

CHAPTER 2

FARMER PARTICIPATION AND FORMAL-LED PARTICIPATORY PLANT BREEDING PROGRAMS: TYPES OF IMPACT TO DATE

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General Characteristics of Formal-Led Participatory Plant Breeding (PPB)

Formal sector institutions (e.g., national plant breeding programs, Consultative Group on International Agricultural Research [CGIAR] institutes, or extension services) are increasingly experimenting with farmer participatory approaches in plant breeding to strengthen farmer production systems in different ways. In contrast to “farmer-led PPB” projects (McGuire et al. 1999), those led by the formal sector have a strong institutional orientation. Formal-led PPB programs have an obligation to feed information back to the formal research sector, and to feed forward to farming communities. They are expected to improve or complement the formal sector research system (e.g., refining breeding strategies) or possibly reorientate entire programs. Mostly, formal-led PPB programs also involve strong linkages to the formal variety release and seed production system. Finally, scientists involved in formal-led programs have a mandate to extrapolate their results beyond the individual farmer or community with which they work, and programs often need to show the advantages of farmer participation compared to breeding work centred at research stations or standard on-farm approaches. Thus this dual need to focus on end-users and on the formal sector institutions themselves shapes the types of participation, the types of products used or targeted, and the types of data needed for formal-led PPB programs (Weltzien/Smith et al. 1999).

Formal-led participatory breeding programs are relatively new. Most of the cases identified date from the last 10 years, with only two or three initiated earlier. Mostly they were relatively small in scale, working only at one or two sites and usually involved fairly intense types of direct farmer and scientist interaction. We would characterize much of this small-scale research work as functionally motivated and aiming at “functional participation”, that is, trying to understand better what farmers want or need to feed back insights to formal research for improving future on-farm productivity. Formal-led PPB programs that have addressed what may be called capacity building or more empowering approaches (“empowering participation”) are those programs that have tried to scale-up the work to involve more farmers, representing more households, and a larger target region. These programs have more often focused on farmers’ skill building needs, and have searched for a clear division of labor between farmers and scientists that builds on the comparative advantage of each and that ultimately devolves much of the decision making to farmers and their communities.

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Most of formal-led PPB to date (some 40 different field programs) have centered breeding efforts on major crops, that is, the crops to which the formal sector normally gives priority. Should researchers truly move to strengthen the minor crops (also known as “neglected crops”), the division of responsibilities and types of participation with formal-led PPB could radically change, with researchers offering strategic support to what are essentially farmer-driven programs.

Goals of Formal-Led PPB Programs

Formal-led PPB programs can have a diversity of overarching goals, and hence a diversity of anticipated impacts. The most common goals have been to contribute to increased production in farmers’ fields and to increase farmer income through developing and enhancing the adoption of suitable, usually improved, cultivars. These are the basic goals of any formal-led breeding program, and participatory approaches are often experimented with to achieve them more effectively and more efficiently. In this context, formal-led PPB programs sometimes seek to refine their knowledge of farmers’ needs or preferences, or reorient general breeding directions such as type of base germplasm used, the priority traits sought, and the management and organization of station trials. Institutional and organizational changes that facilitate decentralization and/or scaling up of the breeding program often come hand in hand with these efforts to meet farmers’ location-specific varietal needs.

Biodiversity enhancement is another broad goal towards which some PPB programs strive. Participatory breeding programs with this goal tend to work more often with the farmers’ own germplasm or a combination of local and exotic materials; many also involve farmers in the screening of a wide range of varieties in the preadaptive stages of research, either in on-station trials or in community plots. In several cases, PPB programs have also released populations or have purposely promoted breeding strategies that result in heterogeneous materials.

Another important goal of PPB programs is to provide benefits for specific types of users (e.g., the rural poor, women, and farmers with marginal soils) or to deliberately address the needs of a broader range of users. Such a goal necessitates an extensive diagnosis among well-defined types of potential user and stakeholder groups. This goal is often in contrast to traditional centralized breeding programs, which work under the assumption that benefits from routine station-based research or research-controlled on-farm trials are “user neutral”.

When addressing issues related to improved adoption of breeding products and/or biodiversity enhancement, PPB programs often find themselves confronted with the need to address modifications in policy, whether these be seed regulations or variety release criteria and procedures. Most modifications are sought to accommodate the expanding and institutionalizing of approaches that better serve farmers’ aims. These may include modifications in the scales of testing and of desired cultivar adaptation, the kind of data required for release, and the number of cultivars released at any one time.

Finally, some programs specifically work towards enhancing the farmers’ own breeding process, that is, providing technical knowledge and insights so that farmers themselves are more successful in their own selection and seed production efforts. This skill-building goal is often

addressed together with a more general effort towards strengthening the capacities of farming communities to interact and derive and demand benefits from the formal research institutions—whose mandates are to address local-level needs.

In conducting an overview of formal-led PPB programs, we became aware of how much the goals set for PPB programs shape the entire research design and of secondary effects that PPB programs achieve. Set goals greatly influence what is on offer (skills or varieties), the type of germplasm used, the type of farmer involved, the scale worked at, the trial design, and the seed multiplication procedures. However, we found that the goal-setting process itself was rarely articulated or transparent—that is, goal setting was not seen as something that needed to be discussed within and between the scientific and farming communities.

Table 1 summarizes the primary goals guiding 40 PPB programs that the formal sector has initiated or led. The comprehensive review shows that most (78%) programs have focused on various aspects of production increases, the same goals toward which classical breeding programs strive. The programs examined have most often targeted marginal environments, where impact from classical breeding programs was less than expected or completely unsatisfactory. Thus, many programs were oriented toward identifying better varieties, those that offer clear advantages over farmers’ own local varieties or locally-available cultivars. Often linked with this objective has been the need of scientists to better understand farmers’ selection criteria and preferences for a range of traits, possibly traits with which farmers have had no previous experience (68% of PPB programs). This knowledge usually feeds back directly into on-going breeding efforts, to change priorities for testing and selection criteria. Another closely related objective, of specific importance to marginal environments, is the possibility of releasing varieties adapted to specific zones of cultivation (13% of formal-led PPB programs).

Table 1. Formal-led participatory plant breeding: Goals of program development (n = 40 cases^a).

Goal (motivation)	Number of cases	Percentage of cases
Productivity increase (better varieties)	31	78
Research efficiency (farmer varietal criteria, approved testing)	27	68
Biodiversity conserved/ enhanced	8	20
Policy changes (release, seed multiplication)	5	13
Facilitate farmer learning	3	8
Other	3 ^b	-

a. Some cases are listed twice because they had multiple primary goals.

b. This category includes two different motivations: empowerment, and benefits to specific users.

Although the review identified programs that targeted other goals, such as enhancements in biodiversity or farmer capacity-building directly, these were most often deemed secondary goals in the overall PPB program. It thus appears that the full range of goals has not been systematically explored in formal-led PPB programs (and that the full range of potential impacts has not been identified). The relative narrowness of present aims shaping PPB work is perhaps a

feature of the newness of the approach. Certainly future efforts should more consciously aim to explore the bounds of the potential of different participatory breeding approaches.

Farmer Participation in Different Stages of a Breeding Program

The technical process of variety development for any crop of any pollination or propagation system can be classified into three major steps. These constitute the technical process of plant breeding and variety development. Schnell (1982) describes them as:

- (1) Generating variability,
- (2) Selection, and
- (3) Testing of experimental cultivars.

The first step is achieved in most programs by making deliberate crosses between diverse parents with complementary trait combinations. In some specific cases, this could also be achieved by assembling germplasm on a larger scale, for example, at the beginning of a new program. In some cases, breeders use mutagenesis to induce new variability within a target breeding material. In cross-pollinated crops, where population improvement methods are common, the building of base populations and the generation of new progenies for testing, are part of this step of generating variability for further improvement activities.

The second step comprises the process of narrowing down the new variability generated from a few thousand or hundred plants or progenies to a limited number of potential new varieties, usually about 10 to 40, and often referred to as experimental varieties. In self-pollinated crops, or when developing hybrid parents this is usually referred to as selection in segregating generations. In population improvement schemes this is the phase of progeny testing. For clonally propagated crops this is the phase of narrowing down the many new clones to a few clones with more planting material for more detailed testing. At this stage usually only minimal seed or planting material of every plant, progeny, or clone is initially available. During this process of narrowing down numbers, the quantity of seed or planting materials is also built up to allow more thorough, multi-location testing of candidates that usually have to fulfil a set of minimum criteria, that is, experimental varieties. Thus the seed increase ratio of the crop partly determines the length of this stage.

Step three is the testing of these experimental varieties for productivity traits, their range of adaptation, and acceptability. The experimental varieties are tested in replicated trials over an increasing number of locations, with increasing plot sizes. This testing phase normally begins with trials that are named initial variety or hybrid trials, and continues until varieties are proposed for release and/or distribution.

This classification helps compare among different crops and crop types. It also allows comparing and optimizing resource allocation in the different stages of a program. Comparing results from long-term breeding research within this framework allows comparing across species and within a crop; and technical education in plant breeding is often conducted within the framework of these categories. Because education in plant breeding is mostly technical in nature, it is usually limited to these three stages.

A successful breeding program, however, needs two additional stages that go beyond purely technical issues. The technical process needs to address and be matched to fit a set of identified goals and objectives with well-defined targets for the breeding program. Primary and secondary goals need to be identified, as discussed above. To fulfil them, specific objectives for the breeding program must be identified and prioritised, and targets set. In identifying appropriate objectives and targets for a breeding program, knowledge about the target farming system(s) and farmers' needs are important, and farmers' selection criteria is helpful. Although breeders are rarely trained to elicit this type of information, farmer participation can be a powerful tool to achieve a meaningful reorientation of a breeding program.

To be successful, the technical process of the breeding program also needs to feed into an efficient system for varietal release and dissemination, that is, an identified system for delivery of the technical product to potential users. Evaluations of past impact of breeding programs have often pointed out that weaknesses in such delivery systems limit or slow adoption. In view of the unsustainability of large-scale, state-run or directed efforts for seed production and distribution in many developing countries, areas for reflection might be the strengthening of the local seed sector or the catalysing of more local seed suppliers (whether private sector or otherwise). Some estimates suggest that, worldwide, the local seed sector provides at least 80% of farmers with most of their seeds (Cromwell et al. 1992).

To examine the potential for, and actual farmers' involvement in, this whole process of a breeding program, it may help to depict these stages in a cyclical fashion (Figure 1). This makes it clearer that feedback between the different stages is possible and should be institutionalised in programs. In participatory breeding projects, many of which are exploratory to a large extent, envisaging this feedback and influencing and opening up opportunities throughout the cycle of stages of the program for farmer input is particularly important, even if the degree of input may vary by stage.

In conducting the overview of formal-led PPB work to date, it became clear that most programs involved farmers in the testing of varieties, materials that were genetically fixed and often already released. Several programs addressed the setting of breeding priorities and targets. Relatively little work has been done on exploring farmers' contributions to setting overall goals of a breeding program, generating variability, or selecting experimental varieties from segregating populations. The variety diffusion process is a step that has also received relatively little attention, but is starting to attract interest.

Farmer Participation and Crop Type

Most PPB efforts to date are focused on staple food crops or are in areas with locally important quality preferences. For instance, several PPB programs were found with the staple potato in the Andes, but not in Central America where potatoes are something of a luxury vegetable. Rice PPB was found in Asia and Africa, but not in Latin America where rice is grown with mechanized production as more of an industrial crop. None of the cases examined dealt with crops grown using mechanized production.

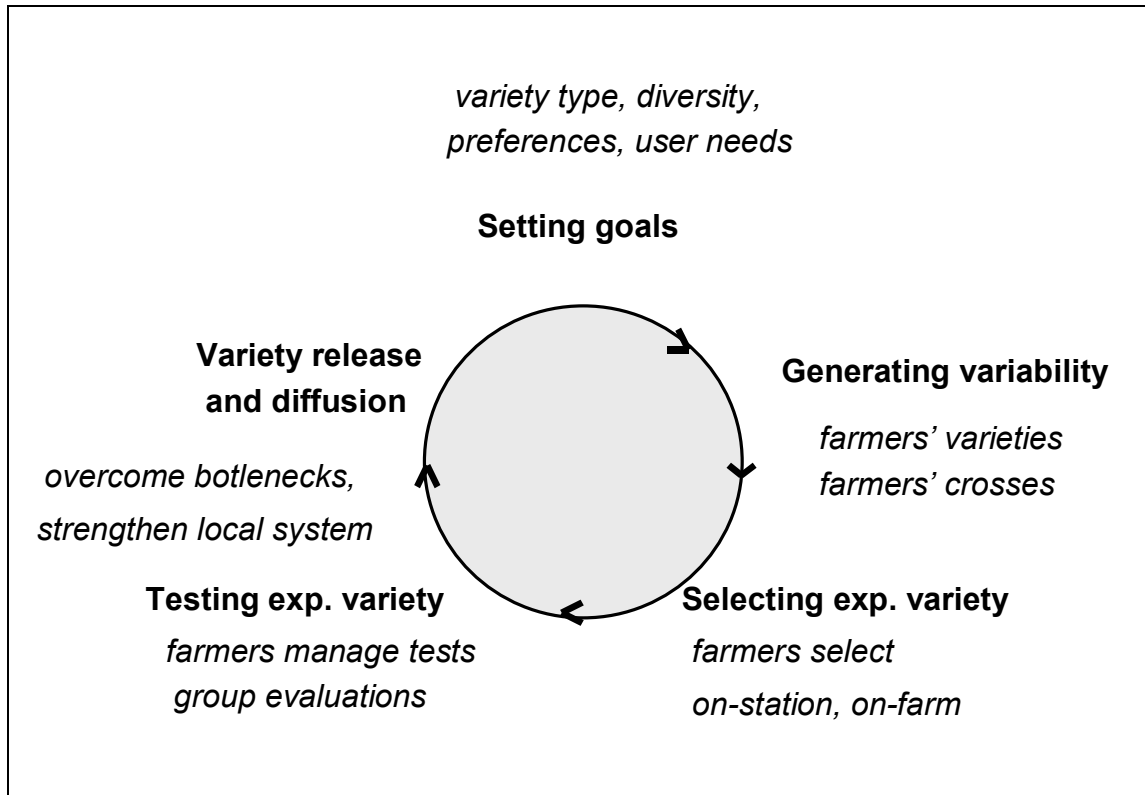


Figure 1. The cycle of plant breeding stages, with examples for farmers' contributions (in italics).

Of the crop experiences examined, most (24 of 46 crop examples) are with self-pollinated crops, followed by cross-pollinated crops (15 examples), clonally propagated crops (7 examples), and agroforestry tree species (two examples). For all crop types, most of these projects involved farmers in some form of participatory variety selection, and few involved farmers in generating variability or selecting within segregating populations (Table 2). Several of the projects linked work on varietal selection with achieving a better understanding of farmers' selection criteria and varietal needs. This information usually feeds back into breeding programs immediately and affects the setting of priorities. However, only a few projects implicitly involved farmers in jointly setting overall priorities.

Table 2. Numbers of participatory plant breeding projects classified by crop pollination biology and general stage of farmer involvement^a.

Pollination biology	Testing varieties	Selection in segr. populations	Setting priorities
Self-pollinated	19	7	7
Cross-pollinated	9	3	7
Clonally propagated	6	1	4

a. Classification is, of necessity, approximate. We took description of stages of the breeding as a guideline (Schnell 1982).

Although our working definition of PPB limits it to selection within a species, a few comments on between-species selection are needed. The recent review includes two cases where farmer-participatory methods were used for selection among tree species for potential use in agroforestry breeding projects (Franzel et al. 1995). Clearly situations exist where selecting the most appropriate species is a necessary first step before any type of breeding work is contemplated.

In addition to pollination biology, the seed increase ratio of a crop (i.e., how many seeds can be harvested from one plant) also influences the type of participation feasible and the farm-level impact. In crops with low seed increase ratios, it may be difficult to produce enough early generation seeds to allow for on-farm testing of progenies with a representative set of farmers. In such cases, community representation and community plots are possibly the better route for involving more farmers in the evaluation process.

Similarly, the sowing method that farmers use may limit the type of trial design, which is feasible for farmers' fields, and thus the kind of experimentation that farmers can do. In regions where hand-sowing in hills is predominant, one can easily envisage testing many varieties in a relatively uniform part of the field. If sowing is done by machine, only a few large plots are possible. The time available for optimal sowings may also vary. For many dryland crops, this is the critical factor for successful cultivation, thus only trial designs can be implemented that do not slow down the process of sowing. If this sowing time is also highly unpredictable, the researcher will find difficulty in being present at the time of sowing and farmers will be mostly fully responsible for trial designs and their implementation. Another factor that may influence the type of farmer participation envisioned is the level of diversity among the locally grown cultivars. In highly diversified cropping systems, with a range of differing crop uses, new germplasm may require more long-term testing with a wider variety of users, and for a broader range of uses, before farmers can take adoption decisions.

These observations show that the biology of the crop and crop management systems in the target region also determine the type of participation in a breeding program.

Types of Farmer Contribution Found in Formal-Led PPB programs

A way of differentiating farmers' contributions to a participatory breeding program is to examine the nature of this contribution. We have identified four main thrusts where farmers:

- (1) Contribute key information based on their knowledge and experiences,
- (2) Contribute genetic materials,
- (3) Conduct trials, and
- (4) Select and evaluate germplasm.

Farmers' knowledge and information

In the cases we examined, farmers' knowledge was often integral to achieving a better understanding of the varieties farmers presently grow. Farmers' descriptions of their cropping system, major constraints, key aspects of the farming system, and social institutions are all information that makes an important contribution to the orientation of a breeding program. Another important requirement for a breeding program is to understand farmers' needs and preferences for the specific traits of a crop. This kind of understanding often leads to descriptions of appropriate type of varieties, a reorientation of the breeding program in terms of selection strategy, and germplasm used for breeding. Farmers' knowledge is also essential to better understand a local seed system, and opportunities for increasing its efficiency and its ability to serve a wide range of farmers.

In some of the cases we examined, the description of locally-grown varieties in the target areas allowed breeders to become familiar with the varieties that farmers grow and helped breeders choose appropriate materials for testing and breeding that could fulfil some of the farmers' basic requirements; or it allowed the breeder to choose materials for testing that differ sufficiently from the locally grown varieties for key traits (Witcombe et al. 1996). The description of the local process of seed production and management is another example where farmers' information was key to a program's success. Based on a careful analysis of farmers' strategies for seed potato, production technologies for improved seed health and storage conditions were developed in the Andean region and in eastern Africa (Haugerud and Collinson 1990). Another example where farmers' information played a key role in orientating the breeding program, is the work on pearl millet in the desert region of Rajasthan. Farmers in this region do not differentiate particularly between different varieties, but rather between different plant types. They associate strongly between adaptation to specific growing conditions and specific plant types. Farmers who regularly produce their own seed often select panicles representing very different plant types for their seed lots. For a breeding program targeting this region, adoption of any new variety will depend on its capacity for contributing to the success of these diverse seed lots (Dhamotharan et al. 1997).

This type of farmer contribution thus provides breeders with necessary information for identifying the appropriate type of variety, both in terms of genetic make-up (hybrid or heterogeneous open-pollinated variety) and in terms of key plant traits. Similarly, research efforts aimed at improving institutional support for seed production and distribution can derive key interventions from a sound analysis of farmers' information. Better understanding key

production constraints may allow breeders to modify the testing environments on the research station to test materials more effectively for key adaptations. This understanding, especially when combined with an understanding for the major uses of a crop or varieties, will also help breeders reorient their programs and be better able to meet farmers' key needs.

These examples indicate that the types of impact that a PPB program can expect from letting farmers contribute their information to the joint program are largely related to making research more effective and improving the dissemination of new technologies. Farmers' information may have some impact on the level of biodiversity maintained in the target farming system if the breeders start targeting a wider range of plant types, or if more variable types of varieties are available for dissemination as a result of these discussions with farmers.

An important advantage of explicitly searching for and including farmers' knowledge for developing and implementing a PPB program is that it is easy to involve many farmers and, with appropriate care, stakeholders can also be involved who are often overlooked or excluded (e.g., women, poor farmers, and minorities). Discussions with farmers on specific topics related to the breeding effort do not have to be conducted during the growing season when farmers' time is often limited and valuable.

Farmers contribute genetic materials

Farmers often contribute genetic materials to breeding programs, especially participatory breeding programs focusing on adaptation to specific stresses, production systems, or niches. Specific quality traits or crops, for which little breeding has been done so far, rely strongly on farmers' contributing their own genetic materials to a joint breeding effort. In such cases, farmers' genetic materials are commonly **key** to success.

Farmers' genetic materials can be used in different ways. In a few cases with cross-pollinated crops, the farmers deliberately create new variability by facilitating outcrossing between highly diverse types of varieties, often their landrace and an introduced modern variety. These outcrosses often reveal enormous genetic variation and many new combinations of traits. In the case of pearl millet in Namibia, one such population was used as the base for creating a new breeding population (Bidinger 1998). In several cases, farmers have contributed landraces as parents for crossing, or for targeted improvement efforts. A good example for this is the project on breeding for chilling tolerance in rice in Nepal. Breeders identified the local landrace in a series of tests as highly tolerant of chilling temperatures during the early growth phase and during grain filling. This variety was crossed with a high yielding, chilling-susceptible variety. Farmers used the progenies from this cross for selection of a new variety (Sthapit et al. 1996).

Farmers' varieties usually form the basis for further improvement in projects that mainly aim at improving farmers own skills in improving the genetic composition of their varieties and seed stocks. An example is a project, led by the national program of Honduras and Cornell University, with a component of teaching farmers techniques for pollination control for maize in a region with a high degree of local varietal diversity (Gomez 1996). Thus the base material for the efforts for improvement are the farmers' varieties or possibly other materials that are available to them.

Farmers' genetic materials often broaden the genetic base of the participating breeding program considerably. The material derived and disseminated from these efforts can also represent a wider range of diversity than the products of previous efforts. The use of farmers' genetic materials sometimes contributes to conserving landrace materials in the local farming system, particularly in cases that focus on building farmers' skills. The types of impact that were observed or expected from using the farmers' genetic materials have been mostly related to enhancing biodiversity or conserving local germplasm in the farming community and enhanced productivity in specific production systems.

Farmers conduct trials

In almost all the cases examined, farmers manage trials on their own land as part of the PPB program. Farmers normally decide how to experiment, that is, they choose the field for growing the trial(s), manage the nutrients and other aspects of crop husbandry, choose the control variety, and contribute to the trial design. In many of the cases where farmers evaluate stable varieties, this contribution is key to the breeding program's success. Farmers provide the appropriate testing conditions, which enhance the selection program's efficiency.

An example is the work with potatoes in Ecuador, where farmers test varieties over a wide range of altitudes and fertility conditions. Research stations do not cover this range of altitudes, and usually do not manage trial fields at different levels of input. In this case, farmers selected new desirable clones for adoption after only 2 years of testing, whereas officially released varieties had scarcely been adopted earlier (Andrade H, personal communication, 1998).

Another example where farmers' trials are key to the joint breeding effort is the case of pearl millet in southern Africa, where farmers grow nurseries of diverse pearl millet varieties and germplasm accessions usually in community plots for selecting material for further testing on their own farms. In this case, the farmers' fields also provide more appropriate testing conditions and better access to farmers (Monyo et al. 1997). More farmers can come and see and assess the new breeding materials.

The key impact from farmers' contributing trials to a participatory breeding effort is an increase in research efficiency through providing appropriate testing conditions. Through on-farm trials, farmers get early access to new genetic materials and have the option to adopt these varieties. Increases in productivity and initial adoption can be immediate results from farmer-managed trials. This would normally lead to further dissemination and adoption of the new varieties. Farmers may also decide to use them in their own breeding work and thus influence the level of genetic diversity in their farming system. Farmers' experimentation with new germplasm is a powerful tool to create the basis for a range of impacts on-farm.

However, among the cases examined, several report that poor farmers or women can experience greater difficulty in growing trials. Better-off farmers often have more time to devote to farming or have a stronger role in decision making about land allocation on their farm. If poor or women farmers are among the targeted group, specific planning is needed so that they can benefit from the planned activities.

Farmers select and evaluate

This contribution of decision making among a set of varietal choices goes beyond providing information alone. Farmers in these cases make judgements based on multiple criteria; they decide which trade-offs to make and which combination of traits to favour. These are often complex decisions because numerous traits can be considered and because differences between individuals may be small for individual traits. To identify materials that contribute new opportunities for enhanced productivity or stability of production requires an intimate knowledge of the target farming system, production system, and social system.

In many PPB programs, farmers make the final selection decisions, for example, among entries in an on-farm trial, or among entries in larger nurseries grown on-farm or on-station. Selection usually involves evaluating a variety for a number of traits in combination simultaneously. Trade-offs are assessed between the different traits, for example, yield potential and earliness, or panicle size and tillering behaviour. A farmer is often the better judge in predicting which combination of traits may have potential use for specific growing conditions and production goals on his farm or in his area of cultivation. Several well-documented cases show that farmers' selections indeed performed well, better than breeders' selections, in the conditions for which they were selected (Sperling et al. 1993). Breeders often find it difficult to have a broad enough understanding of the diversity of growing conditions and the corresponding relative weaknesses of the local cultivars to make appropriate selection decisions that anticipate the full range of potential adoption possibilities.

Thus, farmers' involvement in decision making can have far reaching impacts and often leads directly to more adoptable varieties especially in areas where none were before. Researchers usually gain a better understanding of farmers' assessment processes and can thus target their program better towards meeting these needs.

Most programs use several types of contributions from farmers and to different degrees. They also change their organizational set-up to adapt to the needs of the farming communities and to improve the program's impact. The fast and comprehensive learning experience for the participating scientists is a basis for these rapid changes in the operational forms of PPB projects. The other basis is the rapidly increasing role of farmers in the decision-making process and in guiding the project toward other areas of work (e.g., seed system support) to improve the scope and scale for impact.

Impacts of Formal-Led PPB

Impact of PPB projects led by formal sector institutions was analyzed for both groups of partners in this process: the farmers, their families, their communities, and associations; and the researchers and their institutions. The farm-level impacts have in many cases exceeded researchers' expectations.

Framework for thinking about PPB impacts

Like any type of plant breeding, PPB is a process that may take 2 to 5 years to have initial results and still several more years before its true impact begins to be realized. Recognizing this, a group of PPB practitioners (drawn from the plant breeding group of the Participatory Research and Gender Analysis program) has begun conceptualizing a set of intermediate impacts with accompanying indicators.

Table 3 shows two examples of possible intermediate impact indicators being used in two ongoing PPB field programs. A challenge of this developing PPB work is to assess the trade-offs of aiming for different intermediary impacts—and ultimately goals.

Table 3. Examples of types of intermediate impacts anticipated for major impact categories from two ongoing participatory plant breeding (PPB) research programs.

Impact categories effects on:	Intermediate impacts: Example 1	Intermediate impacts: Example 2
Formal breeding process (feedback to research)	Changes in the selection strategy: selection criteria selection environment type of germplasm used gender differentiated selection criteria identified	Positive change in the way formal breeders view PPB Strengths and weaknesses of available germplasm better understood (for researchers or for farmers) Farmers' preferred traits, user- and gender-differentiated, better understood
Acceptance (adoption)	Increase in adoption: number of lines requested for independent testing number of farmers requesting lines More requests from farmers of different wealth categories Farmers retain seed for further testing	Identification of farmer-acceptable varieties Particularly disadvantaged users (e.g., women) identify acceptable varieties Rate of varietal spread quickened Seeds of preferred varieties given to neighbors
Farmer production	Varieties show yield advantage on-farm	

Continued.

Table 3. Continued.

Impact categories effects on:	Intermediate impacts: Example 1	Intermediate impacts: Example 2
Farmer-held diversity	Number of varieties used on-farm increased (no. of varieties being a rough proxy for variety diversity)	Enhanced diversity through deliberate cross-pollination in farmers' fields
Farmer breeding / seed processes (technical / social)		Enhanced farmers' capacity to mass select Enhanced farmers' ability to maintain open-pollinated varieties
How local people are organized to manage crop development: - breeding/ select - seed supply issues	Farmer group formed to produce and distribute seed of preferred varieties in the village	Nodal seed experts in community identified Enhanced farmer ability to produce quality seed
How formal research organizations organize breeding: - breeding org. - supply org.	Move to replicate farmer conditions on research stations Greater percentage of trials in farmers' fields The role of decentralization vs. participation understood Changes in variety release procedure considered	Better understanding (by researchers) of farmer seed flow system
"Empowerment"		Farmers set their breeding objectives Farmers control breeding methodologies Farmers perform breeding activities Farmers work through existing or newly formed community-based organization or farmers' groups

Specific PPB impacts

Changes in orientation of breeding program. Many participatory breeding projects were initiated in regions that are marginal in terms of the environmental conditions for crop growth and productivity increase. These regions are often where plant breeding programs have had limited prior impact. The PPB research targeting these types of environment has examined the suitability of specific breeding strategies in achieving better genetic gains under such conditions through insights gained from farmers, and farmer expertise in selecting among plants, progenies, or varieties. Such close interactions can profoundly influence the overall strategy of an evolving breeding program.

An example is the pearl millet breeding program of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). The program is for the dry zones of the state of Rajasthan, and was initiated in 1989 in response to findings indicating that local landraces tended to show higher grain yields under severe stress conditions. The approach taken was to improve testing sites in the target region and develop breeding populations using the local germplasm. Farmers were involved in the project implicitly to identify their needs and preferences and thus contribute to refining the program's goals and objectives. The initial findings of this work indicated that farmers in different regions and representing different social strata and gender had widely differing preferences and needs (Weltzien-R et al. 1998).

A more detailed understanding of farmers' seed management practices revealed that farmers often use small quantities of modern varieties as components of seed mixtures and thus considerably broaden the genetic base of their own seed lots. Farmers could thus enhance their chances of obtaining increased yields under better growing conditions. At the same time, poor farmers, especially women, expressed concern over this practice of mixing improved varieties with local ones, because the seed produced from these mixtures shows less adaptation to the predominantly poor soil conditions. Poor farmers are often dependent on seed from better-off farmers, but the seed these provide does not serve the poor farmers' needs as well as it used to. Because poor farmers dominate in these regions and better-off farmers also own field with poor soils, the breeding program decided to fill this gap by focusing its efforts on developing materials specifically targeted towards poor fertility soil conditions and a higher stability of grain yield. This constituted a profound change, because it required changes in the management of research station fields and in the germplasm base for breeding, and further research into the methodology for achieving these goals, including sharing responsibilities with farmers. The program also helped a local nongovernment organization (NGO) identify farmer-preferred sources of landrace-type seed for increase and distribution to those farmers who are facing difficulties with seed production. In collaboration with the national authorities, steps were initiated to change release procedures for pearl millet so that varieties specifically adapted to these marginal conditions would have a higher chance of being identified as superior by the national variety testing scheme, and thus a chance to be released.

Another example where farmers' involvement in the breeding program has led to profound changes in the orientation and operation of the breeding program itself is the case of potato breeding in Bolivia (Thiele et al. 1997). The research program focused on developing techniques for farmer evaluation of potato clones, which had previously been tested for potato late blight resistance and yielding ability on research station trials. During these experiments, the researchers gained an understanding of farmer-relevant criteria, which have been incorporated into the breeders' selection strategy on-station. At the same time, farmer groups are now involved routinely in evaluating a larger number of clones on the research station and subsequently on their own land. These farmers usually remain involved with the breeding program and often multiply seed potatoes for further distribution in their villages. Thus farmer tests have become an integral part of the routine testing procedure for new potato clones in Bolivia.

Improved varieties for marginal areas. Because farmers were involved in the selection in segregating generations, a rice variety (*Oryza sativa*) was bred that combined the high level of

chilling tolerance of landrace rice varieties of the Nepal mountains with the increased productivity from modern varieties. So for the first time the farmers in these hilly regions could benefit from a plant breeding effort targeting their region (Sthapit et al. 1995; 1996). Initial adoption of this variety was high and, more interestingly, the success of farmers' selection encouraged them to continue further selection in this and other material. They were thus carrying the process further even with reduced support from researchers (Sthaphit, personal communication, 1998).

Bean (*Phaseolus vulgaris* L.) breeding in Brazil was successful through involving farmers in breeding a variety that combined disease resistance (*Macrophomina* and *Fusarium* wilt) with the preferred seed coat color, drought adaptation, and yield characteristics for the dry zone of northeastern Brazil. Farmers were involved in selection in segregating materials on-station and later in testing experimental varieties on their own farms. Before the variety could be formally recommended for cultivation in this region, farmers were growing it and demanding more seed (Zimmermann 1995).

Immediate adoption and yield increases. Farmers in a remote area of India, where soils are highly degraded and production is subsistence oriented, could identify varieties of several major crops that provided them with new options, more food, and greater stability of production (Witcombe and Joshi 1996; Witcombe et al. 1996). The documentation of adoption of the rice variety "Kalinga III" is a good example of the spread of a variety identified through farmers' participation in variety testing. This study shows that adoption of the variety began in the study villages the year following the first trials conducted by farmers. Seed of the preferred variety began spreading to other villages in the second year following farmers' trials. Although the project helped spread the seed in several ways, much of the found spread resulted from farmers' own initiatives in selling and giving away seeds to others, inside and outside the village. The spread of this variety continues, but official release in the state of Rajasthan (where the project is located) pends and thus government subsidies for producing and distributing seed of this variety are not available to farmers. A study of the impact of this one rice variety, identified through farmer participation, estimates rates of return for the overall project between 47% and 70%. This figure is as high or higher than for regular successful, non-participatory agricultural research. This indicates that participatory research with a comparatively local focus, and thus a smaller target region, can have similar rates of returns. In this case, it was mainly because this variety provided farmers with great yield benefits and more production stability. The advantage of participatory variety testing is precisely that these attributes can be rapidly identified because varieties are being tested under a wide range of conditions that farmers manage themselves.

Benefits for women and poor farmers. Breeders have often worked under the assumption that benefits of new varieties are scale- and user-neutral, that poor and rich farmers, or men and women can achieve the same type of benefit from these new varieties. In many cases of widespread adoption, differences in preferences and potential benefits were observed, but the conventional approach to breeding (of variety release and of extension) has often been unable to offer effective solutions to meet these diverse needs.

Participatory approaches are often designed to involve as partners in their program a wide range of farmers representing different social groups, gender, or otherwise differentiated groups.

These approaches potentially have the in-built capacity to respond to specific groups' needs and to make use of different user talents. Women in particular are often plant breeders in small-scale farmer production systems, responsible for domesticating wild species, selecting germplasm, and saving seed.

In many instances, women's criteria may be significantly different from men's—dual involvement in breeding/selection is necessary to meet each partner's needs. In Mali, maize evaluations showed men putting production and early maturity as the main criteria, with women focusing on organoleptic and processing aspects (Kamara et al. 1996). Rice work in West Africa had a similar gender division, with scientists from the West Africa Rice Development Association (WARDA) reporting that men focused on yield and yield-related traits, such as plant vigor, and women concentrated on quality attributes, such as bold grains.

Involving women in PPB can confer benefits for all the community not just poor women. Over a 3-year period, Rwandan experts selected a pool of varieties (21 separate bean types) that outdid breeders' choices in their own production terms by up to 33%—and met quality characteristics of interest to diverse community groups (Sperling et al. 1993). Not involving women or poor users may bring negative, not just neutral, consequences. In the Gambia, men's production systems involved almost 100% adoption of high yielding variety (HYV) rice, and female production systems remained based on the use of *Oryza glabberima*, a rice species indigenous to West Africa. This wholesale adoption by men marginalized women's products and transferred other rice lands into the hands of men who received all benefits from commercial sale (S. Hecht, personal communication, 1998, citing the work of J. Carney).

The overview of formal-led PPB cases pointed to specific ways in which PPB has helped researchers focus their efforts on the poorer sectors and highlighted some strategies for addressing their particular needs:

- (1) Testing in low-input situations,
- (2) Emphasizing the development of some early varieties (often grown by farmers among an array of varieties that fill different use niches),
- (3) Paying attention to multiple crop uses in the selection process,
- (4) Identifying a diversity of varieties so as to stabilize production, and
- (5) Ensuring that varieties grown for the market have characteristics that can fetch good prices.

Varietal diversity increased. Many of the examined cases of PPB involve farmers in the testing of more varieties than traditionally takes place during the adaptive or extension phase of formal research. It is commonly observed that farmers' selections differ as their needs differ, for example, farmers who own poor land tend to prefer different varieties than farmers who have better fields. Women farmers often select more explicitly on grain quality characteristics and make different choices than do men farmers. The outcome of PPB programs is usually that different farmers in different communities select different varieties and thus PPB in most cases has contributed to increased varietal diversity.

A clear example is the “Informal Research and Development” (IRD) program initiated in Nepal with the explicit objective of increasing the varietal diversity of rice varieties suitable for

early planting under irrigated conditions (*chaite* rice) (Joshi et al. 1995). Potentially useful rice varieties identified by researchers were distributed to about 1800 households in the target area for this project. Farmers were given some written information about the variety they received and were encouraged to compare it with their own variety in their own fields. Researchers did not participate in these evaluations, but returned 2 years later to a sample of the recipient farmers to assess the effect of the approach.

The follow-up revealed that about 35% of farmers who had received a seed packet had adopted from one to four varieties of the six distributed for testing. In this area, a single cultivar was dominating cultivation prior to the participatory work. Most of the farmers who decided to adopt a new variety belonged to the group of farmers who regularly produce sufficient or surplus food for their families. Only 15 % of the adopters belonged to the food deficit group. Interestingly, the preferences for specific cultivars seemed to differ between farmers belonging to these different groups, indicating that they have different needs for cultivars and their key characteristics. A conclusion of this report is that not any one single variety could meet all these needs. This IRD approach proved to be a powerful tool for offering a wide range of diversity to a wide range of farmers.

Similarly impressive PPB results relating to enhanced varietal diversity occurred in two major cassava-growing regions of Colombia: a seasonally dry ecosystem in the north (an area with poor soils and 800-1000 mm rainfall annually, bimodally distributed), and more recently the highlands of southwest Colombia (Iglesias et al. 1990). Researchers from the Centro Internacional de Agricultura Tropical (CIAT) and a branch of the Corporación Colombiana de Investigación Agropecuaria (CORPOICA) initiated a participatory crop improvement effort in 1996. The aims were to learn more about farmer criteria for choosing cassava varieties for consumption, marketing, and processing, and to evaluate traits within a genetic base that had not been preselected, hopefully to generate varieties that were both more acceptable and more “biodiverse”. An average of 28 communities per year were involved in the clonal evaluation effort in northern Colombia, with community participation organized via chip-drying cooperatives.

Researchers quickly realized that effective varietal comparisons could be made only if the planting material for local varieties and new breeders’ clones was produced under similar conditions, to avoid bias caused simply by its health and vigor. This concern was addressed by producing all planting material in a common location under conditions approximating those of the farmers. It also became clear that farmers and researchers often used different terms for variety evaluation; a glossary of farmer evaluation terms was compiled.

Farmer evaluations of advanced clones from cassava breeding programs resulted in the release of three new varieties in northern Colombia (a significant addition to the two varieties in use). Through this process, researchers acquired a better understanding of farmers’ selection criteria and were able to quantify certain of them in ways that would facilitate researchers’ selections (e.g., farmers’ preference for “hard” roots corresponded to roots of over 35% dry matter.) A unique aspect of this work is that researchers developed a cost comparison between their farmer-participatory approach and traditional variety evaluation, indicating that data points

from farmer-participatory trials cost about US\$ 0.50 and those from typical researcher-managed advanced yield trials cost about US\$ 0.80.

Changes in variety release procedure and seed production system. Centralized fora or committees for any individual country usually enforce variety release procedures. Needs of specific regions, especially in marginal areas, and those specific consumers or users are not easily considered in such centralized procedures. As PPB tends to reveal such differentiated needs and those for diversity, recommendations on how to change the existing release procedures are often a direct result of working more closely with farmers. Participatory research also contributes to making farmers more aware of these procedures and can spur ways for farmers to initiate policy changes.

A PPB program in India is working to encourage formal committees to give greater official weight to farmer evaluations. The program argues that data synthesized from farmer varietal evaluations (i.e., qualitative assessments) should be used as a base for varietal release decisions. In many cases, such data may be more predictive of future adoption than the standard yield measurements, which form the core of most release decisions (J. Witcombe, personal communication, 1998).

Work with potatoes in eastern Africa further demonstrates how standard, but more rigid, procedures can become more flexible. A thorough survey and enhanced interaction between farmers, breeders, and social scientists led to changes in the selection and release procedures for potato varieties in Rwanda. The main difference was that testing of varieties for release was done under no external input conditions. The program resulted in the release of several new varieties during the first 5 years, a short time. Farmers readily accepted these varieties and two varieties could be found countrywide 5 years later (Haugerud and Collinson 1990).

Often PPB goes hand in hand with recommendations to develop or build on local, more decentralized seed systems, which can provide location-specific varieties that farmers themselves effectively multiply and distribute. For instance, prior to the civil strife in the early 1990s, both Rwanda and Burundi Ministries of Agriculture and Rural Development tabled plans for decentralizing seed services—partly to accommodate more decentralized breeding (Sperling, personal communication, 1998). Programs of PPB are also increasingly including seed production components, which are integrated and innovative, to quickly deliver the positive impacts that PPB can achieve. Good examples of this come from the PPB and seed work with cassava in Colombia (Iglesias et al. 1990) and with potato in Bolivia, Peru, and Ecuador through a set of collaborations between the national seed projects and the Centro Internacional de la Papa (CIP) (Thiele et al. 1997; Thiele 1999).

Changes in institutional organization. Organizational innovation often proves central to the kinds of impact that PPB programs strive to achieve. Decentralization of screening can link testing to truly local conditions, and give a leap to the seed multiplication and diffusion process. Several PPB programs have considered organizational innovation to be at the core of their work.

An example is the barley breeding research of ICARDA in collaboration with national programs in Syria and northern Africa. The program has shown that decentralizing the breeding

program is essential for achieving genetic gains under growing conditions that are common in farmers' fields (i.e., low external inputs) and the high frequency of drought stress and frost during the flowering and seed set stages of crop development. The program has achieved initial forms of decentralization by developing new research stations located in the target region of the specific breeding programs (Ceccarelli et al. 1996). At present, it is experimenting with further decentralization through testing breeding material in farmers' fields in the initial stages of the selection program. In this case, the key partners in the research are a few farmers chosen for their interest in barley improvement and their willingness to accommodate a relatively large researcher-designed and researcher-managed experiment in their fields. Initial results indicate that this further decentralization is highly effective and the breeding program is benefiting from farmers being involved in the selection process.

The issue of decentralization (and its mirror, scaling up) was the direct subject of investigations in the Great Lakes' Region, in both Rwanda and the Democratic Republic of the Congo (DRC). Several options for decentralization were "tested": through the extension service, through self-designated farmer research groups, and through farmers' cooperatives and women's groups. Several seasons of testing showed the most effective channel, for both feedback to research and feed forward to farming communities was the women's groups and cooperatives (which, in this case, were female). In the Rwandan instance, the women's group (supported by an NGO, COOPIBU) multiplied and distributed a ton of bean seed before the other organizations made the final decision on which varieties to multiply. The DRC cooperative, "Women United for the Development of Burhale" (Femmes solidaires pour le développement de Burhale [FESODEU]), chose to multiply and market their selections packaged in small packets of 50 to 100g to their 5000-strong membership and sold all the multiplied material in a matter of weeks. However, using such groups results in sporadic rather than a more universal coverage (Sperling 1994).

The WARDA is also pursuing the issue of decentralization, and on an impressive scale. With its National Agricultural Research Systems (NARS) partners in 17 West African countries, WARDA has initiated PPB programs with a focus on experimental varieties (in some cases also released) relatively late in the selection process. The group is evaluating, with partners such as extension and development agencies, NGOs, and cooperatives, the effectiveness of testing varieties with farmers' participation (M Jones, T Dalton, and N Lilja, personal communication, 1998).

Conclusions

This review of about 40 formal-led PPB programs demonstrates that a wide range of impacts were achieved through use of participatory approaches, despite the short time that most of these projects have been in operation. Through the close collaboration of farmers and formal researchers, breeding progress was made in regions where variety improvement efforts of centralized programs with large uniform target regions have been less than successful. Farmer participation opened new opportunities for reducing the lag-time between variety testing, release, and adoption; and, through making new germplasm available to farmers in experimental quantities, the basis for adoption was repeatedly laid. The improved understanding of local seed production and dissemination systems allowed researchers and project managers to overcome

specific seed system constraints and to make targeted interventions to overcome seed supply problems quickly. This helped farmers gain access to the desired seeds rapidly, from known and reliable seed sources. Farmer participatory breeding programs also led to new alliances between research and development organizations. As a result, changes occurred in the orientation of breeding programs and in variety release procedures, and changes in formal seed regulatory policies were recommended and in some cases (in Latin America, Africa, and Asia) implemented.

Achieving specific benefits for specific user groups, such as poor or women farmers, really only became possible **through** participatory research programs. Enhancing their capacity to voice their concerns and needs was a major outcome of programs that explicitly targeted this type of goal. Such user-driven programs were also often those that had a complementary strong capacity building component—to strengthen farmers' own breeding, selection, and seed management skills. In the cases examined, such skill building proved integral to the scaling-up of the specific participatory breeding effort.

Although the impact of PPB to date has been impressive, this review of programs also highlights that many options for farmer participation in the plant breeding process are yet to be explored. Having more widespread goals, focussing on a broader range of crops, working with explicitly more diverse user groups, and experimenting with organizational options may identify wider and more varied benefits that PPB can achieve.

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