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Poor Farmers' Perceived Benefits from Different Types of Maize Germplasm: The Case of Creolization in Lowland Tropical Mexico

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Summary. — This paper reports on a study of farmers' assessment of different types of maize germplasm—improved varieties, landraces, and creolized varieties—in two poor, but contrasting, regions of Mexico. Results show that these different maize types are planted in both regions. Farmers do not perceive an overall superior maize type in either region; all types have advantages and disadvantages, which entail trade-offs. We examine the hypothesis that creolization lessens these trade-offs and, hence, is a way of enhancing the benefits that farmers obtain from improved germplasm. Results show that creolized varieties occupy a niche that shifts according to the availability of improved germplasm and the orientation of farmers' maize production.

Key words — creolization, maize, Latin America, Mexico, poverty, vulnerability

1. INTRODUCTION

Improved maize varieties [1] have been available in Mexico for more than 40 years, but their dissemination has been limited. Despite repeated government campaigns to encourage use of improved seed, today only about one-fifth of the total maize area in the country is planted with improved varieties. Most of this area is located in the commercial production zones of central and northwestern Mexico (Morris & Lopez-Pereira, 1999). The relatively low adoption rate may give a misleading impression of the true impact of improved

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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. Farmers, 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, produce what many of them recognize as "creolized" varieties (*variedades acriolladas*) [2] (Bellon & Risopoulos, 2001). For example, according to several studies (Aguirre-Gómez, 1999; Perales-Rivera, Brush, & Qualset, 2003), small-scale Mexican farmers describe how they interplant improved varieties and landraces with the express purpose of incorporating desired traits from improved varieties or maintaining desired traits of older varieties. The fact that hybridization between local and improved maize is highly valued by farmers in Central America has also been reported (Almekinders, Louwaars, & de Bruijn, 1994).

Conventional impact studies on maize germplasm usually focus on areas planted with improved varieties (Morris, 2002). In a comprehensive review of the genetic change in maize germplasm under seed recycling (i.e., selecting seed from the previous harvest and replanting it), Morris, Risopoulos, and Beck (1999) conclude that genetic change in maize is ubiquitous and constant, which suggests the need to reassess the traditional way of thinking about categories of maize cultivars such as landraces, [3] improved open-pollinated varieties (OPVs), and hybrids. The recognition that these categories tend to change regularly presents a challenge to impact studies since "it becomes very difficult to define precisely what constitutes 'improved germplasm' and to quantify productivity gains associated with adoption" (Morris *et al.*, 1999, p. 51).

Furthermore, Morris *et al.* (1999) review the evidence of changes in the yield of hybrids under seed recycling. They note that the yield usually decreases significantly the first time seed is recycled; however, it tends to stabilize in subsequent generations and may even increase again if farmers exert selection pressure. In some circumstances, recycled hybrids may outperform landraces and improved OPVs, but this is not always the case, depending on the original difference in yield and the magnitude of the decline. Clearly the relationship between yield changes and seed recycling is not simple and will vary depending on the context in which it takes place.

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, for if creolization is ignored, the benefits generated by formal plant breeding programs may be significantly underestimated. Furthermore, breeders miss out on an opportunity to learn which maize traits respond to poor farmers' conditions and preferences. As many studies have shown, small-scale farmers who plant maize for subsistence and, particularly, those who also sell some of their production value multiple traits in their crop. [4] Usually no one variety can provide all of the valued traits; hence, farmers continually face trade-offs in their variety choices (Bellon, 1996; Smale, Bellon, & Aguirre, 2001). There is a growing body of literature that examines the extent to which different crop varieties supply valued traits to farmers and influence their adoption decisions (e.g., Adesina & Zinnah, 1993; Barkley & Porter, 1996; Edmeades, Smale, Renkow, & Phaneuf, 2004; Hintze, Renkow, & Sain, 2003; Smale *et al.*, 2001). In this literature, adoption decisions are modeled based on the principle that households derive utility from the crop's traits or attributes, rather than from the crop itself. So clearly changes in the supply of valued traits have important welfare implications for farmers, beyond trade-offs between the level of expected yields and the variance (or variability) in yield performance, which have been used to examine partial adoption in early adoption literature (Edmeades *et al.*, 2004).

This study documents how poor farmers in two regions of Mexico's tropical lowlands use and perceive benefits from different types of maize germplasm, from improved varieties and creolized varieties to landraces. We do this by assessing (a) the importance farmers assign to different maize traits, (b) farmers' perceptions of the extent to which different germplasm types supply those traits, and (c) the trade-offs they perceive among the different germplasm types. We also describe some of the key beliefs and practices that influence farmers' preferences and choices.

Our key hypothesis is that poor farmers benefit from improved germplasm through creolization. While improved varieties possess desirable traits not found in landraces, they may lack useful traits that landraces do have (e.g., a distinguishing feature of landraces is their local adaptation); hence, farmers choosing between them face trade-offs in the traits they seek. Creolization lessens these trade-offs by adapting improved varieties to farmers' conditions, thereby giving them new options. In other words, farmers modify the improved technology generated by the formal research system to suit their own circumstances and needs. [5]

Maize is an open-pollinated species—that is, when maize plants reproduce, the pollen that fertilizes the seed may come from the same plant or, more likely, from another growing nearby. This means that the parents of the new seeds or kernels are most likely genetically different. Hence, as stated earlier, there is a great potential for genetic changes in successive generations of maize plants (Morris *et al.*, 1999). Since creolization can be seen as a process that is based on this potential for genetic changes, its significance may be much greater in maize than in other crops such as wheat or rice, which are self-pollinated and hence have much less potential for genetic changes. There is evidence, however, that rice varieties change under farmers' management (Tin, Berg, & Bjørnstad, 2001).

The specific focus of this study is the Tuxpeño germplasm complex. One of approximately 250 maize landraces found in the New World, Tuxpeño has been subjected to intensive breeding, first by a joint Rockefeller Foundation/Mexican Ministry of Agriculture program and later by its successors, the International Maize and Wheat Improvement Center (Centro Internacional de Mejoramiento de Maiz y Trigo, CIMMYT) and Mexico's National Forestry, Agricultural, and Livestock Research Institute (Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, INIFAP). This study was carried out in two regions where Tuxpeño germplasm has been disseminated: the coast of Oaxaca and the Frailesca in Chiapas. The states of Oaxaca and Chiapas are among the poorest in Mexico.

2. METHODOLOGY

Twelve communities were selected for this study. The selection focused on areas in a gradient of poverty levels and contrasting access to improved germplasm. We chose communities in areas of medium, high, and very high marginality (used as a proxy for poverty) defined according to an index used by the Mexican government to target its poverty alleviation program (CONAPO-PROGRESA, 2000). Communities with an indigenous population were also included. It should be noted that while the index does not measure poverty *per se*, it does measure marginality—that is, the lack of access to essential goods and services. The index was calculated using a principal-components analysis of seven community-level census variables.

Some of the studied communities had been involved in government programs aimed at distributing improved seed, and others had not. Site selection also included agroecological considerations since the study focused on tropical maize germplasm, as well as information on government programs for the dissemination of improved seed. Different methodologies were used: (a) focus group discussions on technical issues and on livelihood strategies and vulnerability; (b) qualitative household case studies (including 40 in-depth ones) in which anthropologists spent several months in four of the 12 villages living and interacting with farmers in their homes, fields, and communities; and (c) a representative survey sample of 325 farm households covering all 12 communities. Furthermore, a collection of all maize types grown in the studied communities and an agronomic evaluation of maize samples were conducted as part of this research. [6] A maize taxonomist [7] classified the samples into maize races and by degree of introgression of improved germplasm.

Given the emphasis on poverty, the survey included a section on household consumption. Data were gathered on both purchased and self-produced items to which local prices for similar good and services were imputed. Based on these per capita data, expenditures were calculated and adjusted to adult equivalents and purchasing power. Two poverty lines were constructed according to the methodology of Guevara-Sanginés, Muñoz Piña, Estrada Díaz, and Acosta Romero (2000): extreme poverty (MX$415/capita/month in 2001) and poverty (MX$754.82/capita/month in 2001). Households were classified into three poverty groups: the extreme poor (expenditure below the extreme poverty line), the poor (expenditure between the extreme poverty and poverty lines) and the non-poor (expenditure above the poverty line). The household case studies disaggregated households into extreme poor, poor, and less poor households, using observed characteristics besides expenditure.

The survey included a section on farmers' evaluation of maize varieties, which covered

19 crop traits identified as significant in focus group discussions. The evaluation consisted of two parts: (1) an assessment of the importance to farmers of the identified traits, in which male and female farmers rated each trait as very important, important, or not important, in terms of its relevance for choosing a maize variety; and (2) an assessment of farmers' perceptions of the performance of each variety they grew relative to each previously identified trait. In each household, male and female farmers rated each variety separately as very good, good, poor, or very poor. Since females usually do not work in the fields, they were asked whether they actually participated in planting the variety or not. There were also instances in which currently grown varieties 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 definitions presented in Section 5.

The ratings of the importance of each trait for males and females in each study area were compared. Since males and females were not selected independently of each other, but were members of the same household (they were related), the non-parametric Wilcoxon signed ranks test was used to determine statistically significant differences between male and female ratings for each trait. To test whether the importance of a trait is related to poverty, we ran a non-parametric correlation between the importance rating of a trait and the expenditure of the household.

We used a proportional odds model (Agresti, 1996; Coe, 2002) to systematically examine farmers' perceptions of the varieties' performance with respect to traits they considered important. The model relates a dependent variable consisting of ordered response categories (e.g., farmers' ratings of performance for a trait) to a set of independent variables (e.g., types of maize germplasm grown by farmers and other covariates explained below) (see Appendix A for a brief explanation of the model). The model, estimated using PROC GENMOD in SAS (2001), was run independently for each of the 19 identified traits, separately for males and females, and individually for the two study areas. The estimated coefficients reported in the results section refer to the ratio between the odds that one germplasm type (e.g., hybrids) is rated higher for a trait (e.g., yield by weight) than to the same odds for a different germplasm type (e.g., landraces). An example of the interpretation is presented in that section.

Due to the importance of taking poverty into consideration in the estimated models, we included the predicted expenditure of the household as a covariate to correct for differences in ratings associated with different welfare levels. The predicted expenditure was used because expenditure is endogenous. The predicted values for expenditure were derived from a regression of the log of expenditure against a set of explanatory variables associated with local perceptions of poverty and other measures of marginality. One regression was estimated for each study area (see Bellon *et al.*, 2003). Because females may not have participated directly in growing many varieties and hence may have very limited knowledge and experience of the variety, which could bias their ratings, a dummy variable specifying if they actually had participated in growing the variety or not was included in the regressions of female ratings.

3. THE STUDY AREAS

Included in this study were 12 communities located in two highly contrasting regions: the coast of Oaxaca and the Frailesca, Chiapas. In this paper, the regions are referred to simply as Oaxaca and Chiapas. All 12 communities are located in environments where improved Tuxpeño varieties are well adapted. However, the results reported here are valid only for the communities studied (Figure 1), which were systematically selected so as to sample the range of marginality levels, the degree of improved germplasm adoption, and the ethnicity present in both regions.

Communities in Chiapas have better access to government-provided services and infrastructure, even for similar marginality levels, than those in Oaxaca. Production in Chiapas is more market oriented, and the region has received strong support from state and federal governments, particularly for agricultural development. Chiapas produces significant maize surpluses that are exported to other parts of Mexico; however, agriculture is still dominated by small-scale farmers who produce both for the market and their own consumption. There is an important dairy industry, and farmers can add value to their maize by using it as animal feed. The use of inputs and improved seed has been promoted through several government projects over the years.

Figure 1. *Map of Mexico showing Oaxaca and Chiapas, and the communities included in this study.*

In contrast, Oaxaca has been more isolated and has not received much government support for agricultural development. The state of Oaxaca imports substantial amounts of maize from other parts of Mexico and from outside the country. Although the coast of Oaxaca has a better climate for agricultural production than other regions of the state, it is not an important maize producer. Commercial farming concentrates more on extensive cattle ranching, while maize production is oriented toward home consumption. Development has depended more on tourism, particularly in the southern part of the study area.

Poverty is pervasive in both study areas, even in the more commercialized and developed Chiapas. Most farming households in our sample are under the extreme poverty line: 74.7% and 63.2% in Oaxaca and Chiapas, respectively. Households in the two study areas have diversified livelihoods: they grow several crops, raise different types of animals, and participate in diverse off- and non-farm activities. Aside from maize, farmers grow beans, squash, fruit trees, coffee, tomatoes, red peppers, sesame seed, hibiscus, groundnut, and cacao. Despite this diversification, maize continues to play a key role in the lives of farmers in both regions, since all households grow maize.

There are, however, differences among 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 either study area produce entirely for the market. More than half of the 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 other families in the community and, to a much lesser extent, to local traders. Farmers are much more commercialized in Chiapas. More than 90% produced surpluses in the last five years; almost all sold more than half of the maize they produced. [8] They sold mainly to the government, private businesses and local traders, or a combination of these. Almost none is sold to other families in the community.

Maize production is very important, but risky, for these farmers. There are many sources of vulnerability in maize production, including the weather (mainly rain, drought, and wind), money invested—and, hence, profitability—labor availability, lack of land, pests (insects and mammals), and degraded soils. Although there were differences between study areas, climatic risks were considered the most important source of vulnerability in both. Although farmers in both regions clearly benefit from growing and consuming maize, they also face risks and vulnerabilities. Maize is produced and consumed in a complex environment, not only in terms of agroecological conditions, but also due to socioeconomic and cultural factors. This complexity has led to a great diversity of maize germplasm being grown in these regions.

4. CREOLIZATION: A PROCESS PERCEIVED AND MANAGED BY FARMERS

The qualitative household case studies found that while most farmers did not classify maize varieties as "creolized," they clearly recognized the process of creolization and used it. In terms of perceptions, farmers classified any seed that does not come in a package or bag as "*criollo*" (local) maize, regardless of whether the seed originally came from a bag, was introduced from the outside or inherited from parents or grandparents. It should be pointed out that commercial seed of improved varieties is generally distributed in bags, while farmer-saved seed is not; hence, whether or not the seed came from a "bag" is used as a criterion to distinguish local from improved varieties.

Farmers do not define varieties so much as describe them in terms of their advantages and disadvantages. They have different degrees of confidence in different types of seed. Notably, people have more confidence in *criollo* seed because they are familiar with it. As one informant stated, "We have confidence in it because we already know it, have planted it before, and have no doubts about it." Selecting seed from the previous harvest and replanting it is considered to be creating creolized seed. Most people consider recycled seeds to be *criollo* in a few years. Even large-scale producers in Chiapas expressed their preference for *criollo* seed, although they generally plant improved varieties. Key to being classified as *criollo* is that the seed has been "*acclimatized*," that is, seen as adapted to local soils. According to a farmer in Chiapas, "At first it was like a hybrid and now, later, it is *criollo*... It likes the soil. It has become acclimatized." When asked whether this process was what makes a variety *criollo*, another farmer said, "Yes, that is exactly what makes it *criollo*. After several seasons, it adapts and will produce anywhere, because once it is planted, it knows the land; since the land is good, [it produces]."

When farmers are pleased with their harvest, they try to select and store seeds from it. There is the notion that "it is better to choose my own seed grain, the one I like" than buy bag seed that carries unknown traits. Informal networks are an important source of seed that people trust, particularly because they can observe the performance of a variety planted in the field of someone they know. Very poor farmers are risk averse, which means they need to see the seed maize produce before they will try it.

According to a farmer in Oaxaca, "Sometimes the maize is unknown, and you don't trust it enough to buy it. Instead, you turn to your people because you see that their crop grows well and the ears are pretty. So you ask if they have some seed stored away, and you buy a bit for planting. You can't trust store-bought seed...You have to see a variety growing in your neighbors' fields. If not, you don't buy it."

Informants also said they recycle seed because they cannot afford to purchase seed every year. Although all farmers recycle, the poorer case study informants were more likely to recycle than the richer ones. However, even some less poor informants prefer to plant recycled seed obtained from a neighbor who planted bag (improved) seed. Recycling gives the poor access to improved varieties whose original seed they could not afford to buy. According to informants, the number of years that farmers recycle varies between the study areas: four to five years in Chiapas and longer in Oaxaca. After this process they do not distinguish between the recycled varieties and those long in use.

Farmers believe it is possible to creolize or adapt any seed, and are skeptical that recycling has negative consequences. Many farmers believe that getting recycled seed from their neighbors is a way to improve their harvest, but they also recognize that seeds can degenerate over time. As one informant stated, "We change seed when the soil demands it. Sometimes the land just doesn't want the same seed because sometimes it has degenerated." Overall, however, there is a consensus that the process of recycling and selecting seed, or obtaining seed recycled by other farmers, provides good seed, seed you can trust.

The creolization process is not restricted to improved varieties—it also applies to "foreign" maize populations that are of interest to farmers, including landraces from other regions. After a few planting seasons—sometimes as little as two—a "foreign" maize population that proves successful under local conditions may be referred to as a *criollo* or local landrace. In some cases, farmers give the populations they grow the names *Híbrido Blanco* or *Híbrido Criollo* (White Hybrid or Local Hybrid) and consider them local landraces, even though they may recognize that originally these maize populations were introduced as improved varieties.

The case study research entailed observing maize planting systems to learn how creolization can occur. Farmers frequently divide their maize crop into several plots located on different slopes, and plant different varieties (usually two, sometimes more) under different conditions. In Chiapas, the more commercially oriented farmers plant their plots farther apart and use just one maize variety to avoid contamination. Some farmers, however, said that they planted more than one variety in the same plot, with little or no separation among them. In these cases, mixing maize varieties is not seen as a problem, as the maize is for household use, and deformed or mottled ears are fed to the animals. Farmers also plant different varieties at different times for different purposes and to minimize the risk of loss.

Farmers have varying degrees of knowledge of the creolization process. Some explained that a maize crop is always purest in the middle of a plot, and that plants on the borders show more mixed grains. They know that maize can be altered or contaminated when seeds are mixed through improper handling. Even if cross-pollination is not completely understood, some farmers identify it and do it on purpose. One very poor farmer from Oaxaca explained how:

> A year ago, I planted the maize we call 'tablita' alone in one plot, and together with another variety in another plot. If now I cross it with 526, [9] half of the grains will be yellowish in color and the ear will be a bit narrower... but it will become stronger. That is what we want—to cross a *criollo* with a variety to make it more resistant, so that it doesn't rot.

However, not everyone crosses maize varieties intentionally, nor do they know how to do it. Many just notice the cross because they see a change in kernel color or plant height as a result of having planted two varieties together: "We don't know why it happens, but it happens."

As a way to thank farmers for their participation in the study, project researchers gave them a talk on maize reproduction and ways to improve their maize varieties. Participants appreciated this effort and commented that these issues had never been explained to them and that many things they observed in the field were now starting to make sense.

5. MAIZE GERMPLASM AND USE

Farmers in both study areas plant numerous maize varieties, from hybrids to landraces (or *criollos*, as they are locally called). The authors collected different maize varieties and assembled a total of 126 samples, each representing a distinct type recognized by farmers in a community. [10]

The survey elicited detailed information on the varieties planted: their names, origin, history, and management. Morris *et al.* (1999) note that the dynamic nature of maize makes classifying maize varieties into distinct and well-defined categories difficult and somewhat arbitrary. However, some sort of classification is useful as long as the criteria used are workable, defensible, and consistent. We classified the maize varieties identified in the survey into five categories: hybrids, recycled hybrids, open-pollinated improved varieties (OPVs), creolized varieties, and landraces. Classification was based on (a) the name provided by the farmer, (b) whether the farmer said the seed came from a bag, (c) the number of years the seed had been 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. [11] Table 1 presents the specific criteria used for each category. This classification is also the basis for the analyses presented below and in Section 6.

The relative area planted and the proportion of farmers that plant each of the five types of maize germplasm vary between the two study areas (Table 2). Landraces predominate 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 among the non-poor. Furthermore, the use of landraces, even though they are dominant, is lowest among the non-poor.

In contrast, improved germplasm and, particularly, hybrids are predominant in Chiapas. All farmers, particularly the non-poor, plant improved maize types. All poverty groups also plant creolized varieties and landraces. Creolized varieties are the single, most widely sown maize type in terms of relative area and proportion of farmers, and are planted in roughly similar proportions by all poverty groups.

Despite the widespread adoption of improved germplasm, landraces occupy more than a fifth of the area sown to maize in Chiapas and are planted by more than a fourth of farmers, particularly the poor. The importance of landraces decreases as the poverty level decreases. In both study areas (although on very

Table 1. *Criteria for classifying varieties identified during the survey into five categories*

Category	Criteria
Hybrid	—Name provided by farmer is of a known hybrid or a company that only sells hybrids —First year planted; seed came from a "bag" —Focus group identified name as a hybrid introduced to the community by the government or commercial outlet —Maize taxonomist indicated that sample with the same name was a hybrid or recycled hybrid
Recycled hybrid	—As above, but farmer planted seed from previous harvest up to four years
Open-pollinated variety	—As above, but name provided by farmer was of a known OPV —Seed planted for the first time or recycled up to four years
Creolized variety	—Any of the above, but farmer recycled seed for more than 4 years and up to 15
Landrace	—Name of a known maize race (e.g., Zapalote, Tepecente, Olotillo) provided by farmer —No specific name (*maíz blanco*) but planted for many years by either the farmer or someone else in the community —Did not come from a bag —Focus group identified name as a local variety —Maize taxonomist indicated that sample with the same name was a landrace

different scales), there seems to be a trend toward increasing use of hybrids and improved germplasm with decreasing poverty and a reverse trend for landraces. Creolized varieties seem neutral to poverty level in both areas.

It is important to point out that farmers obtain seed of this diverse set of varieties from different sources, which vary by region and germplasm type. In Oaxaca, only a few farmers purchased hybrid seed from commercial outlets, and almost all seed is either saved by the farmer or obtained from other farmers (mostly family and friends). This is not surprising, since most seed is from creolized varieties or landraces. The same is true of creolized varieties, landraces, recycled hybrids, and OPVs in Chia-

Table 2. *Distribution of germplasm types by area and numbers of farmers*[a]

	Extreme poor		Poor		Non-poor		Total	
	Area (ha)	Farmers	Area (ha)	Farmers	Area (ha)	Farmers	Area (ha)	Farmers
Coast of Oaxaca								
Total	3,011.67	2,645	833.01	666	320.58	228	4,165.26	3,539
Relative distribution (%)								
Hybrids	1.5	3.1	0.0	0.00	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
OPVs	7.0	7.0	2.0	2.8	2.5	8.1	5.7	6.3
Creolized varieties	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 (%)								
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
OPVs	20.0	33.1	12.8	22.8	4.3	10.5	16.4	28.0
Creolized varieties	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

[a] Estimates derived from the sample survey using expansion factors.

pas, but not hybrids, and first-year OPVs, whose seed is obtained through the formal system.

The formal system consists of a combination of transnational and local seed companies that sell mostly hybrid seed, but local seed companies and a farmer's cooperative sell OPV seed as well. There is strong government support for the formal sector through programs that support "*despachos*," private consulting firms that provide technical and administrative assistance as well as inputs (including seed) to farmers and are the conduit for government subsidies. The *despachos* appeared in 1994 with the privatization of extension delivery. Farmers who wish to work with the *despachos* organize into groups and name a representative who deals with the *despachos*. The *despachos* in turn negotiate with seed companies and procure seed for their clients. Most farmers rely on *despachos* to obtain hybrid or OPV seed, but some sidestep the *despachos* and buy independently from seed distributors or agricultural input shops.

6. FARMERS' PERCEPTIONS OF DIFFERENT TYPES OF MAIZE GERMPLASM: THE IMPORTANCE OF CROP TRAITS AND PERFORMANCE

The key hypothesis of this study is that farmers, particularly the poor, benefit from improved germplasm through creolization. Improved varieties provide desirable traits or combinations of traits not found in landraces, but they may lack traits landraces possess; hence, choosing one or the other presents trade-offs to farmers. Creolized varieties can provide traits not supplied by landraces, and they entail fewer trade-offs than improved varieties. To determine the impact of creolized varieties on farmers' well-being, one has to examine the importance farmers give to different traits and the extent to which each germplasm type supplies farmers with traits they value. Although it would be very useful to have an objective measure of the degree to which a variety supplies a given trait, this is seldom possible since trait expression may vary from season to season (e.g., high yield one year, low yield the next) and may depend on the specific circumstances in which the crop is grown (e.g., high fertility, low fertility). Furthermore, many traits are strongly subjective (e.g., food grain quality). It may be more important to assess farmers' perceptions of how well the germplasm they plant supplies the traits they value, for these perceptions should capture their long-term experience with the crop and, as we all know, our perceptions shape what we consider a benefit or a cost, and influence our decisions.

(a) *The importance of crop traits for farmers*

Although a large number of traits were assessed, almost all males and females in Oaxaca and Chiapas rated them as very important or important. Table 3 shows the percentage of farmers who rated each trait as very important, by gender, for both study areas; it also indicates whether a farmer's rating of a trait was correlated to the expenditure of the household he or she belongs to—as an indicator of the importance of a trait for the poor—and whether there were statistically significant differences between the ratings of males and females.

Almost all traits were rated as very important by 50% or more of farmers in both study areas. This suggests that focus groups were very accurate when identifying relevant crop characteristics and that these farmers value multiple traits. Traits rated as very important by the highest number of male farmers in Oaxaca were yield by weight, yield of tortilla dough, ease of shelling, and resistance to lodging (plants knocked down by wind or rain). Yield by weight is a key trait for breeding, tortilla dough yield is a trait that breeders seldom take into account, and lodging is a key source of risk and vulnerability in maize production. As pointed out earlier, farmers in Oaxaca are still strongly oriented toward subsistence farming, so tortilla dough yield and ease of shelling are understandably important to them. Traits rated as very important by the highest number of females are lodging resistance, tortilla dough yield, quality for making *atole* (a maize-based beverage), tolerance to excess rainfall, and *nixtamal* [12] quality. As one would expect, consumption characteristics seem more relevant to females than males, since females are in charge of maize processing and preparation.

Correlations between expenditure and importance ratings showed that to males, length of growing cycle, good for "*elotes*" (corn on the cob), and good for fodder become more important as poverty decreases. There seemed to be no traits that were particularly important to poor male farmers. To poor females, however,

Table 3. *Percentage of farmers who rated a trait as very important, correlations between ratings and expenditure (superscript), and differences of importance between genders in Oaxaca and Chiapas, Mexico*

	Coast of Oaxaca			Frailesca, Chiapas		
	Males	Females	Sign.[a]	Males	Females	Sign.[a]
Number of households	162	162		161	158	
Vulnerability						
Lodging resistance	69.8	98.8	****	82.6	94.3[c]	***
Drought tolerance	75.9	83.3[c]		75.2	72.2	
Tolerance to excess rainfall	54.3	84.6	****	70.8	88.6	****
Ear rot resistance	61.1	75.2[c]	***	68.9	80.4	**
Duration (growing cycle)	49.4[b]	80.9	****	62.1	82.3	****
Field pest resistance	66	83.3[c]	***	69.6	80.4	**
Storage pest resistance	58.6	75.9	***	61.5	80.5	****
Produces even in a bad season (yield reliability)	58	75.9	****	64.6	76.7	**
Good for sale	55.9[b]	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 *elotes* for sale and consumption	50.6[b]	69.8	****	60.2	74.2	***
Good for *antojitos* (special maize preparations)	58.6	75.9	***	65.2	79.2	**
Ease of shelling	70.4	76.5		42.9	73	****
Good for *nixtamal*	61.1	84.6	****	68.9	83.6	***
Good for fodder	27.8[b]	54.8	**	49.1[c]	64.8	
Productivity						
Yield of tortilla dough	77.2	92	****	83.9	89.2	
Yield by weight	84.6	67.9	****	89.4	67.1	****
Yield by volume	67.2[b]	61.1	*	72.7	68.4	

[a] Significance level associated with a Wilcoxon signed rank test comparing the ratings of males *versus* females for the trait. Results of this test indicate whether there were differences in ratings between males and females within the same household. The complete set of ratings was used for the test. *, **, ***, **** Significant at the .10, .05, .001, and .0001 levels, respectively.
[b] Positive statistically significant non-parametric correlation between expenditure and rating of a trait's importance by an individual. It indicates importance decreases with poverty—that is, the trait is less important to the poor.
[c] Negative statistically significant non-parametric correlation between expenditure and rating of a trait's importance by an individual. It indicates importance increases with poverty—that is, the trait is more important to the poor.

three traits were significantly important, according to correlations: drought tolerance, ear rot resistance, and pest resistance. These traits are related to vulnerability factors that in general seem to be more important to females than to males. Finally, the comparison between importance ratings by males *versus* females shows statistically significant differences for all traits except drought tolerance and ease of shelling. In all cases except yield by weight, females gave higher ratings than males—that is, they assign more importance to traits than males do. This suggests that trade-offs between maize types may be more significant for females than for males.

Traits rated as very important by the highest number of male farmers in Chiapas are very similar to those for male farmers in Oaxaca: yield by weight, tortilla dough yield, lodging resistance, drought tolerance, and yield by volume. By the same token, traits rated very important by the highest number of females are similar to those for females in Oaxaca. Consumption characteristics were also more relevant to females than to males. This shows that despite the high level of commercialization—although in Chiapas marketability is considered more important than in Oaxaca—subsistence production is still relevant to females. Correlations between expenditure and importance ratings showed that the importance of "good for fodder" is only associated with poor males, while the importance of lodging resistance, a vulnerability factor, is only associated with poor females.

Finally, the comparison between importance ratings of males *versus* females shows statistically significant differences for most traits except drought tolerance, good for fodder, tortilla dough yield, and yield by volume. As in Oaxaca, for traits where there were gender differences, females gave higher importance ratings—that is, they assigned more importance to traits than males did, except for yield by weight. This suggests that trade-offs between maize types may be more significant for females than for males, except in the case of yield by weight.

In both study areas, most traits were of similar importance to all farmers regardless of poverty status, although there were a few cases where poverty status did make a difference, particularly for females in Oaxaca. Furthermore, though most traits were relevant to both males and females, there were important gender differences in the demand for traits in the two study areas—for example, yield by weight was particularly important to males, as evidenced by the fact that they rated the importance only of this trait substantially higher than did the females.

(b) *Farmers' perceptions of the performance of different germplasm types*

Proportional odds regressions were run for all 19 traits identified in Table 3. Results for Oaxaca and Chiapas are presented in Tables 4 and 5, respectively. For simplicity's sake, only traits for which there were statistically significant differences are shown in the tables, which should be interpreted as follows: the category in a row was rated as being superior to the category in the column for the traits described in the cell located where the row and the column intersect. The number in parentheses is the ratio between the odds that one germplasm type (e.g., hybrids) will be rated higher with respect to a trait (e.g., yield by weight) to the same odds for a different germplasm type (e.g., landraces). For example, in Table 4, male farmers were almost eight times (7.6) more likely to rate creolized varieties high for yield by weight than to rate landraces high for this trait.

Comparisons can be made in the opposite sense as well. By taking the reciprocal of the odds ratio associated with a trait in the intersection of the row and the column, one can see how inferior the maize type in the column was rated compared to the maize type in the row. By comparing the traits described in cells that result from inverting the categories in the rows and columns, one can identify the trade-offs between two types of maize. For example, in Table 4, for male farmers, the trade-offs between creolized varieties and landraces are ease of shelling, good for *nixtamal*, good for fodder, and good for *elotes versus* yield by weight and lodging resistance.

(i) *Results from Oaxaca*

Table 4 shows that for males in Oaxaca, there were statistically significant differences for only

Table 4. *Comparisons of different germplasm types with respect to traits with statistically significant differences in ratings, by gender (female ratings preceded by an "F"), Coast of Oaxaca*

Categories in rows rated superior to categories in columns[a]	Improved varieties[b]	Creolized varieties	Landraces
Improved varieties		F-Produces even in bad season (4.3)*	Lodging resistant (3.8)** F-Lodging resistant (4.5)**
Creolized varieties			Lodging resistant (5.6)*** Yield by weight (7.6)*** F-Lodging resistant (4.6)***
Landraces	Ear rot resistance (3.8)** Ease of shelling (8.8)*** F-Ease of shelling (2.9)*	Ease of shelling (5.2)**** Good for *nixtamal* (4.3)*** Good for fodder (3.4)* Good *elotes* (2.7)*	

[a] The number in the parentheses corresponds to the odds ratio associated with the comparison.
[b] Improved varieties include hybrids, recycled hybrids, and OPVs, which were added together due to the low number of observations by category.
*, **, ***, **** Statistically significant at the .10, .05, .01, and .001 levels. The significance level was adjusted by the number of pairwise comparisons.

Table 5. *Comparisons of different germplasm types with respect to traits with statistically significant differences in ratings, by gender (female ratings preceded by an "F"), Frailesca, Chiapas*

Categories in rows rated as superior to categories in columns[a]	Hybrids	Recycled hybrids	OPV	Creolized varieties	Landraces
Hybrids		Good for *elotes* (5.0)** Good for *antojitos* (5.3)** Good for sale (4.9)*	Good for sale (4.4)*** Good for *antojitos* (5.3)** Good for *atole* (3.4)* Good for *elotes* (3.8)* Good for fodder (3.3)*	Good for *elotes* (3.6)* Lodging resistant (2.7)*	Resistant to lodging (6.9)**** Good for sale (4.4)*
Recycled hybrids	F-Produces even in bad season (17.3)*		F-Produces even in bad season (16.0)*		Resistant to lodging (5.3)***
OPVs	Storage pest resistance (4.8)***				Resistant to lodging (3.2)*
Creolized varieties	Storage pest resistance (4.9)**** F-Storage pest resistance (3.9)* F-Field pest resistance (4.2)*				
Landraces	Ear rot resistance (4.0)*** Storage pest resistance (5.2)*** F-Tolerance to excess rainfall (11.0)*** F-Ear rot resistance (5.1)*				

[a] The number in the parentheses corresponds to the odds ratio associated with the comparison.
*, **, ***, **** Statistically significant at the .10, .05, .01, and .001 levels, respectively. The significance level was adjusted by the number of pairwise comparisons.

seven of the 19 traits rated. No single maize type was rated higher for all of those traits than the other types available; hence, one can say that all types were perceived to have advantages and disadvantages with respect to each other. Most advantages (traits rated as superior) were associated with landraces; however, both improved and creolized varieties were rated high with respect to resistance to lodging—a key vulnerability factor in the area. While landraces were considered to be superior for many traits, improved and creolized varieties provided a trait landraces lack: lodging resistance. Furthermore, creolized varieties, although inferior to landraces for some consumption traits (good for *elotes*, *nixtamal*, and fodder, and ease of shelling) were superior for yield by weight. Clearly these maize types entail some trade-offs between key traits. These results support the hypothesis that creolized varieties offer a combination of traits not provided by landraces nor improved varieties and, hence, entail fewer trade-offs.

Furthermore, creolized seed is much cheaper than improved seed; for example, hybrid seed costs 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.

Poorer informants in some of the household case studies indicated that although they considered that improved seed was very expensive, they would nonetheless "sacrifice" and buy it 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 are another indication that farmers perceive advantages in the former compared to the latter and are willing to pay a premium.

For females, there were statistically significant differences for only three of the rated traits. For two of these traits, lodging resistance and ease of shelling, the results are similar to those of males. Only for yield reliability (i.e., yields even in a bad year) females rated improved varieties higher than creolized varieties, unlike males, for whom no differences were observed. One would have expected creolized varieties to be rated higher in this respect given they have been grown for a longer time in these areas and thus could be better adapted and more stable (low year-to-year variability). There is no clear explanation for these results, which merit further investigation.

As indicated in the methods section, a dummy was included in the female regressions to account for the actual experience of growing a variety. This variable was statistically significant for several traits [13] indicating—not surprisingly—that females' actual experience with varieties influences their perceptions of varietal performance.

(ii) *Results from Chiapas*

Table 5 shows that for males in Chiapas, there were statistically significant differences for nine of the 19 rated traits. As in Oaxaca, no single maize type was rated higher than all other types available, and there were statistically significant differences for all nine traits. Hence, one can say that all types have advantages and disadvantages with respect to each other. A wider range of maize types is available in Chiapas than in Oaxaca, and thus, more comparisons were made. In general, males perceived hybrids had many advantages compared to other types of germplasm available. They rated hybrids higher than OPVs (in particular) and recycled hybrids for several traits (related to consumption and marketing characteristics). However, OPVs, creolized varieties, and landraces were rated higher than hybrids when it came to storage pest resistance, a key trait for subsistence farmers. Landraces were also rated higher than hybrids with respect to ear rot resistance. Storage pest resistance and ear rot resistance are closely linked to vulnerability, suggesting that landraces are valuable for addressing vulnerability issues. Overall, improved varieties were rated superior to landraces for lodging resistance.

Farmers' ratings of creolized varieties do not indicate they perceive these varieties to have many or unique advantages, unlike in Oaxaca. However, the price of creolized seed is on average higher than that of landraces (MX$6.33/kg *vs.* MX$3.51/kg, respectively) and much cheaper than the hybrid price (MX$20.25/kg), suggesting farmers are willing to pay a premium for creolized varieties over landraces.

For females, there were statistically significant differences for only four of the traits rated. Females perceived hybrids to be inferior to landraces, creolized varieties, and even recycled hybrids. They perceived more and unique advantages in creolized varieties and landraces. Recycled hybrids were rated high for yield reliability compared to other types of improved germplasm. As in the case of Oaxaca, however, there were many traits for which the variable indicating actual experience with a type of germplasm was significant, that is, that females' actual experience with varieties influences their perceptions and how they rate traits. [14]

7. DISCUSSION AND CONCLUSIONS

This paper has shown that farmers in the study area plant different types of maize varieties. In neither region do farmers perceive an overall superior maize type; all types have advantages and disadvantages. In the subsistence-oriented farming systems of Oaxaca, landraces seem to have more advantages, while in the commercially oriented systems of Chiapas, hybrids seem to have more advantages, but even there, landraces still play an important role. In both systems, creolized varieties are commonly planted by different socioeconomic groups.

There is no question that farmers are aware of the creolization process, as the qualitative part of the study has shown. However, farmers vary in their understanding of it. Farmers recognized that any "foreign" variety, not just improved ones, can undergo creolization. Furthermore, their comments suggest they value the process because through it, varieties become better adapted to their conditions.

A statistical analysis of their perceptions of the traits supplied by different germplasm types revealed a more complicated picture. Farmers in Oaxaca perceive more advantages in creolized varieties than those in Chiapas. Oaxacan farmers perceive that creolized varieties provide traits that landraces do not, as well as useful combinations of traits that reduce some of the trade-offs between landraces and hybrids. This supports our hypothesis on creolization and the role it plays in farmers' maize production systems.

In Chiapas, however, where there is a wider array of maize germplasm types and, hence, of different traits, creolized varieties were not perceived to have many advantages, and there was no perception of unique trait combinations, at least among males. Females had a more positive attitude toward creolized varieties, particularly compared to hybrids. This suggests that in more commercial systems, with a wider diversity of germplasm types, creolized varieties are not considered as advantageous (although this varies by gender), which contrasts with the situation in more isolated and subsistence-oriented systems. In any case, the data on area planted and the number of farmers who plant creolized varieties indicate these varieties are still widely grown across poverty groups. These results show that creolized varieties occupy a niche that shifts according to the availability of improved germplasm and the orientation of farmers' maize production.

The results presented here will contribute to the growing body of literature on partial adoption that incorporates into farmers' adoption decisions, the degree to which different germplasm types supply preferred traits (e.g., Adesina & Zinnah, 1993; Barkley & Porter, 1996; Edmeades *et al.*, 2004; Hintze *et al.*, 2003; Smale *et al.*, 2001). Our study examined in more detail the trade-offs faced by farmers given that one maize variety or germplasm type is seldom superior in all the traits they value. Furthermore, this study has shown that farmers perceive they can influence the supply of some of these traits through their practices, effectively modifying the trade-offs they face. This is possible due to the reproductive biology of maize, an open-pollinated crop of great plasticity. Increasing evidence from population genetics studies shows how small-scale maize farmers in Mexico shape the diversity of traits in their maize populations (Pressoir & Berthaud, 2004).

Our findings also highlight the need to go beyond a simplistic concept of yield as the yardstick by which to measure impact. It is necessary to take into account the set of traits that farmers value, the degree to which those traits are being supplied by the available germplasm, and the trade-offs they entail. Decreasing these trade-offs has an important, positive impact on farmers' well-being, and that is the particular value of creolized varieties in the systems we studied. Even yield is a more complex concept than just the number of tons per hectare. As shown here, farmers have different concepts of yield that are not necessarily correlated—for example, yield by weight, yield by volume, and yield of tortilla dough.

When dealing with poor farming households, it is essential to take into account the socioeconomic context in which they are immersed to be able to understand the impacts of different germplasm types. What being poor implies for farmers, the importance they attach to different traits, and the constraints they face are not necessarily the same in a subsistence-oriented system as in a commercially oriented one. For example, improved germplasm, particularly hybrids, is better suited to benefiting the poor in a commercially oriented system and has much less value in an isolated subsistence system. An *a priori* classification of areas by the predominant orientation of maize production should be very useful for targeting agricultural research to address the needs of the poor.

Improved maize varieties can change in farmers' hands. Changes are not necessarily negative; in fact, farmers may consider them positive. Changes are associated with farmers' selection and seed management practices, which are in turn affected by their economic, social, and cultural conditions. Rather than ignore the changes, we need to find ways of taking advantage of them. It is not yet clear how best to do this, but the issue merits further research. [15] Since farmers' practices and their impacts are more important among the poor, particularly in more subsistence-oriented systems, this study should be particularly relevant to address the needs and conditions of the poor.

Multidisciplinary discussions are required to analyze the implications of these results for determining breeding strategies and disseminating improved germplasm. Social scientists cannot do it alone. Based on their technical expertise, breeders can judge the feasibility, methods, benefits, and costs of incorporating creolization into the breeding process. Farmers should also be involved in the process through new types of participatory research methods. Through these methods, breeders can learn about farmers' practices, conditions, and preferences and take them into account when developing new varieties; similarly, farmers can learn about maize reproduction from breeders, which enables them to take more informed control of the process to better meet their needs. Analyzing the impact of improved germplasm on farmers' welfare requires new ways of looking at how farmers and germplasm interact.

NOTES

1. An improved variety is a maize population that has been scientifically bred and conforms to the International Union for the Protection of New Plant Varieties (UPOV) criteria of being distinct, uniform, and stable. Improved maize varieties may be hybrids or OPVs. For simplicity's sake, a hybrid can be defined as the result of crossing two inbred lines, while improved OPVs are populations that breeders have selected for a very specific set of traits. If a hybrid seed 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 usually up to three years without major drops in yield; hence, seed can be purchased once every three years.

2. "*Acriollado/a*" (translated here as creolized) derives from the word "*criollo*" which means local variety or landrace to farmers; it can loosely be translated as meaning "becoming a *criollo*." 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. In this paper, creolized varieties are defined as originally improved varieties that have been under farmer management for several generations.

3. Landrace refers to a locally grown maize population, the result of farmer selection and management over many generations.

4. Commercial farmers may value multiple traits as well, but usually not as many as are valued by farmers who are producing for both subsistence and sale.

5. In this regard, farmers are following a similar procedure as breeders from national agricultural research organizations that use germplasm from the Consultative Group on International Agricultural Research (CGIAR) centers to enhance locally adapted varieties. Breeders, however, can adapt only a limited number of varieties to a relatively few niches compared to the number of niches that may exist in a country or region. Creolization, on the other hand, may allow a multitude of farmers to adapt different improved varieties to the numerous niches where they farm.

6. For a complete description of the methodology, see Bellon, Adato, Becerril, and Mindek (2003).

7. Dr. Juan Manuel Hernández Casillas, INIFAP.

8. It may seem surprising that high levels of commercialization coexist with high levels of extreme poverty. This suggests that increased production does not mean less poverty. As these farmers pointed out, nobody overcomes poverty by growing maize. Addressing these issues is, however, beyond the scope of this paper.

9. The informant was referring to V-526, a publicly developed, improved, OPV.

10. The sampling strategy was to collect all the different maize types recognized in each community. Maize types or varieties were identified during focus group discussions and through the survey, which took place before the collection.

11. Farmers were also asked how they classified each variety. They provided four categories: hybrid, improved, landrace, and creolized variety. Sometimes they classified what was clearly a landrace based on its name and origin of the seed as a hybrid, and vice versa. Different farmers in the same community may classify a variety with the same name in different categories. Given these inconsistencies, we preferred not to use their classification, but developed the criteria described above. In any case, both classifications reflect a similar gradient of "scientific breeding" involvement in the germplasm from high to low. Based on similar gradients, we found that the two classifications are different, but also highly correlated (Spearman rho correlation = 0.722, $p <$ .0001). We applied the same statistical analysis to farmers' ratings but using their classification as the grouping category; their categories were different—although highly correlated to ours—but the results are consistent with the ones reported here.

12. *Nixtamal* is the local word for maize grains that have been boiled as the first step toward making tortillas. Tortilla dough is produced by grinding the *nixtamal*. During the survey, we used *nixtamal* when referring to the quality of the dough and yield of tortilla dough (or dough yield) when referring to the rate of transformation between the amount of grain used to produce the *nixtamal* and the number of tortillas produced from it.

13. Traits for Oaxaca included lodging resistance, field pest resistance, good for *nixtamal*, storage pest resistance, and dough yield.

14. Traits for Chiapas included lodging resistance, field pest resistance, ease of shelling, storage pest resistance, yield reliability, yield of dough, and yield by volume.

15. For example, CIMMYT is exploring a method called ''targeted allele introgression,'' which allows the incorporation of valuable traits (such as drought tolerance and storage pest resistance) from elite germplasm into local maize populations, and builds on farmers' seed management practices (Bergvinson & García-Lara, 2004).

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APPENDIX A. THE PROPORTIONAL ODDS MODEL

The proportional odds model (based on Agresti, 1996, pp. 211–213) is based on the cumulative probabilities that a response variable Y falls in category j or below, for each possible j; j refers to ordered categories. The cumulative probabilities reflect the ordering, $P(Y \leqslant 1) \leqslant P(Y \leqslant 2) \leqslant P(Y \leqslant 3) \leqslant \cdots \leqslant P(Y \leqslant J) = 1$. The logits for the first $J-1$ cumulative probabilities are

$$\text{logit}[P(Y \leqslant j)] = \log\left(\frac{P(Y \leqslant j)}{1 - P(Y \leqslant j)}\right).$$

The proportional odds model models the response of the cumulative logits associated with J response categories as a linear function of a set of predictors (X_i)

$$\text{logit}[P(Y \leqslant j)] = \alpha_j + \beta x_i,$$
$$j = 1, \ldots, J-1; \quad i = 1, \ldots, I,$$

where J refers to the number of ordered response categories and I to the number of predictors. Predictors can be continuous, categorical, or of both types.

In our case, the response variable is the ratings (very good, good, poor, or very poor) farmers gave the varieties they plant based on their perception of the varieties' performance for traits identified as relevant. The predictors are the type of germplasm associated with the ratings and predicted expenditure as a covariate. In the case of female ratings, an additional covariate was included to account for their actual experience of growing the variety. Each coefficient reported in Tables 4 and 5 is the ratio between the odds that one germplasm type (e.g., hybrids) is rated higher with respect to a trait (e.g., lodging resistance) to the same odds for a different germplasm type (e.g., landraces). Each coefficient corresponds to a pairwise comparison between two germplasm types; hence the significance level associated with each coefficient was adjusted by the number of pairwise comparisons.