

# Supporting Farmer-led Plant Breeding

by

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**Farmer breeding can be considered as a process for managing gene-flow that operates in parallel with formal breeding. This process includes the introduction of diversity, recombination, selection, storage and exchange of planting materials in farmers' environments. Both formal and informal systems not only influence crop genetic structure and performance, but also determine who receives germplasm and information. Addressing farmer breeding remains a challenge if new technologies, such as biotechnology, are to be made relevant to broader groups of farmers.**

Plant breeding and seed industries are very much dominated by formal research. Although formal research involves millions of dollars, it seems rather insignificant if one considers the percentage of seeds from this source that are actually used. Many farmers adapt the formal systems' seeds into their fields through selection and crossing. At present, farmers are still the main agents of crop development for a significant number of crops and regions. The informal seed system, consisting of farm-saved seed, farmer-to-farmer exchange and informal markets, accounts for roughly 80 per cent of planting material worldwide. For generations, crops have evolved through natural and farmer selection. Yet, despite its importance, very little is known about how farmers breed their crops and manage their genetic resources, or about how this system can be supported and not replaced.

Conventional plant breeding is a linear process of crop development in which breeders direct and implement the research agenda. In contrast, *participatory plant breeding* (PPB) is a set of diverse approaches that enables the deeper involvement of users in crop development and seed supply. Attention so far has mainly focused on *formal-led PPB*, where farmers are involved in work initiated by formal breeders. However, farmer breeding, involving farmers' own systems of crop development and seed supply, could be supported and enhanced in *farmer-led PPB*.

This article is mainly based on a study that evaluated the technical and social aspects of 11 pioneering projects on farmer-led PPB. A broad range of farmers, institutions, regions, crop types and approaches to PPB were represented in the projects. The case studies highlight farmer-led PPB in diverse agroecological and socioeconomic

circumstances. Supporting farmer-led PPB involves increasing farmers' access to germplasm in support of either breeding or *participatory variety selection* (PVS), improving skills training, building linkages with other groups and breaking policy barriers such as restrictive seed regulations.

## Context of PPB

Farmer-led PPB is conducted in varying contexts, in response to diverse farming constraints and demands. There is considerable overlap between contexts.

- *Market failure* occurs as a result of farmers' isolation or in conditions where poor infrastructure restricts the access of farmers to seeds of *modern varieties* (MVs) or other inputs. Markets may also fail to supply farmers with seed options most suited to their conditions. This is the case in Guanxi (China) for instance, where women farmers regenerated their preferred maize varieties, both MV and landraces. Guanxi women rejected the hybrid maize offered by the state for both agronomic and economic reasons, and because the state breeding institutions ignored their request for technical assistance ([see also the article by Song in Monitor No. 37](#)).
- *Unfavourable regions* or marginal areas and limited MV impact can lead to the need for PPB. MVs are often targeted at specific environments, and usually involve high-input cultivation. However, farmers cultivate under a broad range of environmental conditions and farming systems. The *Projects in Alternative Agriculture* network (PTA) for example, a coalition of Brazilian *non-governmental organizations* (NGOs) aims at self-sufficiency in maize seed supply for farmers. PTA organized community genebanks and seed production groups in response to problems of farmers who, due to lack of money, had been replanting hybrid maize seeds for generations, resulting in declining yields.
- *Development of specific traits*. In contrast to the common view, PPB is not only relevant to marginal and unfavourable regions, but occurs across a wide agroecological range. PPB is also relevant in high potential areas, or areas with a favourable environment and infrastructure. For example, farmers engage in PPB in search of traits for specific market qualities, that are not offered by the formal system.
- *Restoration after disasters*. PPB is also pursued in response to dramatic changes, for instance natural disasters and armed conflicts. *Seeds of Hope* (SOH) was implemented as an emergency programme for food and seed relief after the genocide in Rwanda in 1994. SOH involved several institutions, including *International Agricultural Research Centres* (IARCs), *African National Agricultural Research Institutes* (NARIs) and NGOs. Formal seed systems seem to be slower to recover from emergencies than informal systems. After the war, many farmers were able to recover bean seeds either from their own plots or from those of others who were not able to return. Furthermore, farmers' seed channels, especially local markets, worked well in most regions and allowed recovered local bean varieties to be sold and distributed.
- *Biological factors*, such as visible diversity, self-pollinating crops and environmental variation are also conducive to farmers' interest in breeding. Farmers are often curious to test new varieties in their own fields.

## Goals of PPB

The different projects address a range of goals, which can again overlap with one another. The most common are biodiversity conservation and crop improvement.

For example, the *Community-Based Native Seeds Research Centre* (CONSERVE) is an NGO working with rice tenant farmers in the Philippines. Germplasm has been collected and conserved at its community genebank since 1992. A total of 485 rice accessions ([see also the glossary](#)) was mostly collected from the region itself, though 28 per cent came from the *International Rice Research Institute* (IRRI). Farmers have developed a simplified characterization, based on morphology and agronomy, which according to external evaluators, is up to international standards. 123 accessions have been distributed to farmers for screening, though no data have been provided on methods. Crop improvement occurs both at the CONSERVE centre and on-farm, whereby farmers define their own breeding objectives.

Many projects tie conservation closely with utilization, as continued use conserves crop varieties. Given constraints on land and labour, farmers are often only interested in maintaining varieties that are relevant to their needs. Moreover, breeding crops involves time and cost, which may be a constraint particularly for subsistence farmers, but also for supporting institutions. Hence, farmer breeding programmes are often tied to broader and more immediate development goals. For instance, many PPB practitioners first advocate PVS since this is more immediate in supplying germplasm and requires less investment in time and expertise as compared to crossing.

Apart from expanding access to germplasm, PPB can also aim at expanding farmers' options by supplying new crop species. For example, the *Community Committees for Agricultural Investigation* (CIAL), which represent around 50,000 families in Colombia, introduced pea varieties. After testing and adoption, a number of CIALs have become independent seed production enterprises, commercially distributing their own farmer-improved pea seed within and outside their communities.

## Selection and testing methods

Most projects involve selection and testing activities of staple crops, which highlights these crops' economic importance and the level of local knowledge on them. Although the projects employed different approaches, to date we still know very little of the biological impact of farmers' selection and testing of plant varieties. The effectiveness of selecting for desired traits in highly variable farming conditions is shaped partly by genetic diversity and by the heritability of those traits under the actual environmental conditions. Projects tried to address this through various selection methods, and in the number and nature of selection sites.

Instead of traditional mass selection or simply selecting individual plants, in some cases farmers used stratified mass selection whereby at regular intervals in the field, farmers select the best-performing plant, to compensate for micro-environmental variation. Early results from the *Escuela Agrícola Panamericana Zamorano* in Honduras suggest that this may be more efficient than mass selection in achieving yield gains for some situations. However, there is little systematic comparison for effectiveness of selection methods in other cases. To a large extent, effectiveness

depends on the heritability of a trait under specific genetic and environmentally variable conditions. Quantitative traits, or traits not easily observed, such as disease resistance, may be more difficult for farmers to manage. In fact, this resembles the findings in the formal breeding sector.

Testing methods are not only important for researcher projects to understand *genotype by environment interactions* (GxE) but also to find methods that are useful to farmers ([see also the glossary](#)).

PTA noted that farmers generally found information from single, large plots to be more meaningful than that from replicated ones. CIAL also sought experimental methods that farmers could appreciate. With some formal guidance, CIAL results were meaningful not only to farmers but to researchers as well. This suggests that while formal testing methods may not always support the validity of local knowledge about crops, farmers' own testing methods may be more useful to formal research than is commonly assumed. However, we need to know more about farmers' experimental methods to understand how their perspectives converge or differ from formal systems. In reality, these perspectives will vary among and also within regions.

As for GxE, variations in the environment that are both social and agroecological show that number and location of testing sites are important. Some projects worked with a single large community plot, while others decentralized into individual plots. However, testing sites may still differ from the target farms. For instance, one PTA community noticed that soil fertility on their experimental plot was higher than on most of the plots cultivated by their members, so they added another more representative site. Reports from other projects did not mention systematic bias due to testing/selecting locations. If such bias would have been against a particular group, such as poorer farmers, it may not have been noticed.

## **Barriers to institutional cooperation**

Farmer-led PPB embraces a wide range of institutions including farmers' groups, NGOs, and IARCs. NARIs, however, are more conspicuous by their relative absence. This may suggest that NARIs find it more difficult to break institutional barriers to cooperation, probably due to their mandate, and lack of methodologies and resources. The *Community Biodiversity Development and Conservation* (CBDC) programme, which is a global alliance of 14 organizations from developing countries promoting on-farm development of *plant genetic resources* (PGR), may be regarded as an exception. This alliance includes three Southern and two Northern NARIs ([see also the article by Manicad in Monitor No. 26](#)).

Formal and informal institutions may complement each other, for instance in technology. In the case of SOH, formal systems complemented food and seed relief efforts with molecular marker technology to assess the loss of diversity in beans as a result of the genocide. Institutional cooperation could also be valuable for activities such as skills training and developing markets.

CONSERVE is an example of potential complementary roles, particularly with *ex situ* and *in situ* conservation. Since NGOs are in general more community based than formal institutions, they may have better access to a particular area and its people, and

therefore also access to germplasm and information, as is demonstrated by the rich accessions in CONSERVE's community genebank. In this case, all accessions are still grown in the communities from which they originated and provide a back-up source of information and storage. However, the community genebank is only able to handle a limited number of accessions and their methods of seed storage, using wax-sealed glasses with silica gel at room temperature, are only viable for a limited period of time. Such limitations of *in situ* conservation can be overcome by the *ex situ* conservation whose genebanks are better equipped to handle large accessions for long periods. In 1997, CONSERVE entered into a 'black box' agreement with the *Philippine Rice Research Institute* (PhilRice), a NARI. In this arrangement, CONSERVE has exclusive access to the replicates of their accessions kept in the genebank of PhilRice.

However, despite the great potential of formal-informal partnerships, they are rare and often strained. This may be due to structural barriers such as policy and economics or to differences in institutional culture, which undermine understanding and trust. Better collaboration can only result if these barriers are acknowledged, understood and addressed.

Much mistrust stems from ownership and control of germplasm. In PPB projects, most farmers are generally open to sharing germplasm with other farmers. However, some projects are constrained when germplasm is brought out of the community to formal institutions for research. Many of the NGO collaborators in particular are afraid that once farmers' germplasm is brought to formal institutions, it may be exploited and monopolized by commercial industries. It is not clear whether this reflects actual concerns of farmer communities or those of the NGOs.

Involving farmers' knowledge and germplasm in projects raises a host of questions around ownership, access and rights to benefits. PPB is thus inevitably pulled into the complex debate on *intellectual property rights* (IPR). Unless IPR issues are addressed, farmers' interests and rights could be jeopardized. A possible solution is to have a contract agreement between the community and the formal institutions before PPB starts. This contract should deal with the methods of benefit sharing if protected material is used to develop new material. Furthermore, *Material Transfer Agreements* (MTAs) can be drawn if farmers' material is shared with others.

There are cases where institutions have overcome initial barriers. For instance in CIAL, seed is distributed through markets with approval from the national seed certification agency, under the category *farmer-improved seed*, although other countries may not recognize such seed. Another example is CONSERVE's black box agreement with PhilRice. Considering the general rivalries and lack of trust between formal and local institutes, this is a breakthrough in institutional relations.

### **Indications of impact**

This study was the first attempt to move beyond an anecdotal survey of farmer-led PPB. Impact is still very hard to assess, as few projects conducted baseline studies and most experiences in PPB are poorly documented. However, a number of general trends can be identified:

- *Germplasm support* to increase supply of diversity as well as work on crop improvement and seed quality suggested that these contributed to production gains and adoption of new varieties. Support to local seed storage and supply improves security of access with probable production and equity impacts.
- The degree of *genetic improvement or conservation* is not always clear, nor is the balance of the two. So far, while there is encouraging evidence that PPB adds value and support to on-farm conservation, we stress that the relationship between farmers' decision and genetic diversity are only starting to be explored. Measuring diversity is difficult. Most projects consider varietal diversity based on morphology which farmers readily assess. Other measures are hardly explored. For instance, so far only SOH and CBDC are using molecular techniques to complement farmers' assessment.
- *Empowerment* is another important goal in much farmer-led PPB. Although difficult to measure, some cases present clear indicators where farmers gain: *first*, control over the breeding process through access to materials and skills; *second*, skills in selection, testing, and seed supply; and *third*, support (technical and/or in terms of material and policy) through expanding their links to other farmers and institutions.

### **Some implications for biotechnology**

A growing number of *ex ante* evaluations suggest that biotechnology will tend to exacerbate existing trends in agricultural production and social differentiation. In this framework, we argue that current trends in biotechnology may again by-pass many farmers for lack of commercial interest, particularly in regard to minor crops and agroecologically less favourable environments. While many studies have focused on the risks of biotechnology and the greater dangers of narrowing genepools, we would like to focus on how biotechnology may be used in support of farmer-led PPB. In doing so, we hope to contribute to a framework discussion as to how biotechnology can be redirected to enhance PPB. In this sense, it is important to analyse not just the technology but the surrounding institutional relations. For example, if biotechnologies are to reach small-scale farmers, a network approach is needed involving the collaboration of all stakeholders such as farmers, public and private research sectors, NGOs and donors. This is in gross contradiction with most current practices, given that production of *genetically modified organisms* (GMOs) is in the hands of only a few actors almost exclusively from the private sector.

Biotechnology as a tool shows potential in farmer-led PPB. For instance, molecular markers may help us understand the biological goals of farmer breeding, as well as facilitate it. Markers can greatly enhance support to characterization of germplasm and complement farmers' selection; it may also help us understand farmers' practices. This is particularly helpful for quantitative traits. Additionally, molecular markers can be used to maintain and utilize genetic diversity, for instance, in studying relationships between genetic materials of parent lines for breeding, and monitoring genetic developments in *in situ* conservation. A recent molecular analysis of local rice varieties produced by farmers in one of the projects of the *Southeast Asia Regional Institute for Community Education* (SEARICE) revealed that farmers had most likely introduced traits of red rice from farmers' varieties into an IRRI released variety. Markers can also facilitate the breeding process by more efficient focus on desirable traits. *Bert Visser* of the *Netherlands Genebank* (CGN), a partner of CBDC,

hypothesizes that the use of molecular technology may also help farmers overcome restrictive seed regulations. The precision of identifying genetic make-up of varieties may allow for another measure of uniformity, one of the three criteria for the *Distinctness, Uniformity and Stability* (DUS) requirement for seed certification. Due to dependence on phenotypic observations with their limited resolution, the requirement of uniformity has been interpreted as the need for stringent homogeneity. However, the application of molecular markers allows for more detail in establishing a variety's identity. Uniformity may in principle apply to more heterogeneous varieties, as long as the heterogeneity is stably reproduced and can be conveniently documented, given that varieties can be more easily distinguished from each other through the application of molecular markers. The use of molecular markers in such a context would require reinterpretation of current *plant breeders rights* (PBR) regulations.

However, marker technology is expensive, requiring costly facilities and know-how. Again, collaboration with formal institutions may help overcome this limitation. Such collaboration would require open dialogue and clear terms of reference for all parties concerned.

Another biotechnology, tissue culture offers possibilities for rapid propagation of vegetative crops, and enables seed stock to be cleared of diseases. This is relatively inexpensive and the technology can be adapted easily.

*Genetically modified* (GM) varieties might not have much to do with farmer-led PPB in the foreseeable future, but have implications for farmer breeding in general. Further discussions and studies are needed, based on the framework of increasing diversity and access to germplasm within a context of handling biosafety in diverse and complex environments such as farmers' fields. Within such a framework, we would like to pose a few questions:

- Would it be possible to introduce GM varieties in addition to current farmer varieties and not to replace them?
- Can farmers reproduce GM varieties for generations without losing vigour or desired traits, and will companies allow the use of on-farm saved seeds?
- How will farmer breeding be affected since another severe constraint is the fact that most GM varieties are protected by patent rights which do not allow farmers to use these varieties as a breeding source?
- Can farmers afford the economic repercussion of having their crops rejected by consumers?

Studies on farmers' adoption of GM crops are scarce and limited to monocultures in the USA; and figures show that farmers' adoption depends highly on market developments. So far, there are no studies of farmers' adoption of GM seeds in developing countries. Such studies will be important if we are to understand farmers' adoption factors and the context of the introduction of GM seeds.

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