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Farmers, Gene Banks and Crop Breeding

Economic Analyses of Diversity in Wheat, Maize, and Rice

edited by
Melinda Smale

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Melinda Smale

International Maize and Wheat Improvement Center
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15 COLLABORATIVE PLANT BREEDING AS AN INCENTIVE FOR ON-FARM CONSERVATION OF GENETIC RESOURCES: ECONOMIC ISSUES FROM STUDIES IN MEXICO

M. Smale, D. Soleri, D. A. Cleveland, D. Louette,
E. Rice, J.-L. Blanco, and A. Aguirre

15.1. CONTEXT

15.1.1. Perspectives on Conservation

One characteristic of classical crop improvement and genetic resource conservation programs is their physical and temporal distance from one another as well as from the farmers who are their clients. Genetic resources in breeders' working collections or conserved *ex situ* in gene banks are used in crosses, and selection in segregating populations is carried out under experimental conditions. The resulting varieties or advanced lines are eventually tested in a range of sites, but often testing does not include the fields of farmers, especially small-scale farmers in environments beset by biotic and abiotic stresses. The finished products are released after years of research and intended for use over extensive geographical areas. Varieties are developed to be highly responsive to certain growing conditions. Controlling—and thus simplifying—growing environments with respect to water supply, soil fertility, pests, and diseases has been an effective, efficient strategy. Through this strategy, the utilization of genetic resources conserved *ex situ* expands from the local to the global arena, which potentially increases their economic value. Furthermore, the costs of conserving genetic resources of a given crop are not borne directly by the farmers who produce the crop. In this classical system, the goal of conservationists is to preserve maximum allelic diversity in crop populations that they define as having global importance. We refer to this as the "conservationist perspective."

In traditional, low-resource farming communities located in marginal, variable environments, the crop populations that endure are those that meet production and consumption standards and that possess the genetic variability to respond to continual changes in farmers' needs and growing environments. Farmers in such communities choose among crop populations and select within them to meet their needs, given their economic and environmental constraints. Since these needs are defined both in the present and the future, the crop populations maintained by these communities serve both production and "conservation" functions simultaneously, as these are locally defined. Often, genetic diversity eventually has a negative effect on productivity through reduced adaptation, so for farmers the optimal level of diversity may be less than it is for conservationists, even in the absence of other constraints. We refer to this as the "farmer perspective."

When these perspectives are compared, two points emerge that have particular relevance to economic incentives and conservation policy. First, in the locally based system compared to the more classical system, farmers themselves directly bear the costs of conservation. Second, the crop populations that farmers seek to maintain locally are not likely to be those that preserve maximum allelic diversity among populations identified as global conservation targets.

Soleri and Smith (1995) first identified this contrast in analyzing the prospects for conserving traditional crop varieties *in situ*. The same contrast recurs in the context of collaborative plant breeding. "Collaborative plant breeding" is a recently named, but not altogether new, approach to crop improvement for meeting the needs of agricultural communities. It differs technically from more classical crop improvement and conservation efforts, although it may serve similar goals.

The idea behind collaborative plant breeding is that the biological effectiveness of plant breeding and/or the breadth of its social impact can be enhanced by drawing farmers into developing varieties with professional plant breeders or, conversely, by bringing professional plant breeders closer to farmers' local conditions and selection and maintenance practices. The collaborative plant breeding idea has emerged at the same time as, and has been encouraged by, recent interest in conservation *in situ* (see chapters in part III). Potentially this sets the stage for a conflict between the farmer and conservationist perspectives. As a means to improve crops locally, collaborative plant breeding is intended to serve the goals of farmers; as a proposed incentive for *in situ* conservation, collaborative plant breeding serves the goal of conservationists. For example, suppose that farmers considered a collaborative plant breeding initiative to be less successful in terms of crop improvement than conservationists considered it to be in terms of maintaining genetic diversity. Effectively, farmers would be "paying," at a net loss to themselves, for global conservation.

15.1.2. The Goals of Collaborative Plant Breeding

Farmers are themselves plant breeders, but we use the term "professional plant breeder" to refer to persons who practice plant breeding full-time and are paid to do so. Farmers are compensated for their plant breeding efforts indirectly—through the enhanced value of their crop in money or in kind. The livelihood of many small-scale farmers depends not only on the efficacy of their choice and breeding of crop varieties in terms of food production on their own farms, but also on their engagement in activities other than farming. In comparison, the success of most professional plant breeders has traditionally depended on the development of varieties acceptable to a significant proportion of farmers in selected target areas.

Collaborative plant breeding refers to a range of crop improvement activities defined by the relative involvement of farmers and professional plant breeders in the development of new crop varieties. To date, most collaborative plant breeding efforts have attempted to bring farmers into an established breeding agenda earlier than in classical programs, where they enter the picture when choosing among released varieties supplied to them through the seed industry. Building on Biggs' (1989) typology of farmer participation in national agricultural research systems, Witcombe and Joshi (1996) have subdivided this approach to collaborative plant breeding into two categories. Participatory varietal choice operates at the inter-varietal level. In their own fields or in on-station demonstrations, farmers choose "finished" varieties from among those offered by plant breeding programs before release. Participatory plant breeding occurs at the intra-varietal level. In the earlier stages of cultivar development, farmers are included in the choice of plant characteristics to improve, crop populations, and breeding techniques. Within these two broad approaches, there is a wide range of potential farmer and professional involvement, depending on the setting and objectives of the research. Experience is limited with both categories of activities, however. An alternative approach is to ask breeders to contribute to an established, farmer-based breeding or selection regime. Here, although the range of potential contributions by both farmers and professionals is also wide, experience is even more limited.

Among the multiple goals of collaborative plant breeding that have been proposed in the literature, two are of primary interest in this chapter. The first is to enhance the contribution of farmers' varieties to their production goals, by improving yield, stability, or post-harvest traits related to storage, processing, or consumption quality. Through selecting for specific adaptation, breeders may better meet the needs of poor farmers in stressed environments who have not yet received benefits from improved varieties (Ceccarelli *et al.*, 1997). Collaborative plant breeding can enhance the effectiveness of plant breeding programs by increasing the likelihood that selection criteria and methods are relevant for local environmental demands as well as farmers' needs (van Oosterom, Whitaker, and Weltzien, 1996; Weltzien, Whitaker, and Anders, 1996). Similarly, collaborative plant breeding could enable plant breeders to help farmers improve the efficiency of their own plant breeding.

The second proposed goal of collaborative plant breeding is to facilitate the conservation of crop genetic diversity in farmers' fields and storage. Proponents of this approach argue that while professional plant breeders have conventionally sought to develop fewer varieties adapted to a wider range of locations, participatory breeding can support the maintenance of more diverse, locally adapted plant populations (Berg, 1995; Cleveland, Soleri, and Smith, 1994; Witcombe and Joshi, 1995). Collaborative plant breeding can serve as a link between agricultural development and genetic resource conservation (Eyzaguirre and Iwanaga, 1996). Qualset *et al.* (1997) have proposed the improvement of farmers' breeding methods as an incentive for local conservation. For example, local varieties may provide the basis for breeding and introgression of genes from exotic sources.

The biological validity of this second proposed role has not yet been documented. Nor has an economic analysis yet been published on collaborative plant breeding initiatives, according to Witcombe (1997). One reason is that those who work closely with farm communities, such as small non-governmental organizations, are typically too busy implementing projects to document them. Another is that measuring impact with conventional cost-benefit techniques is not acceptable to many who are involved in such initiatives, and more comprehensive methods are needed.

15.1.3. Scope and Purpose of This Chapter

For economists, a fundamental issue surrounding collaborative plant breeding efforts concerns farmers' incentives to participate in those efforts. In this chapter, we explore farmers' incentives to engage in collaborative plant breeding activities designed to support conservation, identifying issues that have been raised by recent case studies on maize in Mexico. The evidence reported here cannot necessarily be generalized to other crops, farmers, or regions, for three major reasons. First, some of the issues we raise regarding the benefits from collaborative plant breeding are specific only to outcrossing crop species like maize. Second, farmers' seed selection practices differ for maize because the seed is typically selected based on the characteristics of the entire ear—representing single (maternal) plant selection. Third, the evidence is limited geographically to Mexico, the center of origin and diversity for maize. The history of a species in an area is one factor affecting the structure of its genetic diversity and farmers' practices. Research in secondary centers of diversity may raise distinct issues or lead to different conclusions. Similarly, the unique sociocultural and economic characteristics of Mexico, deriving in part from its history, topography, and location, imply that caution must be exercised in extrapolating findings to other nations.

The research described in this chapter consists of a set of pilot studies funded wholly or partially through CIMMYT, and additional work is underway. Considerable work has already been conducted on this subject by other international research centers, such as the International Center for Tropical Agriculture (CIAT), and a review summarizing experiences in international participatory breeding efforts has recently been commissioned. Non-governmental organizations and other institutions are already implementing collaborative plant breeding, but few of these efforts have been documented or published.

The next section presents relevant terms and basic economic concepts used in analyzing the questions of farmers' incentives to pursue collaborative plant breeding. The third section presents the key issues raised and evidence gathered in the case studies. In each study, biological and social factors are intertwined, and failure to consider one or the other set of factors leads to an incomplete assessment of the system of interest. The final section recapitulates conclusions and identifies unresolved issues that need to be addressed in future research.

15.2. DEFINITIONS OF TERMS

15.2.1. Farmers' Management of Diversity

To conceptualize economic issues related to collaborative plant breeding as a policy incentive for genetic resource conservation, we need to understand the process by which farmers select and manage their planting material and their crop populations. Bellon, Pham, and Jackson (1997) have identified three components of farmers' management of diversity. "Variety choice" is the process by which farmers decide which crop varieties to plant. The term "seed flows" (flows of seed or other planting material) refers to the process by which farmers obtain the physical unit of planting material from a given variety that they will grow. The material a farmer plants may have been selected from his or her own crop in the preceding season, exchanged or purchased from other farmers or institutions, or derived from a combination of sources. "Selection and management" is the process by which a farmer who retains planting material from his or her own crop (1) selects the material to be used for planting and (2) handles the material from harvest to planting.

These components can be understood as the dependent or behavioral variables in a collaborative plant breeding activity whose purpose is to support on-farm conservation of crop genetic resources (Bellon and Smale, 1998; Cleveland, Soleri, and Smith, 1998). Although these definitions apply across crop species, in the remainder of this chapter the word "seeds" refers to *maize* planting material. "Farmers' varieties" are defined as crop populations that farmers identify and name as distinct local units, be they landraces, modern varieties, or modern varieties that farmers have selected or mixed with their own landraces. This definition reflects the farmer's own perspective about when a population "becomes" local, irrespective of its biological origin or where he or she procured it (see Soleri and Cleveland, 1993)

For maize in Mexico, and perhaps for other crops and regions, it is important to distinguish a named variety from the physical unit that the farmer plants as seed. Recognizing farmers' practice of introducing varieties (and seed for the same varieties) from the stocks of other farmers, Louette (1994) developed the concept of a "seed lot." A seed lot consists of all kernels of a specific type of maize or variety selected by a farmer and planted during a cropping season to reproduce that particular maize type or variety. A variety is then constituted of all of the seed lots that a number of farmers refer to with the same name. *A seed lot is a physical entity; a variety is associated with a name.* Louette used the seed lot as the unit of analysis for characterizing the intra- and inter-varietal structure of diversity in maize.

15.2.2. Farmers' Incentives to Maintain Diversity

In collaborative plant breeding, the costs of conservation are shifted from the publicly funded, classical system of *ex situ* conservation to farmers themselves, farmers' associations, and other non-governmental organizations. Although the costs of local crop improvement or maintenance are already borne by farmers and their communities, collaborative plant breeding is likely to introduce additional costs. To participate in collaborative plant breeding, individual farmers clearly must perceive the benefits from participation as greater than the costs, including the opportunity cost of the time they devote to it.

Further, if collaborative plant breeding is to provide a link between agricultural development and genetic resource conservation, we must be able to identify participatory strategies for crop improvement that generate both private benefits to farmers and public benefits to society. For farmers who both consume and sell their products, we consider "private benefits" to be the value of the output on the market or in home consumption, including the consumption qualities of grain, fodder, and other non-grain products. Private benefits are as perceived by farmers, and may include either the enhanced market or the non-market value of the crop or its traits, as well as other personal satisfaction derived from cultural aspects of the product. "Public benefits" are the perceived potential genetic gains accruing to society as a whole from future use of crop genetic resources by either farmers or professional plant breeders.

Seed has both private and public attributes. When the farmer chooses to grow a certain amount of seed of a variety or varieties, he or she benefits from the crop's output. That choice also affects the genetic diversity of the crop in the region, measured in observable characteristics and populations as well as the unobservable (or observable only with molecular techniques) alleles of interest to conservationists. Genetic diversity is a public attribute: it is impossible for a farmer to observe or predict the effects of his or her own planting decisions as well as those of the numerous other small-scale farmers in the region on genetic diversity in any given year. The extent to which individual farmers consider the relationship of their variety choices, seed selection, and management practices to those of other farmers in their community is a matter of empirical investigation (Cleveland, Soleri, and Smith, 1998; Cleveland and Murray, 1997; Smale, Bellon and Aguirre, 1998). In any case, the configuration of varieties and the area they cover are determined by farmers' choices in meeting their own objectives and may not necessarily be the most desirable for society from the point of view of genetic diversity (see also chapter 14).

As the previous discussion indicates, if farmers are to cultivate varieties that are defined as socially valuable genetic resources but are not necessarily of private value to them within their farming system, incentives must be provided. How can the objectives of individual farmers and those of society be made more compatible? If farmers perceive private benefits from collaborative plant breeding while it contributes to maintaining the genetic diversity of the crop, both farmers and society as a whole will have gained. In the case reported for the Philippines in this volume (chapter 6), Bellon *et al.* identified a cluster of rice varieties that were both genetically diverse at the molecular level and highly valued by farmers for their consumption characteristics and tolerance to biotic and abiotic stresses. Although still cultivated in the rainfed rice production system, in the irrigated rice production system these varieties had been "discarded" for newer varieties. In the irrigated production system, varieties with shorter duration could be grown and two crops produced; high opportunity costs in terms of output foregone were associated with growing the older varieties, with their longer growing cycles. A breeding intervention to reduce the length of the growing period might enhance the desirability of the older varieties in the irrigated system, although the trade-offs in terms of other traits and the role of the varieties in the irrigated system would need to be investigated.

Figure 15.1 illustrates a similar notion. In a given region, in a given year, for a collection of varieties that are available to farmers and can be grown with varying spatial distributions, two outputs are produced: those from which farmers derive direct private benefits, and the public good, which is crop genetic diversity in the region. The vertical axis, Y, is a production index, which might include grain, fodder, or other output characteristics from which the farmer derives utility. In the simplest case, Y has a single dimension, as in the case of grain yield. The horizontal axis, Z, represents crop genetic diversity. The total number of varieties is fixed in a region in any given year, although farmers can choose among different combinations of them, planted to different areas. The production possibilities frontier represents the maximum amount of private and public goods (Y,Z), that can be produced, given a fixed set of resources. The concavity of the production possibilities frontier results from the fixity of land and genetic resources in any given cropping season and region, as well as the fact that some combinations generate more genetic diversity while others generate more yield. Different frontiers express different cropping seasons and/or different genetic resource bases, some favoring current production and others favoring genetic diversity that is unrelated to ongoing production.

Society as a whole gains utility from crop output and crop genetic diversity. The social indifference curves express preferences over productivity and conservation. Some societies prefer more productivity, which generates current private benefits, and others prefer to conserve genetic diversity for perceived future benefits. The tangency of the social indifference curve with the production possibilities frontier provides the socially optimal allocation of genetic resources. Collaborative plant breeding can link agricultural development to genetic resource conservation if it is possible to identify breeding strategies that augment productivity in terms of the crop characteristics valued by local farmers and augment genetic diversity among the populations grown in the reference region. Accomplishing these twin goals would unambiguously improve social welfare—regardless of the society in which it occurs.

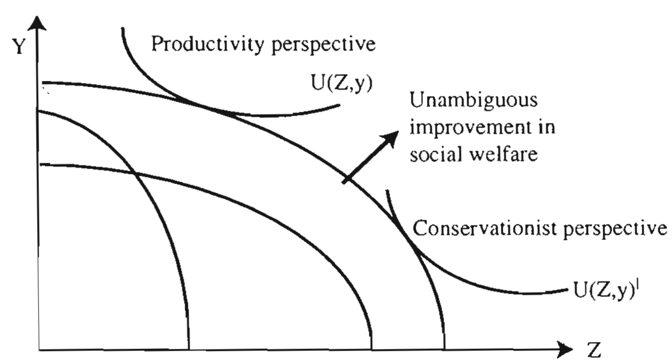

Figure 15.1. Production Possibilities Frontier for Maize Outputs and Genetic Diversity.

15.3. ISSUES RAISED BY RESEARCH ON MAIZE IN MEXICO

Some common features of Mexican farmers' choice of varieties, seed selection, and seed management raise questions about whether they will be able to realize production benefits from their efforts in collaborative breeding. Other features indicate potentially complementary roles of farmers and plant breeders in improving maize landraces on the farm. This section reviews the issues raised by the case studies, which fall into four categories: seed flows; varietal choice; seed selection and management; and farmers' knowledge. To understand these issues fully, however, it is important to understand what is meant by "mass selection" and key biological considerations related to this practice.

15.3.1. Mass Selection in Maize and Implications for Collaborative Plant Breeding

Mexican farmers typically select maize seed based on the ear characteristics of the harvested crop, rather than the characteristics of the plant in the field (SEP, 1982). In Mexico, improved seed selection practices have been recommended, both in the past by the national agricultural research institution and currently by non-governmental organizations. These practices generally include recommendations on selecting the plant from the center of the field in the presence of good competition, followed by the usual selection based on ear characteristics, as well as seed treatment and proper storage (CAECECH 1987; see Rice, Smale, and Blanco, 1997). The practices are intended to improve the effectiveness of farmers' methods of mass selection. With most collaborative plant breeding strategies, some kind of mass selection is likely to form part of the recommendations for maintaining varieties, if not for improving varieties.

"Mass selection" is defined as the identification in a crop population of superior individuals in the form of plants, ears, seed heads, tubers, or stem cuttings, and—in the case of maize—the bulking of seed to form the seed stock for the next generation. If practiced season after season with the same seed stock, mass selection has the potential to maintain or even improve a crop population, depending upon: (1) the extent to which the selected trait is genetically controlled (heritability); (2) genotype-by-environment interaction for the trait; (3) the proportion of the population selected (selection intensity); and (4) gene flow in the form of pollen or seed into the population. Response to mass selection in a cross-pollinated crop like maize is often low. One reason for this low response is that, unless selection for desirable characteristics occurs prior to fertilization and is subsequently controlled based on the selections, selection pressure is exerted only on the maternal plant. Hallauer and Miranda (1988: 213) report that in a composite population, mass selection for grain yield based on only one parent gave an average annual gain of only 1.7%/yr, whereas when both parents were selected the response increased to 7%/yr (Hallauer and Miranda, 1988: 213). Response to selection for traits with greater heritability than yield, such as grain type, is generally higher.

Response to mass selection will also depend on the selection strategy, of which there are many (see Hallauer and Miranda, 1988: 211–215). For low-resource farmers, some form of environmental stratification is likely to be necessary to reduce the confounding effects of environmental variation. In any case, given the parameters involved, an attempt should probably be made to estimate the efficacy of researchers' suggestions to modify local mass selection at the site itself before recommendations are promoted among farmers. In the case of relatively simple qualitative traits such as kernel color, environmental variation will not affect the selection response.

15.3.2. Seed Flows and Seed Lifecycles

The potential of a farmer to reap the rewards of modified mass selection practices also depends on the extent to which he or she retains the seed of distinct populations from harvest to planting, over successive seasons. Louette, Charrier, and Berthaud (1997) have documented that in Cuzalapa Valley of Jalisco, farmers frequently replace, renew, or modify the seed stocks for their varieties by introducing seed obtained from other farmers within and outside the community. Although farmers only rarely pool seed lots of different varieties, poor farmers in particular often mix seed lots considered to be of the same variety to attain enough seed to plant a field. Some farmers believe that they should renew a variety by procuring seed lots for the same variety from other farmers instead of using their own seed year after year.

Table 15.1 shows that for 29 farmers over six cropping cycles, only about half of all of the seed lots, and less than half of the planted area, were from farmers' own harvests. Most of these seed lots were traditional varieties of maize, although some were from advanced generations of modern varieties. The routine use of maize seed stocks produced by other farmers also suggests that in addition to desiring fresh stock, many of these farmers may not have a viable strategy for producing and conserving their own seed.[1]

In southeastern Guanajuato State, which is adjacent to the Bajío (one of the most modernized maize-producing areas of Mexico), Aguirre (1997) also found that some farmers mixed materials in search of "vigor." His research demonstrates, however, that the dominant strategy for procuring seed depends on the different agroecological and economic environments of the farmer (Table 15.2). Aguirre selected his sites to represent contrasts in the degree of market integration and probable length of growing period. Two-thirds of the farmers in the economically isolated environments deliberately introduce and mix their seed. In the more agroecologically marginal and market-integrated environment, the principal strategy is to replace seed. In the most favorable agroecological and economic environment, some farmers retain seed and some replace it. As in the Louette study, most of the maize materials Aguirre found among farmers are traditional varieties or advanced generations of modern varieties.

Table 15.1. Origin of Maize Seed Planted in Cuzalapa, Jalisco, Mexico

Source	Percentage of seed lots	Percentage of area planted
Own seed	52.9	44.9
Seed obtained from other producers in Cuzalapa	35.7	39.9
Seed obtained from producers in other communities	11.4	15.1

Source: Louette (1994).
Note: 29 farmers, 6 cycles, mostly traditional varieties.

Table 15.2. Seed Sources by Environment, Southeastern Guanajuato, Mexico

	80 days moisture		140 days moisture	
Usual practice	**Isolated**	**Integrated**	**Isolated**	**Integrated**
	% producers			
Save seed from year to year	33	23	20	40
Deliberately introduce or mix seed	67	12	69	14
Replace seed	–	65	11	46

Source: Aguirre (1997).

Note: Most are traditional varieties or advanced generations of modern varieties. 160 farmers. Percentage distributions differ significantly by zone with chi-squared test (α=.01)

This finding shows that farmers differ with respect to their seed procurement practices, even for traditional varieties. It also suggests that we may need to consider different types of collaborative plant breeding strategies for different types of farmers or environments. For example, modified mass selection techniques may be inappropriate for farmers who routinely replace, introduce, or mix their seed. Supplying those farmers with a greater range of finished or unfinished materials from which they can choose and select may be more beneficial.

Rice, Smale, and Blanco (1997) recorded in detail the use of recommended techniques over five growing seasons by a small group of farmers participating in the initiatives of the Proyecto Sierra de Santa Marta, a non-governmental organization in Veracruz State. The techniques were introduced to encourage farmers to continue growing traditional varieties by improving them. Farmers had identified maize production problems associated with the late maturity and tall stature of their traditional varieties, and they were taught to select for shorter plant height in the field. Approximately 100 farmers in four communities received seed selection and management training, consisting of: (1) marking desirable plants with chalk or a tie; (2) selecting plants within five rows from the boundaries of the field, to reduce the effects of cross-pollination from adjacent fields; (3) selecting plants under good competition with large ears, to ensure healthy, robust plants; (4) after harvest, selecting seed ears from the ears of marked plants based on other desirable ear characteristics; (5) using seed from the center of the cob only; and (6) dusting the maize seed with insecticide or ash and storing it separately from maize grain in a dry place.

In two of the four communities in which workshops were held, only 16 farmers continued to showed interest in the practices several years later. The percentage of seed lots selected from plants declined in each season and seems to have disappeared entirely by the end of the study period. One reason for lack of continuity in the practices was clearly the time cost of labor. Fields were dispersed on steep slopes, farmers had to make separate trips to mark plants, and maize production competed for labor with coffee production at peak periods. Another key factor was undoubtedly the harsh conditions in which these farm families live and produce maize—which led to a high rate of "seed mortality" (Sperling and Loevinsohn, 1983). The Sierra de Santa Marta is an indigenous zone on the edge of a rain-forested volcano, and the maize crop is continually threatened by winds and tropical storms.

Blanco's idea is that the lifecycle of maize seed is closely interwoven with the farmer's life, as depicted for one farmer in Figure 15.2. Many seed introductions "die" several years later, including introductions of traditional and modern varieties, because of external factors such as tropical storms that result in meager harvests, or internal factors such as a change in family structure. When a farmer reports that a variety has been grown for 20 years, he or she may have changed seed lots a number of times during that period.

For new introductions, these patterns may hold whether or not farmers consider the varieties to be promising; for popular varieties, these patterns may hold even when the varieties are considered to be a mainstay of the local cropping system. Similar findings with respect to the loss of seed of traditional and modern varieties, as well as the high rate of change in seed because of renewal, replacement, and hybridization, have been cited by Almekinders, Louwaars, and de Bruijn (1994) for maize and beans in Mesoamerica, and for beans in the Great Lakes Region and eastern Africa (David, 1997; Sperling, Scheideggger, and Buruchara, 1996).

15.3.3. Seed Selection and Storage

In retrospect it seems clear that the practices proposed by the Proyecto Sierra de Santa Marta may have been inappropriate or unsound given conditions at the site. Based on studies conducted under controlled conditions, Hallauer and Miranda (1988: 116) reported an average estimated heritability of 59.6% for plant height. Under the difficult and variable field conditions in the Sierra de Santa Marta, however, heritability would be substantially lower. In other words, well over 40% of the visible variation for plant height would be caused by non-heritable sources of variation, including environmental variation. Since no attempt was made to control environmental variation, the response to selection was probably low.

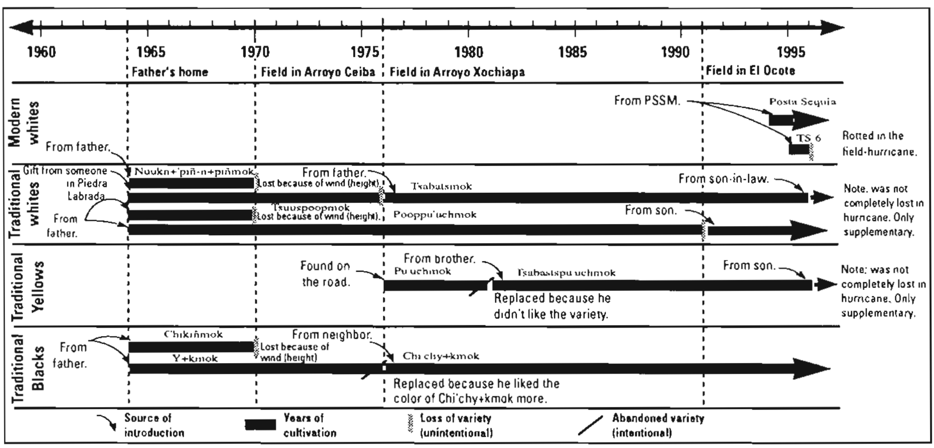

Figure 15.2. Lifecycle of farmer and his maize seed, Sierra de Santa Marta, Veracruz, Mexico.

The apparent simplicity of seed selection and storage practices is also deceptive; as for most agricultural activities in the calendar of subsistence-oriented or semicommercial farm households, gender needs to be recognized when considering the introduction of new techniques. Certainly in the general literature on maize in Mexico, seed selection has been considered the responsibility of farm men (e.g., SEP, 1982). While that is clearly the impression received when men are interviewed, and even when some women are interviewed, observation of households in the Sierra de Santa Marta has led to some different conclusions.

Based on the results of detailed, repeated interviews with men and women from the same household, Rice, Smale, and Blanco (1997) have represented seed selection as an iterative, continuous process that occurs in several stages (Table 15.3). Four of the phases are discrete events: (1) selection of superior plants in the maize field around flowering time, and separation of ears from marked plants at harvest time; (2) selection of a bulk of maize ears when the harvest is brought to the house; (3) a second selection of a bulk of maize ears from the stored maize at some point between harvest and the next season's planting; and (4) selection close to planting time. The first phase was one of the improved seed selection techniques recommended by the Proyecto Sierra de Santa Marta. The second is a setting aside of seed ears from food grain. The third typically happens when stocks are running low following a poor harvest. The fourth is a final revision of the remaining seed stock at planting. A fifth category—putting aside superior ears as women husk maize to prepare food—is distinct from the other phases in that it is more of a continuous process that occurs intermittently from the time of harvest to planting.

Table 15.3. Stages and Features of Seed Selection for Traditional Maize Varieties, Rainy Season, Sierra de Santa Marta, Mexico, 1995

	Phase of selection				
Feature	**From plant, in field[a]**	**From harvested ears, in house**	**Review of stored ears, in bulk**	**While removing stored ears daily for food**	**Before planting, as final review of seed stock**
			% of 56 total seed lots		
Time period	14	50	31	59	97
Storage method					
Shelled and bagged[a]	–	28	9	0	100
Unshelled, bagged	–	61	64	0	0
Hung from rafters	–	11	27	100	0
Selected by					
Men only	60	39	18	12	53
Women only	0	22	64	88	21
Both men and women	40	39	18	0	27

Source: Rice, Smale, and Blanco (1997).

[a] Recommended as part of the modified set of practices.

The participation of women was more evident in some aspects of seed selection than in others. Although women in the households surveyed participated in nearly all phases of selection, when asked directly whether they "select" seed (*seleccionar*), they typically answered "no." They answered "yes" when asked if they "set aside" maize for seed (*apartar*). The term "selection" seems to have a very specific meaning related to the introduced practice of selecting superior plants, or to the selection of seed immediately before planting—both of which were almost exclusively accomplished by men. The handling of maize stocks during the year, and the setting aside of good ears during food processing, was almost exclusively the domain of women. When, as is sometimes recommended, ears from plants marked in the field are reviewed at harvest for desirable ear characteristics, and the seed is shelled and bagged with insecticide, the selection process that later occurs inside the household will be sidestepped.

Both the biological and social implications of proposed changes in farmers' practices must be investigated to determine the impact of practices that are introduced with collaborative plant breeding initiatives. The extent to which women are involved in seed selection in other communities, and whether the exclusion of women's seed selection would have a neutral, positive, or negative effect (1) on the genetic structure of the maize population, (2) on the household, or (3) on farm women's well-being, remains to be studied. For example, it is likely that selecting, shelling, and bagging seed with insecticides just after harvest will cause more substantial changes in the populations' genetic structure than would eliminating women's practice of setting aside superior ears when preparing food. Yet many aspects of these selection systems are not understood; it may be that women's handling and observation of the ears contributes information to the formation of the ear ideotype sought by all members of the household. In general, we cannot assume *a priori* that the introduction of modified selection practices makes farmers' selection more "efficient," especially if other selection practices or activities (such as women's) are eliminated in the process of adopting the modified practices.

15.3.4. Choice of Variety

One of the major promises of collaborative breeding is that it may enhance farmers' effectiveness in choosing varieties for characteristics of importance to them. Which varieties should farmers and professional breeders seek to improve? It is well known that farmers in subsistence-oriented and semicommercial agriculture, or farmers who both sell and consume their own crop output, consider more characteristics than just grain yield and grain price when choosing the varieties they grow. Recognition of this fact has led agricultural economists to apply characteristics models (Adesina and Zinnah, 1993) and multi-output models (Renkow and Traxler, 1994) to the analysis of farmers' choice of variety.

Bellon's (1996) treatment of this aspect of farmer behavior focuses on the way in which the vector of characteristics of importance to farmers (which he calls "concerns") changes in dimension with farmers' adaptation to economic change in the environment in which they live. The dimension may expand or contract, provoking changes in the relative importance of characteristics that farmers value. These changes, in turn, lead to the adoption of new varieties and the abandonment of those which are "inferior" under the new set of conditions and constraints.

Varieties tend to be lost when changes in the local biophysical or sociocultural environment reduce the importance of their environmental or sociocultural adaptation (Soleri and Cleveland, 1993). When biophysical or sociocultural changes make it possible to replace varieties, their actual replacement or abandonment appears to be determined by the availability of seed of new varieties that are similar to existing varieties in their growing characteristics, or the supply of alternatives to products made with present varieties.

The interaction between these factors in determining the fate of a particular variety may be complex, as illustrated in the case of Hopi maize folk varieties and vegetables grown by Hopi gardeners. Hopis retain their blue maize varieties because they are adapted to drought and a short growing season, and meet cultural requirements (blue maize is important in religious ceremonies). However, data suggest that the three or more Hopi varieties of blue maize are being collapsed into one, apparently for a number of reasons. One reason may be that today many farmers have full-time jobs in addition to farming; they do not have the time to maintain many different varieties by sowing populations separately to control cross-pollination and then selecting and storing each set of seed. Another reason may be that the importance of the varieties' unique grain characteristics has been diminished by social changes. For example, the introduction of machine grinding reduced the importance of the softer blue maize variety, while the cash economy reduced the desirability of the better storage qualities of the harder blue maize varieties, since storing two years' harvest against crop failure is no longer necessary (Soleri and Cleveland, 1993). We need to understand farmers' adaptation to change and the factors which determine their choice of varieties to be able to predict, for policy purposes, which populations are most likely to be grown and which households are more likely to grow them (Bellon and Smale, 1998; chapters in part III).

15.3.5. Farmers' Knowledge

Comprehending farmers' subjective understanding of their crop genetic resources is important because it shapes their behavior and affects their crop varieties and farming systems in ways that can be measured objectively. It seems likely as well that understanding farmers' perceptions may contribute to a more viable collaborative plant improvement effort.

Louette's findings from Cuzalapa indicate that farmers' seed selection practices protect the phenological integrity of their traditional maize varieties as they define them, despite numerous factors contributing to genetic instability (Louette and Smale, 1998). Analysis of morphological and molecular (isozyme) data suggests that when farmers' varieties are subjected to significant gene flow through cross-pollination, ear characteristics and linked traits are maintained through farmers' selection even though other characteristics may continue to evolve genetically. These findings indicate that there may be further scope for varietal improvement and potentially complementary roles for professional breeders and Mexican farmers in developing methods to improve maize landraces on the farm.

However, there are indications that farmers' own expectations of what they can achieve through seed selection are limited. Repeated, informal interviews with a small sample of farmers in Cuzalapa suggest that these farmers do not see seed selection as a tool for modifying or improving their varieties (Table 15.4). According to them, seed selection is a means of assuring production but not of transforming a variety. Seed selection also protects the "legitimacy" of a variety (in their words, selection is done "*para que salga legítimo*"). Farmers would change from one variety to another before attempting to change a variety through seed selection.

This finding in no way suggests that farmers are "backward" in their thinking. Instead, it suggests that they may know very well what can be accomplished on their farms with the methods currently available to them. In Cuzalapa, few farmers may produce maize in an environment in which they will be able to obtain perceptible benefits from mass selection within the time horizon that they consider relevant to their decisions.

While recognizing the value of documenting farmers' seed procurement and selection practices, Cleveland, Soleri, and Smith (1998) argue that identifying and understanding the genetic perceptions that underlie them will ultimately provide a more versatile and robust tool for collaborative plant breeding. In two communities in the Central Valleys of Oaxaca State, they have used participant observation and formal interviews structured around a series of scenarios to elicit farmers' perceptions of genetic diversity, heritability, selection expectations, and genotype–by–environment interactions. Preliminary results suggest that while farmers may recognize genetic variation in their maize populations, they cannot make use of that variation with the techniques they possess at present, because of the large amount of environmentally caused variation in their fields. Among traits of importance to them, farmers make clear distinctions between those with relatively high and low heritabilities and respond accordingly in their selection efforts, and some farmers recognize segregation among offspring of a single parental phenotype. Farmers in these locations stated that maintaining different maize varieties for different field locations or types does not warrant the effort. Researchers have interpreted this response as an indication that environmental variation within fields was likely to be greater than variation between fields.

Cleveland, Soleri, and Smith have pointed out that their findings describe farmers' perceptions and behavior in terms accessible to outside scientists, allowing those

Table 15.4. Farmers' Perceptions about Seed Selection and Its Purpose, Cuzalapa, 1997 (in order of decreasing frequency; 25 farmers)

Question	Most frequent response
Which ears do you select?	Well-developed, well-filled ears Large ears
Why do you select seed?	To ensure germination To reproduce the variety as we know it
Can you change the characteristics of a variety?[a]	By changing planting dates, using fertilizer, or planting it close to another variety, but *not by seed selection*

Source: Louette and Smale (1998).

[a] Two types of change were discussed: length of growing period (plant characteristic) and number of rows (ear characteristics).

scientists to use their own knowledge and skills more effectively in collaboration with farmers. Farmers' knowledge is not being tested in this work, nor is it being compared against a "correct" or "scientific" template, as many other factors that lie beyond the narrow parameters of the research accomplished to date contribute to farmers' knowledge about their crops.

15.4. CONCLUSIONS AND UNRESOLVED ISSUES

Collaborative or participatory plant breeding uses the skills and experience of both farmer-breeders and professional plant breeders to improve crop plants. The extent of participation by farmer- and professional breeders varies by case and includes, for example, the identification of characteristics for improvement, choice of varieties, and revision of seed selection practices. One of the proposed goals of collaborative plant breeding is to support on-farm conservation. Proponents of this approach argue that while professional plant breeders have conventionally sought to develop fewer varieties adapted to a wider range of environments, participatory breeding can support the maintenance of more diverse, locally adapted plant populations. Both the biological validity and economic feasibility of this proposition require testing. In this chapter, we have used evidence from case studies of maize farming in Mexico to highlight certain key issues that affect farmers' incentives to engage in such efforts. In each case, biological and social factors are interrelated.

The assumption that modified mass selection practices will benefit farmers cannot be generalized and requires technical investigation—particularly given the patterns of seed exchange and seed mortality mentioned in this chapter, but even for farmers who are able to retain their own seed from harvest to planting, year after year. The effect of farmers' use of either improved or traditional mass selection practices to enhance maize yield or other characteristics *under their own conditions* is not well understood. Modest responses to selection in variable environments, combined with the added costs incurred by collaborative plant breeding, may provide weak incentives for farmers to continue growing crop populations identified as important genetic resources, especially compared to the force of the economic changes they face.

Other issues also remained unresolved. To develop collaborative plant breeding strategies that will have an impact, we need to understand how farmers differ with respect to their management of seed and varieties. Decisions will need to be made. Which farmers should outsiders work with? Which outsiders should farmers work with? To assure that the efforts will be sustained on a community basis, we also need to know in what ways germplasm and practices move from farmer to farmer. We need to understand the "social infrastructure" of the exchange of seed and knowledge among farmers (see Ashby *et al.* 1996).

Asking non-governmental organizations and farmers themselves to improve and diffuse varieties does not make genetic resource conservation cheaper—it only shifts the cost burden from some members of society to others. The question remains if the benefits to be achieved will outweigh those new costs. Collaborative plant breeding promises to benefit farmers who have never benefited from the diffusion of modern varieties through formal seed systems, either because the new seed is not adapted to local agronomic conditions, or local preferences favor certain consumption characteristics, or there are few incentives for the development of commercial seed systems in their locality. Depending on the collaborative breeding strategy that is chosen, it also promises heavy time costs for farmers. Participatory research typically requires a lot of local institutional support and a strong cultural basis, as well as a portfolio of income-earning activities, to involve farmers on a long-term basis.

There is a indeed a keen irony in the notion that some of the world's poorest, most neglected farmers are being asked to shoulder the burden of genetic resource conservation for the rest of society and the world. Aside from collaborative plant breeding, other incentives may be provided in the form of subsidies for producers of landraces in selected regions, although most believe that direct payments would not be advisable from an administrative standpoint. If farmers were paid a premium to grow a particular variety, all would choose to grow it—defeating the purpose altogether. The development of niche markets, seed exchanges, and educational campaigns have also been proposed as alternatives or may be considered in combination.

How big an advantage must be generated by the collaborative plant breeding initiative? The evidence presented here raises questions about the magnitude of the benefits maize farmers in Mexico can obtain through participatory plant breeding. Benefits of the size obtained by initial adopters of green revolution crop varieties are hard to envisage. However, the purpose of collaborative breeding strategies is not to replicate the technical changes of the green revolution but to reach farmers who might never have benefited from crop improvement research without participatory initiatives.

There is certainly far more that is unknown than is understood about collaborative plant breeding and its impact on local crop improvement and genetic resource conservation. It seems clear that the approach has potential for providing benefits in all three of those areas. Still, assessing that potential and entering a collaboration that holds the most promise for a positive outcome will require careful multidisciplinary research as well as an examination of researchers' assumptions about the sociocultural, economic, and biological aspects of traditionally based crop selection and management.

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Notes

1 In interpreting these results, it may be important to recognize that the community of Cuzalapa is located in the buffer zone of a the Biosphere of the Sierra de Manantlán, Jalisco. Because of the area's status as a buffer zone, research may be undertaken in Cuzalapa but only farmers themselves may introduce seed. Farmers in that community share traditional cultural practices and live in a relatively isolated geographical area, although they are affected by numerous modern and external factors, including labor migration and changes in road infrastructure.

References

Adesina, A. A., and M. N. Zinnah. 1993. Technology characteristics, farmer perceptions and adoption decisions: A tobit model application in Sierra Leone. *Agricultural Economics* 9: 297–311.

Aguirre, A. 1997. Análisis regional de la diversidad del maíz en el Sureste de Guanajuato. Ph.D. thesis, Universidad Nacional Autónoma de México, Facultad de Ciencias, Mexico City.

Almekinders, C. J. M., N. P. Louwaars, and G. H. de Bruijn. 1994. Local seed systems and their importance for an improved seed supply in developing countries. *Euphytica* 78: 207–216.

Ashby, J.A., T. Gracia, M. del Pilar Guerrero, C.A. Quirós, J.I. Roa, and J.A. Beltrán. 1996. Innovation in the organization of participatory plant breeding. In Eyzaguirre, P. and M. Iwanaga (eds.), *Participatory Plant Breeding. Proceedings of a Workshop on Participatory Plant Breeding 26–29 July 1995, Wageningen, the Netherlands.* Rome: International Plant Genetic Resources Institute (IPGRI).

Biggs, S. D. 1989. *Resource-Poor Farmer Participation in Research: A Synthesis of Experiences from Nine National Agricultural Research Systems.* OFCOR-Comparative Study Paper No. 3. The Hague: International Serve for National Agricultural Research (ISNAR).

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

Bellon, M. R. and S. B. Brush. 1994. Keepers of maize in Chiapas, Mexico. *Economic Botany* 48: 196–209.

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

Bellon, M. R. and M. Smale. 1998. *A Conceptual Framework for Valuing On-Farm Genetic Resources. CIMMYT Economics Working Paper.* Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT).

Berg, T. 1995. Devolution of plant breeding. In L. Sperling and M. Loevinsohn (eds.), *Using Diversity: Enhancing and Maintaining Genetic Resources On-Farm. Proceedings of a Workshop Held on 19–21 June, 1995, in New Delhi.* New Delhi: International Development Research Centre (IDRC).

CAECECH (Campo Agrícola Experimental Centro de Chiapas). 1987. *Guía para la Asistencia Técnica Agrícola: Area de Influencia del Campo Experimental.* Ocoxocoautla de Espinosa, Chiapas: Centro de Investigaciones Forestales y Agropecuarias en el Estado de Chiapas.

Ceccarelli, S., E. Bailey, S. Grando, and R. Tutwiler. 1997. Decentralized, participatory plant breeding: A link between formal plant breeding and small farmers. In CGIAR System-wide Project (ed.), *New Frontiers in Participatory Research and Gender Analysis: Proceedings of the International Seminar on Participatory Research and Gender Analysis for Technology Development.* Cali: Consultative Group on International Agricultural Research (CGIAR) System-Wide Project.

Cleveland, D. A., and S. C. Murray. 1997. The world's crop genetic resources and the rights of indigenous farmers. *Current Anthropology* 38: 477–515.

Cleveland, D. A., D. Soleri, and S. E. Smith. 1994. Do folk crop varieties have a role in sustainable agriculture? *BioScience* 44:740–51.

Cleveland, D. A., D. Soleri, and S. E. Smith. 1998. Farmer varietal management and plant breeding from a biological and sociocultural perspective: Implications for collaborative breeding. Draft Economics Working Paper. Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT).

David, S. 1997. *Dissemination and Adoption of New Technology: A Review of Experiences in Bean Research in Eastern and Central Africa, 1991–1996.* Occasional Publication Series, No. 21. Kampala: Network on Bean Research in Africa, International Center for Tropical Agriculture (CIAT).

Eyzaguirre, P. and M. Iwanaga (eds.). 1996. *Participatory Plant Breeding. Proceedings of a Workshop on Participatory Plant Breeding 26–29 July 1995, Wageningen, the Netherlands.* Rome: International Plant Genetic Resources Institute (IPGRI).

Hallauer, A.R., and J.B. Miranda, 1988. *Quantitative Genetics in Maize Breeding*. Second edition. Ames: Iowa State University Press.

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

Louette, D., A. Charrier, and J. Berthaud. 1997. *In situ* conservation of maize in Mexico: Genetic diversity and maize seed management in a traditional community. *Economic Botany* 51: 20–38.

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

Qualset, C. O., A. B. Damania, A. C. A. Zanatta, and S. B. Brush. 1997. Locally based crop plant conservation. In N. Maxted, B. V. Ford-Lloyd and J. G. Hawkes (eds.), *Plant Genetic Conservation: The* In Situ *Approach.* London: Chapman and Hall.

Renkow, M., and G. Traxler. 1994. Incomplete adoption of modern cereal varieties: The role of grain-fodder tradeoffs. Selected paper, Annual Meetings of the American Agricultural Economics Association, 7–10 August, San Diego, California.

Rice, E., M. Smale, and J.-L. Blanco. 1998. *Farmers' Use of Improved Seed Selection Practices in Mexican Maize: Evidence and Issues from the Sierra de Santa Marta.* CIMMYT Economics Working Paper 97-03. Mexico. D.F.: International Maize and Wheat Improvement Center (CIMMYT).

SEP (Secretaría de Educación Pública). 1982. *Nuestro maíz-Treinta monografías populares.* Tomo 1 y 2 Mexico, D.F.: Consejo Nacional de Fomento Educativo, Secretaría de Educación Pública.

Smale, M., M. Bellon, and A. Aguirre. 1998. Variety characteristics and the land allocation decisions of farmers in a center of maize diversity. Selected paper, Annual Meetings of the American Association of Agricultural Economists, 2–5 August, Salt Lake City, Utah.

Soleri, D., and D. A. Cleveland. 1993. Hopi crop diversity and change. *Journal of Ethnobiology* 13: 203–31.

Soleri, D., and S. E. Smith. 1995. Morphological and phenological comparisons of two Hopi maize varieties conserved *in situ* and *ex situ*. *Economic Botany* 49: 56–77.

Sperling, L., and M. E. Loevinsohn. 1993. The dynamics of adoption: distribution and mortality of bean varieties among small farmers in Rwanda. *Agricultural Systems* 41: 441–453.

Sperling, L., U. Scheidegger, and R. Buruchara. 1996. *Designing Seed Systems with Small Farmers; Principles Derived from Bean Research in the Great Lakes Region of Africa.* Agricultural Research and Extension Network Paper No. 60. London: Overseas Development Agency.

van Oosterom, E. J., M. L. Whitaker, and E. Weltzien R. 1996. Integrating genotype by environment interaction analysis, characterization of drought patterns, and farmer preferences to identify adaptive plant traits for pearl millet. In M. Cooper and G. L. Hammer (eds.), *Plant Adaptation and Crop Improvement.* Wallingford: CAB International.

Weltzien R. E., M. L. Whitaker, and M. M. Anders. 1996. Farmer participating in pearl millet breeding for marginal environments. In P. Eyzaguirre and M. Iwanaga (ed.), *Participatory Plant Breeding: Proceedings of a Workshop on Participatory Plant Breeding, 26–29 July 1995, Wageningen, Netherlands.* Rome: International Plant Genetic Resources Institute (IPGRI).

Witcombe, J. 1997. Decentralization versus farmer participation in plant breeding: Some methodological issues. In CGIAR System-wide Project (ed.), *New Frontiers in Participatory Research and Gender Analysis: Proceedings of the International Seminar on Participatory Research and Gender Analysis for Technology Development.* Cali: Consultative Group on International Agricultural Research (CGIAR) System-Wide Project.

Witcombe, J.R. and A. Joshi. 1995. The impact of farmer participatory research on biodiversity of crops. In L. Sperling and M. Loevinsohn (eds.), *Using Diversity: Enhancing and Maintaining Genetic Resources On-Farm. Proceedings of a workshop held on 19–21 June, 1995, in New Delhi.* New Delhi: International Development Research Centre (IDRC).

Witcombe, J. R., and A. Joshi. 1996. Farmer participatory approaches for varietal breeding and selection and linkages to the formal seed sector. In P. Eyzaguirre and M. Iwanaga (ed.), *Participatory Plant Breeding: Proceedings of a Workshop on Participatory Plant Breeding, 26–29 July 1995, Wageningen, Netherlands.* Rome: International Plant Genetic Resources Institute (IPGRI).