

PPB assessment and lessons

This section considers the lessons from 25 years of PPB practice globally. It draws from published articles and reports on specific cases, as indicated in Annex 1, as well as a number of comprehensive overview studies on PPB. Annex 1 shows that the majority of reviewed case studies were for improvement of grains. There is some diversity here, including maize, rice, millet, sorghum, quinoa, barley, teff and others. There are a much smaller number of case studies on legumes and vegetatively propagated crops. PPB/PVS on legumes is more common in Africa, and, to a lesser extent, in Latin America. Relatively few of the cases covered more than one crop type in a programme, but there were some.

Following the general structure of a plant breeding programme, literature was reviewed to see farmer active participation in the various stages: genetic materials selection; crossing; selection; in situ experimentation; and then the related multiplication and distribution of newly developed cultivars, formally or informally. Farmers' active participation was most prominent for in situ experimentation (all the cases except two), then late stage selection, followed by selection of parent materials and early stage selection (Annex 1). Few farmers were actively involved in crossing, which is a technically demanding activity. Also, not every PPB programme included crossing as part of the activities. Participating farmers usually have free access to materials used through the process and are able to use and share these materials at will. This underscores a primary aim of PPB to generate diverse adapted varieties for use in local socio-ecological conditions.

Different phases of PPB are variously pointed to as core to the definition. Some say that if farmers are not involved in crossing and early selection, then it is not really PPB. Others say that if farmer materials are not included as parents, then it is not real PPB. Certainly, from the evidence of case studies, at the minimum PPB must involve farmer participation in setting objectives and goals, sharing of genetic materials, in situ experimentation, and some active involvement in selection, whether early or late stage.

Not all cases explicitly mentioned whether farmers were involved in multiplication and dissemination of enhanced materials/new cultivars. About a third of the cases specifically mentioned farmer involvement in multiplication, while just under half mentioned farmer involvement in dissemination (Annex 1). Dissemination was often not through formal channels, and often the materials were taken and shared during the process, rather than only at the end, once there was a finished variety. This is one of the major strengths of PPB activities, because it gives farmers access to a wider diversity of materials that they can take and use, based on their specific contexts. In around one third of the cases, farmers sought registration of the PPB varieties in their own name or combined with formal breeders, while in a quarter of cases it was explicitly indicated that farmers were not seeking registration. In the other cases, there was no specific mention of whether varieties would be registered or by whom. In a number of PVS cases, in particular, varieties were registered in the name of formal institutions, such as the ARIs.

In a comprehensive participatory programme, farmers will be actively involved in all stages. However, this may be a phased process, with farmers introduced to a part of the process, and then gradually their involvement expands with their technical knowledge, interests and goals. PVS is widely viewed as a good entry point to build farmer technical capacity and to generate materials that can be used for further enhancement by farmers in their specific contexts.

It becomes evident that plant improvement/enhancement is a cyclical process, also integrating revival/repatriation, and on-farm conservation and use. There is a constant evolution of materials, introduction of new beneficial materials, improved/enhanced materials feeding back into ongoing processes of selection, crossing/mixing of varieties, further trials and testing and feeding back again. This can be contrasted with conventional breeding, based on a linear approach, which sees raw germplasm at one end and a finished, static and decontextualised variety at the other end. The continued evolution and adaptation of

a species/cultivar, including adaptation to climate change, depend on continuous on farm management of local crop diversity (Sthapit et al., 2012).

Stages of PPB

Setting priorities and objectives

As indicated earlier, ideally a PPB programme should be demand driven but there may be obstacles to farmers initiating such activities. As a result, there is most likely to be some kind of facilitation, and most reviewed projects were formal-led or initiated by researchers rather than farmers. In many cases, this was an NGO that had a history of working directly with farmers. In some cases, the ARIs, CGIAR institutions or universities initiated engagement with farmers directly. Government departments may be drawn into processes, but in the case studies they were seldom, if ever, the initiators.



Despite the fact that women smallholder farmers play a major role in maintaining and reproducing agricultural biodiversity, almost universally women were minor participants in reviewed PPB programmes. There were only three cases where women participated in significant numbers (Hardon et al., 2005; McElhinny et al., 2007; Song et al., 2016). Reasons cited for lack of women's participation included gendered decision-making norms, unreflective exclusion from projects, and lack of expressed interest. In an Ethiopian case, men mostly made decisions on the type of variety to grow, and women were mostly responsible for seed storage and

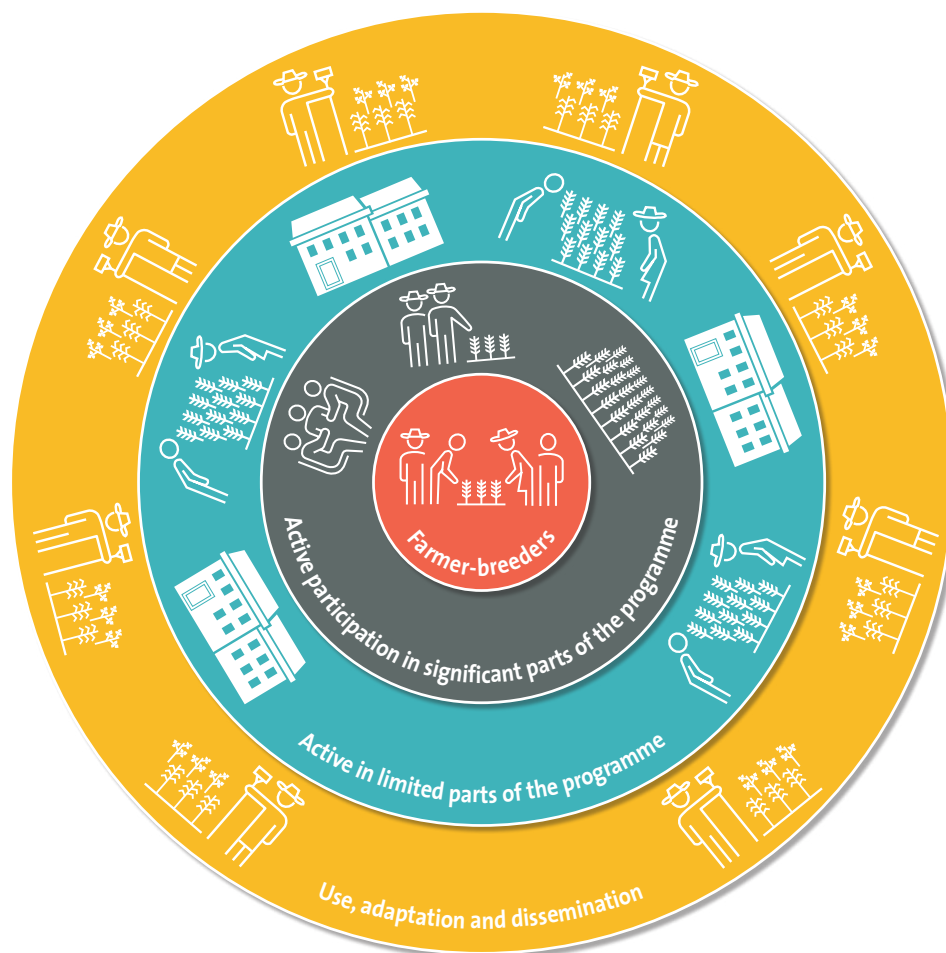
processing, with some joint decision-making. There was some joint decision-making on the number of varieties to use, plot allocation for specific crops and on seed selection (Abay et al., 2008:315). In some cases, there was evidence of interest from women but they were not informed about opportunities, or there was an assumption they were not interested (Humphries et al., 2008; Ceccarelli 2016). In a Brazilian case, the project did not seek to involve women because cassava was considered to be grown mainly by men. However, women do tend cassava fields at times, and also do processing (Saad et al., 2005). These are examples of researcher bias. In other places, lack of interest because of no immediate benefits was stated as a reason for the limited involvement of women (Gabriel et al., 2004). In West Africa, women's domestic demands kept them from participating as fully as the men (Jones et al., 2014).

The importance of including women in PPB programmes is recognised. Women and men will have at least some different trait choices and a combination is needed (Danial et al., 2007). Although it sounds very stereotypical, case studies repeatedly showed men favouring in-field and market characteristics, while women favoured culinary and storage characteristics (for example, Rios Labrada, 2005; Asfaw et al., 2012). This reflects a material division of labour in practice.

Wealth and class differentiation are mostly not reported on in case studies. There was some indication that mixed wealth categories participated, while others tended towards wealthier participants. In a couple of case studies where it was mentioned, women participants tended to be poorer (Smale et al., 2003; Hellin et al., 2008). In a related issue, Rios Labrada (2005) indicated that local innovations were not strictly related to literacy levels, indicating that participation need not automatically be limited to those with formal education.

Case studies showed uneven interest amongst farmers in participating in breeding/crop improvement. Not everyone wants to work on breeding and it is better to identify and work with those who are interested (Aguilar-Espinoza, 2007), for example, seed custodians – those who are

Figure 5: Degrees of farmer participation



actively involved in maintaining, enhancing and saving seed, regardless of whether there is a formal programme or not (Abay et al., 2008; Sthapit et al., 2013). For a community to benefit from plant breeding, only a limited number of really motivated and interested farmers may need to participate as a source for improved plant materials. The number of participants depends on the context (Hardon et al., 2005). According to Smolders et al. (2008:221):

Three categories of farmers can be generally identified within the participating communities. A few individual farmers who are skilled breeders and run their own rice breeding programmes, select parents and perform crosses. A second category of farmers grow out and evaluate segregating selections, supported by the farmers in the first category. The third category of farmers is not actively engaged but interested in further testing and growing the products of farmer-led PPB.

While this will depend on the context, it indicates an example of varying involvement by different farmers in plant breeding processes.

Smale et al. (2003) showed a similar situation, with some farmers only participating in field days, others purchasing seed of elite landraces provided by project staff, a smaller number participating in trials of 'elite' landraces alongside a local control, and some participating in training sessions. Some case studies concluded that clearly defined objectives with fewer farmers can prevent the creation of unrealistic expectations. They argued there should not be too many farmers involved in the breeding process, in order to maintain quality control. It is better to involve fewer farmers but design learning activities that enhance farmers' experimental and analytical skills (Aguilar-Espinoza, 2007).

In one case, many farmers took part in initial screening of materials, but in subsequent seasons fewer farmers were involved. Farmers



were selected based on land availability, experience, communication abilities, interest, and influence in the community. In this case, representivity was not considered because of the high biophysical variability (Saad et al., 2005). In another case, selection was run on an individual basis, but with some collective decisions to select a wide range for further work in farmers' fields (Rios Labrada, 2005). If the smaller group of farmer-breeders are part of democratic farmer organisation, the results will be more relevant to the local population.

A clear point emerging from the case studies is the value of involving end users/buyers in the process of establishing priorities and in selection and evaluation of materials being developed, as well as determining the potential and limitations of the available breeding materials (Manu Aduening et al., 2006; Aguilar-Espinoza, 2007; Danial et al., 2007; Gyawali et al., 2010; Kamau et al., 2011). "A variety may perform excellently under varying types of drought stress, but it will not become a successful variety if it is not tasteful or has no market" (Asfaw et al., 2012). Consultations can include farmers and breeders, consumers, millers and other processors at various scales, and retailers. Users may be willing to pay a premium for a set of post-harvest and organoleptic traits over a single trait, such as aroma or taste

(Gyawali et al., 2010). Market studies on consumer preferences in the Participatory Enhancement of Diversity of Genetic Resources in Asia (PEDIGREA) programme assisted farmers to better understand the market mechanism and identify niche markets for non-mainstream vegetable crops (Smolders et al., 2008:222).

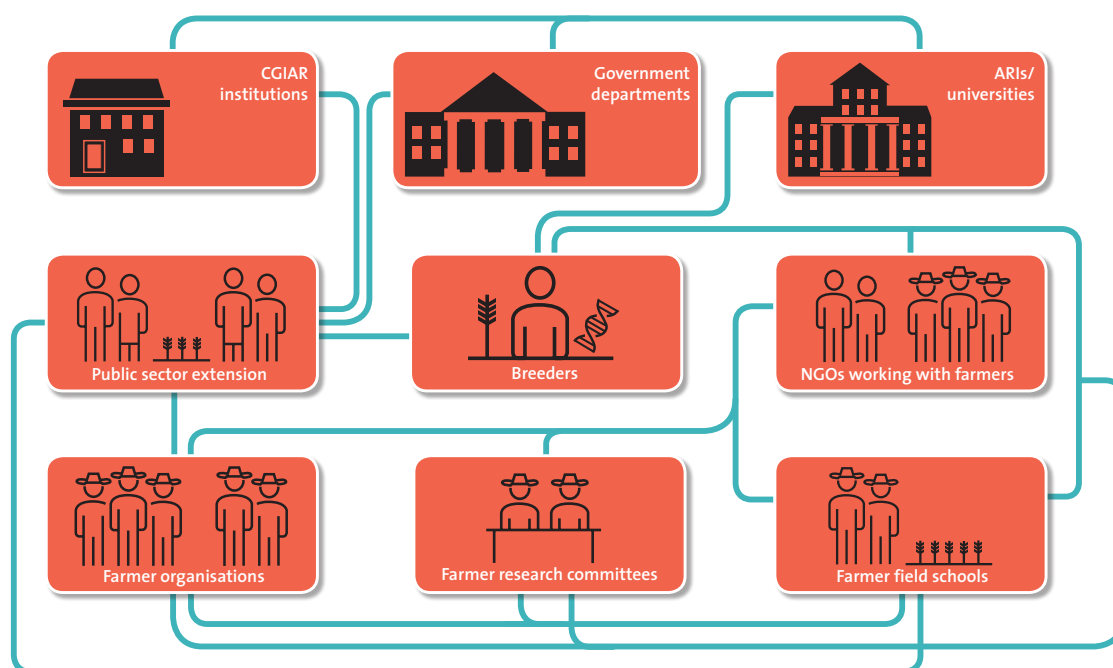
Generally, the evidence shows that farmers seek a diversity of varieties with a diversity of traits, rather than a single dominant trait. In a number of cases, farmers selected for a group of attributes 'on average', rather than for individual traits in isolation (Rios Labrada and Wright, 1999; Hellin et al., 2008; Humphries et al., 2008; Asfaw et al., 2012). This is a notable feature of PPB over conventional breeding, which usually focuses on the development of a single trait, usually associated with yield/productivity.

Farmer organisation

Reviewed cases show that farmer organisation is very important to facilitate participation and knowledge sharing, and that it is better to work with groups of farmers than with individuals (Saad et al., 2005; Danial et al., 2007; Sthapit et al., 2012). The stronger farmer organisation is, the deeper the participatory process can be. A limiting factor in the scaling out of PPB programmes is weak farmer organisation on the ground. It is generally accepted in the literature that it helps if there is some kind of pre-existing farmer association that expresses interest in participating in a programme. The aim is to carry the process institutionally at local level and to ensure farmers are driving and shaping the process. Farmers and farming communities will need knowledge and leadership capacity to evaluate the benefits of a conservation or breeding programme. Activities may be designed to strengthen and empower local communities to maintain and reproduce resources at their disposal.

In a number of cases, PPB projects were introduced through existing community meetings and organisations. These include co-operatives, farmer research committees (the CIALs in Latin America) and FFS, especially in Asia and Latin America. In some of these cases, farmers already had some experience with doing systematic research,

Figure 6: Institutional structure



farmer-to-farmer learning and sharing, and participation in technical skills building processes (for example, Rios Labrada and Wright, 1999; Hardon et al., 2005; Saad et al., 2005; Smolders et al., 2008). In other cases, farmer organisations were established as part of the PPB project, often with NGO support. In one instance, farmers formed a co-operative after the start of the project, specifically to register their varieties in order to produce certified seed for sale (Aguilar-Espinoza, 2007). In other projects, no specific efforts were put into forming farmer organisation (Hellin et al., 2008).

Farmer research committees bring farmers and researchers together in a process of joint experimentation and learning. They establish a direct link between locally organised farmers and research institutions, including but not limited to plant breeding. The CIAL concept was developed by CIAT in Colombia and spread to other countries. It reduces the need for extensive coverage by research institutes and extension services, because farmers take on the task of testing and adapting technologies for themselves (Vernooy, 2003; Humphries et al., 2005). Local innovation groups amongst farmers can assist in introducing and adapting appropriate genetic materials for their contexts (Rios Labrada, 2005).

A lot has been written on FFS as an effective institutional approach for PPB. BUCAP (2002) and PEDIGREA (Smolders and Caballada, 2006) in South East Asia, and more recently CTD in Zimbabwe (Callo et al., 2015), have published field guides on PPB implementation in farmer field schools, and a framework for PPB in FFS has been developed (Smolders, 2006). In farmer field schools:

Farmers get together in weekly or bi-weekly meetings for the duration of one full cropping season to study particular topics in the curriculum. Basic topics in the curriculum on PPB include understanding genetic diversity and crop improvement, baseline assessments, participatory variety selection, and variety rehabilitation. When possible, crop hybridization and selection in segregating populations are included. After the first season, small groups of interested farmers are formed who continue with variety selection and breeding per crop under the guidance of an experienced farmer, extensionist or NGO trainer. (Smolders et al., 2008:218)

CIALs and FFS facilitate farmer networks for learning and sharing knowledge and resources, with farmer facilitators placed with the FFS. Both farmers and extension workers indicated a preference for FFS,



since it is a planned series of interactions rather than occasional field days. It offers a more equitable basis for interaction with extension, and farmer empowerment and a sense that farmer views are being taken seriously. Farmers are partners in developing technologies (Hardon et al., 2005). A related approach is farmer-led extension (Islam et al., 2011) and exchanges or cross visits between participating farmers are common (Abay and Bjørnstad, 2008; Jones et al., 2014). Such exchange visits are viewed positively and contribute to building group cohesion (Hardon et al., 2005). One proposal is for farmer extension agents to be trained through the FFS (Hardon et al., 2005).

Challenges identified include organisational weaknesses at farmer level and maintaining active and stable farmer participation over a number of years (Humphries et al., 2008). Co-operatives may be structured specifically to engage with an external project and there may be uneven buy-in. As indicated earlier, women's participation is often limited, despite their actual centrality to seed practices (Aguilar-Espinoza, 2007). Humphries et al. (2008) suggest that farmer groups involved in PPB should be representative of the user community, otherwise their variety selection and development may not be appropriate for local requirements, and that inclusivity is important, even if it may slow the uptake of new ideas and technologies to

begin with.

Technical and institutional support

In reviewed cases, NGOs played a very important role in connecting farmers with scientists in formal institutions, facilitated ongoing multi-disciplinary rigorous participatory research (Humphries et al., 2008; Humphries 2016), and, in some instances, provided technical agronomic support. Participating NGOs are mostly rooted with farmers, with a long history of working with farmers on different aspects of agriculture and development. PPB as an issue has tended to arise from these ongoing interactions. NGOs are mostly in a better position than farmers to make links to formal institutions. Having said this, case studies suggested seeking ways to strengthen direct links between farmers and scientists in the formal institutions. NGOs should not be gatekeepers to this process, but facilitators to enable it to happen. NGOs can also bring farmers into contact with other national and regional networks (Aguilar-Espinoza, 2007). NGOs contribute a social sensibility, bringing socio-ecological considerations into a process that may otherwise be limited to decontextualised technology development (Humphries et al., 2008).

Hellin et al. (2008) say that participatory processes led by formal researchers may not have sustainable impacts on farmer capacity

and organisation. They recommend breeders teaming up with development institutions, with a presence on the ground, and longer-term contact with farmers. This includes NGOs, the ARIs, extension services and farmer organisations. In some cases, partnerships extended to university students (for example, Hardon et al., 2005) or universities integrated their research programmes with farmer experimenter networks, with the eventual inclusion of the process in educational curricula (Rios Labrada, 2005). Decentralisation, a greater role for social scientists, and involvement of a wider range of actors are recommended from a case study in Ghana (Manu Aduening et al., 2006). Hardon et al. (2005) say it is important to have local ownership of a project, but also for external support to increase understanding and confidence in what is a new approach to breeding.

Ideally relevant government departments and agencies should be involved at least at the planning stages. Public sector extension was involved in a number of cases, and this proved to be of value (Saad et al., 2005; Aguilar-Espinoza, 2007). In some cases, agriculture departments were involved in partnerships but were not often very active. In Nicaragua, PPB was linked to the national Zero Hunger programme (Aguilar-Espinoza, 2007). A number of challenges were experienced with involving government departments. There was mostly limited involvement at policy and management levels, with projects coming about as a result of interest from individual extension workers and breeders and not taken up institutionally. Sensitisation is needed at higher levels, especially once a project has started (Hardon et al., 2005). In practice, government departments did not always show a good understanding of participatory approaches (Hardon et al., 2005).

In the reviewed cases, formal sector breeders in the ARIs, universities and NGOs usually provided training. As farmers become more adept over time, they can take over more of the process themselves. In Honduras, the coordinating NGO provided technical support for the first years, until a team of para-

professional farmers or local facilitators had been identified and trained from amongst the membership. After that, farmers mostly only needed support from a local facilitator and occasional agronomic backstopping for field trials (Humphries et al., 2008). Farmer-to-farmer exchanges are widely used to share knowledge and skills amongst farmers and researchers in partnership, with FFS as a successful example of this in many places, as mentioned.

In Syria, training was provided on experimental design and data analysis in conditions where the research process is not under scientists' control (Vernooy, 2003:22). In Mexico, a training module on seed selection and storage was provided, based on farmer requests (Hellin et al., 2008). In Honduras, farmers were trained in formal agricultural research methods. Tools and methodologies may be required that can enable farmers to replicate processes within their organisations (Aguilar-Espinoza, 2007). Prior support and training in PVS played a big role in the success of the collaboration. The project involved a formal comparison between conventional and participatory breeding approaches. Comparative and verification trials were carried out, farmers employed the use of controls and replicates, learned how to work with segregating materials, and managed negative selections, etc. Intense technical support was provided to farmers (Humphries et al., 2008). This may raise costs in the short term, but the long-term benefits are the flourishing of technical capacity amongst farmers, a seedbed for creativity and innovation. In a project in a number of Asian countries, farmers requested simple learning materials with lots of visuals, and simple written information on FFS and the breeding process (Hardon et al., 2005).

Bob Brac¹⁶ highlights the need for more discussion on the multiplicity of actors and the asymmetry of information and power among them inside a PPB programme. This includes elaboration of the governance mechanisms among researchers and farmers in research programmes as a starting point for dissemination, and multi-stakeholder dialogue for public policy decisions. This

¹⁶ Bob Brac, pers. comm., 13 December 2017.



is a major issue in different international research programmes. For example, EU research programmes offer grant agreements that are not easy to follow for farmer organisations participating in PPB projects (European Commission, 2017). Currently they are trying to negotiate more suitable contracts.

Sources of germplasm and generating genetic variability

In the reviewed case studies, germplasm for PPB mostly came from a combination of CGIAR and national gene bank/ARI materials and farmers' materials. There was only one case of private sector involvement in the reviewed cases, a recently launched global consortium on evolutionary plant breeding with quinoa, with genetic materials from the USDA and private companies (Murphy et al., 2016). Gene bank materials include past accessions of local landraces (for example, Gibson et al., 2011), but also crossed material including hybrids (for example, Gabriel et al., 2004; Laurie and Magoro, 2008; Kamau et al., 2011; Campanelli et al., 2015).

There may be a wide diversity of source material. In Syria, for example, activities started with experimentation with farmers in their fields to compare local barley varieties with other varieties. These included fixed lines; F₃ (third generation) segregating populations from crosses between fixed lines unrelated to landraces; landraces; and crosses including landraces. This increased farmer interest in their own materials because of the

opportunity to systematically compare their own materials with exotic germplasm under local conditions. A second phase on PPB was then carried out. In this phase, farmers requested more of their own landraces to begin with, using materials selected from the previous round (Ceccarelli, 2016).

As Annex 1 indicates, there was limited involvement of farmers in the crossing stage. In quite a few cases there was no crossing done, just the use of existing materials for experimentation and comparison in the field. Crossing is mostly left to formal researchers, even if farmers participated in prioritising traits and identifying parent materials (Hardon et al., 2005; Humphries et al., 2008). In a few cases, farmers were involved in crossing/hybridisation in the field. Farmer participation in crossing proved to be challenging in the reviewed cases. Based on experiences in Asia, Hardon et al. (2005) suggest that institutional plant breeders may be better placed to make initial crosses, possibly at the request of farmers, and then release the resulting breeding populations in more advanced generations (F₄–F₅). However, they also indicated that involvement in crossing increased the understanding of farmers and both options were valuable. Although crossing is a tedious and difficult process, farmers liked to do it themselves and gained greater confidence in their local varieties as parent material. Although a case of farmer participation in crossing in their fields in Bolivia did not work, backup materials from the ARI were distributed to farmers to continue the experiment (Gabriel et al., 2004).

As mentioned earlier, evolutionary plant breeding adopts a different process. In Iran, a large number of wheat and barley lines were selected down by farmers to a few locally adapted varieties for their own use. There was some introduction of crossed materials from ICARDA as part of the genetic mix at the outset, but otherwise crossing takes place 'naturally' within the mixture (CENESTA, 2013).

There is limited, if any, specific discussion on IP for incoming parent materials in the reviewed cases. Generally, it seems to be that materials were made available to the programmes without cost. Even materials

in formal PVS processes generally did not appear to be tightly controlled by breeders. By this time, breeder material has gone through adequate quality controls to reach the stage of sharing with farmers, and is considered to belong to the farmers, who are entitled and encouraged to work on it further, or multiply and distribute the materials (Laurie and Magoro 2008; Smolders et al., 2008). Ownership claims on cultivars developed through a PPB process is a different issue. Providers of the initial germplasm, whether farmers or formal breeders, may want to stake a claim in ownership of these cultivars, if they are to be registered, certified and produced for sale. Theoretically, this stake will allow them to get financial benefits from sales. This aspect of ownership is considered later in the discussion on what happened to improved cultivars in the reviewed case studies.

Formal breeding processes may have annual registration fees for breeding materials being used, which may vary in individual country PVP laws. These fees may be waived for materials coming from public sector and CGIAR gene banks, but this would need to be checked on a case-by-case basis. In Nicaragua, the supporting NGO covered the registration fee on breeding materials, but eventually farmers would be required to take over these costs (Aguilar-Espinoza, 2007).

Selection

Challenges for involving farmers in early stage selection arising from field experience include lack of identity of the entries, as they are still fairly heterogeneous; lack of sufficient plant material; and small plots, which may reduce selection efficiency with a large number of entries (Danial et al. 2007). This has led to recommendations that trials with smallholder farmers should have fewer lines or replications to avoid farmer fatigue during evaluation (Hardon et al., 2005; McElhinny et al., 2007) or that conventional processes are used for initial materials preparation and then selected genotypes go to farmers for selection and evaluation (Gabriel et al., 2004). Diseases are not always immediately apparent in the seed. Farmers have shown some capacity to be able to select for disease resistance, but not always. It may be necessary for researchers/pathologists to remove non-resistant lines

before late stage trials, which may require laboratory screening (McElhinny et al., 2007; Gyawali et al., 2010).

Despite these challenges, farmers participated in early selection in quite a number of the reviewed cases (Annex 1). There is some evidence from the field that farmers are able to handle large numbers of entries and, therefore, could be involved in earlier stages of selection (Vernooy, 2003; Ceccarelli, 2016). In Ghana, farmers were consistent in their selections, even amongst large numbers of seedlings, and could select effectively throughout the breeding cycle (Manu Aduening et al., 2006). In Honduras, in the early stages of the programme, CIAs members learned to handle unstable genetic materials and became “familiar with conducting controlled experiments and are generally regarded by others in their communities as leaders in innovation and



research” (Humphries et al., 2008:210). In a programme in Cuba and Mexico, scientists initially doubted farmers’ capacity to manage four or five trials simultaneously, but, over time, realised that farmers have a deep understanding of their farming systems. The lesson was not to underestimate farmer knowledge (Rios Labrada, 2005). “Decentralized selection in farmers’ fields [also] avoids the risk of useful lines being discarded because of their relatively poor performance at experimental stations (where conditions are almost certainly more favourable, through fertilization or irrigation for example)” (Vernooy, 2003:21).

Generally, where farmers participated in selection, materials were grown by farmers in communal or individual fields with parallel plantings on-station, both for comparison and as a backup (for example, Saad et al., 2005; McElhinny et al., 2007; Gyawali et al., 2010; Campanelli et al., 2015). However, there were some cases where experimental plots for early stage selection were on-station, with farmers going to the station to evaluate the materials (for example, Rios Labrada, 2005; Kamau et al., 2011). In one of these cases, seeds from the preferred five lines were given to farmers for further experimentation in their fields (Rios Labrada, 2005). On-station plots means risk of crop failure is not carried by the farmer, but it is also often not in the same environment as farmer production (McElhinny et al., 2007). If farmers are selecting from on-station trials they may not have a chance to develop any sense of ownership of the material they select (Ceccarelli, 2009a:199).

In reviewed case studies, where experiments were done on-station and in-field, selection choices sometimes differed between farmers and researchers, as well as amongst farmers, and there were also some differences amongst researchers. This shows a diversity of needs (Campanelli et al., 2015; McElhinny et al., 2007). Farmers generally had diverse priorities for selection. Varietal choice is influenced by household preferences and existing natural resources (soil type, rainfall) (Abay et al., 2008).

There are significant gendered differences in selection criteria and it is important to understand the basis of these differences (Vernooy, 2003; Rios Labrada, 2005). As indicated, men tend to orient towards productivity and in-field traits, while women also take into account organoleptic and post-harvest characteristics. In Ecuador, women were reticent to categorise any seed as 'poor' because all seed has some value. More accurate reflections may be achieved with a wider range of choices for evaluation than just three (good, medium, poor) (McElhinny et al., 2007). Men tend to dominate group discussions and it is useful to maintain separate evaluation groups

(McElhinny et al., 2007). In reviewed studies, women played a central role in selection at post-harvest stage to evaluate processing, cooking and food quality characteristics, even if they were actively involved in the breeding programme to this point (Manu Aduening et al., 2006; McElhinny et al., 2007; Abay et al., 2008; Laurie and Magoro, 2008; Jones et al., 2014). Other lessons from practice are that plot sizes should be kept to a minimum, in order to avoid a large burden on farmers who dedicate land for research (CENESTA, 2013) and that a heterogeneity of sites is of value to cover the real conditions facing farmers, although this will require more testing sites (McElhinny et al., 2007).

Testing of experimental cultivars and relation to registration

In some cases, official registration for newly developed cultivars was sought. This is the objective of conventional breeding processes (whether with PVS or not), although some formal-led processes may not aim for official variety release (see Ceccarelli, 2015; Trouche et al., 2011; Almekinders et al., 2006 for cases). In conventional processes with PVS, varieties will usually be under the control of the breeders, who will register in their own name (although the materials may also be shared with farmers as a separate process). In Zimbabwe, farmers in a formal PVS project will not be able to claim full ownership of varieties produced because they only contributed to the development of the cultivars but did not have ownership claims on the starting material (Makumbe and Wing-Davies, pers. comm., 19 April 2017).

Aside from PVS in conventional breeding, in some cases of PPB and evolutionary breeding farmers may also want to register cultivars. One of the reasons PPB farmers wanted to go through the process, in particular early on in PPB programmes, was to gain recognition for PPB and farmers' expertise. It had nothing to do with the notion of making money out of the new variety.¹⁷ Annex 1 indicates that in just under a third of reviewed cases, farmers sought official registration of their cultivars with some possibility of co-ownership, depending on farmer contributions, especially to the parent material. In one case,

17. Ronnie Vernooy, pers. comm.s, 9 January 2018



authors recommended that variety release requirements can and should be included within participatory breeding programmes at the outset (Manu Aduening et al., 2006). There was an example where farmers only decided to register PPB varieties after the breeding programme had started, so this is possible (Aguila-Espinoza, 2007). In other cases, farmers were not looking to register enhanced varieties. There are challenges with institutional frameworks in some cases. For example, in Syria, after farmers had tested the material in their own fields for four years, this was not recognised in the formal process and there was still a requirement for another three years of on-farm trials, from scratch (Ceccarelli, 2016).

Farmers may want to register cultivars because government will not support breeding/crop improvement programmes or purchase and dissemination of varieties, unless they are registered and certified. This will restrict the dissemination of farmer cultivars developed through PPB programmes (for example, Manu Aduening et al., 2006; Gibson et al., 2011). In Syria, for example, the agriculture department was told to stop working with ICARDA on a PPB project and government even tried to close down the project because varieties were not officially released and therefore

could not legally be cultivated, exchanged or sold. Failure to secure registration meant the programme could not use government facilities to produce and distribute seed. This was despite there being no evidence in the law that exchange of unregistered seed is prohibited. Farmers were given intermediate technologies to clean and treat the seed themselves and some commercialisation of the seed resulted (Ceccarelli, 2016). In Honduras, the municipal government was involved in the PPB programme and had the authority to recognise varieties emerging from the process as belonging to the regional CIAL Association. However, the farmers lacked the capacity (including land size) to multiply the variety, resulting in others doing multiplication for sales and distribution without any benefit to those who had done the work on enhancing the seed (Humphries et al., 2008).

Multiplication and distribution

In almost all cases, farmers gained access to genetic materials at any stage of the process, including the cultivars they had contributed to developing. It is generally accepted that participating farmers should have free access to the materials they would like to use. This facilitates local biodiversity and availability of improved genetic materials (for example, Humphries et al., 2008). In South Africa after

the trials, planting material of new sweet potato varieties was established in nurseries and farmers had access to cuttings (Laurie and Magoro, 2008). Farmers in Uganda were already distributing sweet potato clones being used in participatory trials four years before official release (Gibson et al., 2011:631).

Genetic materials and cultivars are often exchanged and distributed through informal channels beyond the sites, although this may be relatively limited in geographical range, mainly short distances (for example, Dorward et al., 2007; Gyawali et al., 2010; Gibson et al., 2011). According to Baloua Nebie at ICRISAT Mali (pers. comm. 19 November 2017), “farmers themselves are efficient actors for variety diffusion in their zones as the adoption of these varieties is more based



on trust. They can also easily reach others farmers even in the remote areas, where seed companies and extension services cannot go”. For varieties developed for the specific local context this is fine, especially if farmers did a lot of the work and there is no pressure to commercialise or scale up. The use of any materials throughout the process, not only the final cultivars, was actively encouraged in most reviewed programmes, notwithstanding occasional national government opposition, as indicated in the Syrian case above. One of the key objectives of farmer involvement in PPB is access to a wider diversity of genetic materials, so it defeats the purpose if farmers are restricted from freely using and sharing the material. This is clearly an area where the legal framework needs to be adjusted to accommodate these practices and not criminalise them.

In most of these cases where multiplication was explicitly mentioned, there was an overlap with farmers having registered the cultivars, although this was not always so. Sometimes individual farmers (for example, Rios Labrada, 2005) and sometimes farmer seed production groups were established for the purpose of multiplication of new PPB cultivars. In Nepal, for example, community seed production groups were established to maintain and multiply the seed, with a seed network connecting village seed production groups, and providing foundation seed to village level. The network was led by one producer group that was formally registered with district agriculture, and there was NGO and public sector support (Gyawali et al., 2010). In Zimbabwe, a farmer-owned company with subcontracting arrangements with smallholder farmers is contracted to produce seed from participatory processes (pers. comm. Makumbe and Wing-Davies, 19 April 2017; pers. comm. Mushita, 27 October 2017). Generally, reviewed cases did not touch on the question of certification. As previously mentioned, officially farmers are not meant to sell uncertified seed but may still do so, especially when there is limited access to certified seed (Rios Labrada, 2005). In other cases the certification process may have been followed, but there was no explicit mention. In an Asian programme, farmers did not feel certification was necessary because return customers are enough incentive to sell good quality seed (Hardon et al., 2005).

PPB successes

Reviewed PPB projects showed a number of tangible successes, including superior performance of PPB varieties over conventionally bred and local varieties; a shorter and less costly process; increased availability and earlier access to genetic materials and consequent expansion of biodiversity; farmer empowerment and building organisation amongst farmers.

A large number of projects show evidence that PPB is more effective than conventional breeding in producing varieties with enhanced yields and traits in the specific local contexts in which they were developed. Research has also shown that farmers often prefer local varieties over certified varieties

and imported genotypes, especially in stress-prone and marginal conditions (Rios Labrada and Wright, 1999; Abay and Bjørnstad, 2008; Laurie and Magoro, 2008; Humphries et al., 2008; Humphries 2016). In Ghana some local land races simply being used as controls were selected ahead of certified varieties (Manu Aduening et al., 2006). Farmer controls also outperformed introduced materials in a PVS project in Asia, even though researchers were primarily concerned with the performance and acceptance of their own varieties (Hardon et al., 2005).

Local adaptation and buffering capacities meant local varieties and landraces performed more predictably than registered cultivars (Abay et al., 2008). In Germany, polycross progeny performed better on yield than inbred lines (Ghaouti et al., 2008). In Italy, selected varieties exhibited strong GxL interaction of cross-over type, fully justifying decentralized selection and testing (Campanelli et al., 2015). For wheat in Iran, there were aroma and quality benefits from evolutionary populations (CENESTA, 2013). In Brazil, a PPB variety was the best performing for nitrogen use efficiency in comparison with local varieties and commercial hybrids (Machado and Fernandez, 2001).

In Nicaragua, in six out of seven trials, farmer assessors selected varieties derived from farmer-breeders over those derived on-station from professional breeders. Farmer assessors were not told which lines came from which process. However, breeder-selected varieties did provide superior lines for grain yield and also produced some varieties favoured by farmers. This indicates an important role for breeders, and the key issue is working closely with farmers (Trouche et al., 2012). In Uganda, cultivars that involved farmers met a wide range of positive characteristics, while those involving researchers were ranked very well on specific characteristics. Researcher-bred (improved, certified) varieties scored best on top three traits ('specialist') but PPB and local varieties scored better than researcher varieties on a wider number of traits overall ('all-rounder') (Gibson et al., 2011). This reinforces the argument that farmers seek a bundle of traits, whereas breeders prefer to focus on a single trait or a few traits.



Very limited work has been done on calculating the financial costs and benefits of PPB, compared with conventional breeding. In one study in Mexico, net financial benefits of participation were shown (Smale et al., 2003). In Ghana, farmer involvement added little to costs and provided economic benefit in some aspects (Manu Aduening et al., 2006). A different study in Ghana concluded that lower cost programmes will be conducted largely by farmers and local organisations (Dorward et al., 2007). In South Africa, participatory approaches served the needs of more marginalised farmers, and proved to be a rapid and cost effective way of assessing and selecting potential varieties (Laurie and Magoro, 2008:675). Grassroots breeding is considered to be relatively easy to scale up, as it requires fewer resources than PVS or PPB and can also serve as a precursor to PPB (Sthapit and Ramanatha Rao, 2007).

Others have indicated that training and active farmer participation may increase costs. This is especially because it includes identifying and selecting communities, preparation of training materials, and doing training and capacity building. It is not just production of a new variety, so costs are not directly comparable with conventional breeding (Gabriel et al., 2004). However a full cost-benefit analysis should also consider adoption of the varieties over time, after the project, not only immediately at the conclusion of the breeding process (Humphries et al., 2008). If the participatory process is successful, the benefits will accrue more generally over time, as other farmers adopt the PPB varieties and as the varieties are cycled back into ongoing on-farm selection and enhancement processes.

Crowdsourcing methodology is considered to be up to 80% more cost effective than conventional PVS.¹⁸

Another area of success for PPB is increased farmer access to genetic diversity and clean planting material, earlier access and adoption of new materials and generally more rapid development and delivery of varieties in the local context (Machado and Fernandez, 2001; Saad et al., 2005; Manu Aduening et al., 2006; Aguilar-Espinoza, 2007; Gibson et al., 2011; Campanelli et al., 2015). More time spent on involving farmers in early stage selection can be recouped at the stage of adoption. Early involvement of farmers may facilitate early release, an important factor in cost effectiveness (Gabriel et al., 2004; Manu Aduening et al., 2006). Access to fresh planting materials may be a key motivator for farmer participation. According to Smale et al. (2003) participation in training did not translate into changed practices for most farmers and “by all appearances, farmers wanted the seed more than the practices” (Smale et al., 2003:269). In cases in Cuba and Mexico, involvement in PPB was the first time farmers had access to genetic diversity, and seed production was integrated into farming systems (Rios Labrada, 2005). In many places ARIs no longer have dissemination capacity and PPB can be a local alternative (Aguilar-Espinoza, 2007).

Some related benefits of PPB highlighted in case studies include the medium-term impact of farmers adopting a more integrated approach to conservation, breeding, seed production, crop production, and consumption, which are separated in conventional programmes. Diversity in the field is one of the most important risk mitigation strategies for farmers (Rios Labrada, 2005). Some cases indicated that participation led farmers to realise the importance of local varieties, and farmers also expressed interest in expanding to other crops (Hardon et al., 2005; Danial et al., 2007). Decentralised selection leads to a wider range of diverse varieties being adopted across target environments, with a positive impact on agricultural biodiversity (Campanelli et al., 2015).

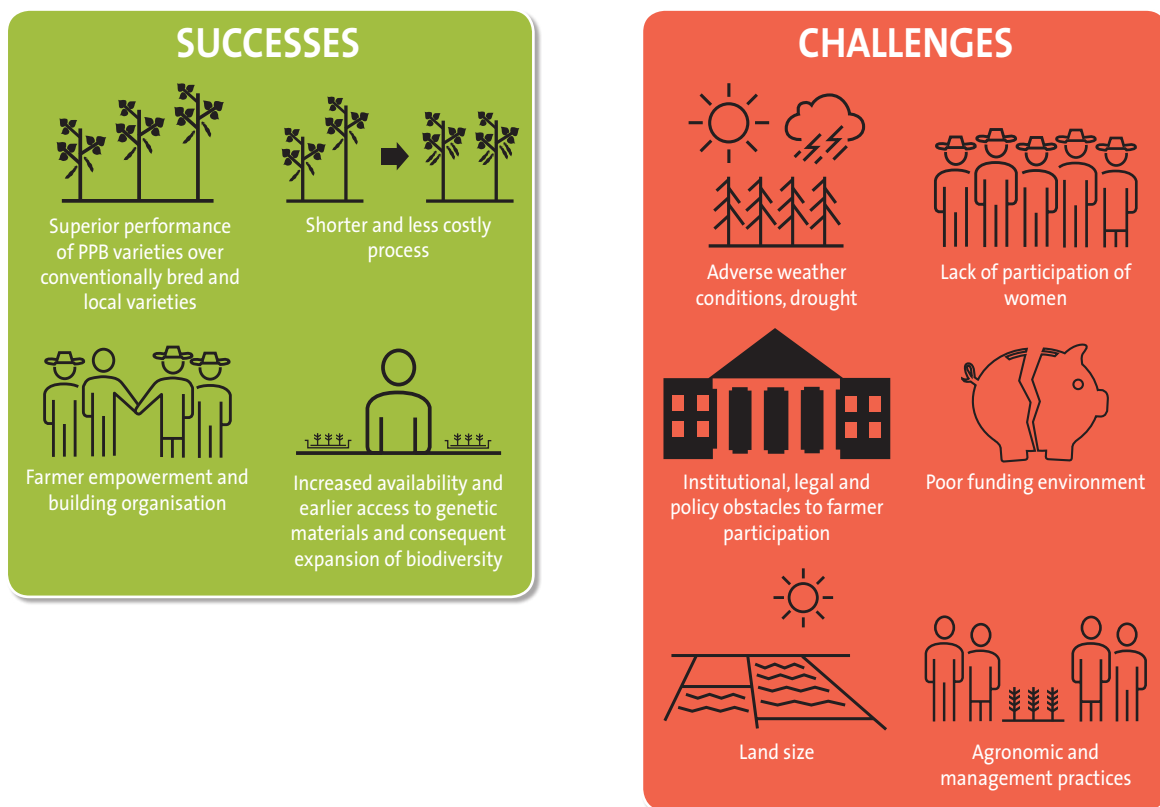
PPB projects can be a conduit for building organisation and collective action amongst farmers (Aguilar-Espinoza, 2007). PPB has a generally recognised empowerment effect on farmers, increasing confidence and motivation to engage in breeding activities (Smolders et al., 2008). In Honduras, learning to do research gave poor women and men self-confidence. Self-confidence allowed women to use their liberty effectively and empowered them to make important household decisions (Humphries 2016). In Cuba and Mexico, experimenter farmer networks were supported through the project after selection and four agrobiodiversity centres established between farmers and scientists. The programme also expanded into others parts of the two countries (Rios Labrada, 2005). PPB in Asia stimulated interest from communities around the sites (Hardon et al., 2005). In West Africa, collaboration with technicians and scientists opened space for farmers to develop their own peer learning network (Jones et al., 2014).

Challenges

However, participatory breeding is not all plain sailing. Projects may encounter ecological, social, institutional and technical challenges. Ecological challenges encountered include regular adverse weather conditions and drought (Humphries et al., 2008; Smolders et al., 2008; Asfaw et al., 2012; Rahmanian et al., 2014). Social challenges included lack of participation of women in many of the projects, as indicated earlier, and illiteracy amongst farmers (Humphries et al., 2008). Some projects showed a decline in participation over time (for example, Gabriel et al., 2004; Hardon et al., 2005). Farmers may need to spend a great deal of energy and resources on maintaining quality and production, especially for sale, as well as obtaining administrative and technical capacity in their organisations. As a result, developing more varieties or spreading the experience may not be feasible in all conditions (Aguilar-Espinoza, 2007). Some studies raised the question of what the incentives are for farmers to invest in the process (Manu Aduening et al., 2006).

18. <https://www.biodiversityinternational.org/innovations/seeds-for-needs/crowdsourcing/>

Figure 7: PPB successes and challenges



Farmers already use their own seed and cost is not a major issue. Going through the hard work of improving varieties, including cost of registration, certification, maintaining the variety, etc. may reduce the incentives. Is participatory breeding justified in terms of recouping costs of production through sales (Aguilar-Espinoza, 2007)?

This relates to institutional challenges, which make it difficult for farmers to navigate their way through the statutory requirements for registration and certification of varieties. These are onerous and do not accommodate decentralised and diverse processes and products; they favour uniform and standardised procedures and outputs. Not all farmer materials conform to the specific and tight definition of a variety found in the law. This has been discussed elsewhere in the paper. Even where farmers do follow the procedures, bottlenecks in multiplication, dissemination and promotion may limit greater adoption (Gabriel et al., 2004).

PPB is a long-term undertaking, requiring stable funding for the different partners and continuous dialogue between researchers,

NGOs and farmers (Humphries, 2016; Trouche et al., 2012). Donor projects have short time frames, and this may restrict farmers to PVS. PPB is possible but because it is a long-term process that needs resources, it must be situated in government for the long term. Few donors see the intrinsic value of PPB (pers. comm. Makumbe and Wing-Davies, 19 April 2017). Decentralisation is a key to PPB, but includes decentralisation of resources, incentives and decision-making (Manu Aduening et al., 2006).

Specific technical challenges mentioned include lack of uniformity of trial plots (variation in soil fertility, watering) and management of trials (gaps in plots, poor weeding and damage to plants as a result of late weeding) (Laurie and Magoro, 2008), seed storage (Hardon et al., 2005) and, for cassava, slowness to mature and few cuttings generated were major limiting factors to replication and maintaining farmer interest (Manu Aduening et al., 2006). For evolutionary plant breeding, very small plots of land may not be enough for farmers to grow their own evolutionary populations (Rahmanian et al., 2014).