go to trade and make a little money it is to buy something else, for example sugar, soap and what we need at home"). Although people in Chiapas are mostly interested in selling their crops, maize cultivation assures basic subsistence, and is particularly important for the poorer farmers. As one extreme poor farmer in Dolores explained: "It is necessary to take out the portion that is our food because there is no work and if we don't plant we will die of hunger." Still, for many, maize is most important as a source of money, although they take out a portion of it for their annual consumption.

Maize also plays important non-economic-economic roles in people's lives, though these sometimes also have economic effects. For example, maize plays a role in the cargo system (known as *mayordomia),* a ritual cycle where people sponsor parties honoring a saint's feast day. This especially affects the extreme poor, who have to sell early to help pay for holiday expenses. An early harvest causes people to lose significant income. A few case study informants in Oaxaca said that they planted maize because of traditions. They also interpret the material benefits of corn in light of this. One man held, "I cannot accept not planting, because ever since I was little this was the job of my father, so I can't keep from planting, because when there are tender ears, you go and harvest whenever you want and the amount you want, and if you go to buy it isn't the same."

4. History of Diffusion and Adaptation

Maize Germplasm

Farmers in both study areas plant numerous maize varieties ranging from hybrids to landraces. A collection of different maize varieties was carried out and a total of 126

samples assembled. Each sample corresponds to one distinct type recognized by farmers in a community.[7]

The survey also elicited extensive information on the varieties planted, their names, origin, history, and management. We classified the maize varieties identified in the survey into five categories: hybrids, recycled hybrids, open- pollinated improved varieties (OPVs), creolized varieties, and landraces. The classification is based on: (a) the name provided by the farmer, (b) whether the farmer said that the seed came from a "bag," (c) the number of years seed was used, (d) information on its origin from the farmer and focus group discussions, and (e) classification by a maize taxonomist of a collection of maize samples from all communities in the study. Table 2 presents the specific criteria used for each category. Because the classification is based on our

Table 2—Criteria to classify varieties identified in survey into five categories

Category	Criteria
Hybrid	• Named provided by farmer of a known hybrid • Seed came from a "bag" and first year of planting • Focus group identified the name as being introduced to the community by government or commercial outlet • Maize taxonomist indicated that sample with same name was of a hybrid or recycled hybrid
Recycled hybrid	• As above, but farmer had planted the seed from the previous harvest up to four years
Open pollinated variety	• As above, but name provided by the farmer was from a known OPV • Seed had been planted for first time or recycled up to four years
Creolized	• Any of the above, but farmer had recycled the seed for more than four and up to 15 years
Landrace	• Named provided by farmer of a known maize race (e.g., Zapalote, Tepecente, Olotillo) • It did not have a specific name (*maiz blanco*) but had been planted for many years either by the farmer or somebody else in the community • It did not come from a bag • Focus group identified the name as a local variety • Maize taxonomist indicated that the sample with the same name was a landrace

[7] The sampling strategy was to collect all the different maize types recognized in each community. The types or varieties were identified during the focus group discussions as well as from the survey, since the collection occurred afterward.

judgment, there may be misclassifications. The criteria however, were applied systematically, and we are confident that on average the classification is correct. This classification is the basis for the adoption and impact analyses presented below.

A key finding of the household case studies is that local categories of seed types are not the same as the ones defined above. People generally classify seeds that do not come in a new package as *criollo,* regardless of whether they are recycled, creolized, or landraces according to formal definitions. In discussions of the case study findings, we use the local terms when referring to perspectives of the informants. In Oaxaca people distinguish between *criollo* and "variety" maize. The latter includes all those that come from agricultural secretariat programs. In Chiapas, people distinguish between *criollo*s and seeds from a bag. Among bagged seeds, they distinguish between those from the secretariat and hybrids or commercial seeds from veterinarians. In neither region do people distinguish between old or "original" *criollo* seeds, i.e., landraces, and those that were "creolized" (*acriollado)* over time. Both types are called *criollos*.

Furthermore, people do not necessarily define varieties so much as describe them in terms of their advantages and disadvantages. Only in Oaxaca did some people refer to *criollo* as the original maize, i.e., a landrace. They do have positive associations with these varieties: "It is good; it was the first one that began to help us." People in Oaxaca generally have better knowledge about the characteristics of each variety, probably related to a longer tradition of maize cultivation than exists in Chiapas.

Nonetheless, people have different confidence in different types of seed. Notably, people have more confidence in *criollo* seed (i.e., the combined local category), because they know it: "We consider it with confidence because we already know it, we have planted it before, and we have no doubts about it." Recycling, i.e., selecting seed from a previous harvest and replanting, is considered to be creating creolized seed. Most people consider recycled or *acriollado* seeds to be *criollo* in a few years. Even in Chiapas large-scale producers expressed their preference for *criollo* seed, despite the fact that they plant improved varieties. Key to classification as a *criollo* seed is that the seed has been acclimatized to local soils, i.e., seen as adapted to these soils. According to one farmer in

Chiapas: “At first it was like a hybrid and now, later, it is criollo.... It likes the soil. It acclimated.” When asked whether this process was what makes a variety *criollo,* another farmer said “Yes, that is exactly what makes it *criollo*. After some seasons it adapts and will produce any place. Because they planted it once and now it knows the land, and since the land is good [it produces].”

Sources of Seed

Farmers in both Oaxaca and Chiapas distinguished between maize kernels as grain and maize kernels as seed, although from a biological perspective they are the same. In the case of recycled seed, maize kernels used as seed are usually subject to a rigorous selection process. In farmer-to-farmer seed transactions, kernels for seed and grain show important price differentials. For example, landrace seed costs MX$3.88/kg[8] and MX$3.51/kg in Oaxaca and Chiapas, respectively, while landrace grain costs MX$2.41 and MX$1.82, respectively.

People’s memories are not very precise regarding the particular history of introduction and adaptation of each variety. But they are aware that the old *criollo* varieties have been replaced by improved ones. One informant explained that the new seeds arrived “through institutions that came offering improved seeds and the ones we had been planting for so long were left behind.... They said, ‘Look this seed is good.’ And since our land no longer wanted to produce as much with the seeds we already knew, so we were encouraged to try them.” According to informants in the case studies, farmers can obtain seed in six manners: select it from their own harvest, obtain it through social networking (this includes buying and selling, and reciprocity from relatives, neighbors and friends), buy from the government through the *ejido* commissary, buy from *campesino* organizations, buy (at a greatly reduced price) through political campaigns, and buy in veterinary clinics or seed stores. The previous harvest and social networks were the most common sources in both study areas, and prevalent among all social

[8] The average exchange rate for the period of the fieldwork was MX$9.25/US$1.

groups. Data from the survey supports these findings. During the rainy season of 2001, most farmers in Oaxaca planted seed from the previous harvest (61.4 percent of seed lots).[9] In Chiapas, this was much lower but still significant (39 percent of seed lots). The rest of the seed was acquired either from other farmers, the government, or stores. In Oaxaca, the most common outside sources of seed are farmers' social networks—family, friends, and neighbors—the government and the store. In Chiapas, on the other hand, the government is the main source, followed by social networks and stores. These patterns again illustrate the contrasting nature of maize production in both study areas, with the Oaxaca relying more on local sources of seed and Chiapas more on outside sources, particularly the government. Social capital plays a key role in accessing seed in Oaxaca, while this role is much weaker in Chiapas.

Once inside a community, new seeds spread mainly by informal networks. Social networks are key to diffusion because they are trusted, more so than the government, and because people can observe the fields of others and obtain successful varieties by buying or trading for them. Occasionally, they receive them as a gift. This practice of observing the performance of varieties is widespread, especially among the poorest farmers in Oaxaca who can tolerate less risk: "Sometimes the maize is unknown and you don't trust to buy it. Rather, you go with your people because you see that the crop grows well and the ears are pretty. So you ask if they have some stored and you buy a bit for planting. With the seed from the stores, there is no confidence.... You have to see it growing in the fields of your neighbors who have grown that variety. If not, you don't buy it."

In the opinion of producers in Chiapas, good and guaranteed seeds are expensive, and sold by seed companies. Even if they are considered the best, they are too expensive. In fact, people defined poverty in part by what kind of seeds one uses: "Poor people around here are the ones who plant ordinary varieties."

[9] A seed lot is defined as "all kernels of a specific type of maize selected by a farmer and sown during a cropping season to reproduce that particular maize type" (Louette et al. 1997: 24).

The government has played an important role in supporting maize cultivation, especially for less well-off farmers, through programs to promote access to seed, credit for purchase of inputs, and technical support. A number of programs have existed, but with many problems. This experience has influenced people's perceptions and attitudes about the reliability of government support and the quality of government seed. Significantly, experience with government seed and related programs have made people wary of using improved seed more generally.

The Agricultural Secretariat is the main government program and promoter of seeds in both study areas. The agency manages two important programs: Alianza para el Campo and the Programa de Apoyos al Campo (Procampo). The former provides, among other things, subsidized seed from both public and private sectors, known as the Kilo por Kilo program. The latter provides farmers with a cash subsidy for the area planted to certain crops, including maize. Farmers can use Procampo money to purchase seed and agricultural inputs—but that is a farmer's decision. These programs, but especially Procampo, are distrusted, and many do not register all or any of their land, because people feel that the programs aim to take land from them. In both study areas, the *ejido* commissaries are the most important local institution that connects government programs and farmers. The Kilo por Kilo seed is channeled through the *ejido* commissaries, which become an important source of seed. The majority of improved seeds used by *ejido* producers come through inexpensive technological packages. These packages have been, and remain, the principal source of improved seeds for our case study households, although they are not the most popular. The quality of the seed often is poor. An agronomist working in the region explained that government seeds are poor because municipal governments limit themselves to providing cheap seeds that are poorly adapted to local soils.

Another problem in both study areas is that seeds arrive at the wrong time, e.g., when it is too late to plant: "There is no faith in the government now, because they don't come through with what they promise.... The support comes so late that nothing can be done." In communities in both study areas, farmers expressed a strong need for

government technical assistance, but also a lack of faith in the motives and reliability of government: “We need someone to come and study the soils to know about the pests.... We need to know what kind of insecticide to spray.... Some people have died because they got some on them.... Well, later some technicians from the secretariat came by, but they came...when the time that we needed them has already passed. I think they come only so that we can get to know them, but when we need their knowledge, we never see them.”

Politics also enters into seed distribution. In one community in Chiapas people explained the influence of political parties: “The commissary gives the seed to his group of people and sells what is left over to the townspeople. He calls his people very secretly and writes their names on the list.” Another way that seed is politicized is through political campaigns, when improved seeds are introduced in communities and given as gifts to or at low price to supporters. Complaints about politics are also heard regarding agricultural support services more broadly. In Chiapas, the poorest people complain that support is mainly given to the people close to authorities. Another problem attributed to politics (though it may also relate to economics) is the frequent complaint that government programs stay in regional centers, with little reaching small towns.

In Chiapas, some expensive but subsidized seeds can be obtained by belonging to regional *campesino* groups, which also channel government support such as subsidized fertilizers, credit and soil analysis. To belong to such a group can be difficult and expensive, however, and inaccessible for poor farmers. But it said that it is worth the effort for those who are able to achieve it.

Seed Management and Flows

Recycled seed from one’s own harvest or from other farmers is the most important source of seed, even in the more commercialized Chiapas. Beyond its value as a source of seed, seed recycling has important genetic consequences for the maize varieties that farmers plant. Varieties change under farmer selection. By selecting the

plants, and hence genes, that are carried from one generation to the next, farmers play an important role in shaping the genetic structure of their varieties.

The case studies revealed seed recycling to be a widespread practice in both study areas. When people are content with their harvests, they try to select and store seeds from it. Some farmers consider it embarrassing to "waste" seed from their fields. There is also the notion that "it is better to choose my own seed grain, the one I like" rather than buy bag seed that carries with it unknowns. Recycling is seen locally as one way in which *criollos* are created—through successive plantings, seeds are seen to adapt to local soils. Additionally, most consider seed too expensive to buy every year. In fact, we did not find a single person who bought all his seed every year. Nonetheless, farmers in Oaxaca were more likely to recycle selected seed than those in Chiapas, and they buy seed less frequently from government or informal networks. If the extreme poor plant maize from a bag, generally it means that the seed was free or cheap and that they obtained it through a government program.

Though all farmers recycle, poorer ones among the case study informants were more likely to do so than richer ones. However, some less poor informants prefer to plant recycled improved seed that they obtain from the harvest of a neighbor who planted bag seed. Recycling provides access for the poor to improved varieties that they otherwise could not afford as original seed. The number of years that farmers recycle varies between study areas: from four to five years among informants in the case study communities in Chiapas, and longer in Oaxaca. After this process they do not distinguish the seed from those long in use. Farmers here consider that it is possible to creolize or adapt any seed and do not believe claims that replanting has negative consequences: "They tell us that the hybrids will not produce from one year to the next. But I think that this is a lie, because the seed companies are making money." Many farmers claim that getting recycled seed from neighbors is a way to improve their harvest.

When asked why farmers preferred to recycle, one explained: "Because we have always done it like this and, like I told you, we can't spend a lot on seed. Also, this way is safer because we have seen how the seed produces in the lands around here." However,

there is recognition that seeds also degenerate over the years: “We change when the soil demands it, because sometimes the land just doesn’t want the same seeds, because what happens sometimes is that the seed has degenerated.” Because people observe other farmers’ fields and see results, everybody buys and trades seed as well.

Another way farmers shape the genetic structure of their germplasm is by fostering gene flow among different varieties, something that has been documented in other parts of Mexico (Aguirre-Gómez 1999; Bellon and Berthaud 2001). In Oaxaca, farmers have mixed seed acquired from outside into 8.9 percent of their seed lots in the course of planting a seed lot, while this happened in 7.8 percent of seed lots in Chiapas. By mixing seed, we mean that a farmer added seed from a different variety or source to the seed lot that he planted. This means that when planted, there is a high chance of cross-pollination. Other evidence of potential gene flow are that farmers in Oaxaca said that in 2001 they gave seed to other farmers (exchange, sale, etc.) from 26.4 percent of their seed lots, while they received seed from other farmers for 29.7 percent of the seed lots they planted. This was much lower in Chiapas, since farmers only gave seed to other farmers from 7.8 percent of their seed lots and they received seed for only 5.5 percent of their seed lots. In Chiapas, farmers seem to play a more limited role in shaping their germplasm than in Oaxaca, but they still play a role.

The case studies collected information on and observed systems of maize planting, to learn how creolization may occur. Many *ejido* farmers divide their crop in several parcels, which are located on different slopes, and they plant each variety in different conditions. Most commonly, they will plant two varieties; however, some plant more. In Chiapas, those who have the highest production of commercial maize maintain their lands separately and planted exclusively with only one kind, avoiding the contamination of the ears. However, we also found farmers who said that they planted more than one variety in the same plot, with little or no separation among them. This way of planting often presents a mixture of maize varieties that is not seen as a problem, as this maize is for household use and the deformed or stained ears are fed to the animals.

Farmers also plant different varieties at different times that serve different purposes and minimize risk of loss.

Regarding the deliberate crossing of maize varieties, it appears that most farmers have limited knowledge about the process. However, farmers are crossing maize, intentionally or by accident. In Chiapas, they know that a maize crop is always purest in the center of a plot, and that one finds mixed grains of different varieties on the borders. They are not very knowledgeable about the characteristics of different kinds of maize. They know that the maize can be changed or contaminated when seeds are mixed through improper handling. Even if the process of cross-fertilization is not understood completely, some farmers recognize it and do it on purpose, while in other cases it happens unintentionally. A number of farmers in the case study households in Oaxaca explained ways in which they had crossed improved maize with *criollos* when they saw plants that they liked. In Oaxaca they tended to know more about this process than in Chiapas, possibly because Oaxaca has a longer tradition of maize cultivation, and because the offices of the agricultural secretariat are in Nopala, with eight technicians and demonstration plots. An extreme poor farmer from Nopala explained how: "A year ago, I planted the one we call 'tablita' in one plot and in another together with another variety. But if I cross it now with 526 it produces half yellowish grains and the ear is a little bit narrower...but it became stronger. That is what we want—to cross a criollo with a variety to make it more resistant, so that it doesn't rot much." However, not everyone crosses maize varieties intentionally, nor do they know how to do it. Many just notice the cross because they observe a change in the color of the kernels or height of the plants as a consequence of having planted two varieties together: "We don't know why it happens, but it happens."

5. Adoption

Extent of Planting by Maize Type

The relative area planted and the proportion of farmers that plant each of the five types of maize germplasm varies between both study areas (Table 3). Landraces dominate in Oaxaca**,** followed by creolized varieties. The importance of creolized varieties is very similar across poverty groups. Few farmers planted improved germplasm, especially hybrids, and those that planted improved varieties did so in a small area. The use of hybrids and recycled hybrids is most common between the nonpoor-poor. Furthermore, the use of landraces, even though they are dominant, is the lowest between the nonpoor-poor. In contrast, the use of improved germplasm, and particularly hybrids, is dominant in Chiapas. All farmers, particularly the nonpoor-poor, plant improved maize types. All poverty groups also plant creolized varieties and landraces. Creolized varieties are the most widely planted single maize type in relative area and

Table 3—Distribution of type of germplasm, by area and number of farmers

	Extreme poor (hectare)	Extreme poor (number of farmers)	Poor (hectare)	Poor (number of farmers)	Nonpoor (hectare)	Nonpoor (number of farmers)	Total (hectare)	Total (number of farmers)
Coast of Oaxaca								
Total	3,011.67	2,645	833.01	666	320.58	228	4,165.26	3,539
Relative distribution (percent)								
Hybrids	1.5	3.1	0.0	0.0	7.1	6.7	1.6	2.7
Recycled hybrids	2.0	3.1	8.5	8.7	12.2	13.3	4.1	4.8
Open-pollinated varieties (OPVs)	7.0	7.0	2.0	2.8	2.5	8.1	5.7	6.3
Creolized	14.3	10.4	12.8	15.4	24.2	20.0	14.8	12.0
Landraces	75.2	84.2	76.7	85.3	53.9	66.7	73.9	83.3
Frailesca, Chiapas								
Total	5,789.36	1,261	2,213.81	521	1,035.85	212	9,039.03	1,994
Relative distribution (percent)								
Hybrids	19.8	30.9	22.2	31.1	63.3	54.8	25.3	33.5
Recycled hybrids	8.8	9.9	18.5	26.0	3.9	17.5	10.6	14.9
Open-pollinated varieties (OPVs)	20.0	33.1	12.8	22.8	4.3	10.5	16.4	28.0
Creolized	26.6	36.7	31.8	38.8	25.3	37.6	27.7	37.4
Landraces	24.9	32.6	14.8	10.3	3.1	11.1	19.9	24.5

proportion of farmers and are planted in roughly similar proportions by all poverty groups. In spite of the wide adoption of improved germplasm, landraces occupy more than a fifth of planted area and are planted by more than a fourth of farmers, particularly among the poor. The importance of landraces decreases with the poverty level. In both study areas (although at very different scales), there is a trend of increasing use of hybrids and improved germplasm with decreasing poverty and a reversed trend for landraces. Creolized varieties seem, however, neutral to poverty level in both areas.

Factors Explaining Adoption

Adoption is a complex process, affected by many factors and circumstances**.** These factors can be group into five categories: (1) adaptation, (2) management intensity, (3) cultural values associated with maize consumption, (4) risk, and (5) participation in the regional/national economy. Adaptation refers to the performance of the germplasm in a particular agroecological environment. A well-adapted variety is one that performs well in a particular environment, while a poorly adapted one does not. Management intensity refers to the quantity and timing of inputs required by a variety for a good performance. A management-intensive variety requires a large amount of inputs and strict timing of planting, weeding, and fertilizer application to perform well; otherwise its performance is drastically reduced. A nonmanagement-management intensive variety is one that can withstand delays in these operations and responds to low quantities of inputs without a dramatic reduction in its performance. Cultural values associated with maize consumption are important because maize cultivation in Mexico is not just an economic activity, but also has strong cultural values and preferences associated with it. Preferences for special characteristics, especially for culinary and ritual uses are common among small-scale farmers, particularly indigenous farmers. Maize cultivation is a risky endeavor, particularly under the rainfed conditions faced by these farmers. Risk is not only related to biotic and abiotic stresses associated with maize cultivation, but also with the knowledge and understanding of the performance of different varieties when faced

with those conditions. Participation in the regional/national economy provides farmers with opportunities to sell their surpluses, acquire seed of improved varieties, purchase inputs, and enjoy other income opportunities and access to cheaper consumer goods—including maize.

Actual adoption of a particular type of germplasm by a farming household depends on the interaction between the above-mentioned factors, the assets controlled by the household, and the conditions that it faces. To examine actual adoption, we included variables related to these factors in the survey and included them in a regression framework to explain the area planted to the five different types of maize germplasm defined in Section 4. The variables included are farmer's age, household language, percentage of indigenous speakers in the community, household expenditure,[10] source of labor used in maize production, land quality, fragmentation,[11] access to extension services, participation in government programs, and distance to the main town. For a detailed presentation of the models used and the econometric estimation procedures and detailed results see Bellon et al. (2003). Here just a summary of the results is presented.

Table 4 presents the hypothesize relationships between the independent variables and the dependent variables (area planted to each of the different maize types) and the rationale for the hypothesized relationship. These relationships are based on certain expectations about the performance of the different maize types. Improved varieties (particularly hybrids) are hypothesized as having a limited local adaptation; being suitable mainly to the best environments; being management intensive, because they have been selected under optimal management conditions in research stations; not having been selected for culturally important consumer traits, which are subjective and difficult to select for; riskier, particularly because they are less well known and understood, although

[10] This variable is endogenous. A regression of the log of expenditure as a dependent variable against a set of explanatory variables associated with local perceptions of poverty and other measures of marginality thought not to affect adoption decisions was estimated for each region and the predicted values used in the adoption regressions.

[11] The number of plots a farm is divided into.

Table 4—Hypothesized relationships between variables and adoption, and rationale

Variable	Rationale	Improved varieties	Creolized varieties	Landraces
Age	Indicator of risk attitudes. Older farmers more likely to be risk averse and have better knowledge of local landraces.	–	+	+
Household language indigenous	Indicator of cultural identity. Speakers of indigenous languages more likely to attach stronger values to maize consumption.	–	–	+
Household language exclusively Spanish	Indicator of the ability to interact with national economy. Spanish speakers better able to interact with regional and national economies and access new technologies.	+	+	
Percent speakers of an indigenous language in the community	Indicator of cultural identity. Even if indigenous languages not spoken by a household, there may still be strong attachment to maize culture in community.	–		+
Predicted household expenditure	Proxy for welfare and poverty. Poorer households more constrained to afford inputs and seeds and less likely to take risks.	+	–	–
Exclusive use of family labor	Indicator of constraint to mobilize labor to deal with labor-intensive varieties, particularly hired labor.	–	+	+
Land quality	Indicator of adaptation. Not all land equal.	+		–
Landholding fragmentation	Indicator of adaptation. Farmer has to deal with different local environments.	–	+	+
Landholding fragmentation	Indicator of management intensity. It can make coordination and mobilization of labor more difficult.	–	+	+
Landholding fragmentation	Reduce risk by reducing chance of crop failure due to multiple production conditions.	+		
Extension	Indicator of links to regional/national economies. Access to new information and inputs.	+	+	
Participation in Kilo por Kilo program	Indicator of links to regional/national economies. Access to new seeds.	+	+	
Participation in Procampo program	Indicator of links to regional/national economies. Access to additional funds	+		
Distance to nodal town	Indicator of links to regional/national economies. Determine costs of interacting with the outside.	–		+

they may actually not be riskier; and associated with good integration and interaction with the regional and national economies, since these would be sources of the seed, information, and incentives to grow them. Landraces, on the other hand, are hypothesized as having good and broad local adaptation, because they have evolved in the particular environments; being nonmanagement intensive, since they have been selected under suboptimal management conditions, e.g., late planting, high weed

infestations, low inputs; having been selected for culturally important traits, since they are the products of selection by farmers who value these traits; less risky because they are well-known and trusted, and even if they entail risk, farmers can evaluate these risks well. Integration into the regional and national economies may not be important, since access to their seed and knowledge are related to local social networks knowledge. Creolized varieties are expected to be somehow in-between, but are probably more similar to improved varieties than landraces.

Table 5 summarizes the regression results for the different maize types and both study areas. In general, land quality is an important factor in the adoption of most maize types, both in Oaxaca and Chiapas, particularly for creolized varieties. Even if land quality per se is not important, the size of landholdings is, except for improved varieties in Oaxaca that are planted in a very limited area. This indicates that adaptation is an important consideration for adoption. Fragmentation is another factor that was significant for most types of maize germplasm, which indicates the importance of both adaptation and management intensity. Language and culture are also factors that play a role in adoption, particularly for creolized varieties and landraces, particularly in Chiapas. The use of family labor (and conversely hired labor) is a factor in the adoption of certain types of maize germplasm, but not in all, indicating that certain types are considered more labor intensive than others. Expenditures, and hence welfare and poverty,[12] were not a significant factor in the adoption of any type of maize germplasm, except for creolized varieties in Oaxaca, where there was an inverse relationship between expenditure and adoption of creolized varieties, indicating that the poor tend to adopt these types of varieties. The lack of significance of expenditures indicates that there is not a direct relationship between the level of welfare of a household—at least in the narrow sense of expenditures—and its adoption decision, except in the case already

[12] Obviously expenditure is a partial indicator of welfare, since there are many other important dimensions of welfare that are not taken into account by this variable. It is, however, easy to measure and widely accepted, even with these limitations.

Table 5—Regression results of the adoption models for different type of maize germplasm in Oaxaca and Chiapas[a]

	Oaxaca			Chiapas			
	Improved varieties	Creolized varieties	Landraces	Hybrids	Recycled hybrids and OPVs[b]	Creolized varieties	Landraces
Total area[c]				+			+
Land type 1[d]		+	+			+	
Land type 2		+			+		
Land type 3			+				
Land type 4			+		+		
Land type 5			+			+	
Fragmentation	+			–		+	+
Age	+						+
Household language[e]		+					
Percent indigenous language		+				–	+
Expenditure		–					
Family labor only	–				–	+	
Extension							
Kilo por Kilo				+		+	
Procampo						+	
Distance				–		+	

[a] Only the variables that were statistically significant at least at the 0.10 level are reported. The sign indicates the nature of the relationship between the variable and the area planted to the maize type.

[b] Open-pollinated varieties.

[c] If total area is significant it indicates that land quality did not have an effect on adoption; otherwise land quality has an effect on adoption and the specific land types that were significant are reported. Two regressions were estimated. In one, all land qualities were combined into total area; in the second, land quality was disaggregated into five land types. If land quality effects are not important both models should be equal, if they are not, land quality effects contribute to explaining adoption. Both models were compared statistically. If the models were statistically similar the results from the simpler one (land quality not disaggregated) are reported.

[d] Landholdings were classified into five land categories depending on the production system used and the quality assessed by the farmer (very good, good, poor). Production system refers to whether farmers plow the land (locally know as *arado*) or not (locally known as *pedregal*). The production system is correlated with the slope and stoniness of a plot; plots in *arado* being flatter and with low stoniness, while *pedregal* plots may be on steeper slopes or flatter but with high stoniness.

[e] This variable was not included in the Chiapas regressions, since there is almost no variation among households. Most only are Spanish-speaking.

described. Distance of the community to a main town was a factor that only influenced the adoption of certain types of germplasm in Chiapas, but not in Oaxaca. Government programs do not play a significant role for adoption decisions in Oaxaca, although they do for certain types of germplasm in Chiapas, particularly for creolized varieties. Directly they do not seem to have a negative impact on landraces in either region. However, in both study areas the different types of germplasm seem to compete with

each other.[13] As will be shown in the next section, this is not completely consistent with the perceptions of traits and trade-offs of farmers, which indicate that one type of germplasm may complement another by providing some traits that the other does not.

The hypothesized relationships between dependent and independent variables for the different types of maize germplasm were corroborated in most cases where there was a statistically significant association, except in the case of age and improved varieties in Oaxaca, where the relationship was the opposite. This suggests that older farmers may be less risk averse, or alternatively, improved varieties may be less risky than thought. Because the qualitative data stresses the lack of confidence and trust of farmers for these varieties and the perception of riskiness associated with them, the first alternative is more plausible.

Case Study Findings on Factors Affecting Adoption

The case study findings complement the results presented above by examining the reasons given by people for adoption or lack of adoption. The most frequently cited factor that discourages adoption of improved varieties was expense: "It would be better to buy [seed from] the bags, since the yield they give is better. The only problem is that the seed is too expensive. Another problem with the bags is that you have to plant them very close together, with only one grain. It takes more work, more liquids, and fertilizers." Interestingly this reason was only given in Chiapas (though far less often by the less poor farmers). This may be related to the more commercial orientation of farmers in Chiapas, who use a larger amount of purchased inputs. Also, the maize grain they produce has to comply with commercial standards; hence, there may be a greater need to purchase improved seed, and thus price is a consideration. In Oaxaca, this is not the case, given that farmers are subsistence oriented, use small amounts of purchased inputs, and use improved varieties in a very limited way. Curiously, a number of

[13] This is based on an analysis of the correlations between residuals of the regressions for the different types of maize germplasm. For details, see Bellon et al. (2003).

Oaxacan farmers said that price is not a determinant—they would find a way to buy it if they thought it was good quality.

The most commonly cited factor in Oaxaca explaining nonadoption was that new seeds are risky. The issue of risk comes up repeatedly throughout the studies; particularly among poorer farmers. However, even a less poor farmer said, "I already decided that right now only the pure criollo is the safest; that way there is no risk." This concern over risk also explains one of the main factors explaining why people make the decision to adopt or not—observation of good or bad yields and other characteristics in new maize varieties planted by family, friends, and neighbors. The issue of observing before doing came up repeatedly. The majority of our informants in both Oaxaca and Chiapas said that people prefer to observe how new seeds produce before trying them. The tolerance of risk followed a clear pattern: the poorer the farmer, the less willing he is to risk his harvest. An average poor informant from Tiltepec, when asked if he would plant a seed an outside organization was actively promoting, said, "No. Even if they would give it to me for free I would wait to see someone else's crop. Since I have my seeds, I will plant my own**.** Why should I investigate? All I would do is expose myself to losses." Even where people have seen experimental plots planted by the agricultural secretariat that look nice, some suspect that maybe the technicians have added some secret substance and wonder if the varieties will yield as well on their lands.

The relationship between soil type and maize varieties was an important one among the case study informants. They have some ideas about the correspondence between certain varieties of seed with certain soil types, though they are not explicit in this regard. For example, in Oaxaca it is said, "the land chooses the seed," which they learn "by trial and error." However, no one in Oaxaca specifically mentioned soil type as an argument for explaining whether or not to plant a given variety. In Chiapas, farmers were somewhat more explicit on this point. They consider that a good and expensive seed only is justifiable if it is planted on good soils—flat bottomlands. For poor soils—those overfarmed, with considerable slope, where proper fertilization is not possible (it washes away)—it is most advisable to plant *criollo* seeds. Informants say that *criollo*

maize does well on any type of soil, even those that are worn out and weed-covered. This again reflects the notion that *criollos* have acclimated to the soils.

Another set of factors explaining adoption relates to access to different types of capital. Financial capital, needed to purchase seeds, fertilizers, and pesticides, was particularly important in Chiapas. Social capital is also needed to obtain seed—through informal social networks, peasant organizations, and political campaigns. Political capital is also helpful, in the form of political contacts and party affiliation**.** Human capital helps as well—access to labor in good health, able to work the land, and knowledge. Natural capital also plays a role. Access to good quality land in sufficient quantities—and the right type of soil—make adoption worthwhile.

Finally, an important set of factors explaining adoption were characteristics of the different varieties. These factors and explanations are developed in more detail through the survey data, elaborated in the following section on impacts. Case study informants said the main characteristics they admire were the appearance of the ears, large kernels, flavor, resistance, and heartiness of *criollos*. The principal disadvantage that they find in these seeds is their height, which is so tall that the plants blow over. Farmers appreciate the weight, good yields, and lower height of improved varieties. However, they are not fond of the small ears, fragility, and propensity to rot and for the kernels to crack. They also claim that these plants are so short that animals eat them. Additionally, improved seeds are expensive and require greater care and investment of time and inputs, and yields decline over the years. Finally, some farmers said that the improved varieties taste bland.

6. Impacts

A key hypothesis of this study is that farmers, particularly the poor, benefit from improved germplasm through creolization. While improved varieties provide desirable traits or combinations of traits not found in landraces, they may lack traits found in the landraces. Hence, choosing between one or the other presents trade-offs to farmers.

Creolized varieties can provide traits not supplied by landraces, while they entail fewer trade-offs than improved varieties. Hence to look at the impact of these varieties on farmers' well-being one has to examine the demand and supply of crop characteristics by different types of maize germplasm.

The survey included a section on farmers' evaluation of maize varieties. This evaluation was done for 19 crop traits or characteristics identified as significant in focus group discussions. The evaluation comprised two parts. The first consisted of an assessment of the "demand" of characteristics by farmers. Male and female farmers rated each trait as very important, important, or not important in terms of their relevance for choosing a maize variety to grow. The second consisted of an assessment of the "supply" of these traits by each variety they grew. Male and female farmers rated each variety in terms of its performance for each of the 19 traits as very good, good, poor, or very poor. The varieties rated did not always refer to varieties grown, particularly in the case of women, but to varieties known. Also there were instances in which varieties currently grown were not rated, because the farmer did not feel that he/she knew enough about their performance. Later we grouped ratings of varieties by maize types according to the definitions presented in Section 4.1.

Demand of Characteristics

Even though a large number of characteristics were rated, almost all farmers in both Oaxaca and Chiapas rated them as either very important or important. Table 6 presents the percentage of farmers who rated each characteristic as very important by gender for both study areas. Almost all characteristics were rated as very important by 50 percent or more of the farmers in both study areas. This suggests that focus groups were very accurate at identifying pertinent crop characteristics and that these farmers value multiple traits. To test whether any of these traits are particularly important to the poor, nonparametric correlations between the expenditure of the household and the ratings of importance were run for each trait. A significant negative correlation indicates that as

expenditure decreases importance increases, i.e., the trait is more important to the poor. Table 6 reports the statistically significant correlations as well.

Table 6—Percentage of farmers who rated a characteristic as very important in Oaxaca and Chiapas, Mexico, by gender

	Coast of Oaxaca				Frailesca, Chiapas			
	Males	Correlation[a]	Females	Correlation[a]	Males	Correlation[a]	Females	Correlation[a]
Number of households	162		162		161		158	
Vulnerability								
Resistant to lodging	69.8		98.8		82.6		94.3	–.120*
Tolerant to drought	75.9		83.3	–.117*	75.2		72.2	
Tolerant to excess water	54.3		84.6		70.8		88.6	
Does not rot (good husk cover)	61.1		75.2	–.162**	68.9		80.4	
Duration (growing cycle)	49.4	.169**	80.9		62.1		82.3	
Resistant to pests	66.0		83.3	–.145**	69.6		80.4	
Resistant to insects in storage	58.6		75.9		61.5		80.5	
Produces something even in a bad season	58.0		75.9		64.6		76.7	
Good for sale	55.9	.181**	65.4		63.8		81.8	
Consumption-related								
Good for consumption	59.9		80.2		70.2		84.9	
Good for atole	59.3		91.4		68.9		90.6	
Good "elote" for sale and consumption	50.6	.118**	69.8		60.2		74.2	
Good for "antojitos"	58.6		75.9		65.2		79.2	
Easy to shell	70.4		76.5		42.9		73.0	
Good for nixtamal	61.1		84.6		68.9		83.6	
Good pasture	27.8	.155**	54.8		49.1	–.122*	64.8	
Productivity								
Yield of dough to make tortillas	77.2		92.0		83.9		89.2	
Yield by weight	84.6		67.9		89.4		67.1	
Yield by volume	67.9	.120**	61.1		72.7		68.4	

[a] Nonparametric correlation between predicted expenditure and rating of importance. A negative sign indicates that the importance increases with poverty, and vice versa.

Notes: *, **, correlation significant at the .10 and .05 levels, respectively.

The characteristics that were rated as very important by the highest number of male farmers in Oaxaca are yield by weight, yield of dough to make tortillas, ease of shelling, and resistance to lodging. Yield by weight is a key trait for breeding. Yield of dough to make tortillas is a trait that is seldom taken into consideration by breeders. Lodging is one of the key sources of risk and vulnerability in maize production. As pointed out earlier, farmers in Oaxaca are still heavily oriented to subsistence farming, so yield of dough to make tortillas and ease of shelling are understandably key characteristics. The correlations showed that as poverty decreases, duration (growing

cycle), good for *elote* (corn on the cob) and good for fodder become more important. There were no traits that seem to be particularly important for poor male farmers. For females the traits that were rated by the highest number are resistance to lodging, yield of dough to make tortillas, atole quality, tolerance for excess water and *nixtamal* (the dough used to make tortillas) quality. Clearly, consumption characteristics seem more relevant for females than males, as would be expected, since females are in charge of maize processing and preparation. The correlations show that three traits are significantly more important for poor female farmers: tolerance to drought, susceptibility to rot, and resistance to pests. Clearly these traits are related with vulnerability factors, and those seem to be more important to females than males.

The characteristics that were rated as very important by the highest number of male farmers in Chiapas are very similar to those for males in Oaxaca: yield by weight, yield of dough to make tortillas, resistance to lodging, tolerance to drought, and yield by volume. Only the importance of one trait is associated with the poor: good for fodder. For females the traits that were rated by the highest number are also similar to those for females in Oaxaca. There is a consistent pattern of consumption characteristics being more relevant for females than for males. This shows that even with the high level of commercialization—although marketability is considered more important than in Oaxaca—subsistence production is still relevant for females. Only the importance of resistance to lodging is associated with the poor, again a vulnerability factor.

Supply of Characteristics

To examine systematically the farmers' perceptions of the performance of the varieties available with respect to the characteristics they demand, we ran ordinal regressions (Agresti 1996; Coe 2002) to test whether there were systematic relationships

between farmers' ratings and the five maize categories defined in section 4.1.[14] The regressions were run for all 19 traits identified in Table 6. The results[15] are presented in Tables 7 and 8 by gender for the Oaxaca and Chiapas, respectively. For simplicity these tables only present the characteristics where there were statistically significant differences. The table should be interpreted as follows: the category presented in the row was rated as superior to the category in the column for the characteristics described in the cell that results from their intersection. For example, in Table 7 for male farmers, creolized varieties were rated as superior to improved varieties for yield by weight, while improved varieties were rated as superior to creolized varieties for good *elote*. By comparing the characteristics described in cells that result from inverting the categories in the rows and the columns, one can identify the trade-offs between two types of maize categories. For example, in Table 7 for male farmers, the trade-offs between landraces and improved varieties are resistance to ear rot, ease of shelling, good for *nixtamal,* and good for pasture versus resistance to lodging.

Results from Oaxaca

Table 7 shows that for males in Oaxaca, there were statistically significant differences for seven of the 19 traits rated. There is no overall superior maize type; all types have advantages and disadvantages. Most advantages were associated with landraces; however, both improved and creolized varieties were superior with respect to resistance to lodging—a key vulnerability factor in the area. While landraces are

[14] These categories were further grouped for the regressions due to low number of cases. In the case of Oaxaca, hybrids, recycled hybrids, and improved OPVs are in one category called "improved," since there were relatively few cases of each category. In Chiapas, recycled hybrids and OPVs were grouped for the same reason.

[15] The result of an ordinal regression in this context is the ratio of the odds that farmers rated a maize category as superior compared to another maize category. In this regression, we included the predicted expenditure, used in the adoption section (see footnote 11) as a covariate to correct for differences in ratings associated with different levels of welfare. For more details and implications, see Bellon et al. (2003).

considered to be superior for many traits, improved varieties and creolized provide a trait lacking by them—resistance to lodging**.** Furthermore, creolized varieties, although

Table 7—Comparisons of different types of germplasm with respect to traits with statistically significant different ratings, Coast of Oaxaca, by gender

Categories in row rated as superior to categories in column	Improved varieties	Creolized varieties	Landraces
Males			
Improved varieties		• good *elote**	• resistant to lodging***
Creolized varieties	• yield by weight*		• resistant to lodging*** • yield by weight***
Landraces	• does not rot*** • ease of shelling**** • good for *nixtamal** • good for pasture**	• does not rot** • good "elote"** • ease of shelling**** • good for *nixtamal**** • good for pasture**	
Females			
Improved varieties		• produces something even in bad season**	• resistant to lodging** • resistant to pests** • produces something even in bad season*
Creolized varieties			• resistant to lodging****
Landraces	• ease of shelling**		

Notes: *, **, ***, ****, statistically significant at the .10, .05, .01, .001 level, respectively, for a two-tailed t-test.

inferior for *elote*, are superior in yield by weight with regards to both improved varieties and landraces. Clearly these maize types show some trade-offs between key traits. These results support the hypothesis that creolized varieties provide a combination of traits not provided by landraces nor by improved varieties, and hence entail fewer trade-offs.

Furthermore, creolized seed is much cheaper. For example hybrid seed cost on average MX$17.44/kg compared to MX$5.33/kg for seed of creolized varieties, while seed of landraces costs MX$3.88/kg. This coincides with the results of the qualitative study where farmers said that while they considered that seed of improved varieties were very expensive, they would "make the sacrifice" and buy them if improved varieties were truly superior, which they did not consider to be the case. The price differentials between seed of creolized varieties and landraces also illustrate that farmers perceive advantages in the former compared to the latter, since they are willing to pay a premium.

For females there were statistically significant differences for only four of the traits rated. Females have a much more positive outlook on improved varieties compared

to males. Improved varieties were rated as superior to landraces and to a lesser extent creolized varieties for many more traits. Landraces were rated as superior only for ease of shelling. Surprisingly, there were no differences for any consumption characteristics—unlike the case with males—and females rated improved varieties superior for yield reliability (yields something even in a bad year) with respect to both landraces and creolized varieties. One would have expected landraces or even creolized varieties to be superior in this respect, since they have been grown longer in these areas and may have been better adapted and possess more stable year-to-year variability. Males did not consider differences among maize types in this respect. There is no clear explanation for these results, which merit further investigation.

Results from Chiapas

Table 8 shows that for males in Chiapas, there were statistically significant differences for 11 of the 19 traits rated. While there is no type that is superior for all traits, males have a very positive opinion of hybrids. Hybrids were rated as superior to both creolized varieties and landraces for seven and eight characteristics respectively, which turned out to be very similar. Surprisingly males rated hybrids as superior for many consumption characteristics. Landraces, however were rated as superior with respect to hybrids for traits related to agronomic performance and highly linked to vulnerability, e.g., resistance to ear rot and to insects in storage. Creolized varieties, although not particularly superior for many traits, either with respect to hybrids or landraces, show an interesting combination of superior traits relative to those two maize types: resistance to lodging with respect to landraces and resistance to insects in storage with respect to hybrids. So at least for those two characteristics that are important sources of vulnerability to farmers, creolized varieties present an interesting and valuable combination. Compared to Oaxaca, the advantages of creolized varieties are more limited in Chiapas, but provide unique and useful combinations that lessen some trade-offs that exist among maize types. The cost of seed from creolized varieties is more

Table 8—Comparisons of different types of germplasm with respect to traits with statistically significant different ratings, Frailesca, Chiapas, by gender

Categories in row rated as superior to categories in column	Hybrids	Creolized varieties	Landraces
Males			
Hybrids		• resistant to lodging*** • good for sale*** • good for atole** • good for elote*** • good for antojitos** • yield of dough** • yield by volume**	• resistant to lodging*** • good for sale*** • good for *elote* • good for atole** • good for *antojitos* • good pasture** • yield by volume
Creolized varieties	• resistance insects in storage****		• resistant to lodging***
Landraces	• tolerant to excess water** • does not rot**** • resistance insects in storage****	• does not rot**	
Females			
Hybrids			
Creolized varieties	• tolerant to excess water**** • does not rot** • resistance to pests* • resistance insects in storage** • good for *nixtamal***		• resistance insects in storage**
Landraces	• resistance to lodging* • does not rot** • tolerant to drought*** • tolerant to excess water**** • resistance to pests** • good for *nixtamal**** • good for pasture** • good for sale** • yield of dough*	• tolerant to drought****	

Notes: *, **, ***, ****, statistically significant at the .10, .05, .01, .001 level, respectively, for a two-tailed t-test.

expensive, on average, than that of landraces (MX$6.33/kg vs. MX$3.51/kg respectively), but much cheaper than hybrid seed (MX$20.25/kg). In any case, as in the case of Oaxaca, the price differentials between seed of creolized varieties and landraces also illustrate that farmers perceive advantages in the former compared to the latter, since they are willing to pay a premium.

For females there were statistically significant differences for 11 of the traits rated. Females in Chiapas have a very negative outlook on hybrids. They did not rate hybrids as superior for any trait, but inferior for several ranging from tolerance to drought

to yield of tortilla dough, even for resistance to lodging for which all others in both study areas had rated landraces as inferior. Creolized varieties were also rated as superior to hybrids but for fewer traits; they were rated as superior to landraces for resistance to insects in storage but inferior for tolerance to drought. Males and females in Chiapas have very different perceptions of the different types of maize.

In summary, neither in Oaxaca nor in Chiapas is there an overall superior maize type; all types have advantages and disadvantages. In the subsistence-oriented farming systems of Oaxaca, landraces seem to be more advantageous, while in the commercially oriented systems of Chiapas, hybrids seem to have more advantages. In both, creolized varieties present a useful combination of traits that reduce some of the trade-offs between landraces and improved germplasm.

Case Study Perspectives on Impacts on Poverty and Well-Being

The case studies reveal a number of ways in which creolized maize contributes to the well-being of poor farmers in the study areas. Unlike the survey results, the case studies did not emerge with as many accounts of direct benefits from improved maize "from the bag," though certainly commercial production using improved maize was observed among some farmers in Chiapas. The scarcity of positive feedback may reflect the fact that even where improved maize was providing important economic benefits, there were still problems, and people tend to express these when given a chance to talk about their experience. Nevertheless, the benefits of creolized maize, where improved maize has changed over time, emerged strongly in both Oaxaca and Chiapas, among farmers at all poverty levels.

The main way in which creolized maize improves well-being seems to be through a reduction of vulnerability. Poor farmers in both study areas depend on maize for their survival. Thus, the introduction of germplasm that improves yields and reduces vulnerability to crop losses reduces vulnerability to food insecurity: "It is the food of our families, since we are all poor, we have no money to buy maize and if we don't plant it,

what will we eat?" By reducing expenses needed for inputs, as well as reducing the cost of the seed itself, creolization also releases cash for other basic household expenses, as well as reduces vulnerability to price and currency fluctuations. Farmers expressed the idea that creolized seed combines the benefits of resistance and acclimation to local conditions, with traits of improved seeds such as yield, height, and wind resistance. Finally, the case studies support the survey findings that creolized varieties provide people with traits that they want and reduce trade-offs.

It is also worth noting that associated with the perceptions of recycling and acclimation, there is a perception of security provided to farmers by "knowing" the seed, which was expressed repeatedly as being particularly important. Farmers need to see it perform before trying it, even if it means using a second generation. The fact that creolized varieties are trusted contributes to farmers' well-being in a subjective—but no less real—way by providing a sense of security and of not worrying so much, which is particularly important for poor and vulnerable farmers.

That the introduction of new germplasm has improved people's well-being is illustrated by the words of an informant from Nopala: "It has given us results. Since we bought that seed many things began to improve for the people, because before we had to buy lots of maize around here...but now we buy less. And, last year I was even selling maize; this year we harvested less, but for September we will have new maize." Still, adopting different varieties does not seem to significantly change people's livelihood strategies. Rather, the risks involved with maize cultivation of any kind drive these strategies. It is not possible for poor people in either of the two study areas to meet their vital necessities (which depend more and more on cash earnings) with the income obtained—if any—from growing maize. They also need to make investments beforehand to grow maize, which for the most of the extreme and average poor case study informants has not been sustainable. For this reason, people say that it is not possible to live only from maize cultivation and emphasize the difficulties related to cultivation: "No one can get rich here growing maize.... With the cost of fertilizers and liquids, our time in planting, processing, and transportation, if you do the numbers you see that you don't get

anything back. Maize produces, but very little is left over. We are content just to be able to grow enough to eat." The more options people have for a better and safer income, the less maize they plant.

In spite of these problems and the limitations of maize production as a route to escape from poverty, our study reveals the enormous importance that maize continues to play in people's livelihoods, from ensuring food security to providing cash income for other basic needs. As one informant said, "We need it to live; without it we don't eat." For less poor farmers engaged in commercial production, improved maize creates a better chance of prospering rather than just getting by. In both cases, there is no question that providing maize germplasm (through scientific improvement and creolization in the field) that increases yields and reduces risks will make a significant difference in people's well-being. It may not mean an escape from poverty, but this requires a more comprehensive poverty-reduction strategy more far-reaching than agricultural technology.

7. Conclusions

The coast of Oaxaca and the Frailesca, Chiapas are highly contrasting regions. Poverty is pervasive, even in the more commercialized and developed Chiapas. Maize continues to play a key role in the livelihoods of the poor in both regions.

This paper has shown that modern varieties, and particularly creolized varieties, are widely planted in the study areas of Oaxaca and Chiapas. While we cannot establish a direction of causality between the adoption of improved germplasm and poverty alleviation—we do not have a baseline study to compare the situation before and after adoption—we have shown the contribution of improved germplasm, and particularly of creolized varieties to the well-being of poor farmers. Creolized varieties are perceived to provide traits that the landraces do not have and have fewer trade-offs than improved varieties. Creolized seed is also cheaper. Adoption patterns show that the poor plant them. In Chiapas, hybrids and other improved varieties seem to be neutral, i.e., the poor plant as much hybridized seed as the rest. The impact of creolized varieties is less

straightforward compared to Oaxaca, but they are still widely planted. Although their advantages compared to hybrids are less marked, they also provide advantages over landraces and farmers in both study areas are willing to pay a premium for creolized seed compared to landrace seed. Linguistic and cultural factors, and agroecological factors to a much lesser extent, seem to play a key role in decisions to adopt different types of maize in both study areas. In general the evidence supports our hypothesis about creolization and their role in farmers' maize agriculture.

Although farmers discuss varieties and their traits, farmers' distinctions between creolized seed and landraces are blurred: all seed that is not "from the bag" (improved varieties, in a sealed package) is widely referred to as *criollo*. Furthermore, improved varieties are said to be quickly converted into creolized. This is seen to occur through seed recycling where seed is seen as "acclimating" to the land and therefore improving. Even where seed is seen to degenerate through recycling, it is still a popular practice because of the high cost of new seed. The second way in which creolization is seen to occur is through planting different varieties near each other so that they cross. This occurs with different levels of intention. Some farmers deliberately plant varieties close together in the hope of getting better characteristics in the new variety. From whichever method, farmers have a high level of confidence in these creolized varieties, because they have proven themselves over time and are seen as better adapted to local conditions.

In addition to selecting from one's own harvest, seeds are mainly obtained through informal social networks and, to a lesser extent, through government programs. Surprisingly, commercial seed outlets still play a very limited role. Social networks are key because they offer many options, are trusted, and most importantly, provide the opportunity for farmers to observe plants in the field before adopting. This need to see performance and reduce risk is true for all farmers, but particularly the poorest. Maize is seen as a highly precarious undertaking, involving numerous risk factors. Thus varieties that are known—and those that reduce these risks—are important, especially to the poorest, most vulnerable farmers.

Government programs play a more important role in Chiapas than in Oaxaca, but they suffer from a lack of credibility in both study areas. Farmers' experiences with these programs have been problematic, including seeds arriving late, restricted access to credit, absence of technical support, politicization of seed distribution, and quantity and quality requirements that the poorest farmers cannot meet. Experience with poor quality seed has left farmers suspicious of government seed and improved seed more generally. They also often do not trust advice about maize management practices or cannot afford to follow them. These accounts suggest that improved experience with government programs could accelerate the benefits of improved maize in a number of ways.

This research also illustrated the value of combining different methodologies and approaches. This combination strengthened the evidence presented and the ability for interpreting results, since complementary insights were gained and similar conclusions were reached by applying different methodologies to the same issues. The sustainable livelihoods framework was useful for this research because it pointed to issues that are not usually addressed in impact studies, such as vulnerability, understanding the role of maize in a wider context of farmers' knowledge and lives, and the processes and institutions that shape the impacts of technology, e.g., farmers' local seed networks and the interaction between farmers and government programs. These programs were not assumed to be inherently good or positive, but while their positive aspects were recognized, their limitations and constraints, particularly from the perspective of farmers, were also taking into consideration.

Several implications can be drawn from these results. First, it is important to get away from the dichotomy of traditional versus modern varieties that is common in adoption and impact studies. As shown here, there are many different types of germplasm, with different advantages and disadvantages. All are influenced by different factors and have different impacts on farmers' well-being. It should be recognized, however, that moving away from this simple dichotomy also entails methodological challenges that may require the use of multiple methodologies, including some that are

not commonly used in adoption and impact studies—such as participatory and ethnographic methods and collection of maize samples from farmers.

A second implication, closely related to the above, is that we need to question the conventional adoption model for improved germplasm. This model assumes that the breeding process finishes once farmers have adopted a variety, and that a variety once adopted should stay unchanged. If the variety does change, the changes are likely to be negative; therefore the seed should be replaced either with new seed of the original variety or of one that is even "better." Improved varieties do change in farmers' hands, and these changes are not necessarily negative; farmers may consider them positive. These changes are associated with farmers' selection and seed management practices. Rather than ignoring them, we should try to investigate ways to take advantage of them. It is not clear yet how to do this, but it is an area that merits further research. Since these practices and their impacts are more important among the poor, particularly in more subsistence-oriented systems, this research should be particularly important to address the needs and conditions of the poor. It should be noted, however, that creolization as a process may only be valid for open-pollinated crops[16] and may not be applicable for self-pollinated crops such as wheat or rice, and certainly not for clonally propagated crops such as potatoes. This clearly limits the applicability of the results of this research to other crops.

Third, there is need for a dialogue between scientists of different disciplines to analyze the implications of these results for breeding strategies and diffusion of improved germplasm. Clearly, this is something that social scientists cannot do alone. Breeders need to bring their technical expertise to judge the methods, feasibility, benefits, and costs for linking creolization into the breeding process.

Fourth, there is a need to go beyond a simplistic concept of yield as the yardstick of impact and look at the set of traits that farmers' value, how those traits are being

[16] Open pollination occurs when pollen from one plant fertilizing another is the dominant process; self-pollination occurs when pollen from the same plant does the fertilization.

supplied by the germplasm available, and the trade-offs they entail. Decreasing these trade-offs has an important and positive impact on farmers' well-being. That is the particular value of creolized varieties in the systems that we studied. Even yield is a more complex concept than tons/ha. As shown here, farmers have different concepts of yield, which are not necessarily correlated, e.g., yield by weight, yield by volume, yield of dough to make tortillas.

Fifth, extension strategies should pay more attention to understand local innovation and adaptation of improved varieties. Extension agents should not assume that an "improved" variety is automatically superior, especially for all characteristics that matter to farmers. An improved variety may be indeed superior for some traits but not for others, hence the value of local adaptation and creolization. There may be a role for extension in terms of strengthening the capacity of farmers to innovate and adapt improved varieties to their needs and circumstances, not just to promote adoption. For example farmers can be trained to understand maize reproduction better in order to support their capacity to creolize improved varieties. This is another area that merits further research.

Sixth, researchers and extension agents should be aware of farmers' actual practices with regard to management and recycling of improved and creolized seeds, which is explained by their resource base, local beliefs, and access to and trust in different sources of information. This provides a window of understanding into the usefulness of different varieties under different conditions and likely outcomes of introduction, adoption and creolization.

Seventh, the implications of being poor for farmers, their demand for traits, and the constraints they face are not the same in subsistence- and commercially-oriented systems. For example, improved germplasm, particularly hybrids are better able at benefiting the poor in a commercially-oriented system, but have a much more limited value in a more subsistence and isolated system. An *a priori* classification of areas by the dominant orientation of maize production should be very useful to target agricultural research to address the needs of the poor.

Finally, the results suggest that tools used by poverty alleviation programs are useful for a broad targeting of agricultural research. By focusing our research efforts on areas of high and very high marginality, we can target the research to address the needs and issues relevant to the poor as a first step. Once the targeted regions have been identified, it is important to understand people's asset base, perceived risks, beliefs and experiences, social networks, and the local political economy—and the relationships among them—to understand likely patterns of adoption and impact. This can best be accomplished through a combination of conventional survey and participatory and ethnographic methods. Our research has shown that this can be achieved within a reasonable framework of time and resources—and is worth the effort if helping poor farmers is a central objective.

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