CHAPTER 21

Variety release and policy options

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21.1 HISTORICAL DEVELOPMENTS AND CONTEXTS

Empirical evidence shows that for millennia farmers selected plants from their local landraces and saved their own seed for planting. In the 1880s, early attempts in scientific plant breeding began and the first agricultural research stations were established in some European countries (Kåhre, 1990). The history of the organized seed sector is linked to the introduction of new crops and knowledge-based agriculture, including scientific plant breeding, mechanization, commercialization and diversification at various stages of agricultural development (Tripp, 2001; Thomson, 1979). Continued specialization eventually brought significant changes in seed provision, giving birth to an integrated and market-oriented organized seed sector in developed countries (Groosman, 1987).

In many developing countries, however, information on the history of agricultural research and organized seed production prior to 1950s is rather scanty. The introduction of highly productive semi-dwarf wheat and rice cultivars in the late 1960s and 1970s, which triggered what is referred to as the *Green Revolution*, probably served as a stimulus for introducing agricultural research and the establishment of organized seed production throughout the developing countries, particularly for economically important and strategic food crops. From the outset the seed system was inherently service-oriented, with no or limited commercial interests.

21.1.1 Seed system definitions

The entire seed supply of a country comes from different sources, including off-farm from commercial sources such as the public or private sector (formal sector) or farm saved or through local exchange and trading (informal sector). In recent times the concept of seed system has been broadened to include the role of the 'informal' sector in seed provision. Van Amstel *et al.* (1996), apart from providing a comprehensive definition of the seed system, recognize two distinctive, but interacting seed delivery systems: the formal and the informal sectors. A farmer may have adopted a modern variety from the formal sector, but may decide to save seed from their own harvest or exchange through social networks for the next season's planting: seed that is produced informally (Bishaw, 2004).

Formal seed system

The formal seed system is composed of several interrelated components, namely: (i) variety development, evaluation, registration and release; (ii) seed production, processing and storage; (iii) seed marketing and distribution; and (iv) seed quality assurance. It is a highly interdependent chain of operations whose overall performance can be measured by the efficiency of the different linkages in the chain (Pray and Ramasawmi, 1991). In general it is a vertically organized (Louwaars, 2002), large-scale operation, mostly with commercial interests.

Informal seed system

At present, in developing countries, over 80 percent of crops are sown from seed stocks selected and saved by farmers or exchanged and traded locally (Almekinders, Louwaars and de Bruijin, 1994; Alemkinders and Louwaars, 1999). The informal seed system operates at local level (Cromwell, Friis-Hansen and Turner, 1992), and may depend on indigenous knowledge of plant and seed selection, sourcing, retention, management and local diffusion mechanisms (Bishaw, 2004). Apart from farmer or community practices it also includes various local-level seed production initiatives organized by farmer groups or NGOs, or both, working outside the regulatory regime of the organized seed sector.

21.2 CURRENT PRACTICES IN VARIETY RELEASE

Crop improvement has been an important strategy for the development of the agricultural sector in both developed and developing countries. Modern crop varieties, the results of science-based breeding, are the backbone of the seed industry and indisputably the most critical output of investments in agricultural research. These varieties should be made available to farmers through an efficient, effective and transparent release system to benefit producers and to realize the impacts from investments in plant breeding and variety development. The procedures described below presents the requirements applicable to varieties developed through formal plant breeding by the public and private sectors some of which could be of limited relevance to those emerging from participatory approaches.

21.2.1 What is a variety?

The definitions of variety are many and varied, but the following is probably more practical and concise. According to Carson a '*variety*' is defined as:

> *an agricultural unit created and maintained by man, the first essential being that it should have an individuality which can be reproduced over a number of years, and secondly that it should be distinguishable by inherited morphological or physiological characters from other varieties.*

At present, however, the term variety extends beyond the production field of farmers into expectations of industry and consumers.

21.2.2 What is variety release?

'Variety release' encompasses a broadly interrelated series of activities, from identifying promising lines for further testing to releasing a new variety and making available breeder seed for further multiplication, and the activities may include: (i) identifying promising lines with preferred traits for further evaluation from advanced variety trials; (ii) testing of new promising lines for registration (Distinctness, Uniformity, Stability = DUS) and performance (Value for Cultivation and Use = VCU) by a competent independent authority; (iii) approval of the new varieties for commercial use by a release committee; (iv) inscription of the varieties in the national catalogue; and (v) making available breeder seed of new varieties for further commercial seed production and distribution. Variety release procedure is a collective term that refers to the release type, the attached terms and conditions, the protocols and administrative procedures used in releasing a new variety for seed production and distribution (Delouche and Goma'a, 1999).

21.2.3 Origin of variety release

The beginning of scientific crop improvement enabled skilled breeders and farmer breeders to develop new crop varieties and make available the seed by themselves or through local traders. However, maintaining the identity and purity of the new crop varieties and the proliferation of variety names (Parsons, 1985; Hackleman and Scott, 1990) became a great challenge for the emerging seed industry. Thus, systematic plant breeding brought two important developments in the seed industry: (i) varietal release, i.e. a procedure and criteria for introducing new varieties to commercial seed production; and (ii) varietal certification, i.e. a procedure for maintaining the identity and purity of new varieties during seed production and supply. According to Tripp (2001), listing varieties based on morphological characteristics and performance was started as early as 1905 (in Germany), whereas seed certification was started in 1888 (in Sweden).

The establishment of the International Crop Improvement Association (now the Association of Official Seed Certifying Agencies (AOSCA; www.aosca.org) in 1919 (Parsons, 1985) and the Organisation for Economic Co-operation and Development (OECD; www.oecd.org) seed schemes in 1958 (Thomson, 1979) were some of the first attempts to standardize variety release and seed certification schemes. These organizations put in place evaluation, registration and release procedures for accepting and listing eligible varieties, and strict generation control to maintain the varietal purity and identity by establishing standardized certification schemes for commercial seed production (OECD, 2007). Likewise, many governments enacted national variety and seed regulations to implement such types of schemes. Despite a long history of organized seed sectors, many developed countries enacted comprehensive variety and seed regulations only fairly recently.

21.2.4 Current procedures and practices

Once new and potential promising lines are identified by agricultural research, it is essential to commercialize and make their seed available to farmers. Variety release requires simultaneous testing of these promising lines for registration (DUS) and performance (VCU) before approval for large-scale seed multiplication and marketing for commercial use. The distinctness (uniformity and stability) of the variety to establish its identity (registration testing) and its commercial value for cultivation (farmers) and use (consumers) (performance testing) are the basis for final reelase.

The ability to discriminate and identify varieties of agricultural and horticultural crops is fundamental in the modern seed trade. Variety description is essential for effective implementation of: (i) variety maintenance (purification); (ii) seed multiplication (roguing); (iii) seed certification (field inspection); (iv) granting intellectual property rights (plant variety protection); and (iv) protection of producers and consumers (seed certification).

The degree to which the breeders are involved and the way release procedures are organized and conducted is described as a compulsory (e.g. European Union) or a voluntary (e.g. United States of America) release system.

Variety registration testing

Variety registration (DUS) testing is a descriptive assessment to establish the identity of the new variety using morphological characters, as well as its sufficient uniformity and stability. DUS testing usually runs for two independent growing seasons or years, where the new variety is compared with a wide range of existing varieties to establish its identity. A detailed DUS testing procedures and crop specific guidelines are available from the International Union for the Protection of New Varieties of Plants (UPOV; http://www.upov.int/en/publications/tg_rom/tg_index.html).

- *Distinctness*: A new variety must be different from existing varieties and must be recognizable to verify its identity and purity during seed production and use. Distinctness refers to a difference from any other variety whose existence is a matter of common knowledge.

- *Uniformity*: It relates to the degree of variability within the variety. The variation observed must normally be of a demonstrable and repeatable order. The variety must be sufficiently uniform within its population so that individual plants could be identified to guarantee constant quality.
- *Stability*: It refers to the capacity of the variety to reproduce itself during seed production without losing its distinctive characters. The genetic make-up of the variety should remain the same during subsequent years of seed production and commercialization.
- *Varietal Identity*: The identity of a new variety is established by examining and describing the morphological characters of growing plants. The purpose of registration testing, whether backed by legislation or not, is the recognition of varietal unit as a unique entity and to establish its identity.

Variety performance testing

Performance (VCU) testing, referred to as 'variety trials', focuses on the merit of the new variety to the end users, i.e. producers and consumers. The test ensures that only varieties that are found better than the existing varieties in one or more agronomic character, such as grain yield or quality, or tolerance to biotic or abiotic stresses, are released for use by farmers. The multi-location and multi-year variety trials are conducted in different agro-ecological zones to identify better performing varieties, which could meet diverse agronomic or consumer requirements or socio-economic conditions. As a result, different agronomic management practices are used and the new varieties are compared with well established commercial varieties. VCU tests usually run for two to three years, where the best performing varieties are eventually recommended for cultivation. In some countries (e.g. Ethiopia) the variety is tested in on-farm verification trials under farmer management practices before the final release.

Variety release

Variety release is a culmination of several interrelated activities, where a decision is taken to approve a new variety for commercial use, based on the results of registration and performance testing. Almost all countries have a variety release procedure in place, whether that is done by an *ad hoc* committee (e.g. the Syrian Arab Republic) or by a legally sanctioned authority (e.g. Turkey). The varieties that meet the requirements for registration and performance are officially released and the owner makes breeder seed available for commercial seed production and marketing. In some countries, however registration testing (DUS) is not yet everywhere part of the requirement for variety release (e.g. Ethiopia).

Variety registers

The new variety, upon approval, will be listed in a variety register to inform the stakeholders, i.e. seed producers, farmers, consumers and the industry. The list could be informative or recommendatory. The register is periodically updated by removing obsolete and entering new varieties that are eligible for commercial seed production at national or provincial levels (e.g. Pakistan). Many countries have a national variety register (e.g. Crop Variety Register in Ethiopia), while OECD has a common variety catalogue (www.oecd.org), which enables the variety to be produced and marketed in all member countries.

Variety protection rights

New crop varieties can be granted breeder's rights in countries with plant variety protection (PVP) laws. DUS testing is part of the requirement, irrespective of the performance or agricultural value of the new variety. However, simple DUS testing alone does not qualify the variety to receive protection. Under the UPOV convention, the variety, apart from being distinct, uniform and stable, must be novel, without prior commercialization and must have an acceptable denomination, before granting the rights for protection.

21.3 RATIONALIZATION OF THE VARIETY RELEASE SYSTEM

At present, there are many policy, regulatory, institutional, organizational and technical constraints affecting the seed industry in many developing countries. The increasing trend towards commercialization of agriculture, the development of private seed industry, the effects of IPRs and the continued decline in public sector agricultural research calls for public-private sector partnership in agriculture research (Morris and Ekasingh, 2002). In the face of changing seed industry, it is imperative for many countries to either reform or to consider revising their policy and regulatory frameworks, as well as technical guidelines and procedures for variety development, evaluation, registration and release. These include rationalizing and developing policy guidelines for variety release systems, enacting variety regulations, review of release procedures, participation of stakeholders, and seeking protection for new varieties. The policy and regulatory reforms must strike a balance between public sector interests, opportunities for promoting private enterprises, and consumer protection.

21.3.1 Policy reforms

It is important that the policy for a variety release system, including the guidelines, processes and procedures, is transparent, equitable, documented and officially sanctioned. Developing flexible and responsive variety development and variety release options are necessary, given the diversity of crops, the level of research conducted on each, and variations in their economic importance, as well as the diversity of seed producers and suppliers.

Public or private plant breeding?

In developed country seed industries, the private sector plays an important role in plant breeding as part of product development strategy. For example, multinational seed companies tend to reduce transaction costs through vertical integration of the research–seed production–seed distribution continuum to recoup their investments (Morris, 2002). In contrast, in many developing countries, historically the public agricultural research sector predominates and has sole responsibility in setting the national research and crop improvement strategies and priorities. Past government policies always tended to support public over private sector plant breeding and may restrict the development of both domestic and foreign private sector operations (Tripp and Louwaars, 1997). Particularly for crops considered strategic for a country, there are general protectionist tendencies for public sector plant breeding and varieties (Bishaw, Manners and van Gastel, 1997). It is important for governments to encourage public-private collaboration and partnership in agricultural research and plant breeding (Morris and Ekasingh, 2002) to exploit synergy and make available a wider choice of varieties to different sectors of the farming community.

Unrestricted or exclusive variety release procedures?

Commercialization of public-bred varieties can follow unrestricted (open) or exclusive releases. 'Open' releases do not provide adequate incentives for investments in promoting varieties because the participation of other seed companies diffuses the benefits. In exclusive release, however, one or a limited number of seed producers get access to varieties under specific terms of negotiated fees or royalties, and is the most common procedure in countries where PVP exists. Delouche and Goma'a (1999) suggested different variety release options for public-bred varieties. Some of these and other options are presented and discussed below.

- *Open and unrestricted release without royalties.* To date, many participatory plant breeding and alternative seed delivery systems are operating at the local level, aimed at improving farmer access to varieties and seeds in less favourable environments and remote areas. Such initiatives focus on small-scale farmers growing minor crops, which are of great importance for their livelihoods and food security, but with limited commercial value, and so attract investment from neither the public sector nor the private sector. To ensure local-level seed initiatives, small-scale seed enterprises should have open and unrestricted access to public varieties. This procedure is most suitable for minor crops with little commercial potential due to limited area planted and a very slow rate of variety replacement, or for varieties emerging from participatory approaches.
- *Open and restricted release with royalties.* Under these conditions all qualified seed producers can get access to Breeder seed of new varieties, but also pay royalties proportionate to commercial seed sales. It could probably continue to be a common variety release procedure for major self-pollinating crops (e.g. wheat) until there is tangible progress in private sector participation and provision of PVP. The public research organizations may be interested in generating additional resources to augment declining funding and support their breeding programme by charging royalties or selling variety rights. In some countries, in the absence of PVP, royalties are paid for public-bred varieties (e.g. Egypt).
- *Exclusive release with royalties.* Exclusive releases should be considered, especially when PVP becomes available and could also extend to some major self-pollinated crops (e.g. wheat). The exclusive releases can be made to a single company, group of companies, associations or cooperatives. Experiences from developed countries show that exclusive release of a variety with broad adaptability justifies investments in the promotion and market development strategies that are critical for gaining rapid and wide variety adoption by farmers. It is also possible to broaden the scope of variety release by transferring the proprietary rights to other private seed companies for commercialization purposes.

Compulsory or voluntary variety releases?

Previously, variety release schemes developed independently without prior knowledge of what happened in other countries, but later improved and expanded to meet the challenges in plant breeding, seed production and farmers' interests (Parsons, 1985; Hackleman and Scott, 1990).

EU member countries follow a compulsory variety release system where both registration and performance testing are handled by an independent agency. In many developing countries, following the examples of EU, the governments strictly regulate the introduction of new varieties, prohibiting seed production and marketing until the variety is tested by a government agency and approved by the release committee (Gisselquist and Sirvastava, 1997). The variety should meet both DUS and VCU criteria for release. The problem is exacerbated by lack of a competent agency to implement an impartial release system.

In the United States of America, both variety registration and performance testing is voluntary, where, based on the available data, the responsibility and decision lies with the plant breeder to release the variety for commercial use. In India and the Philippines, a mixed mandatory and voluntary variety release system operates, based on the crops (major or minor) or the enterprises (public or private). Voluntary variety release systems favour competition, lowers the cost, allows easy entry of new seed companies, and offers more choices for farmers. Breeders ensure that the variety meets the requirements of the producers and users for commercial success.

To date, more and more collaboration can be seen between breeders and the variety release agency, including countries that have adopted the compulsory system. Therefore, governments have to adopt policy changes and encourage voluntary variety registration and performance testing, where greater responsibility is given to the breeders and the industry.

Single or multi-country variety lists?

In many developing countries, the National Agricultural Research Systems (NARS) receive almost similar sets of breeding lines of major food crops, supplied through a network of International Agricultural Research Centers (IARCs). Despite similarities in agro-ecology, farming system and germplasm, there is no mechanism for sharing data in making decisions concerning variety release, even between neighbouring countries, with the result that often the same breeding line is released under different names across countries. Each country organizes its own independent mandatory registration and performance testing for variety release, leading to single-country variety lists. Although the EU has mandatory variety registration and performance testing, any variety that is registered in the common catalogue can be marketed freely in all member countries. It is important that countries accept varieties that are listed in other neighbouring countries with similar agro-ecology without going through repeated lengthy release system, i.e. that there be a multi-country variety list. In Turkey, foreign-registered varieties from member countries of EU, OECD and UPOV are exempt from DUS testing and are accepted as part of the requirement for variety release.

In 2005, apart from providing breeding materials through international nurseries, ICARDA initiated a regional testing scheme where all released wheat varieties from the Central Asia and Caucasus are tested for adaptation across the region. It is highly desirable to encourage countries to move from mandatory to voluntary, and from single- to multi-country lists, in variety release (Gisselquist, 1997) to increase the choice and movement of varieties and to harness the impact of plant breeding research at national, regional or global levels.

Access to public sector varieties

National agricultural research systems serve as direct conduits of public-bred varieties to farmers. They directly channel Breeder seed of new varieties to public companies for further seed production and distribution. The access of the private sector to public bred varieties remains a major stumbling block in many developing countries. This is particularly important for domestic, small, private seed companies and small-scale seed enterprises operating at local level serving farmers in less favourable areas, but which rely on varieties from public-sector sources. Such seed companies have neither the resources nor the technical capacity to engage in plant breeding programmes. It is essential to have a transparent and equitable mechanism to guarantee access to public-bred varieties, as discussed under the variety release options.

21.3.2 Regulatory reforms

Variety development, evaluation and release are closely interconnected, and it would be difficult to draw distinctions between the regulatory frameworks that govern these as two separate activities. Accordingly, variety regulatory frameworks are the rules and regulations associated with variety development, testing, registration and release (Tripp, 1997). In effect, it includes the procedures and practices that guide the conduct of plant breeding; the rules governing the official release of new varieties; and restrictions on the type of varieties that may be offered for sale.

Tripp *et al* (1997) described the key features and limitations of variety and seed regulations, and their introduction to developing countries. Most of these regulations are modelled upon and influenced by past historical relationships and source of donor support to national seed programme development. They are at times excessively strict and inflexible, limiting the range of varieties and seeds available to farmers. Tripp (1995) argues that regulatory reforms must be seen as a continuing process, and must be sufficiently flexible to respond to and promote the evolution and diversification of the national seed sector in developing countries.

In general, the majority of developing countries lack well established variety release protocols and procedures in place. The level of regulation is commonly not in line with the level of institutional development of the country, leading to incomplete implementation and insufficient transparency. This creates a serious lack of credibility and inconsistent application of these regulations by the authorities. Tripp *et al.* (1997) identified four key constraints that need to be addressed in regulatory reform, namely: (i) the efficiency of operation; (ii) application of objective and relevant standards; (iii) participation of stakeholders; and (iv) transparency in managing registration and performance testing for variety release.

Harmonization of variety regulations

The regulatory requirements governing registration and performance testing are critical elements in variety release mechanisms. In the past, where these regulations existed, they were prepared and implemented within their specific national context. Some countries have comprehensive variety regulations, whereas others still have no or outdated legislation, which consequently do not meet the needs of a modern seed industry. With globalization, these inflexible regulations are a serious impediment to movement of varieties across national boundaries, thus severely limiting opportunities in regional and global seed trade. Harmonized variety regulations (e.g. East African Community) would increase the choice and movement of varieties and seeds across national borders and stimulate regional seed trade. Given the diversity of national seed systems and the globalization of the seed trade, it would be appropriate to develop a variety regulation and release procedure that is both flexible nationally and harmonized regionally.

Introducing plant variety protection

Plant breeding is a long-term process with substantial financial investments. To encourage investment in plant breeding it is important to have legal protection for companies to recuperate their investments. Lack of PVP is often considered a major constraint for the limited or non-engagement of multinational and domestic private seed companies in seed markets of developing countries. As discussed elsewhere in this chapter, however, in practice things seem to be changing, where public bred varieties are auctioned (e.g. Morocco) or public sector breeding programs enter into bilateral agreements on royalty payments with seed companies in the absence of PVP system (e.g. Egypt).

It is anticipated that strengthening PVP would encourage private sector investment in plant breeding and diversification of the seed sector, making more varieties available to farmers. For example, within Central and West Asia and North Africa region some countries are UPOV members (Azerbaijan, Jordan, Kyrgyzstan, Morocco, Tunisia, Turkey, Uzbekistan) whereas others (Algeria, Egypt, Pakistan and Tajikistan) are preparing laws to join the Union. Some countries (e.g. Ethiopia, Yemen) have legal instruments for variety protection that may satisfy TRIPs requirements, though not in conformity with UPOV convention. Although the expansion of the IPR concept has generally appeared to strengthen the incentive for private-sector investment, there is still lack of conclusive evidence on its impact on the commercial plant breeding industry (Morris and Ekasingh, 2002), on diversity of varieties in farmers' fields (Fischer and Byerlee, 2002), and as a precondition for the development of the private sector (Louwaars *et al*., 2005).

Introducing biosafety laws

The Cartagena Protocol on Biosafety (CBD, 2000) sets out a comprehensive regulatory system for ensuring the safe transfer, handling and use of living modified material (LMOs) resulting from biotechnology and subject to transboundary movement. The protocol is envisaged to encourage innovation, development and capacity building in relation to biotechnology, while also achieving the goals of conservation, sustainable agriculture and equitable sharing of the technological benefits. However, the introduction of transgenic crops forced countries to develop biosafety regulations that make the release of 'biotech crops', both for testing and for commercial use, dependent on extensive release procedures. Should the use of such varieties become more widespread, there might be stricter and comprehensive release procedures under the pretext of biosafety laws.

21.3.3 Technical reforms

Apart from policy and regulatory frameworks, there is a need for technical reforms responding to the needs of diverse stakeholders.

Availability of farmer-preferred varieties

Formal plant breeding received considerable criticism for not paying sufficient attention to the crops and conditions of farmers in less favourable areas. For example, yield performance is given considerable weight compared with farmer-preferred traits such as cooking quality, taste, marketability and storability under traditional farming systems. Moreover, the strategies tend to favour wide adaptability and selection of material under favourable crop management, where both the environment and the trial management are unrepresentative of actual farmer circumstances. In the end, only a few 'average best' varieties (Alemkinders and Louwaars, 1999) become available from public plant breeding, which too often will subsequently be produced and distributed by inefficient public seed companies, limiting the choice of varieties and availability of seed to farmers.

In contrast, farmers in diverse, complex, dry and risky environments are interested in varieties with a broad genetic base with the capacity for individual and population buffering in stress environments, such as heterogeneous populations. Consequently, several varieties with specific adaptation are preferred over a few varieties with wide adaptation. Although selection is more effective in the target environment, marginal environments are inadequately represented in national breeding programmes, or even ignored.

In many developing countries, the responsibility for variety development rests with public NARS. Therefore, the NARS plant breeding strategy, protocols and procedures have greater influence on the type and number of varieties available for release. There are serious concerns regarding efficiency and effectiveness in the variety development process, the criteria used in evaluating breeding materials, the degree of stakeholder involvement and the transparency of the system (Witcombe and Virk, 1997).

Criteria for variety release testing

In many developing countries, registration and performance testing for varietal release have appeared to be a bottleneck for the flow of modern crop varieties from agricultural research to farmers. The major criticism of the variety release system is the stringent requirement and application of detailed DUS and narrowly defined VCU criteria implemented by public-sector agencies. For varieties produced by conventional plant breeding, it is important to develop clear, simple and flexible registration and performance testing systems based on criteria developed by all stakeholders. It is important that for variety registration some key descriptors are identified and used to help seed producers and certification agencies recognize varieties, instead of detailed examination and recording using a large number of morphological characteristics. Although conventional regulation might intend to abandon variety registration, the introduction of variety protection laws does require a detailed registration of the protected entity. Tripp *et al* (1997) suggested that requirements for conventional registration and for granting PVP be treated differently and handled by separate agencies to minimize complications. Similarly, they suggested that the performance testing should reflect the circumstances and preferences of farmers, where suitability instead of superior yield is used as the criterion for variety release.

Prolonged testing in variety release

Developing a new crop variety to enter testing for release may require more than 10 years. Thereafter, the variety must also pass through series of preliminary yield trials and meet the requirements for registration and performance testing for official release. It may take another two to six years before the variety is finally approved for release. Seed production can only be initiated following the official release, meaning that it might require an additional five or more years for a sufficient quantity of commercial seed to reach the farmers. In general, there is considerable delay and cost in the process from variety development through to its release and availability of seed for commercial use, which is a very lengthy process. The variety development and release process may take up to 15 years (e.g. Uzbekistan) from the initial crossing nursery to the end of official state variety testing for variety release.

In the public sector, variety development, variety release and seed production and marketing are conducted by different institutions, which are not properly linked and this may exacerbate the problem and prolong the period compared with the private sector, where these activities are integrated. Seed production and marketing start only after the official release, and there is no inbuilt mechanism for pre-release seed multiplication of public-bred varieties to expedite the availability of seeds, with a few exceptions (e.g. Ethiopia, Uzbekistan and Zambia).

Harmonizing testing and release procedures

The UPOV protocols are becoming internationally accepted standards in DUS testing for variety description, registration and protection. Under the UPOV convention, to maximize use of available information and minimize the time for examination, there is cooperation among countries or authorities, where some institutions have been identified and specialized in DUS testing for specific crops. The EU is a good example of a regionally harmonized release system, where varieties released in one country are acceptable in all member countries. Such an approach provides great opportunity for developing testing protocols and sharing data, as well as establishing flexible and harmonized variety release systems in regional or international contexts.

Harmonization of release procedures are naturally an extension of harmonized variety regulation. As discussed earlier under regulatory reforms, collaboration among countries and sharing of data could enable much quicker decisions on variety release. Using data from other countries to reduce the number of years or to waive requirements based on data submitted from tests carried out elsewhere is critical. In recent years, for example, efforts have been underway to harmonize variety release procedures to integrate national seed systems to attract foreign investment and promote regional trade as part of harmonized variety and seed regulation (e.g. Community of Andean Nations). Regional harmonization of technical aspects of variety release systems may reduce cost, save time, encourage private investment, increase choice of varieties and benefit farmers.

Managing registration and performance testing

In principle, testing for variety registration and performance should be managed by an independent and impartial agency established for the purpose. In reality, such agencies vary from country to country, and the responsibility may be vested in a single agency or two different institutions. In some cases it is possible to make decisions based on tests carried out by the breeder, but at the discretion of the agency. For example, in Ethiopia, Algeria and Jordan, for release their National Variety Release Committees depend on performance testing data supplied by the breeder and on-farm verification trials conducted by the breeder, but reviewed by a special technical committee.

In many developing countries, however, there is lack of an impartial authority responsible for implementation of a variety release system and responsibility rests with the national public agricultural research organizations, which also have the responsibility for plant breeding. In general, the research organizations may have limited infrastructure and financial resources, coupled with possible professional bias, thus precluding operating an independent, effective and efficient variety release system unless some level of impartiality is instituted within its variety evaluation system (Morris and Ekasingh, 2002).

Tripp *et al.* (1997) suggested that it is most important for the agency to perform its task with greater efficiency and expediency by using appropriate criteria in a very transparent and participatory approach. The participation of wide range of stakeholders in the process, particularly the private sector, farmers, development agencies and NGOs, increases the transparency and accountability of the variety release system. It is envisaged that variety release systems accommodate both public- and private-sector-bred varieties in an equitable manner.

There are also suggestions to create linkages between variety registration and performance testing, with demonstration and popularization of varieties to create farmer awareness of the merits of new varieties before final release. In the private sector, variety development, seed production and marketing are integrated because commercial success is dependent on the efficiency of the system. They conduct extensive testing of new varieties early on with on-farm demonstration in farmers' fields as part of their product promotion and market development strategy, with the immediate effect of entering commercialization upon release (Ansaldo and Riley, 1997).

The most important criticisms leveled against variety release committees is their lack of transparency and representation of all seed sector stakeholders. Most often the committee is dominated by plant breeders and public-sector officials, and excludes representation from the private sector and farmers. For example, in Turkey, of 12 members of the Variety Release and Registration Committee, only two represent the private sector and one the farmers, while in Ethiopia, all 10 members of the National Variety Release Committee are drawn from public-sector institutions. Apart from being unrepresentative, variety release committees are quite often marred by professional biases, being dominated by breeders, and meet infrequently, so decisions are not timely. Experiences from many developing countries show that most of the committees have no legal backing and run on an *ad hoc* basis, where the decisions carry less weight in implementing an effective variety release system.

21.4 PARTICIPATORY PLANT BREEDING AND VARIETY RELEASE

In parallel to recognition of the informal sector in seed supply (Almekinders, Louwaars and de Bruijin, 1994), there is also growing interest in farmer participatory approaches, for example in genetic resource conservation (e.g. Ethiopia, see Worede, 1992) and in plant breeding (e.g. Syria, see Ceccarelli *et al.,* 2000). The products of participatory approaches, however, must eventually reach and benefit a sufficiently large group of farmers in order to justify the investment in crop improvement.

Farmers' perceptions and varietal choices

Louwaars (1995) indicates that farmers' varietal choice is influenced by ecological (adaptation), economic (marketing, consumption) and cultural (local use) factors. The perception and preferences of varieties is somewhat different between commercial and subsistence farmers. The former is more likely to prefer varieties with higher yield and productivity, whereas the latter may consider diverse varieties with more stable yield and multiple end uses. In commercial agriculture, farmers are more likely to increase production and productivity by intensifying agriculture through use of purchased inputs like fertilizers, pesticides, etc., to maximize profitability. Moreover, mechanization, intensification and commercialization of agriculture require uniform varieties for farm operation, industrial processing and consumer requirements. Therefore, in situations where farmers are connected to markets, the potential yield, industrial quality and marketing are the driving forces in varietal choices for production.

In contrast, subsistence farmers practice complex patterns of farming, which may involve the cultivation of many crops, with the primary objective of meeting household food security while still having some marketable surplus, if possible, to meet additional expenditures. The main effort is to maximize the use of land and available resources to minimize the risks associated with farming, through diversification of crops, cultivars, farming and off-farm activities in an attempt to stabilize their income. Small-scale farmers' perception of varieties is different from that of many plant breeders. Apart from yield, factors like grain quality, storability, suitability for intercropping and the use and value of crop residues may all influence their decisions about variety adoption (Haugerud and Collinson, 1990). Small-scale farmers perceive local landraces to be more adaptable to their agro-ecology, give stable yield, perform better under low soil fertility or low inputs, have good grain quality and are suitable for preparation of traditional foods (Bishaw, 2004).

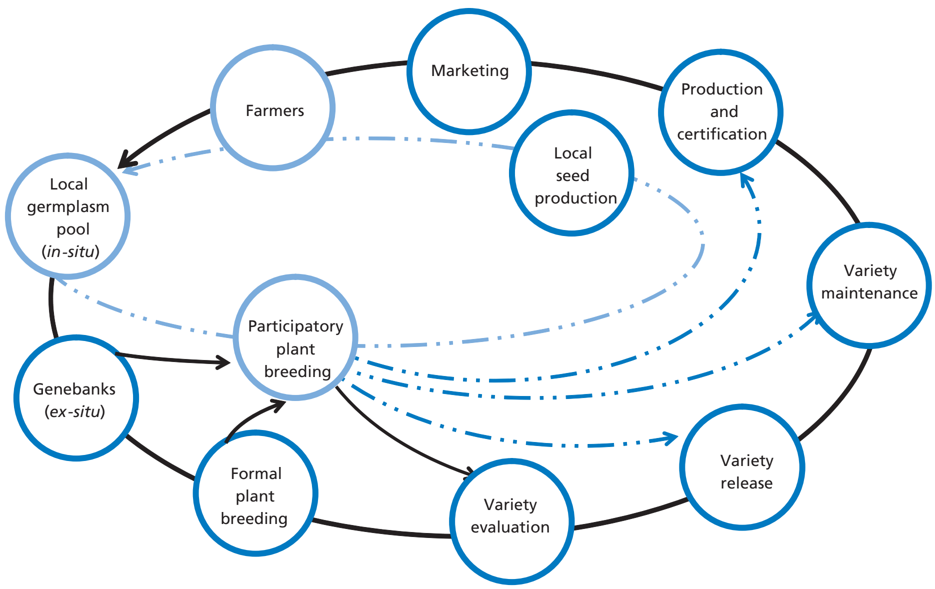
Participatory plant breeding

In many developing countries, conventional (formal) plant breeding (CPB) has shown spectacular progress in developing new crop varieties for uniform and favourable areas where the formal sector managed to produce and market seeds to farmers. However, as the environment becomes complex, dry and risky, there is a clear challenge to breed new varieties to meet farmers' preferences and that are adapted to diverse environmental conditions. Weak rural infrastructure and poor socio-economic conditions further exacerbate these problems.

The limited success of CPB in meeting the need of smallholder subsistence farmers in less favourable environments of the developing world led to the emergence of participatory approaches, focusing on farmer preferences and involvement to encourage rapid adoption and diffusion of new varieties. This could be achieved by bringing the selection process much closer to the farmers, in terms of both the selection environment and their participation in improving the effectiveness and impact of agricultural research. A number of authors described examples of participatory approaches, for example in Rwanda (Sperling, Loevinsohn and Ntabomvura, 1993), India (Joshi and Witcombe, 1996), Nepal (Staphit *et al.*, 1996), Syria (Ceccarelli *et al.*, 2000) and Ethiopia (Belay *et al.*, 2006), and for a wide range of commercial and indigenous crops, including beans, rice, barley, tef, maize, sorghum and pearl millet. The extent of farmer involvement ranges from selecting among nearly finished varieties (participatory variety selection, PVS) to participation in selection on research stations, or to handling segregating populations on farmers' fields (participatory plant breeding, PPB).

The role of participatory approaches in

FIGURE 21.1
Linkages between participatory plant breeding and seed supply



Source: adapted from Bishaw and Turner, 2008.

increasing diversity at farm level, shortening the breeding cycle, identifying well-adapted and acceptable varieties, quicker availability of varieties and seeds, empowering the farmers and lowering overall breeding programme costs have been discussed by several authors (e.g. Staphit *et al*., 1996; Witcombe *et al*., 1996, 1999; Mangione, Ceccarelli and Grando, 2006; Ceccarelli and Grando, 2007). Bishaw and Turner (2008) discussed the potential linkages between PPB and seed supply systems to exploit farmers' knowledge in crop improvement and ensure rapid adoption and diffusion of varieties (Figure 21.1). They advocated national policies that recognize the role of PPB and support strategies to release, produce and market varieties developed through these approaches. They also noted critical issues to be addressed for the PPB approach to function properly such as the need for maintaining identity and integrity of participatory varieties, applying flexible variety release procedures, and establishing alternative seed delivery systems. Some of these options are presented and discussed in more depth below.

Institutionalizing participatory plant breeding

Participatory approaches are evolving and still lack clearly defined procedures compared with long-established formal breeding programmes. At least two major forms of participatory approaches have been recognized: PVS and PPB, the latter with many variant forms (breeder/farmer-led PPB, decentralized PPB, highly-client-oriented plant breeding, etc.) and some differences in methodological approaches, type of breeding materials, and stage and degree of involvement by farmers.

Some successes have been reported with participatory approaches, including PVS and PPB in recent years. However, PVS appears less problematic as it deals with already released or nearly finished varieties to derive farmer's varietal choices. At the same time, an attempt to institutionalize PPB in NARS breeding programmes in its own right is still under debate and its future remains uncertain. Were PPB officially recognized and institutionalized, the issue of variety release and its commercialization would have long been resolved at the national level. Therefore, outcomes from PPB need to be documented and its impacts demonstrated to influence national polices to overcome the hurdle.

Maintaining varietal identity and integrity

There are two key factors for adoption and diffusion of a variety: (i) genetic integrity (the inherent capacity of the variety to reproduce itself during seed multiplication); and (ii) varietal identity (its unique distinguishing characteristics established during its development). CPB generates defined outputs (cultivated varieties) with the responsibility for maintaining the variety (identity and integrity) vested in the breeder, or a designated agent, and ensuring a continuing source of pure material as long as it remains in commercial seed production. This system of variety management is absolutely critical in formal systems, since it provides a secure point of reference and, by limiting the number of generations, it also reduces the risk of contamination.

Similarly, it is therefore highly desirable that the identity and integrity of PPB varieties are systematically maintained and made available to more farmers. To achieve this, responsibility should be vested either in the formal sector, in an 'individual farmer-breeder', or more likely, in farmer groups established to produce and market the seed. This provides a basis for some continuity of pure seed supply and to maintain the identity of the material. In the absence of such arrangement, the purity and identity of the variety may dilute and diffuse over years.

Flexibility in varietal release

The disadvantages of formal variety release procedures are discussed elsewhere. However, in PVS, a limited choice of 'finished' or 'nearly finished' varieties bred through conventional or other means are exposed to numerous groups of farmers across villages in widely dispersed geographical areas for farmers to select according to their preferences. In reality, PVS is closer to conventional breeding as it involves farmers only towards the end of the selection programme. Therefore, PVS presents less challenge compared with PPB in variety release systems, particularly if the varieties used are from conventional plant breeding programmes.

In PPB, a few representative farmers are involved in selecting varieties from large segregating populations. It is believed that the PPB approach gives greater opportunity because of wide dispersion of sites that reflect the actual environments of crop production. Consequently, PPB should encourage the use of more adapted material, and development of many varieties with specific adaptation, particularly to less favourable environments. This may increase farmer choice, but it may create challenges for the formal variety release system, and ultimately for seed production as well.

Varieties developed through PPB do not always meet the stringent DUS and VCU criteria because they may lack sufficient uniformity and might not always perform well across the majority of test sites compared with varieties from conventional plant breeding. Applying identical testing criteria would be unrealistic, and alternative variety release procedures must be considered. The criteria for registration and performance should be flexible and accommodate less uniformity within a variety and allow a wide range of varieties with specific adaptation to increase the choice of niche varieties available to farmers. Possible scenarios for release of materials from PPB are considerd below (Bishaw and Turner, 2008).

Linking to formal plant breeding

Conventional plant breeding exploits indigenous knowledge by involving farmers at different stages in the selection process. The materials identified or selected by farmers can be further refined and the varieties ultimately evaluated and released through the official process and the seed become available through the formal sector. Sthapit, Joshi and Witcombe (1996) described where PPB products entered national trials using scientist-led breeding schemes run in parallel with those of the farmers, with the main purpose being to purify the variety and select for uniformity to meet criteria for formal release. Belay *et al.* (2008) demonstrated where both conventional and participatory approaches were used in a complementary mode for official release of a variety in Ethiopia.

Linking to formal variety release

PPB products identified by farmers can directly enter official variety release and registration trials, but they may encounter difficulties in terms of either uniformity or performance for reasons already explained. It is suggested that release committees accept PPB data on farmer perceptions and demand for seed rather than yield data from scientist-managed trials (Witcombe *et al.*, 1996). Ceccarelli and Grando (2007) outlined the PPB model for barley, where early generation materials (farmers involved from F_3 bulk) go through four cycles of selection, when farmers are involved in selecting and testing the materials during the subsequent years. Farmer-selected varieties in large-scale trials (fourth cycle) are considered adopted and should be released. Alternatively, they suggested that testing pure line (pedigree) selection from selected bulks can be conducted on-station and released in situations where there are stringent variety release requirements.

For PPB varieties, any detailed examinations for VCU appeared to be redundant since farmers are already part of the selection process and identified those meeting their preferences. Some countries also release varieties purely based on performance testing where DUS requirement would not be problematic if farmers criteria are accepted (e.g. Ethiopia). The alternative approach is to release PPB products through a separate registration system established to accommodate these varieties, or even make an outright decision to release them without testing (e.g. Jordan). However, even if the DUS criteria are relaxed, some level of description is essential to identify the variety for purposes of seed production and marketing through formal channels.

Linking to formal seed supply

PPB varieties could be exempted from release systems and directly enter seed production. The formal sector may take direct responsibility for large-scale seed multiplication and marketing of PPB varieties identified by farmers. Given the fact that PPB varieties may have a larger recommendation domain beyond the initial testing sites, it is suggested that large-scale seed production and distribution and external intervention be used as a strategy to accelerate diffusion (Joshi, Sthapit and Witcombe, 2001).

Alternatively, the formal sector could limit itself to variety maintenance and Breeder seed production, in order to ensure small but secure supplies to local seed producers. Virk *et al*. (2003) emphasized the importance of formal sector (research, universities, department of agriculture), NGOs and self-help groups, supported by government, to ensure seed production and dissemination once farmer-preferred varieties have been identified through a participatory approach. Ceccarelli and Grando (2007) advocate the need for linking PPB varieties to formal and informal channels to ensure adoption and realize impact.

Linking to local seed supply

At present there is limited information on scaling up seed production to diffuse PPB varieties. Despite apparent strengths, local seed systems may not adequately meet requirements for wider distribution of PPB varieties unless they are properly strengthened and linked. Almekinders, Thiele and Danial (2007) consider that there is a tendency to overestimate the role of informal farmer-to-farmer seed exchange as a diffusion mechanism for PPB varieties. In India, a follow-up study for a rice variety identified by PVS showed seed diffusion from farms to relatives or friends in adjacent or nearby villages typically over distances of less than 10 km, despite project intervention in providing seed through village seed pools, seed merchants and NGOs (Witcombe *et al.,* 1999). Some institutionalization of local seed systems is, however, necessary by involving, for example, existing community groups, farmer's cooperatives or associations, local traders and entrepreneurs, NGOs, extension services or rural development agencies, and linking them to the formal sector. For local initiatives to succeed they must address the key issues of financial viability and sustainability without external support (Bishaw and van Gastel, 2008).

Protecting PPB varieties

In the last decade or so, access to genetic resources and protection of plant varieties has become an important part of an increasingly intense debate in formulating policy and regulatory framework at national and international levels (see also Chapters 23 and 24 in this volume). Chapter 23 argues for Farmers' Rights (FRs) under International Treaty, whereas Chapter 24 proposes Plant Breeders' Rights (PBRs) under national IPR laws. In reality there is no contradiction between the two as they address two separate issues. However, quite often there is confusion, mixing farmers' rights with breeders' rights. In Ethiopia, the government has enacted two separate regulations for plant breeders' rights and community farmers' rights,

There are many forms of IPR protection for plant varieties through biological (e.g. hybrids) or legal control including trade secrets, contracts and licenses, patents, and PVP laws. Among these patents for asexually propagated materials (since the 1930s) and latterly for genes, gene combinations and biotechnology products, while PVP laws for plant varieties have been long established as IPR protection systems in the field of agriculture.

First, in conventional plant breeding, describing a variety using morphological characters and establishing its identity is a prerequisite both for release and for protection. For example, under the UPOV convention, granting PVP is based on DUS and novelty of the variety. Theoretically, if PPB varieties meet these criteria it is assumed they could be granted immediate protection under national PVP law. At the same time, it is argued that PPB varieties may not meet the stringent requirements of the formal seed system and should be hence given special treatment. Could protection rights therefore be given for a variety whose identity is not clearly established? Is it possible to enforce protection in case of infringements of rights?

Second, the fundamental purpose of PVP is to enforce PBRs, which is a private and exclusive ownership right over new varieties, and enforced by breeders to recuperate their investments. Technically, PPB varieties are products of collaboration among different stakeholders, including farmers, communities and breeders. Who is the owner of PPB varieties: the individual farmers, their communities, the collaborating breeders or a 'collective' ownership? Who are the ultimate users or beneficiaries of PPB varieties? Does the legal protection promote or hinder wider use of PPB varieties?

Third, at present, neither FRs nor PBRs provide sufficient regulatory framework to protect PPB varieties, because of complex legal and technical issues. According to the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA; FAO, 2009), FRs are clearly defined irrevocable rights arising from the past, present and future contributions of farmers in conserving, improving and making available plant genetic resources and the opportunity for access and benefit sharing from their use by a third party. At the same time, PBRs are about private rights given on a product whose identity is clearly established and for specific period of time. Who is the source of breeding materials for PPB varieties? Does the scope of FRs under the International Treaty meet the criteria of protecting PPB varieties?

Fourth, the purpose of PPB is to circumvent formal sector constraints in developing and making available farmer-preferred varieties, and their wider adoption and diffusion. It should avoid as much as possible the legalistic and bureaucratic ramifications that might undermine its novel approaches. What is the purpose of protecting PPB varieties? Should PPB varieties be considered a public good for the entire farming community? Is the protection meant to address the public good nature of these varieties?

Does simply invoking FRs as a means to protect PPB varieties necessarily serve the interest of farmers? It is therefore advisable to further elaborate the many uncertainties and unanswered questions surrounding the protection of PPB varieties and develop a working mechanism acceptable to all parties. This will do justice in rationalizing an already burgeoning and complicated legal arena in agriculture. Ultimately, one must acknowledge that countries have the right to design IPR regimes that are compatible with their own agricultural development and serve the interests of their farmers.

21.5 CONCLUSIONS

According to Srivastava (1997), there are profound structural changes and emerging trends in the seed industry, including globalization of agricultural research, shifting to private-sector plant breeding, increased investment in biotechnology, liberalization of seed trade, emergence of private seed companies, entry of multinational seed companies, greater attention to the informal sector, and debate of regulatory and trade agreements on IPR and biodiversity. These changes call for establishing an effective, efficient and transparent variety release system to serve the needs of diverse economies.

At present, however, many countries in both developed and developing countries require comprehensive and mandatory tests for registration and performance testing for new varieties to be released for commercial seed production and use by farming communities. Despite similarities in agro-ecology, farming systems and germplasm there is lack of coordination, collaboration and cooperation among developing countries towards streamlining a common and harmonized variety release system. Moreover, each country has its own variety release system in place. This could be a lengthy process that might be repeated in many separate countries, making it very costly and also leading to serious delays limiting the choice of varieties available to farmers. Countries could accelerate the flow of new varieties to farmers by moving from compulsory to voluntary registration and from single to multi-country lists by harmonization of the system at supra- or sub-regional levels. It is high time to make a critical analysis of policy, regulatory, technical, institutional and organizational constraints and develop a responsive variety release system at both national and regional levels.

Varieties developed through participatory approaches pose new challenges and do not always meet the traditional stringent DUS and VCU criteria because they may lack sufficient uniformity and not always perform well across the majority of test sites compared with varieties from conventional plant breeding. Applying the same testing criteria would be unrealistic and alternative variety release procedures must be considered. The criteria for registration and performance should consider farmer preferences and be flexible and accommodate less uniform varieties, and also a wide range of varieties with specific adaptation to increase the choice of niche varieties available to farmers.

In an era of liberalization and globalization, it is important for national governments to take the lead in providing an enabling policy and regulatory environment to support the development of a competitive and pluralistic seed industry that meets the varietal requirements of the farming communities, given the diversity of seed suppliers, farmers, crops and farming systems.

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CHAPTER 22

Participatory seed diffusion: experiences from the field

Humberto Ríos Labrada

22.1 CONVENTIONAL SEED PRODUCTION SYSTEMS IN CUBA

During the golden years of the eastern Socialist countries, a centralized plant-breeding model was a standard component of the high-input agriculture practised in Cuba, and particularly for the country's cash crops (Begemman, Oetmann and Esquivel, 2000). Foreign varieties, hybrids, landraces and varieties obtained by mutation were the principal sources of genetic variation used for varietal development in Cuban plant breeding programmes (Ríos, 1999). At the end of the 10–12 year period typically spent in varietal development for a specific crop, the breeding programmes usually released only one or two varieties for the entire country, therefore assuming a geographically wide adaptation. Wide geographical adaptation characteristics were encouraged by policy-makers, with most Cuban governmental organizations providing incentives to scientists involved in releasing a variety for use over a large area.

Ambitious plant breeding programmes were developed in the 1980s for sugar cane, roots and tubers, rice, tobacco, coffee, horticultural crops, pastures, grains, fibres and some fruit trees, undertaken by fifteen research institutes and their corresponding networks of experimental stations that spread over the island (Begemman, Oetmann and Esquivel, 2000).

As a part of the varietal release process, each new variety had to pass through a series of steps. The research institutes sent their results to the Scientific Forum (*Consejo Cientifico*) at the national level. This Forum checked their scientific validity and, if approved, they sent them on to an Expert Group (*Grupo expertos*), which consisted of researchers, teachers and production directors. If this group approved the results, they were then sent to the Vice-Minister of Mixed Crops (*Vice-Ministro Cultivos Varios*). This Minister would send the results to the provincial delegations, which would incorporate them into their production plans, so that producers were obliged to adopt them. This procedure took a top-down approach without consulting the producers. Some researchers did visit farms, but still the research agenda came from the decisions of the researchers (Trinks and Miedema, 1999).

Some plant materials collected in Cuba with useful characteristics, such as disease resistance, short growing cycles and good food qualities, were not used by the formal plant breeding sector due to their low yields under high-input conditions (Castiñeiras, 1992).

Following the disintegration of the USSR in 1989, the Cuban agricultural sector had to cope with a drastic reduction in input and trade support, shifting gradually towards more self-sufficient and rational forms of production.

Many remarkable technical and social transformations occurred as a response to this challenge. In the 1980s, Cuba had carried out 87 percent of its external trade under preferential price agreements, imported 95 percent of its fertilizer and herbicide requirements, and owned one tractor for every 125 ha of farm land. After the collapse of the socialist block, foreign purchase capacity was reduced from US$ 8.1 billion in 1989 to US$ 1.7 billion in 1993. This greatly affected the country's ability to buy agricultural inputs (Funes, 1997).

To address the crisis, the Cuban government implemented changes in all sectors to reduce the negative impact on the national economy. During the early 1990s, severe social and economic changes were made in order to maintain the social guarantees of the government while simultaneously reconstructing the Cuban economy (Enriquez, 2000; Rosset and Benjamin, 1993). Cuba thus undertook one of the most dramatic changes in farming systems, having to move from being the highest agrochemical consumer in Latin America, to very-low-input agriculture in less than three years (Funes, 2002).

However, the plant breeding sector has been slower to adapt. Even though the professional plant breeders faced a difficult economic situation and researchers had few incentives, they pursued top-down approaches and adopted rigid reductionist perspectives. Within this existing system, the solution was not as simple as technology substitution. Due to the financial crisis, research institutions faced various constraints, such as lack of access to, or maintenance of, important genetic resource collections; energy blackouts; incapability to refresh seeds; and a decrease in the number of international programmes that had formerly supported Cuban research institutions in the 1990s. The national seed supply system urgently needed to expand, but lacked the financial resources to do so. In the 1990s, its seed production capacity for maize and bean had fallen by 50 percent (Ríos and Wright, 1999).

Through the informal system, the production of seeds of the basic staples of the Cuban diet became a major issue in many parts of the country. These genetic resources had provided a basis for plant breeders to select commercial genotypes during the industrial agriculture period. However, relatively little attention has been paid to this informal seed management system and much genetic variability had already been eroded (Esquivel and Hammer, 1992). Usually, the maintenance of genetic diversity was considered very close to environmental protection, with an altruistic rather than profit-making approach. The public plant breeding sector in Cuba and other Latin American regions considered agro-biodiversity management and plant improvement as an exclusive activity of professional researchers.

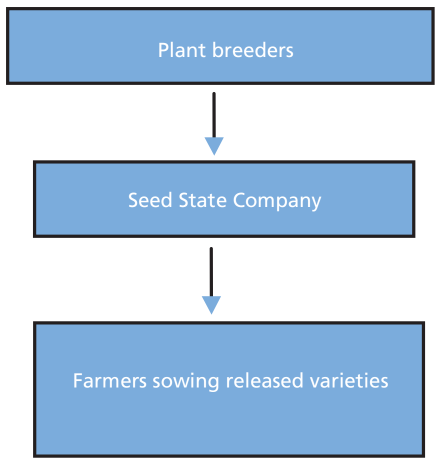
Making use of the space opened up by the economic crisis, a participatory seed dissemination programme emerged, inspired by some former work with pumpkins (Ríos, Soleri and Cleveland, 2002), and aiming to develop participatory seed production, improvement and distribution practices. This programme uses a variety of tools, including seed fairs and participatory variety selection, as strategies for seed diversification to improve the yield and genetic diversity in Cuba.

22.2 CHANGES IN THE PARADIGM: TOWARDS PARTICIPATORY SEED DIFFUSION

In principle, the Participatory Seed Diffusion (PSD) concept emerged in Cuba to integrate diversity seed fairs with farmer experimentation. A seed diversity fair is an approach where plant breeders, farmers and extension agents have access to diversity in one or more crops. Varieties from formal and informal seed systems are sown under the usual cultural practices of the target environment. Stakeholders have the possibility to make selections in the field. They do not know the seed sources of the varieties in the plot. After the farmers have taken and experimented with selected seeds on their own farms, discussions on varietal performance take place within the communities between farmers and researchers. This discussion is considered the start of the farmer experimentation period.

The two models – the centralized, conventional breeding model developed

FIGURE 22.1
The centralized seed diffusion model in Cuba



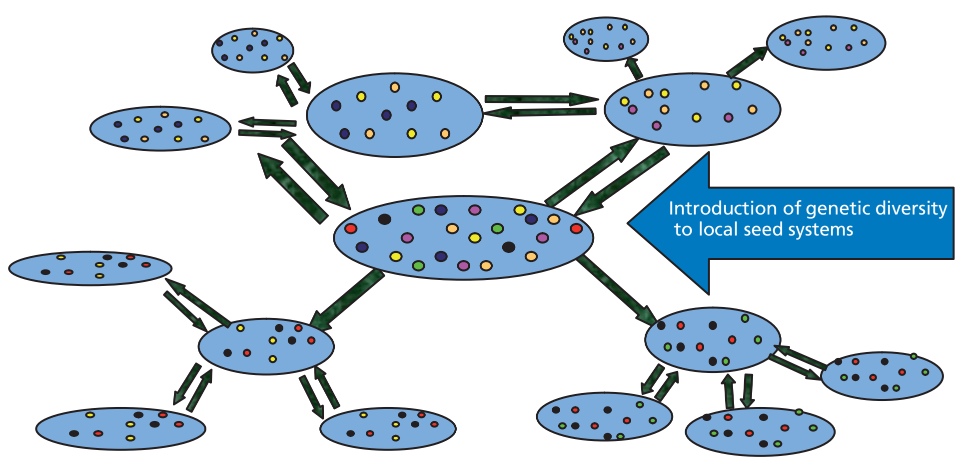
in Cuba during the 1980s, versus the decentralized, participatory plant breeding model – are shown in Figures 22.1 and 22.2, respectively.

In contrast to the centralized model, PSD is based on the individual farmer, through Agricultural Production Cooperatives, farmer experimenters, and groups or clubs, among other entities, which test and spread throughout the community varieties of high interest. Starting with the introduction of genetic diversity, through a process called chain reaction (Ríos, 2003), a diversity nucleus is built up that provides genetic diversity to others, and that grows exponentially through farmer participation. Once farmers see the favourable effects of experimenting with genetic diversity, they organize themselves into farmer research groups. Each diversity nucleus promotes knowledge, social organization and entrepreneurial centres characterized by intensive genetic flows and continued discussion around local innovation.

22.3 THE DIVERSITY SEED FAIR

The first diversity seed fair was held at the National Institute for Agricultural Science (INCA) in 1999, as an approach for disseminating maize seeds suitable for low-input agriculture (Ríos and Wright, 1999).

FIGURE 22.2
Participatory Seed Diffusion promoting a "Diversity Chain Reaction"



Source: Ríos, 2003a.

There, professional breeders provided farmers with access to diversity from the formal and informal seed systems, and the seeds were sown under relatively low input conditions (Ríos and Wright, 1999).

Some months before the first diversity seed fair, two breeders undertook maize seed collection missions to a farming community in the province of Pinar del Rio, and to Santa Catalina in Havana province. A selection was made for hardiness under low-input conditions, and 66 landraces (entries) were collected, including 10 from the focus communities in Havana province. In addition, four commercial varieties were supplied from research institutes. These were planted in December on an experimental plot at INCA. Each of the 70 lines was sown in three rows, and wide border strips were sown with a mixture of different lines.

Because of lack of financial resources, the experimental plot received only one irrigation treatment and no fertilizer or pest control inputs. Eighteen farmers from regions of high-input production, along with formal-sector maize breeders, social scientists from the National Agricultural Research System (NARS), and representatives from the National Small-Farmer Association and the former Cuban Association of Organic Agriculture (ACAO) attended the first seed diversity fair.

The farmers were taken to inspect the maize experimental plot and to examine cobs of all the maize lines from this plot, with each farmer selecting five preferred lines. Seeds from these lines would later be given to the farmers for experimentation. Short questionnaires were used to gather information on the farmer's evaluation of each line chosen, and the results were discussed. The main problems associated with seed management and use were low seed quality, low seed availability, and the incidence of pests and diseases. Availability of training and extension, exchange of seeds, and input availability were considered less problematic.

TABLE 22.1
Selection criteria for maize varieties, accepted as important by farmer participants

Criterion	Percent of farmer acceptance
Plant yield	87.5
Plant height	87.5
Positioning of leaves	62.5
Number of leaves	60.0
Leaf colour	45.5
Leaf size	41.3
Stalk width	76.3
Number of cobs	57.5
Ear colour	32.5
Ear size	40.0
Susceptibility to lodging	31.3
Cob weight	50.0
Cob height	40.0
Cob fullness	40.0
Husk colour	28.7
Cob diameter	37.5
Cob husk cover	55.0
Cob size	42.5
Cob shape	55.0
Insect damage	35.0
Cob length	45.0

Source: Ríos and Wright, 1999.

In the field, farmers rapidly selected from the large number of lines on offer. They showed an immediate preference for the mixed varietal border stands as these showed a better response to low input conditions than the mono-varietal rows. The importance of each of their selection criteria is shown in Table 22.1.

In the selection, 80 percent of the farmers identified different preference criteria for each of the five lines they had selected. Participants observed better results from mixed-variety rather than single-variety planting, which led researchers to conclude that they would have to overcome contradictions in the practice of maintaining varieties through strict isolation, as demanded by the formal system.

It became clear that farmers looked not only at yield, but also valued aspects such as plant height, stalk size, number of cobs, and number and position of leaves. This is an indication of the need for alternative breeding objectives.

Selection criteria chosen for maize varieties indicated that farmers, in general, did not practice seed saving. In fact, during the discussion period, several of them asked how to save seeds.

The general reception given to this new participatory approach was positive, given that farmers were historically accustomed to a more top-down management procedure. Farmers had rapidly and easily selected between the 70 lines on show, and a very large range of new seed lines had been extended to them. The plant breeders who started to work in PSD felt that this diversity indicated the need to refocus seed management so that yields and cob quality could be improved under low input conditions (Ceccarelli and Grando, 2002; Ríos, 2003; Acosta *et al.*, 2003; Martínez and Ríos, 2003b). Stimulating the flow of genetic resource variability has shown the potential available for increasing yield performance on trial plots for farmer acceptance.

22.4 FARMER ACCESS TO GENETIC DIVERSITY

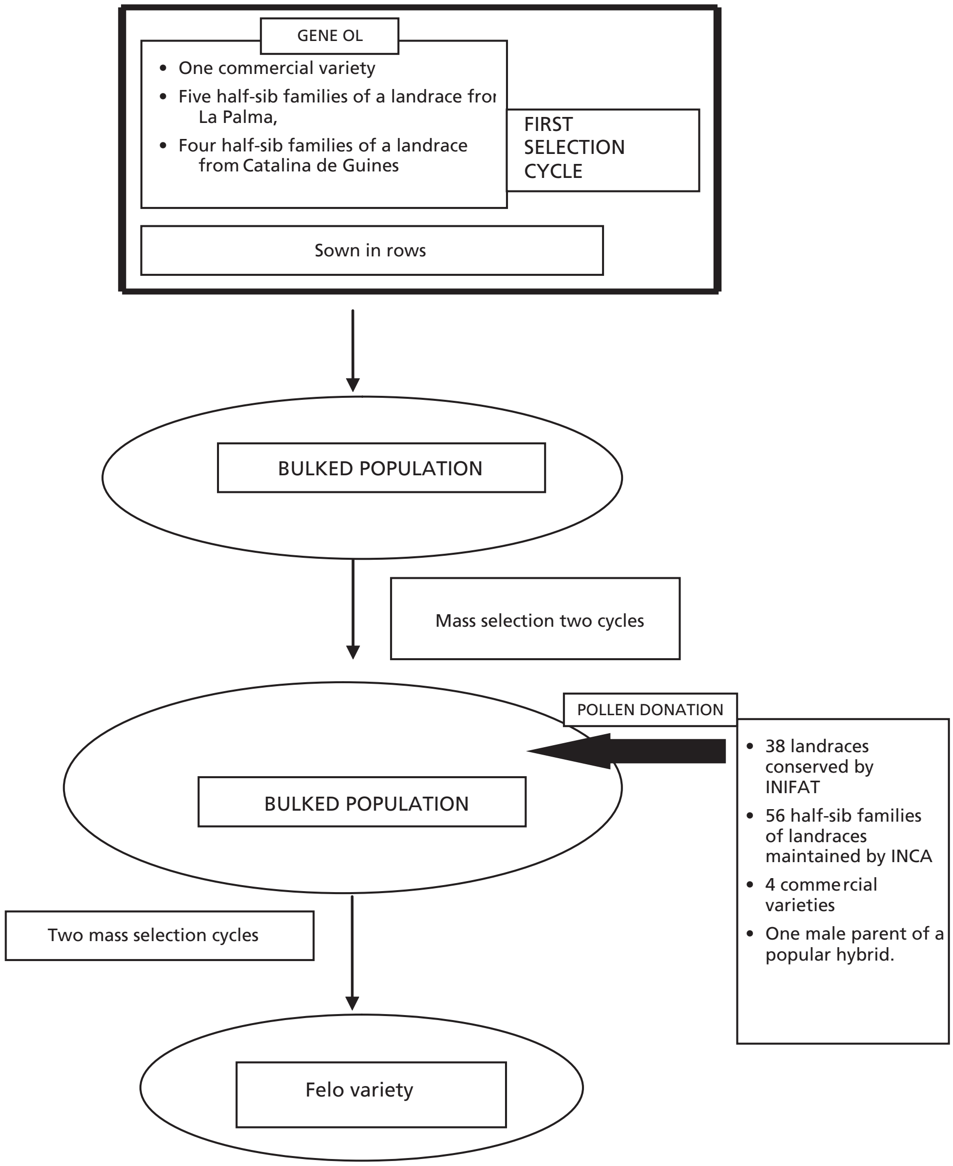
22.4.1 Cross-pollinated crops: the example of maize

Three months after the Diversity Seed Fair, the farmers' capacity to develop maize populations was assessed among nine farmers working on three cooperatives and one private farmer; all ten had attended the maize seed fair. Three of these farmers were unable to maintain their seeds because they lacked the conditions required for conservation from season to season, having relied for more than fifteen years on the formal seed sector, which supplied improved seeds every season.

The gene pool of the maize population of one Havana farmer who selected from the seed fair was found to be composed of different seed origins: one commercial variety from the formal seed sector, five half-sib families of a landrace from La Palma (a neighbouring province), and four half-sib families of a landrace from Catalina de Guines (a neighbouring municipality of the same province) (Figure 22.3). Later the same farmer bulked all materials and selected in the field the best 1 500–2 000 plants according to cob size, plant cob height and husk covering, during three cycles. Afterwards, at a seed fair prepared by his cooperative, this bulked population was sown along with 38 landraces conserved by the Fundamental Research Institute (INIFAT) gene bank, 56 half sib families of landraces maintained by INCA, four commercial varieties and a male parent of a popular hybrid (Ortiz *et al.*, 2006, 2007).

Subsequently, the bulked population was named Felo (the nickname of the local farmer breeder) and two mass selection cycles were done. Gradually, this new seed pool, under farmer management, increased maize production and diffusion amongst cooperatives, and the area intercropped with maize increased over the years (Table 22.2). Maize rose from being one of the most neglected crops in the cooperative to the third important profitable crop (Ortiz *et al.*, 2003a). Currently, this population, cv. Felo, is under seed multiplication and continued selection, having gained recognition from all

FIGURE 22.3
Maize selection scheme used by Felo – a farmer in Cuba



Source: Ríos, 2003a.

the municipality stakeholders, and has been registered as an official variety in Cuba.

Usually, the conventional model of breeding cross-pollinated crops entails recombining in the first stage of the breeding programme, and once breeders identify a certain population with desired characteristics, this population is maintained in isolation (Ríos, 2003). The interesting fact learned through the Felo experience was

TABLE 22.2
Maize production in Cooperative Gilberto Leon, Havana, Cuba

Year	1999	2000	2001	2002	2003	2004
Maize area (ha)	36	52	65	72	96	120
Maize area of seeds improved by farmers (ha)	0	10	65	72	96	120
Intercropping (ha)			25	50	60	

Source: Ortiz *et al*., 2003a.

TABLE 22.3
Origins of bean varieties grown at seed diversity fair

	Commercial varieties	Genetic diversity conserved in gene bank	Accessions collected in the participant communities (Landraces)	Total
Black beans	17	30	16	63
Red beans	16	15	8	39
White beans	4	14	4	22
Total	37	59	28	124

Source: Lamin, 2005.

the possibility of improving yields by disseminating seed diversity. Each genetic pool built up by farmers could probably be continuously recombined, choosing for yield improvement as well as other important traits holding cultural or market values.

According to the first results of PSD in Cuba, seed diversity fairs should become a recombination process whereby farmers can have access to genetic diversity at community level. In this sense, farmer experimentation can play two roles, first in continuously providing the best progeny to the diversity gene pool at community level. and second in providing farmers with the opportunity to select the best recombined family in a certain cycle in the field. Thus, PSD in a cross-pollinated crop such as maize seemed to be a simple method where the recurrent selection principle can be applied (Maldonado *et al*., 2006).

22.4.2 Self-pollinated crops: the example of beans

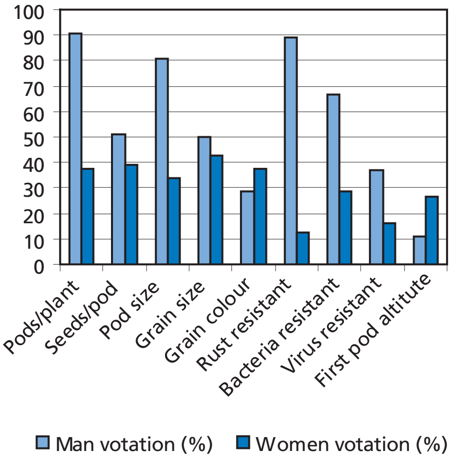
In the case of common bean, a self-pollinated crop, PSD in Cuba has been working mainly with released varieties and landraces, using a non-segregating population. Farmers could access up to 124 varieties of bean from different sources (Table 22.3) grown under low-input conditions at the INCA Experimental Station. Each variety was sown in a small plot, where participants could select up to five varieties to be taken home and tested on their farms under their prevailing production circumstances.

After more than half of the varieties had reached the stage of physiological ripening, a meeting was held with the farmers.

In the case of bean, farmer participants came from different biophysical and socio-economic contexts. Both marginal and industrial farming systems were represented by 42 farmers, as well as some NARS scientists, members of NGOs, functionaries and technicians of the Ministry of Agriculture.

The bean seed diversity fair was attended by male and female farmers. It was planned to carry out varietal selection for women and men separately (Verde *et al*., 2003). A questionnaire was used in

FIGURE 22.4
Differences in plant selection according to gender focus



order to see whether there were differences in selection criteria according to gender. At the same time, 60 varieties were cooked and participants were grouped in small teams of 3 men and 3 women to evaluate 10 varieties each, with an extra questionnaire on cooking qualities to be completed by participants. Team members facilitated the processes of understanding and filling in questionnaires by participants.

Male farmers voted for varieties with high yield and associated characters, such as number of pods per plant, pod size and disease resistance. In contrast, female participants voted for varieties with large pods, grain size, shape and grain colour. Female farmers' criteria seemed to be more closely related to culinary properties than those of the males (Figure 22.4)

Most farmer participants associated grain colour with variety, and because of this it was interesting for farmers to see agro-morphological differences within colour in the first bean diversity fair; they commented on the degree of variability of disease resistance within the same colour (Miranda, 2005).

At the beginning, the selection exercise was run on an individual basis; however, some farmers collectively decided to chose a wide range, as they wanted to test a range of varieties in their region. They were keen on organizing a seed diversity fair exercise in their own communities. During the selection exercise in the field, the team noted that none of the farmer participants had previously had the opportunity to gain access to genetic diversity.

In the cooking test, males noted that more than 80 percent of the varieties tested had good quality, whereas females showed more rigour in testing beans for cooking quality (Table 22.4).

After the bean seed selection, the project focused on supporting experimenter farmer networks as had been initiated for maize. In the case of bean, the mission was to compare and release varieties according to the farmers' traditional farming systems. Workshops on experimental designs were held at community level. Experimenter farmers' networks started to grow at community level, the reaction of farmers

TABLE 22.4
Gender comparison of cooking quality in common bean

	Male (n = 100)			Female (n = 80)		
	Good	Medium	Bad	Good	Medium	Bad
Flavour	80	13	7	63.7	26.3	10
Softness	95	3	2	73.8	21.3	5

Source: Verde *et al.*, 2003.

confronted with bean diversity was overwhelming, and nobody expected genetic diversity to be of such importance to farmers.

In fact, the main interest of farmers in maize and bean was to be able to select amongst the wide range of varieties according their own criteria. Numerous varieties conserved in the gene bank showed good performance even though some had been lost off the official varieties list. The spirit of experimentation, the opportunity for more such productive options, and the gender differences detected in the first participatory seed selection exercises in Cuba, inspired farmers, scientists and others stakeholders to further explore PSD in Cuba and abroad. Consequently, a Mexican and Cuban team started to collect seeds from different sources, promote diversity seed fairs and farmer experimentation in their local context.

22.5 COLLECTION OF SEED DIVERSITY

A collecting mission was carried out as a multidisciplinary effort. Teams composed of scientists from INCA and local stakeholders, in Cuba and Mexico, collected beans, maize and rice landraces in different provinces and municipalities (Table 22.5).

In terms of the results of these diversity collection missions (Ríos *et al*., 2006), the teams in Cuba, La Cuenca del Papaloapan and Chiapas reported potential interesting material for certain breeding programmes. In general terms, the farmers donated their seeds freely. In the case of Mexico, the phenotypic diversity of collected seeds of maize was enough to organize different plots in both Chiapas and La Cuenca de Papaloapan. In Cuba, an important bean collection was donated by the Fundamental Research Institute in Tropical Agriculture (INIFAT), and rice germplasm was donated by the Rice Research Institute (IIR), in addition to collected material.

For maize, most of the diversity collected in Mexico came from local seed systems, with 8 lines provided by CIMMYT. In Cuba, most collected maize came from local seed systems, with only four commercial varieties coming from professional breeders. In every case, each maize, bean and rice accession collected per family farm was considered as a variety. In comparison with maize and bean, only very narrow rice diversity was found in the field (Moreno *et al.*, 2003).

In Cuba, several public organizations were very open to providing materials for seed diversity fairs, and these have been considered an important support to the PSD process. The main problem in Cuba was the resistance of conventional plant breeders to facilitate segregating populations.

In Mexico, it was extremely difficult to break the barriers for access to public germplasm for developing seed diversity fairs at community level. At the same time, the reaction of some public plant breeders was conservative.

22.6 FARMER'S ACCESS TO GENETIC VARIABILITY

The genetic diversity conserved in conventional gene banks, accessions collected during the collecting mission undertaken by the project, and commercial varieties donated by breeders of bean, maize and rice, were sown in 2001 in Cuba at farm level. In La Cuenca del Papaloapan (a catchment covering the tropical area of Oaxaca and Veracruz states), Mexico, two seed diversity fairs were held for maize and bean, and rice plots were attempted but it was not possible to obtain a harvest (Table 22.6).

TABLE 22.5
Characteristics of collection missions

Crop	Region	Number of accessions	Number of farmer donors	Number of municipalities involved	Number of communities involved
Maize (*Zea mays* L.)	Cuenca del Papaloapan	204		11	43
	Chiapas Highland	368	221	20	66
	Cuba	254	82	25	65
Beans (*Phaseolus vulgaris* L. & *P. coccineus* L.)	Cuenca del Papaloapan	52	48	8	20
	Chiapas Highland	201	125	19	40
	Cuba	150(1)	—	—	—
Rice (*Oryza sativa*)	Cuenca del Papaloapan	8	2	3	4
	Chiapas Highland	3	2	2	2
	Cuba	16	15	2	8

NOTES: (1) 60 accessions were donated by INIFAT gene bank.

TABLE 22.6
Location and number of varieties grown in seed diversity fairs in the 2002–2003 period in Mexico and Cuba

Diversity plot location	Crops and no. of varieties per location	Farmers selecting varieties	Altitude (masl)	Experimental field plot topography
Chenalho, Chiapas, México	Maize: 84 Beans: 75	37 in maize; beans could be harvested owing to high rainfall regime.	1500	Heterogeneous
Comitán, Chiapas, México	Maize: 139 Beans: 74	No growth because of drought.	1600	Homogenous
San Cristobal de Las Casas	Maize: 95 Beans: 68	49	2120	Homogenous
Ejido Valle Nacional, Municipality Santa Maria de Jacatepec	Maize: 131	163	40	Homogenous
Doroteo Arango Municipality Acatlan de Perez Figueroa	Maize: 97	100	54	Homogenous
San José de las Lajas. La Habana, Cuba	Beans: 70	42	132	Homogenous
San Antonio de los Baños, La Habana, Cuba	Beans: 97	35	150	Homogenous
La Palma, Pinar del Río, Cuba	Beans: 53	81	60–80	Heterogeneous
Los Palacios	Rice: 80	41	60	Homogenous

Source: Ríos *et al*., 2006.

In Chiapas, four experimental plots were cultivated with collected genetic diversity: at Villa Flores Agriculture University in the lowland, and the other three in the highlands of Chiapas at La Albarrrada (San Cristobal de Las Casas Municipality), Yabteclum (Chenalo Municipality), and Comitan (Comitan Municipality). In the case of Mexico, most of the maize diversity grown in the different places was mainly donated by farmers. Consideration was made of the altitude where the seed was collected, in order to avoid mis-adaptation.

All cultivation of the diversity plots was undertaken according to the traditional practices of the participant communities, except in Chiapas lowlands and Cuenca del Papaloapan, where a half-technical package was applied. Each accession collected was considered a variety. In all diversity plots, farmers were allowed to choose five or six varieties to take home.

22.7 PARTICIPATORY PLANT BREEDING AND SEED PRODUCTION

In both Mexico and Cuba, the facilitation of farmers' genetic diversity through seed diversity fairs increased the early reaction obtained from the first two seed diversity fairs carried out in Cuban communities. In Chiapas highlands, only one seed diversity fair was held, the other three did not reach harvest due to drought or flood.

In every place where seed diversity fairs were held, farmers showed great interest in introducing greater genetic diversity into their own farm system (Table 22.7).

In Mexico, participants appreciated that some traditional varieties were grown in seed diversity fairs. In this way, traditional varieties which had almost become extinct were chosen and multiplied by participants.

After farmers took seeds to be grown on their farms, different workshops were conducted to discuss selection methods at community level and experimental design principles. In La Cuenca del Papaloapan, the follow-up process in maize was focused in two communities: Doroteo Arango and Vega del Sol.

In Doroteo Arango, after one selection cycle working with professional breeders, the farmers had to move off their land because of conflicts of land tenure, and so their maize breeding programme was completely halted as all the farmers' efforts had to be oriented toward land recovery.

In the other community, Vega del Sol, germination of distributed seeds was poor with farmers losing all the varieties selected at the fair, so then the farmers and professional breeders decided to start a new collection mission in their communities. They collected 91 accessions in neighbourhood communities, setting up four experimental plots, one per colour.

After three years of mass selection, farmer participants had sown 17 ha of land with four maize gene pools: white, yellow, red and black, choosing the best cob each cycle. Farmers from the community started to make some negotiations with tortilla

TABLE 22.7
Genetic diversity chosen by farmer participants in the seed diversity fairs

Place	Crop	No. of participants	No. of varieties grown in seed diversity fair (b)	Chosen diversity (a)	Percent effective diversity (a/b × 100)
San Cristobal de las Casas	Maize	51	84	51	60
La Palma, Pinar del Rio	Beans	74	52	47	90.4
Ejido Valle Nacional, Municipality Santa Maria de Jacatepec.	Maize	163	131	91	69.5
Doroteo Arango Municipality Acatlan de Perez Figueroa	Maize	100	97	70	72.2
San José de las Lajas	Beans	42	70	46	65.7
San Antonio de los Baños	Maize	35	97	47	48.5
Los Palacios, Pinar del Río	Rice	41	80	60	75

Source: Ríos, 2005.

companies to provide maize for specialized markets.

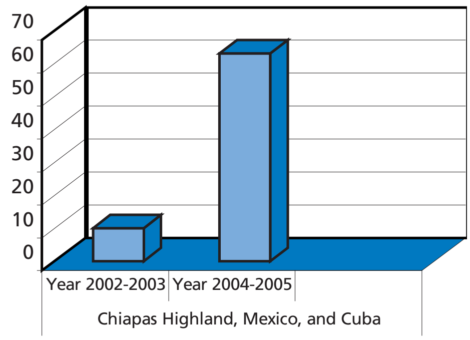
The General Farmers and Workers Union (UGOCP), which was coordinating PSD in La Cuenca del Papaloapan, had since the 1980s lead an Agrarian Reform, and its members were facing strong conflicts over land tenure. Once the farmers had land, UGOCP needed different approaches for enhancing rural development more independent from external resources. Indeed, involving farmers in plant breeding meant a new, more civil approach and orientation for UGOCP for the enhancement of local innovation and participation in making agriculture more sustainable.

PSD was an attractive initiative not only for farmers but also for technicians, researchers, functionaries, politicians and policy-makers, who learnt about the opportunities offered by genetic diversity for cropping systems using less agrochemicals, and about their and its relationship with indigenous knowledge. In practice, PSD showed to be a concrete approach for improving farming systems with interesting entrepreneurial opportunities.

In Chiapas and Cuba, the process developed so fast that the number of seed diversity fairs increased exponentially in rural and urban areas (Figure 22.5). Simultaneously, the number of different crops grown increased from 1 in 2001 to 18 in 2004.

In the particular case of Cuba, PSD in the period 2003 to 2008 increased from three communities in the western part of the country to a national group of practitioners. This means that training programmes could be designed and implemented with the participation of local stakeholder to strengthen local seed systems. Master in Sciences projects and PhD programmes have been implemented in the communities, with local universities starting to integrate their research work with farmer experimenter networks.

FIGURE 22.5
Number of farmer's experimental plots in Cuba and Chiapas



Source: Ríos, 2005

In rice cultivated under high and low potential environments in Cuba, farmers grew different varieties selected in seed diversity fairs. Interesting evidence has been reported by Moreno *et al.* (2005) and Lopez *et al.* (2005), who proved that varieties unpopular in seed diversity fairs had been officially promoted by the conventional seed system. In fact, PSD was adopted by the Popular Rice Movement as a national strategy to enhance rice genetic diversity to fulfil the different biophysical and socio-economic demands of popular rice growers in Cuba (Aleman, 2005, *Arroz con amor se paga*, video).

In Chiapas, Mexico, the process was initially introduced by UGOCP, and afterwards, the Development Secretary of Chiapas Highlands and the Indigenous People's Secretary of Chiapas endorsed the PSD approach as a key alternative for enhancing indigenous culture in the current social life of Chiapas State. During the scale-out process, two main reactions emerged: one where farmers were willing to start experimenting with varieties as never before to rescue maize and bean landraces in Chiapas; the other where economic support was requested to grow experimental plots. The second reaction appeared to be conditioned by other rural programmes, which supported subsidies for food production in the region. Some farmer leaders in favour of the second reaction decided to pull out of PSD.

In Cuba and Mexico, according to the perceptions of the participants, yields have improved in crops under the farmer experimentation process, and farmers were able to diversify and disseminate varieties to the rest of the communities after three years of testing (Lamin, 2005).

In general terms, the amount of seed produced by farmers increased exponentially in the participating communities.

22.8 DECENTRALIZED SEED PRODUCTION SYSTEM

After four working years, the research team noted some differences in seed production concepts between PSD and conventional plant breeding. In PSD, a defining characteristic is the integration within the household or community of genetic resource conservation, plant breeding, seed production, crop production and food consumption. In contrast, in conventional plant breeding, these functions are institutionalized, specialized and separated (Ríos, 2003; Cleveland *et al*., 2005). Therefore, most of the farmers working with PSD test genetic diversity and subsequently multiply their best options to fill different demands from the family, neighbourhood and local market.

In marginal and industrial environments, the tendency was to retain as much diversity as possible. The reaction of some farmers from marginal environments in keeping diversity was: "We need to keep various options because who knows how hard is the next season" (A. Alda, pers. comm.; Mohamed, pers. comm.). Through PSD, farmers reinforce seed production to be exchanged for experimenting next crop season or simply for culinary testing, and they use seeds for promotion or in barter for other products. In some cases, farmers who never grew seeds are selling seeds to farmers or to the state seed company. Unfortunately, the team has no details of the volume of seeds sold through PSD.

Actually the official scheme of releasing certified seeds to be adopted by farmers has partially broken down. In PSD, as in other participatory plant breeding methods, farmers adopted varieties by experimentation, and released their best options once disseminated varieties were certified (Ceccarelli, 2005, pers. comm.). In this sense, the seed production process in centralized plant breeding, with no participatory element, officially starts when improved varieties are multiplied and certified for dissemination. In PSD, because farmers are participating in the process of selection from the beginning and they are continuously accessing genetic diversity, seed production is an integral element of the process through which farmers decide the varieties or crops that have to be multiplied and disseminated.

Currently, four agrobiodiversity centres have been built by collaborative efforts between farmers and professionals scientists in Cuba, to promote diversity through diversity seed fairs, farmer experimentation and seed production by farmer decision. Primary diversity centres are farms with capacity to introduce, test and disseminate genetic diversity.

The speed at which PSD has spread in Cuba and Mexico has caused an interesting conflict: on the one hand, the legislation does not allow free national seed flow because seeds are not certified, and on the other hand, national food security depends on informal seed production in both countries. Therefore discussions to reconcile the differences are taking place in both Cuba and Mexico.

22.9 FARMERS' GENETIC GAINS

As yields were increasing in the communities, a discussion emerged in different communities implementing PSD about the real influences of farmer selection on yield response. In fact, the team and scientific community looked for hard evidence on farmer selection efficiency.

In conventional breeding programmes, one of the common indicators for determining the impact of selection consists of estimating genetic advance through selection (Falconer, 1960), which is described as follows:

$$S = h^2 \times DS$$

where: S = selection advance; h^2 = heritability and DS = selection differential, as discussed in detail in Chapter 2.

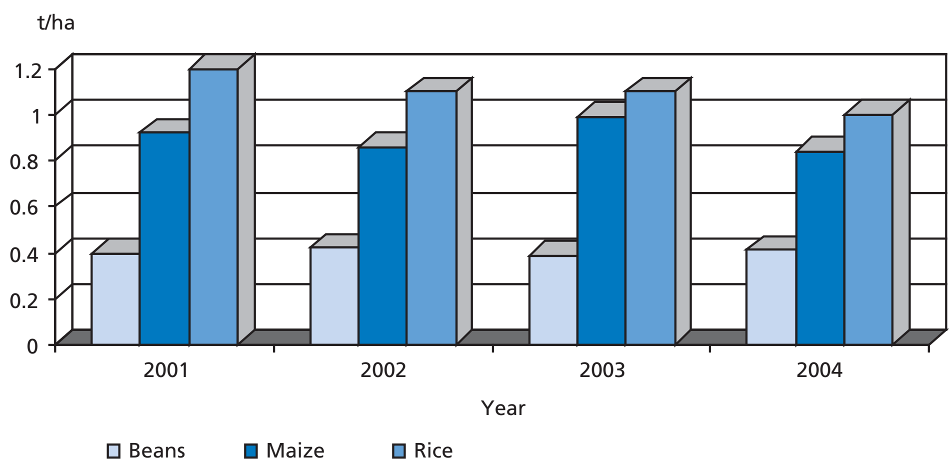
In the case of PSD, such estimation has been applied to each grower who has selected varieties during diversity fairs (Figure 22.6).

Indeed, the differential selection reached by farmers gave evidence of their capacity for obtaining superior materials amongst certain populations. The results strongly imply that farmers participating in plant selection and seed diffusion could collaborate in simultaneously increasing yields and diversity. In practice, access to diversity in the form of released varieties and segregating populations could provide an interesting fit at local level (see Rosas, Gallardo and Jimenez (2006) for segregating populations).

Other interesting evidence is the case of pumpkin breeding (Table 22.8). The farmers who choose gene pools on farm, according to their criteria, had more efficient use of energy for producing food and more profitable crops

Conventional pumpkin breeding in Cuba provides an example of the possible negative economic effects when

FIGURE 22.6
Average selection differential attained by farmers in 18 bean, 10 maize and 6 rice seed diversity fairs in Cuba



Source: Ortiz *et al*., 2005.

TABLE 22.8
Economic impact of pumpkin breeding under low input conditions

Indicators (calculated as averages)	Varieties bred under high input conditions sown in low input conditions	Varieties bred and sown under low input conditions
Cost per ha under low input conditions (Cuban pesos)	702.3	708.3
Fruit yield (t/ha)	1.5	6.7
Total income (@ 0.16 Cuban pesos per kg)	240	1080
Net income per ha (Cuban pesos)	-462(1)	372
Benefit:cost ratio	0.34:1	1.5:1

Notes: (1) average net loss.
Source: Ríos *et al*., 2002.

TABLE 22.9
Socio-economic and biophysical contexts of scaled-out Participatory Seed Diffusion

	Indigenous culture	Farmer literacy	Research-development policy priority	Production potential
Republic of Cuba	Low	High	Public sector	High-Low
Cuenca del Papaloapan	High	Low	Private sector	High
Highland Chiapas State	High	Low	Private sector	Low

varieties are selected in an environment not representative of the target area. The occurrence of a cross-over response (Ceccarelli *et al*., 1994; Ceccarelli and Grando, 2002) suggests the importance of having a realistic view about who will be using the products of plant breeding.

The experience described in this chapter attempts to maximize the role of local multi-sectoral efforts, including international, national and local stakeholders, through promoting the generation of benefits at local level by using PSD.

22.10 SCALING UP PARTICIPATORY APPROACHES

As a result of the outcome of the two breeding cycles in Cuba, the team and other partners decided to expand the pilot experience from the western part of Cuba in the form of a PSD programme for the central and western parts of Cuba, and to the Highland of Chiapas and La Cuenca del Papaloapan, Mexico. The working team was eager to know how PSDs, emerging from the western part of Cuba, could be practically adapted to other Cuban zones and abroad, with different biophysical and socio-economic contexts (Table 22.9).

What did we scale out? Chiefly we scaled out:

- The diagnostic phase, looking for local genetic diversity, intervention entry points and enabling institutional environments, for a change of paradigm.
- Seed diversity fairs in maize, bean and rice, to stimulate varietal demand and enhance farmer participation in generating benefits.

It was very effective to discuss the idea of PSD with a wide range of stakeholder participants; in fact, a constructive reaction was received from government, civil society and farmers. They built up the different teams and planned the activities, and immediately started to work. Local organizations were extremely cooperative in supporting the process.

The teams' main work objectives were to understand the seed flows, leadership relations and reaction of local policy-makers in terms of supporting the idea. In parallel, and as a key activity, teams collected genetic diversity from the formal and informal seed sector, mainly of maize and beans.

In addition, Cuba had a Popular Rice Movement which was highly suited to the application of PSD. The Popular Rice Movement is a people's movement to produce rice under low input conditions for self-consumption and markets within Cuba. This movement aiming at producing the main staple food emerged in the 1990s in response to the collapse of conventional rice production handled by the large state farms. Farmers were then allowed to plant rice everywhere, and the government made the land available for this (Moreno *et al.*, 2005).

In terms of farming approaches, in Cuba, farmers were experiencing a 'special period' due to the collapse of the Socialist Block in the late 1980s (Ríos, 2003), which in general terms meant that they had very limited access to agrochemicals and improved seeds of basic grains. In Chiapas, in contrast, upland farmers had no choice but to grow their crops in a marginal environment. In comparison, La Cuenca del Papaloapan was a high-potential environment and had received enormous agricultural investment in the 1980s for maximizing yields according to Green Revolution philosophy. In 2001, however, farmers in this region had, for various reasons, lost a major part of the official financial support.

According to the diagnosis phase carried out before the PSD intervention, farmers who have more diversity and dynamic seed exchanges in maize had more profits, in both Cuba and Mexico. The experimentation capacity of farmers seemed to be an important element for successful family business under restricted financial conditions (Ríos, Soleri and Cleveland, 2002).

In maize, a cross-pollinated crop, there were significant agromorphological differences between farmer-collected accessions, even though the local maize population had the same name: criollo, pintico, amarillo, negrito, blanco, etc. One hypothesis is that such diversity made it possible to improve certain complex characteristics, such as yield, through farmer participation (Acosta *et al.*, 2003; Martinez, 2005). In the case of beans, a self-pollinated crop, few bean types existed in industrial farming systems, and in certain lowlands of Chiapas farmers decided to stop growing beans due to disease attacks, whereas in the upland it was possible to collect different types of beans to be intercropped with maize.

In general terms, with beans, farmers perceived increased disease susceptibility and loss of genetic diversity over the previous decade. Limited access to new genetic diversity from either the formal or informal seed sectors was evident. Some morphological differences were found to be limiting genetic diversity within grain colour of farmers' beans prior to the PSD intervention (Miranda, 2005).

Finally, the team's work showed that the situation for Cuba and Mexico was common in terms of limited access to financial resources to buy seeds and agrochemicals for the production of basic grains. In the particular case of Mexico, stakeholders felt threatened by the USA policy of selling cereals at very low prices. In fact, the limited economic situation faced by Cuba, in relation to Green Revolution concepts, was not exclusive; other regions were suffering from similar problems and local innovation was emerging as a response for overcoming obstacles to producing food.

22.11 EXTERNAL COSTS OF PARTICIPATORY APPROACHES

Apparently PSD seemed to be an attractive process for local stakeholders; however, after four years of PSD implementation, one important question emerged: What will happen once PSD is no longer financially supported by external donors?

One of the key discussion points about public innovation systems in agriculture is in regard to financial support. NARS have been losing funds, and the international core budget of the CGIAR centres has fallen over the last 14 years (CGIAR, 1990–2004). As a consequence, both national and international institutes have been forced to be more innovative in their activities in poor regions.

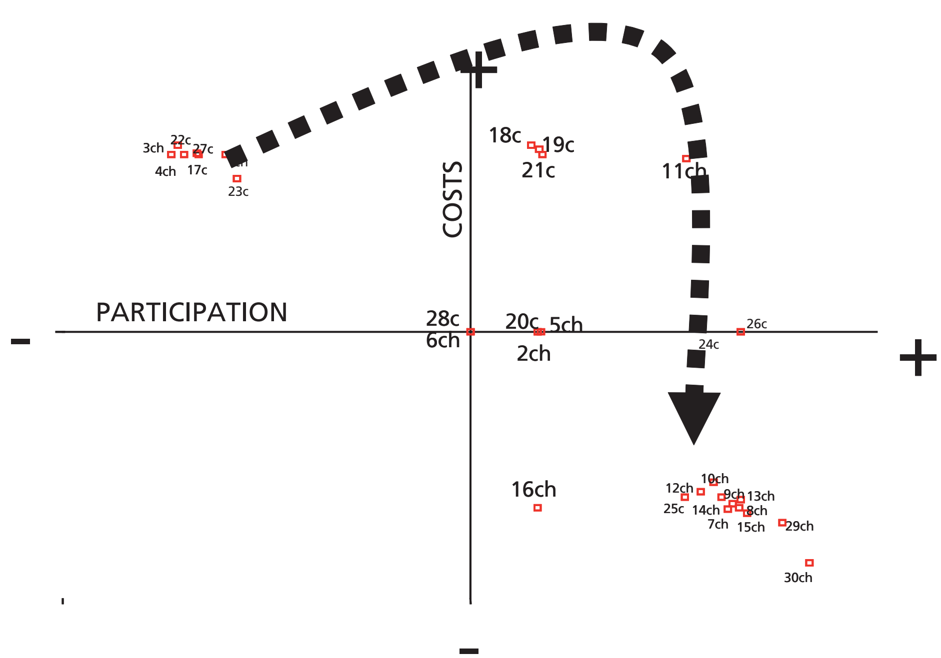
Taking this into account, the team estimated the external cost tendency and its relationship with the participatory approach in PSD.

An analysis of participation and external costs was carried out for all the maize and bean seed diversity fairs organized in Cuba and Chiapas over the last four years. To reach a better understanding of the relationship between participation and external costs, a graph (Figure 22.7) represents the two components plotted.

In the x component, participation was represented by different categories as follows:

- *Very high*: Farmers organized seed diversity fairs on their farms with varieties and technologies brought by themselves, they were able to involve communities in undertaking participatory approaches.
- *High*: Farmers organized seed diversity fairs on their farms with technologies

FIGURE 22.7
Participation versus external cost of participatory diffusion of bean and maize seeds in Cuba and Mexico



and varieties brought by professional researchers, farmers, NGOs, private companies, etc. Farmers were able to involve communities in undertaking participatory approaches.

- *Medium*: Farmers organized seed diversity fairs on public property, and seeds and technologies were supplied by farmers and professional researchers; farmers were partially able to call on participants for undertaking participatory approaches.
- *Low*: Public or private institutions organized seed diversity fairs on experimental stations, and researchers, extension agents, public or private functionaries took decisions. Farmers could not involve other farmers in undertaking participatory approaches.

The y axis was represented by three categories of external costs as follows:

- *High*: The expenses for food, participant transportation and implementation of diversity plots was covered by the project.
- *Medium*: The food expenses and participant transportation was paid for by the project. The expenses of implementing diversity plot was covered by communities.
- *Low*: The implementation of experimental plots, food and transportation was covered by the communities.

Figure 22.7 shows how the external cost decreases with an increase in participation over the four years of project implementation. The results show that external costs could be reduced gradually when local stakeholders adopt participatory methodologies, and the recognition of farmer knowledge as well as the economic benefits of farmer experimentation seems to be an important incentive for developing PSD. Farmers decided to incorporate trials as organic components of their farming systems.

The PSD in Chiapas was largely focused on the highlands, with farming systems on sloping areas, and with farmers having very low literacy levels. However, most of the characteristics represented by the high participation and low external support in Figure 22.7 belonged to the seed diversity fairs developed in that region.

The results confirmed the hypothesis that local innovations are not strictly related to literacy levels. Even though farmers had a high literacy level in Cuba, the relationship between professional scientists and farmers was weak before the collapse of the socialist countries, and it was currently taking some time to establish a new relationship. It has been a difficult process to convince the professional scientists to consider farmer participation as a scientific element of their profession.

In general terms, the agricultural education systems did not consider farmers as collaborators or partners of research work, scientific services or policy-making, and decisions in agriculture had a very strong top-down character. However, research institutes and development organizations have worked directly in different ways to quickly adopt participatory plant breeding methodology, even though the concept was not well documented. Personal influences of researchers have played a critical role in scaling-out PSD (Chaveco *et al*., 2006).

22.12 CONCLUDING REMARKS

Usually, the route of plant genetic resources collected in communities ends at research institution gene banks, to be used in conventional plant breeding programmes (Almekinders *et al*., 2000). The experiences discussed in this chapter provide evidence of how material from collecting missions could be tested, multiplied, improved and disseminated by farmers and local stakeholders. In practice, PSD maintains landraces by using farmer experimentation. Traditional varieties were re-evaluated within local and national contexts.

Due to the progress of seed diversity fairs and farmer experimentation, farmers in Cuba and Mexico started to add diversity to their farming systems with additional species. They were able to organize seed diversity fairs, simple experimental designs on-farm, and diffuse diversity among themselves, in their communities and to professional scientists. Farmers were able to produce seeds to be distributed.

Interesting combinations of cropping systems with new and old crops and new technologies emerged from the collaborative efforts. Currently, two instances have emerged so far: hundreds of concentrate formulas for animal feeds were built up from the collaborative efforts promoting agrobiodiversity enhancement and farmer participation (Ponce and Rodriguez, 2005, pers. comm.).

Recently in Chiapas, technical education is being organized with farmers using more than 30 seed diversity fairs, and the University of Villa Flores is implementing some maize breeding protocols in different regions of Chiapas State (Espinosa, 2005; Aguilar, 2005, pers. comm.).

Professional scientists actually doubted the capacity of farmers to simultaneously manage four or five trials of different crops, but finally they realized that farmers had a more profound conception of their farming system than had been imagined by professional scientists.

Conventional plant breeding has an enormous capacity for diversity generation in major crops. Moreover, powerful selection methods for fixing important genes into certain populations are undertaken by international and national research centres. However, the explicit aim of reaching wide geographical areas is a limiting factor when developing capacity for seed diffusion in diverse biophysical and socio-economic contexts. In this sense, organizing farmers into local innovation groups can maximize local, national and international efforts.

To consider only conventional research and development organizations as partners in plant breeding could be underestimating other strong forces for driving demand and having positive impact in rural and urban areas. Public and private innovation initiatives need to involve farmers and other local stakeholders as a key forces for agricultural benefit.

In fact, the PSD has been a continuous learning process in action. The professional breeder participants become more efficient in their interventions, and farmers more precise in their experimental systems, so it is crucial to enhance collaboration between farmers and scientist-technicians for generating and sharing benefits at community level. The action of the project has been able to influence the inclusion of the PSD concept into the education curriculum, nurturing new, critical students capable of combining biological and social sciences in Cuba and Mexico.

The institutional participants noted that involving farmers in the process of plant selection helped to recognize the enormous value of diversity generated by national and international centres as well as the genetic diversity managed by farmers. Before PSD, national scientists had few collaborators and limited impact from their work. However, currently and because of the increasing demand for genetic diversity, they have hundreds of collaborators multiplying local, national and international efforts in diffusing genetic diversity.

Currently, the public research institutions are suffering from severe financial restrictions; they are strongly influenced by external budget changes, which are very vulnerable to socio-economic or political changes. The field experience described in this chapter provides a clue that genetic diversity could lead to a viable, small, economic initiative for many local stakeholders.

New institutional arrangements for enhancing collaborative efforts between scientists and farmers seem to be an important issue in reaching a better understanding of local seed systems and agrobiodiversity incentives (Vernooy, 2003) as 'development cells' for national and international development.

It is quite clear that the experience accumulated from PSD in Cuba and Mexico shows that innovation in agriculture is not exclusively a business for professional scientists, but that by involving local stakeholders and farmers the impact of plant breeding in different contexts might increase. PSD has been able to revive the professional plant breeding role and farmer knowledge in a current context. Perhaps the results obtained by the collaboration of farmers and scientists, and the difficult economic situation faced by national and international public plant breeding, could facilitate new approaches towards more diverse, productive, socially and economically fair plant breeding in future years.

The economic and energy efficiency of selecting varieties under real environmental conditions, and farmers' attitudes to experimentation, become important arguments to convince policy-makers to apply PSD as a transformative tool in agriculture. Officially, PSD has been focused as a method to encourage public welfare and re-evaluate public institutions in Cuba. At the same time, the organizations leading PSD in Mexico are focusing on more entrepreneurial tendencies to show how people marginalized by top-down approaches can be recognized as innovators and potential local managers of plant genetic resources. In practice, both country cases are dealing with their own contexts. However, both countries are enhancing diversity, farmer participation and new technological and institutional arrangements towards more integrated food production.

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CHAPTER 23

Towards new roles, responsibilities and rules: the case of participatory plant breeding

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Yiching Song and Sally Humphries






23.1 INTRODUCTION

This chapter discusses three interrelated topics: the roles of the people involved in new, participatory plant breeding (PPB) approaches; the type of research management process that best guides these approaches; and a number of institutional issues that influence the space for doing things differently. These three topics will be illustrated with concrete examples of new practice from around the world. New plant breeding approaches were developed in order to do things differently, complementing and providing an alternative to conventional plant breeding. Hence, the focus of this chapter is on practice. However, we argue that this new practice could benefit from theory, and that many interesting and valuable theoretical insights are available. Brief mention will therefore be made of a number of relevant theoretical insights from fields such as participatory learning and action research, development studies, and organizational development studies. At the same time, we also hope that the new practices presented here inform and advance participatory plant breeding theory.

23.2 PARADIGM SHIFT

As we have argued elsewhere (Vernooy, 2003; Vernooy and Song, 2004), a new scientific practice is warranted to address persistent rural development issues such as food security, biodiversity conservation, environmental management and empowerment. This also affects crop science. Conventional plant breeding in most countries has been and remains largely centralized. Key research decisions are made at the top of the organizational hierarchy: Which crops to focus on? Which researchers to fund? and Which methods to use? Experiments take place at one or a few experimental stations. Variety release requires approval from a central body, and seed regulations are defined centrally. This practice is characterized by top-down decision-making and information flows. Farmers or others interested in variety diversity and improvement have little or no meaningful say in the process. The research process is very much inward oriented and often disconnected from farmers' experiences of the diverse and often rapidly changing environment(s) on which they depend.

This kind of practice is informed by reductionist thinking. This implies two main things. First, reductionist measurement fails to take into account the multiple and interrelated variables that farmers rely on to judge the value of a crop and cropping system. These farmer variables are often, if not always, site- and season-specific, embedded in particular genotype-by-environment (G×E) variations, informed by social variables such as gender, class and ethnicity, and influenced by socio-economic factors, such as market access and access to services such as credit, research and extension.

Second, conventional crop research tends to disregard local biodiversity, or at best considers it very instrumentally: as inputs for breeding, and best maintained *ex situ* in the proximity of the breeding station. It neglects the importance of biodiversity at the landscape and agro-ecological levels. If you reduce agrobiodiversity you weaken the resilience of agro-ecosystems and their capacity to deal with change. When this happens, communities face more limited options in managing their land and resources. The end result is that opportunities for the creation and re-creation of farmer knowledge and experimentation – the very processes that are essential for agrobiodiversity conservation, evolution and improvement – are lost. This relationship between social and biological diversity is often overlooked (Vernooy, 2003).

Conventional crop research is also positivist in nature, seeking the accumulation of objective knowledge through the production of empirically testable hypotheses. This paradigm is mirrored in a so-called reproductive learning perspective (van der Veen, 2000) that assumes that there is a body of objectively verifiable knowledge and that this can be taught by breaking down content into its essential elements. Such a perspective has serious limitations. An alternative is provided by a social constructionist perspective that views the role of science as the creation of concepts or theories that expand flexibility and choice (Röling, 2000). This view postulates that all social action is open to multiple interpretations, none of which is superior in any objective sense.

Social constructionist learning assumes that important features of the external world are uncertain and disputed, and that people actively construct their understanding of it. Rediscovery and innovation, not repetition, are essential parts of this construction process. In practice, researchers and development workers often assume roles as facilitators, rather than instructors. They encourage work in groups and shared planning, action and reflection. A social constructionist perspective also can be informed by transformative learning (van der Veen, 2000). In this approach, learners together build a more integrated or inclusive perspective of the world. Through the learning process they jointly transform some part of their worldview, for example, their understanding of social relations in their own community. Manifestations of transformative learning in natural resource management include, for example, new values or patterns of decision-making that farmers generate and apply outside the immediate arena of the learning intervention.

23.3 INTERACTIVE ROLES

From a practical point of view, the foregoing implies working toward a new division of labour, new partnerships and new forms of decision-making and learning. PPB approaches developed during the last decade have made significant inroads into giving concrete shape to these new roles and responsibilities. One of the goals of PPB is to involve farmers in the research in ways that are meaningful and useful to them, improving the quality of their participation as a means of empowerment. Farmers are no longer just the passive (end-of-the-line) recipients of technologies, seeds and information. In participatory approaches, they are encouraged to take on active roles, help set direction, and take part in decision-making. Women farmers in particular have a priority place because they often have intimate knowledge of crop production and reproduction. They often also have particular needs and interests in food security, and play leading roles in households, extended families and social networks.

Participatory approaches focus on meaningful, fair and iterative interaction. From a decade of PPB experience around the world, we know that all this is easier said than done. PPB requires a lot of effort. Concretely, it means that those who take the initiative to practise PPB, be they originally (more) farmer or (more) scientist-driven, need to pay special attention to:

- Getting to know the various people involved, and building trust.
- Getting to understand and respect different (and sometimes initially opposing) perspectives, interests and expertise.

- Acknowledging personal, social and institutional constraints to collaboration.
- Communicating clearly and in a timely manner.
- Finding common ground through discussion, reflection and negotiation.
- Defining tasks to be accomplished and agreeing on who will do what and when up-front, e.g. setting objectives; selecting germplasm to be used; choosing breeding, propagation and selection methods; selecting sites where the research will be carried out; identifying the type of end-product to be produced; and agreeing on the means by which the product(s) will be distributed (i.e. benefit sharing).
- The time and effort that any change process requires, and the often very slow pace of change in everyday life.

These points imply exploring the practical meaning of participation, its potential and limitations.

23.4 PARTICIPATION: INTENT, DECISION-MAKING, CONTEXT

There are many ways in which participation in a research cycle can be organized and managed. Participation is a normative concept and implies argumentation and negotiation, and sometimes contestations and struggles over knowledge, intent, interests, direction, results and benefits. Whether we practise participation in a project setting or as part of a broader development process, it means having to deal with politics: Who defines the agenda? Who makes decisions? Who reaps the benefits? Who is included or excluded? Participatory research can take a variety of different forms in terms of who participates, how and when, and who decides about what, how and when. The forms it takes also depend on context. In the case of a research project, this context includes the organizational set up, but also the wider societal configuration, including the economy, policies and laws, and the social make-up. After all, research endeavours do not operate in a void. A useful typology of participation is the following:

- **Contractual participation.** One social actor has sole decision-making power over most of the decisions taken in a research process. Others participate in activities defined by this social actor in the sense of being formally or informally 'contracted' to provide services and support.
- **Consultative participation.** Most of the key decisions are made by one social actor, but emphasis is put on consultation and gathering information from others, especially for identifying constraints and opportunities, priority setting and evaluation.
- **Collaborative participation.** Different social actors collaborate and work on a more equal footing, emphasizing linkages through an exchange of knowledge, different contributions and a sharing of decision-making power during the innovation process.
- **Collegial participation.** Different social actors work together as colleagues or partners. 'Ownership' and responsibility are equally distributed among the partners, and decisions are made by agreement or consensus among all, from identification of the research problem or opportunity, through to final assessment.

It is useful to differentiate between types of participation in order to understand how this influences research results. 'Community' participation in research can be differentiated according to the level of control over the process (who sets the agenda), when (at what stage of the research), and according to the nature of representation (who speaks for whom). We conclude this section by arguing that there is no right or wrong amount, or a single manifestation of participation. It depends on intent. Participation is always a social product, i.e. it emerges from people interacting and joining forces in practice. The actual process and outcomes depend on many factors and will be shaped and sometimes constrained by unforeseen events. Outcomes sometimes include unintended consequences, some perhaps considered negative, some perhaps positive. To illustrate some of the points made so far, we present the first case study.

23.5 CASE STUDY 1: NEPAL

In the late 1990s, the non-governmental organization (NGO) Local Initiative for Biodiversity Research and Development, better known as LI-BIRD, based in Pokhara, Nepal, undertook a study in the low hill region of Nepal to document and analyse farmers' knowledge of upland rice (*Ghaiya*) varieties. A team of one plant breeder and four agricultural technicians carried out the study, with the involvement of men and women farmers of five villages where local Ghaiya diversity was predominant (Joshi, Rana and Subedi, 2001). The study was done and directed by the LI-BIRD team using techniques such as resource and social maps (through transect walks), participants observation, interviews, group discussion, and the collection of farmers' preferred varieties.

At the same time, the team initiated a so-called participatory landrace selection process, similar to a participatory variety selection (PVS) process. In this case, selection concerned landraces from the region collected and selected by the research team instead of modern varieties that are often used for PVS. The landraces were selected by the team on the basis of the results of the documentation study, i.e. to match farmers' interests in particular varieties or traits in varieties, such as drought tolerance, grain quality and yield potential on poor soils. These were the breeding variables about which farmers were most concerned. The research team designed the outline of the subsequent experiment, in which a number of farmers took part in testing the newly introduced varieties.

The LI-BIRD team decided how to distribute seeds, how many, and to how many farmers. Farmers themselves decided where to test the varieties received, how to grow them, and with which varieties to compare them. The team later documented and analysed these farmer decisions. During various stages of the cropping cycle, the research team documented farmer assessments of the new varieties, individually and collectively, using questionnaires, farm-walks and group discussions. The collective assessment served as a means to interact with all the farmers about their experiments.

The research team concluded that this process of participatory landrace selection was an effective means of broadening the range of suitable Ghaiya landraces available to farmers, at little risk to them and at a relatively low cost to the researchers. Farmers were able to evaluate new options under their own farm conditions, observe results at other farms, and to come to useful conclusions in a relatively short time (two years of experimentation). LI-BIRD also concluded that now that this methodology has proven effective, it should be easier to use it in the future, given that costs per unit would be lower. In particular, given that there is very little institutional support for Ghaiya rice, this would have great merits for (poor) farming communities. LI-BIRD and partners in Nepal continue to build on this experience, expanding it to other sites as well as to other crops.

Working *in situ*, and decentralization

The Nepal case study points to a number of important features. Perhaps the first to note is that the LI-BIRD research team worked *in situ*—on farms and in communities—with farmers as research colleagues, each complementing as much as possible the other's knowledge, skills and experience. In this case, the research project was and remained strongly LI-BIRD directed, as the team decided where to work and also maintained a generally strong hand in directing the research process, i.e. selection of varieties to be tested, seed quantity, and number of farmers invited to grow the 'new' varieties. These decisions clearly affected the results. Although farmers benefited from introduced varieties, it is likely that their relatively limited decision-making restricted the potential for a more transformative change. (This is an observation about the relationship between intent and result, and should not be seen as a critique.)

Another feature that emerges from the case study is that decentralization replaces centralization as the main organizing principle in order to address specific local contexts, i.e. G×E interactions, and socioeconomic variables including age, class or caste, gender and ethnicity. Although the research described took place at only one site, as a means to validate the approach, LI-BIRD subsequently concluded that this principle of decentralization could be used on a wider scale, and probably countrywide. Again, here we are dealing with a researcher-directed intervention, but one that could have potentially a much broader impact as it concerns an organizational principle at the programme, and even national research policy, level.

Decentralization (see also Chapter 9) has been at the heart of many alternative approaches, but, as with participation, it comes in many forms and degrees. The International Centre for Agricultural Research in the Dry Areas (ICARDA) participatory plant breeding efforts in the Middle East and North Africa are based on it. One of the advantages it offers in terms of efficiency is that selection in farmers' fields avoids the risk of useful lines being discarded because of their relatively poor performance at experimental stations, where conditions are almost certainly more favourable. Decentralization as an organizational practice could be looked at with the same perspective as participation.

23.6 CASE STUDY 2: ICARDA

This study is adapted from Vernooy (2003), and based on various ICARDA research results and publications.

In the late 1990s, a team of researchers at the ICARDA pioneered a new way to work with farmers in marginal rainfall environments of Morocco, the Syrian Arab Republic and Tunisia. They set out to work together with farmers and aimed to fulfil the needs of people living and working in the harsh conditions of the region. In Syria, for example, researchers worked with 'host farmers'. In the context of Syrian farming, these were men who accepted the invitation made by the researchers to partake in the research in nine communities (identified by the researchers) and with two regional research stations. These host farmers and their neighbours, varying from a few to a dozen or more, took care of the trials, which involved experimental lines from the research station and the farmers' own varieties. Farmers and breeders assessed the results independently in successive trials from 1997 to 1999. Several promising new varieties were identified from these trials.

It quickly became apparent that the farmers' selection criteria, largely based on environmental factors, were quite different from those used by the national breeding programmes. To the surprise of many, the selections made by the farmers were at least as effective as those made by the breeders. The newly introduced materials gave good yields, and this in areas where plant breeding had not previously been successful. Farmers also gained access to varieties that responded to preferred traits such as tall plants, large kernels, good early growth vigour, high tillering and lodging resistance. Seeing these promising results, breeders quickly adopted the new ideas and attitudes, becoming supporters of the participatory approach and expanding it to other areas and to other crops. The team learned that earlier plant breeding programmes were ineffective on marginal lands because they seldom included among their selection criteria those traits that are important to farmers.

In addition, it became clear that decentralized selection in farmers' fields 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. Decentralized selection combined with farmer participation from the initial stages of the breeding process is a powerful methodology to fit crops to specific biophysical and socio-economic contexts, and to respond to farmers' needs and knowledge.

The researchers learned a number of other critical lessons from the project. Among them is the fact that farmers can handle a large number of lines or populations, or both. Most notably, in Syria in phase 2 of the work, the number of lines assessed in some villages increased from around 200 up to 400! In fact, farmers warmly welcomed the ability to select among a large number of lines; some farmers have started seed increase of selected varieties. This has opened the window to a more dynamic process, with new materials being introduced at any time.

The researchers also noted that women's selection criteria often differed from the men's, highlighting the importance of ascertaining when and why they differ. They also noted that farmers became empowered by their involvement in the research process, gaining the confidence to take decisions on crosses as well as on factors such as plot size and the number of locations. Perhaps of equal importance to the researchers themselves, the project revealed the need for specific training in areas such as experimental design and data analysis suitable for situations where the environment (a farmer's field under farmer management) cannot be under the scientists' control as it is in the research stations. ICARDA and national partners have continued to expand their efforts by scaling-up the approach in the national systems in the region and by trying out the methodology on other crops.

Research management

What becomes apparent from the above discussion and case studies is that such new approaches require a different way of organizing time, labour and the research process, i.e. the roles and responsibilities previously described. The emphasis is on step-wise producing or co-producing as effectively and efficiently as feasible 'a project' through face-to-face interactions, especially in the field. Bringing different disciplines to the table and field is one important element. Research management requires flexibility. It is not about implementing blueprints. This new method of organizing time and labour will therefore benefit from adaptive process management knowledge and skills. Farmers usually already have a significant amount of this capacity, and it is useful to build on their expertise, and perhaps, where useful, explore ways to strengthen it. Researchers may need to be trained to acquire this capacity. Insights from learning theory can be of much value, as well as from participatory monitoring and evaluation approaches.

Start-up periods of collaborative research are usually very labour intensive, requiring a good deal of time and effort to lay a foundation of trust and to build working relationships, both within the research team, and between the core team and others involved in the research. Longer-term commitments are important, to be able to create meaningful and effective collaboration and to cope with unavoidable setbacks, such as a crop failure due to drought. Experiments, particularly in plant breeding, usually require various cycles of selection to produce useful results, and thus time horizons should not be too restricted. Organizing regular feedback opportunities and using the results promptly to adapt or change directions is another important element.

23.7 CASE STUDY 3: CUBA

The study is adapted from Vernooy (2003), and draws on National Institute for Agricultural Sciences (INCA), Cuba, research results and publications.

In 2000 an interdisciplinary group of dynamic researchers at INCA took on the challenge of reshaping agriculture on the island. They began a project designed to improve the yield and quality of the maize and bean crops in both unfavourable and more favourable production areas, through a combined effort of increased varietal diversity and strengthened local farmer organizations. The project is already making an important contribution to improving Cuba's food security options.

The key element in the project has been to involve the farmers, and this has been achieved through farmer research in experimental groups. The project team believed that strengthening the organization of farmers increases their capacity to experiment and innovate and to make stronger demands on the formal agricultural research system. One method the researchers used to introduce farmers to new or unknown varieties or lines was the seed fair. Initially, this took considerable planning and facilitation efforts as fairs were organized by the INCA team and at the INCA station. Farmers were wary of this new approach (none had ever visited the INCA station), but many attended out of curiosity. What they saw overcame their reservations. The researchers managed to collect genetic materials for many maize and bean varieties (later, fairs were organized for other crops), including commercial and local varieties, as well as promising new lines. The farmers were impressed.

The fairs demonstrated to farmers the diversity of their staple crops. The researchers subsequently allowed the farmers (men and women) to select materials for testing in their own fields, under local conditions. This proved very popular and successful. It proved that farmers are able to assess and select from a large number of options alongside breeders. Ultimately, the fairs have proved to be hugely popular, so much so that farmers quite spontaneously started to organize similar fairs in their own communities. Initially, the researchers guided and supported the farmers in doing this, but subsequently farmers organized fairs mostly or all by themselves. Farmers, breeders and extension agents now continue to rub shoulders at fairs, assessing varieties, and selecting the ones they like best. Breeders continue to assist farmers with experimental design on-farm, but all trials are adapted to the local context.

Farmers say that in addition to introducing new and higher yielding maize and bean seeds (e.g. bean yields in the Havana experimental site have gone up on average by 15 percent and in the La Palma site by an average of about 35 percent), some of which are also more resistant to diseases, the fairs provide new knowledge about how to handle and conserve seeds. By developing closer links between farmers and researchers from the formal system, the fairs have also increased the farmers' capacity for experimentation. And last, but by no means least, the fairs have become social and cultural events that bring rural people together, young and old, and give them an opportunity to share their knowledge and experiences.

The project team also organizes regular field days as another way to learn more about farmers' preferences. Here the farmers, both men and women, are interviewed about their preferences. The information gathered is crucial for the INCA plant breeders in identifying parental materials and selection criteria. To date, the project has been successful at both broadening the genetic base and improving the quality of varieties. INCA is currently extending the methodology and results to other provinces through collaboration with other Cuban agricultural research entities. Envisioned is the creation of a national network to exchange experiences, new ideas and seeds, and to provide inputs into the policy-making process.

Interdisciplinarity and facilitation

The case studies presented so far indicate that interdisciplinarity is desirable. Understanding natural resource and crop dynamics requires taking into account both the biophysical and the social dimensions of the processes involved in managing and maintaining productivity and agrobiodiversity. Plant breeders have much to gain from working with social scientists in an interdisciplinary research mode to document and analyse the social nature of farming, plant breeding, and of doing research. Social scientists have the opportunity to ground their work in real-life situations.

Facilitation and convening are new and important additional roles for traditional plant breeders. Additional training is an important investment if these skills are lacking (among researchers or farmers, or both). Working with a diverse group of people – including scientists in various fields, women and men farmers, and extension workers – means balancing a variety of ideas, interests, skills and personalities. Managing the process of participatory planning, implementation, monitoring and evaluation means paying significant attention to interactions and communication, as well as ensuring openness and fairness. Building and strengthening the participatory process becomes a central part of the agenda. The following case is a good example.

23.8 CASE STUDY 4: CHINA

This study is adapted from Vernooy (2003), Vernooy and Song (2004) and various Center for Chinese Agricultural Policy (CCAP) documents.

In China, new plant breeding approaches have been pioneered by CCAP, a leading agricultural policy research institution that is part of the Chinese Academy of Sciences (CAS), and by the Guangxi Maize Research Institute (GMRI), part of the Chinese Academy of Agricultural Sciences (CAAS). The CCAP/GMRI research aims to identify technical and institutional options for developing more effective linkages and mutually beneficial partnerships between the formal and farmers' seed systems. The main hypothesis is that only such new institutional development can enhance sustainable crop development. and *in situ* and on-farm management of genetic resources. It also aims to strengthen women and men farmers' research and management capacities to maintain agrobiodiversity in the specific Chinese context.

A major PPB project was implemented in Guangxi province in south-west China following an impact study carried out from 1994 to1998 by the International Maize and Wheat Improvement Centre (CIMMYT) to assess the impact of CIMMYT's maize germplasm on poor farmers in south-west China. That study critically analysed the processes of technology development and diffusion. One of the key findings of the impact study was the systematic division between the formal and the farmer seed systems. This resulted in inadequate variety development, poor adoption of formally bred modern varieties, an increasingly narrow genetic base for breeding, and a decrease in genetic biodiversity in farmers' fields.

The project team supported farmers' groups through training, linkages and network building, and market involvement among farmers and with the formal system actors. Policy-changes aim to bring about conceptual change among formal research and seed system actors so that they better understand farmer roles and enable farmer participation. The project is implemented by a team of women and men from various institutions and groups, from different disciplinary backgrounds and operating at different levels. Five women farmer groups, six villages, six township extension stations, two formal breeding institutes and CCAP have been directly involved in project design and implementation. The team is engaged in an ongoing dialogue in order to integrate the very many contributions from the very broad expertise base. This is not always easy, but so far efforts have been very productive.

The research uses a participatory plant breeding methodology adapted to the local context. Trials in six villages and on-station have included both participatory plant breeding and participatory variety selection experiments. The trials allow for comparison in terms of locality, approach, objectives and the types of varieties tested. Varieties include landraces, open-pollinated varieties, so-called waxy maize varieties, and varieties introduced by CIMMYT. Some of the CIMMYT varieties have been locally improved through crossings and selections. Agronomic traits, yields, taste and palatability of these improved varieties are satisfactory. They are showing better adaptation to the local environments. Varietal diversity is increasing.

The project's PPB field experiments, both in farmers' fields and on station, have been functioning successfully as a platform to involve the main stakeholders from both formal and farmer systems. They have facilitated effective interaction, communication and collaboration among them. Through this platform, the approach and results have reached high-level decision-makers (at the provincial and national levels), and some inroads have been made into the policy process. Farmers, women in particular, are now speaking up in meetings and expressing their ideas, needs and interests. In a still strongly top-down research and policy environment, this represents a major change. PPB has also strengthened the local-level organizational and decision-making capacity of farmers. Groups of (mostly women) farmers have started to define specific support that they would like to receive from the extension service.

They have put forward the idea of initiating seed production and marketing, in particular of pollen variety maize seeds. Marketing research is underway in Guangxi and neighbouring provinces. The aim is to add value to the women farmers' produce. This is expected to make the on-going activities and process of PPB and agro-biodiversity management more sustainable. In addition, following the organization of a first successful diversity fair in 2003 in the township, they are now planning follow-up fairs in their villages, and possibly in the city of Nanning, the provincial capital. They plan to sell theirs seeds at these fairs.

Creating an enabling environment: institutional issues

Roles and management process questions lead to the consideration of a number of institutional issues. Perhaps the most important ones are incentives and rewards that recognize and value promising and successful efforts. Perhaps the basis for all PPB approaches involves two tenets: farmers have a key role to play in crop improvement; and farmer-researcher collaboration can produce added value that farmers or researchers alone could never realize. Acknowledging and institutionalizing these two tenets then becomes paramount. But there are other institutional issues of importance. Farmers should be officially recognized as 'co-authors' of new varieties and recognized in publications that document PPB processes and final results. Plant breeders should be recognized and rewarded not only for the release of new varieties, but also for their contribution to the process leading to the final products. Increasingly, so-called access and benefit sharing issues are moving to centre stage. This theme is discussed in more detail in Chapters 9 and 24.

Research policies and grants should be targeted to proposals that deal adequately with process management questions, including the redefinition of roles, as outlined above. This means nothing less than a shake-up of most organizational practices, rules and regulations. Creating an enabling environment will therefore take time and effort. Although projects, with clear time and resource boundaries, have an important role to play to try out new ways of doing things, changes will be required that go beyond projects and must become embedded in everyday practices. This kind of change will probably not come easily, and could be frustrated by vested interests and opposing powers. Setbacks are to be expected. Accepting and fostering a learning-by-doing approach is still very novel.

The key organizational capacities required for promoting and supporting new approaches include staffing; infrastructure, technology and finances; leadership; management; and linkages and networking (Horton *et al.*, 2003). In many countries, organizations (be they part of the NARS, NGOs or Community-Based Organizations), have difficulties in sustaining, let alone strengthening, these capacities. Moreover, in several countries, there are numerous and often vast regions where there is no organizational presence at all for rural development. The challenge then becomes to look for alternatives (see the following and final case studies).

Other, very important, institutional issues relate to seed systems, at both the local and informal levels, as well as the national and formal levels, where one has seed regulatory frameworks dealing with varietal and seed quality; variety release systems regulating the spread of varieties of proven quality to farmers; phytosanitary law; seed certification schemes that aim to control varietal identity and purity; and seed quality control mechanisms that check viability, purity and health. This theme is discussed in more detail in Chapter 21.

These so-called regulatory framework components are embedded in broader societal institutions, including policies affecting rural development and agricultural research more broadly, e.g. land tenure, taxation, marketing, financing of public research, provision of credit, and provision of extension services. Depending on context, research into these broader institutional questions may be highly relevant. The current trend of shrinking budgets around the world for public national agricultural research seems to make this area particularly relevant.

Looking for opportunities to build on local change processes already in motion or to explore spaces for change becomes an important skill. The following case studies are examples of how spaces for change were found or created.

23.9 CASE STUDY 5: HONDURAS AND NICARAGUA: CREATING SPACE FOR EXPERIMENTATION, ENHANCING LOCAL ORGANIZATIONAL CAPACITY

The Honduras case builds on Humphries *et al.* (2005), and the Nicaragua case on Vernooy *et al*. (2000) and Vernooy (2003).

Local agricultural research committees, or CIALs to use their Spanish acronym, have sprung up all over Latin America. CIALs bring farmers and researchers together in a process of joint experimentation and learning. The concept was developed at the International Centre for Tropical Agriculture (CIAT) in Colombia, and it quickly caught on. They vary in size and characteristics, but they all have one thing in common: they provide a direct link between locally organized farmers and the formal agricultural research systems.

Honduras

In Honduras the number of CIALs has grown rapidly and there are now 82, comprising around 900 farmers in different regions of the country, most of them in remote mountainous areas where they are frequently excluded from conventional agricultural research and extension services. The CIALs are organized into five regional associations of a national CIAL federation, the Honduran Association of CIALs.

Fifty-five of the farmer research teams are supported by a Honduran NGO, La Fundación para La Investigación Participativa con Agricultores de Honduras (FIPAH), which began as a project entitled Investigación Participativa en Centroamérica, which was supported initially by CIAT and then by the International Development Research Centre (IDRC) between 1995–2000; since 2000 it has been supported by a Canadian NGO, USC-Canada, under its Seeds of Survival (SoS) Program, with financial backing from the Canadian International Development Agency (CIDA).

With a team comprising four local agronomists with the collaboration of a Canadian rural sociologist, FIPAH's agronomists have successfully bridged the divide between plant breeders at the region's largest agricultural research institution, La Escuela Agrícola Panamericana, Zamorano, and poor hillside farmers (Humphries *et al*., 2005).

Achieving organizational integration between farmers and scientists in Honduras is quite remarkable. In the countryside there are few strong community organizations available to national and regional institutions seeking to support local development, and local social capital has frequently been characterized as low. Thus FIPAH had to basically start organizing from scratch. Following years of regional conflict and military repression, local people were generally distrustful of group endeavours and building up the CIALs has required very strong facilitation skills. Farmers had to learn to trust the agronomists and their own capacity to undertake research, often in the face of local ridicule concerning the small size of the test plots. This necessarily took some time and therefore was not without cost. However, as CIAL members' research has grown to include the testing and evaluation of a broad range of technologies and, more recently, the successful improvement of local maize and bean landraces, they have earned their communities' admiration. Local CIALs are now supported by a group of farmer facilitators, local CIAL experts, who have increasingly taken over regular support to the CIALs from FIPAH agronomists. Today, the FIPAH agronomists mainly play a backstopping role behind the scenes, supporting the regional CIAL associations and farmer facilitators.

For plant breeders at Zamorano, the skill sets in agricultural innovation-testing and development that CIAL members have acquired present an extraordinary research opportunity. The plant breeders are now in a position to reach into remote agricultural areas, far from the experiment station, where they have never been able to work before. The recent results of participatory bean breeding, conducted both on-station and in farmers' fields, showed how different the choices made by breeders and farmers in marginal agricultural areas can be: none of the materials selected by the breeder at Zamorano was subsequently chosen by farmers once these were added to farmers' own F_6 trials.

Zamorano breeders who were once sceptical of involving farmers at an early stage of plant breeding, when segregation of materials is underway, are now convinced that farmer researchers are better placed than they are to decide what seeds work best in communities where biodiversity is high and where small socio-economic differences between families can lead to very different choices of technologies. This has led Zamorano breeders to conclude that the best strategy is to provide such farmers with a diversity of segregating materials as well as advanced lines to allow them to select what is best for them (Rosas, Gallardo and Jiménez, 2003). In addition, as Zamorano provides agricultural research support to countries throughout Central America and the Caribbean, recognition of the importance of participatory research as complementary to conventional breeding represents a considerable step forward in conceptual terms.

The final step is to engage the different CIAL Associations and their members in scaling up the PPB varieties. At the present time, Macuzalito, an improved, small red landrace bean, released by the CIAL Association of Yorito, Victoria and Sulaco in August 2004 (Humphries *et al.*, 2005) is being tested in the different CIAL regions prior to being multiplied up for wider use in the near future. A strong federation of farmers' organizations is vital if PPB is to have an impact beyond the locality where it was originally conducted.

Nicaragua

In one region of Nicaragua, a CIAT research team initiated a process of CIAL formation in 1999. The initial assessment of the organizational context in this region (the Calico river catchment) revealed on the one hand that very little formal agricultural research was carried out in the area or that the results of research carried out elsewhere (by the NARS) reached the area; on the other hand, it was learned that farmers themselves were not known to experiment very widely.

The CIAT team hypothesized therefore that there would be space for the implementation of the CIAL methodology in terms of providing a tool for farmer experimentation and strengthening of the organizational processes in the area. CIALs could create new groups or could build upon existing groups, and introduce new roles in the community, such as by providing a service through doing research for and with the community, opening the door to participatory decision-making, problem diagnosis and experimental design, and establishing new communication patterns among farmers and between farmers and external agencies, such as through CIAL-led presentations, field-days, and direct demand for support directed to outside agencies from the NARS.

The CIAT team also thought that CIALs could be players in changing the very much supply-driven mode of operations of most NGOs in the area into a more demand-driven one, as well as getting government agencies and universities interested in the area and problems and needs of farmers. The core idea behind the CIAT team efforts to initiate a process of CIAL formation was to provide local communities with a (new) way to carry out research collectively, focusing on and solving a locally felt natural resource management problem (to be identified through participatory problem analysis), and thus further enhance local organizational capacity.

At first, two CIALs were formed; over the years the number grew rapidly. Several committees have since moved on to experimenting on a larger scale, addressing new aspects of problems in their communities, such as soil fertility. A number of new farmer-leaders have emerged, including several women. Where possible, CIALs are linking to each other to exchange ideas and results within the catchment and beyond, through participation in the annual CIAL meetings in Honduras, for example. They also are building bridges to formal research and technology organizations in the country.

The Honduras and Nicaragua experience suggest that positive change is possible despite very difficult institutional contexts. Through sustained efforts, new organizational forms can emerge, a demand-driven research process can be set in motion, and useful linkages can be developed with and between local, farmer-led initiatives and national or international units, expertise and resources. These changes do not come about easily, and set-backs have been numerous. However, the CIALs are contributing to revitalizing rural innovation and to defining many new rules for the research and development game.

23.10 SYNTHESIS

This chapter has addressed three interrelated elements of the division of labour in participatory plant breeding: the roles of the people involved, the nature of the research management process, and a number of institutional issues that influence the space for doing things differently. Underlying these three elements is the need to pay attention to:

- Getting to know the various people involved and building trust.

- Getting to understand and respect different perspectives, interests and expertise.
- Bridging these perspectives, interests and expertise through an interdisciplinary, iterative, learning-by-doing approach.
- Acknowledging the very real personal, social and institutional constraints to collaboration, and actively finding ways to overcome them.
- Communicating clearly and in a timely manner.
- Finding common ground through deliberate planning, monitoring and evaluation efforts.
- Defining tasks to be accomplished, jointly and up front, and agreeing on who will do what and when, e.g. setting objectives; selecting germplasm to be used; choosing breeding, propagation and selection methods; selecting sites where the research will be carried out; identifying the type of end-product to be produced; and the means by which the product(s) will be distributed.
- Recognizing the time and effort that any change process requires, including the often very slow pace of change in everyday life.
- In other words, recognizing the need to explore the practical meaning of participation, its potential and its limitations.

PPB experiences to date, including those documented in this chapter, suggest that significant progress has been made in terms of the development of an alternative and complementary approach. This has not been without difficulties, constraints and setbacks. New challenges, such as scaling up (e.g. institutionalization) and scaling out (e.g. application and adaptation to more favourable production environments), have emerged and are now being researched in a number of countries, involving farmers, researchers, extensionists and policy-makers. These efforts tell us that organizational and institutional questions, such as those addressed here, are central to (participatory) plant breeding, deserving as much attention as more technical issues.

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CHAPTER 24

Breeders' rights and IPR issues

Susanne Somersalo and John Dodds

24.1 INTRODUCTION

Since Gregor Mendel in the 19th century laid the foundations for genetic improvement of crops and animals, several technologies have been successfully applied to improve characteristics of the crops. The improved plant breeding methods include among others cell culture techniques, mutation breeding and hybridization. Genetic modification of plants is one of the main milestones in plant breeding techniques during the last decades of the 20th century. Along with transgenic plants came the need to identify and detect genes and their products. Genome mapping and proteomics are the new areas of research, which are of importance also to modern plant breeding.

Traditionally, plants and plant varieties have been treated as common property. However, in the beginning of 20th century plant variety protection (PVP) arose by means of intellectual property rights (IPR). Originally, the need for protecting new varieties was raised by the breeders of ornamental plants. The Plant Patent Act of United States of America was implemented in 1930 to protect vegetatively propagated plants, excluding tuber crops. In the Netherlands, the Breeders' Ordinance was enacted in 1941, and Germany enacted its Plant Variety Protection legislation in 1953. The first International Convention for the Protection of New Varieties of Plants (The UPOV Convention) was signed in Paris in 1961, and established the International Union for the Protection of New Varieties of Plants (UPOV).

The rationale for PVP is to provide an opportunity for breeders to gain returns from the investment made in developing a new variety. It is also believed that protection may stimulate private sector investment and facilitate technology transfer, thereby benefiting the framers and consumers. Another voice has been raised, arguing that protection ruins the tradition of farmers having the right to save and exchange seeds, thereby forcing farmer dependency on seed companies.

Along with the development of plant breeding methods, the means to protect the innovations have diversified. Not only is there a need to protect the improved crop varieties, but there is also a need to protect the methods of producing these varieties, the genes incorporated in them and the gene products that are known to give the plant its specific character. Furthermore, there is a need to protect databases containing information on the improved genes, and a need to protect methods for use of certain characteristics of improved crops, for example.

Generally speaking, the prime form of intellectual property (IP) to protect technical innovations is a patent, while the most well known means to protect plant varieties is plant breeders' rights (PBR). Recently, other forms of intellectual property, such as copyrights, trademarks and trade secrets, have also become important, not only in other fields of life sciences but also in plant breeding.

During the recent decades, the plant breeding industry sector has changed a lot: a traditionally public funded sector is today fairly much privatized. Furthermore, during the era of globalization, most countries have joined the World Trade Organization (WTO) and thereby are under duty to respect several international treaties regulating various aspects of trade and industry, including intellectual property. Despite the international frames set by various treaties, countries still have lot of flexibility in terms of enforcement. Furthermore, the breeders are still left with various means to control newly developed varieties, research results and so on.

In this chapter we shall first introduce the different means to protect intellectual property. We shall then discuss international treaties and conventions providing the frames for intellectual property legislation of the member countries. We shall also shortly discuss the alternative ways of protecting intellectual property by contracts, material transfer agreements (MTAs) and physical means to prevent unauthorized use of improved germplasm.

24.2 FORMS OF INTELLECTUAL PROPERTY

A breeder can choose today from a menu of different IP protection options. The following sections introduce the basic forms of protection.

24.2.1 Plant breeders' rights

The best known form of IP in plant breeding is plant breeders' rights (PBR). Often *sui generis* protection is mentioned in connection with PBR. *Sui generis* means 'of its own kind' or 'special', and *sui generis* protection refers to protection of plant breeders' rights with forms other than patents.

The best known known *sui generis* system is the one that is provided under the UPOV Convention. Under UPOV, PBRs are called Plant Variety Protection (PVP).

As of 9 November 2004, the UPOV Convention had 58 member countries. UPOV sets forth the minimum protection that the member countries should grant for the developers of new and distinct plant varieties (UPOV, 1991). Those minimum requirements are discussed below, in Section 24.3.1.

A specific form of *sui generis* protection is a plant patent, which is granted in the United States of America. A plant patent is different from a 'regular' utility patent. A unique feature of the protection system in the United States of America is that it provides two forms of *sui generis* protection (PVP protection and Plant Patent protection). The Plant Patent Act was enacted in 1930. A plant patent may be granted to new and distinct plant varieties that are invented or discovered, although excluding tuber-propagated plants and plants found in uncultivated areas. Plant patents are issued for 20 years from the date of filing.

24.2.2 Utility patent

Historically, a patent was a grant made by a sovereign that would allow for the monopoly of a particular industry, service or goods. Over time the concept has been refined from a public policy perspective and it has evolved to an agreement between the government and the inventor or creator.

In return for the right to exclude others from the practice of the invention, the government requests the inventor to fully disclose the enablement of the invention. Furthermore, the monopoly is limited by time, and clearly it is only applicable in the territory under the jurisdiction of the government granting the right.

In exchange for a limited-term right (usually 20 years) to exclude others from making, using or selling the invention, the inventor must provide a complete and accurate public description of the invention and the best mode of 'practising' it. This provides others with the ability to use that information to invent further, thus promoting technology development for the benefit of the society.

This right to exclude means that a patent is a 'negative right', since a patent holder may only exclude others from the using, manufacturing, copying or selling their invention during the lifetime of the patent right. Markedly, one can have a patent and still have no right to practise the invention, for example due to lack of approval of some government instance. An example related to plant breeding is an inventor having a patent for transgenic plant in a country where genetically modified plants are not approved by the government.

Originally, utility patents were typically granted for various kinds of mechanical and chemical inventions. Along with the development of biotechnology rose the question of patentability of human-modified living organisms. A significant decision was made by the highest court in the United States of America in 1980 in Diamond v. Chakrabarty: a living artificially-engineered micro-organism was found to be patentable (Diamond v. Chakrabarty, 447 U.S. 303, 1980). The creation of a bacterium that is not found anywhere in nature constitutes a patentable 'manufacture' or 'composition of matter' as it is made by man.

Five years later the Board of Appeals and Interferences of the U.S. Patent and Trademark Office made a decision of patentability of a higher organism. In a case where genetically modified maize cell culture was sought to be patented, the Board held that sexually reproduced plants are eligible for patent protection (In Re Hibberd, 227 USPQ 433,185).

Today the international treaties set forth the frames for minimum protection of IP, but no treaty regulates how far a member country may extend the protection. Accordingly, there are variations among the countries as to what extent living organisms can be protected. The rulings of the United States of America courts, even if having effect only in the jurisdiction of the United States of America, have been important because they set a new tone into discussion of patentability of life forms everywhere in the world.

24.2.3. Copyrights

A copyright is a type of IP protection for 'authors' of original works. Basically, a copyright protects an original work and allows the author an exclusive right to reproduce the work, prepare derivatives of it, distribute copies of the work and perform the copyrighted work publicly.

Historically, copyrights have been important in protecting the rights of artists and authors. Today, copyrights are becoming more and more important in protecting the rights of database developers. In relation to plant breeding, copyrights may be a relevant means of protecting, for example, GIS databases supporting breeding, or databases containing gene sequences. Currently there are a number of projects that aim to sequence the genome of various crops; some of this information may be copyrighted.

The European Union (EU) provides an additional protection mechanism for databases: database protection can be sought in addition to regular copyright protection. Under the Directive on the Legal Protection of Databases, the database creators can protect unauthorized extraction and utilization of contents of their databases for a period of fifteen years from completion of the database. The Directive applies, however, only when the database creator is a citizen of an EU member country.

24.2.4. Trademarks

A trademark is a word, phrase, symbol, design or a combination of those, that distinguishes the source of one's goods or services from those of others, e.g. Kodak®. A trademark can be valid only when it is used in connection with the goods or services in commerce.

As in other industries, trademarks are also becoming increasingly important for the seed industry to brand its products. A remarkable advantage of a trademark is that it is valid as long as it is in use in commerce. When the limited protection time of a patent or plant variety protection expires, a trademark can still be used to inform the customer of the specific qualities of the product. Outside of breeding industry, Kodak® is again a well known example: the patent right of the regular black and white film of Kodak expired about a hundred years ago, but still everybody knows exactly what they buy based on the strength of the trademark.

24.2.5 Geographical indications

Geographical indications are a kind of IP that has already been in use for rather a long time, but has been widely recognized as a means of protection only recently. A geographical indication is a sign used on goods that have a specific geographical origin and which possess qualities or a reputation that are linked to the place of the product's origin. Geographical indications serve as assurance of source or quality, and they are important in sense similar to a trademark.

In various countries, protection for geographical indications is provided under different concepts: geographical indications may be protected under laws against unfair competition, consumer protection laws, or laws for the protection of certification marks. In some countries there are special laws for the protection of geographical indications. In the United States of America, geographical indications are treated as trademarks.

Most commonly, a geographical indication consists of the name of the place of origin of the goods. Agricultural products typically have qualities that derive from their place of production and are influenced by specific local factors, such as climate or soil. Examples of geographical indications are 'Idaho' for potatoes from the state of Idaho or 'Roquefort' for the specific kind of French cheese.

The Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS Agreement) provides a high level of protection of geographical indications for wines and spirits. Currently, extension of this high level of protection to other products, such as agricultural products of developing countries, is under discussion in the World Trade Organization (WTO).

Note that geographical indications, akin to trademarks, do not protect the information embodied in the goods nor any method of producing or processing the goods. Rather geographical indications are rewarding groups of people that have developed a product, often over centuries of collective knowledge. Accordingly, geographical indications are considered as a part of wider policy to award protection for indigenous knowledge.

24.2.6 Trade secrets

Trade secrets are probably the oldest and the cheapest way to protect one's IP: having a trade secret simply requires as the term indicates, that the IP is kept secret. A trade secret could for example be a composition of a culture medium or a method to transform a plant species. A typical trade secret in the context of plant breeding is having the parent lines of a hybrid variety kept secret.

The positive aspect in trade secrets, in addition to its low cost, is that there is no expiration date. However, the negative side is that once the secret is out, the protection is gone and anyone is free to use the know-how.

24.3 PLANT BREEDERS' RIGHTS UNDER THE UPOV CONVENTION

As the UPOV Convention provides the framework for the most common and well known of the *sui generis* systems for Plant Breeders' Rights we shall discuss the convention in more detail here.

The International Union for the Protection of New Varieties of Plants (UPOV) was established in 1961, and since then the provisions have been revised in 1972, 1978 and 1991. UPOV is a separate intergovernmental organization and is partially monitored by the World Intellectual Property Organization (WIPO). Currently UPOV has 58 Member countries, 25 of which are bound by the UPOV Convention of 1978, 31 by the Convention of 1991 and 2 by the Convention of 1961/1972. All the important agricultural producer countries are members of UPOV. More than half of the member countries are developing countries.

The goal of the convention is to provide an incentive to breeders to develop new varieties for the benefit of society by granting a limited monopoly to the breeders to commercialize new varieties. The Convention requires granting of protection for the varieties of all plant genera and species. New member countries of the Convention of 1991 must provide protection to at least 15 plant genera, and within ten years from joining UPOV they have to provide protection to all genera. The fact that a number of important countries, such as former Soviet Union countries, have joined UPOV only during the last years means that there is currently a situation where not necessarily all plant genera and species can be protected in these countries. Contrary to the requirement of all species being protectable, the Convention of 1978 requires protection of at least 24 species. An example of a 1978 Convention member is China, which became a member in 1999 and has currently a national list of protectable species containing 41 agricultural species. Even though the list covers the most important crop species, a large number of species cannot be protected in China.

PBR under the UPOV Convention provide the breeder of a distinct, uniform and stable variety with an exclusive right for a limited period for multiplication, offering for sale, selling, exporting, importing and stocking for these purposes. These breeders' rights do however not extend to acts done for non-commercial or experimental purposes, nor for purposes of breeding of new varieties. In other words, the UPOV Convention provides protection to distinct, uniform and stable varieties but also leaves certain exemptions for further breeding and non-commercial purposes.

24.3.1 Comparison of the UPOV Conventions of 1978 and 1991

Because most of the member countries are bound by the UPOV Conventions of 1978 or 1991, we briefly compare the minimum requirements set forth in these two conventions and discuss their implications.

Both of the Conventions require the variety to be <u>d</u>istinct, <u>u</u>niform and <u>s</u>table (DUS) before protection can be granted. DUS-testing is mainly based on growing tests carried out by the competent authority of the member country where protection is sought. The Convention of 1991 additionally requires that the variety be novel, meaning that it has not been sold or commercially exploited for more than a year in member countries where an application has been filed, and not been sold in a non member country where an application for variety protection is filed for more than 4 years (for 6 years in case of trees and vines) before the application in the member country.

The Convention of 1978 protects commercial use of reproductive material of the protected variety, while the Convention of 1991 protects varieties and products, including those that are essentially derived. The essential derivation provision is a similar concept to 'doctrine of equivalence' in the patent laws, aiming to prevent plagiarism. Essential derivation is a concept that has recently created a lot of discussion and therefore we shall return to it later in this chapter.

Of note is that UPOV 1978 restricts the countries where both patent and *sui generis* protection are available to grant only one type of protection for one and same botanical genus or species. The Convention of 1991, however, does not include this restriction. Accordingly, in the United States of America, which is a member of 1991 UPOV, the Supreme Court ruled in 2001 in J.E.M. AG Supply v. Pioneer Hi-Bred International that a plant breeder can obtain multiple protection for newly developed plant varieties; having a *sui generis* based variety protection does not exclude issuance of utility patent for the same if requirements for novelty, non-obviousness and usefulness are fulfilled as required for patents in the United States (J.E.M. AG Supply v. Pioneer Hi-Bred International, 122 S.Ct. 593, 2001).

The Convention of 1978 gives a 15-year protection from filing date for crops and 18 years for trees and vines. The most recent Convention, of 1991, grants 20 years of protection from filing date for crops and 25 years for trees and vines.

The Convention of 1978 grants so-called Breeders' Exemption, which means that breeders are allowed to use the protected material, without a licence, to breed new varieties. In the 1991 Convention, Breeders' Exemption is optional and it is up to the national government to implement legislation that respects Breeders' Exemption.

An essential and much discussed issue in UPOV is the concept of Farmers' Rights or Farmers' Privilege. Traditionally, farmers were free to save, re-use and sell harvested seeds. UPOV has brought some limitations to these rights. The Convention of 1978 did not include any specific requirements for Farmers' Privilege. This means that the farmers were left with the right to save and re-use harvested seeds of a protected variety. The United States of America implemented the Farmers' Rights of UPOV 1978, so that the farmer was allowed not only to save but also to sell the saved seeds, as long as the income from the saved seed was less than 50 percent of the total income of the farm. Now, as the United States of America is a member of 1991 UPOV, the farmer may no longer sell the saved seed, but does not need to pay royalties on re-used seeds. The European Union implements the 1991 Convention by allowing small-scale farmers to save and re-use seed without royalty payments, while re-use of seed of large-scale farmers is subject to reasonable royalties, which usually is 50 percent of regular royalty rate. Colombia, which is a member of Convention of 1978, but has rules mostly according to Convention of 1999, allows farmers having less than 5 ha to save seed (Louwaars *et al.*, 2004).

24.4 INTERNATIONAL GOVERNANCE OF INTELLECTUAL PROPERTY

IPRs are based on national legislation and therefore the rights are usually territorial, so a patent is valid only in the country of the jurisdiction that granted it. However, during this era of globalization, there are several international treaties and conventions that are setting global frames for the IP legislation of the member countries. Below we review the treaties most relevant to plant breeding.

24.4.1 TRIPS Agreement

The World Trade Organization (WTO) originates from the GATT (General Agreement on Tariff and Trade) Uruguay Round negotiations during 1986 to 1994, and it is the main global instrument to support trade liberalization. Since 1994, WTO has gained a lot of influence and as of 13 October 2004 it had 148 member countries. The member countries are bound to several agreements covering goods, services and IP under the umbrella of WTO.

WTO administers the TRIPS Agreement of 1995. TRIPS attempts to harmonize the rules of IP protection of the member countries by establishing frames for minimum protection that each government has to provide to the IP of other WTO countries. WTO provides also a dispute settlement system for member countries having trade disputes over IP rights.

The basic concepts of the TRIPS Agreement are national treatment and most favoured nation (MFN) treatment. Accordingly, each member shall accord to the nationals of other members a treatment as favourable as it accords to its own nationals, and any advantage, favour, privilege or immunity granted by a member to the nationals of any other country in regard of IP protection shall also be accorded to the nationals of all other member countries. In simple terms, the member countries are bound to treat IP of any member country in an equal way.

The TRIPS Agreement builds on the Paris Convention for Protection of Intellectual Property of 1883, setting forth the patent system in the member countries. Similarly, the Berne Convention for the Protection of Literary and Artistic Works of 1886 is appreciated in setting forth the copyright system in the member countries. Both the Paris Convention and the Berne Convention are administered by WIPO, headquartered in Geneva, Switzerland.

Patent protection provisions of the TRIPS Agreement

The TRIPS Agreement describes the minimum rights that a patent owner must be provided in the member countries. Patent protection must be available for at least 20 years, which is the length of protection that almost every member country currently provides. Some countries, such as the United States of America and Australia, provide an extension of the 20-year protection for pharmaceutical inventions that need to be approved by other government agencies before the product can be offered in commerce. In the United States of America, human drug products, medical devices and food and colour additives, as well as animal drugs and veterinary biological products, are eligible for patent term extension. So far there are no similar extensions for utility or plant patent terms, even if, for example, transgenic plants need to be approved by other government agencies (in the United States of America by USDA, EPA or FDA) before they may be cultivated or offered for food or feed production.

Protection must be available for both products and processes in all fields of technology. However, the TRIPS Agreement has provisions giving governments a right to refuse to issue a patent for an invention if its commercial exploitation is prohibited for reasons of public order or morality. Also, the agreement allows governments to exclude from patentability diagnostic, therapeutic and surgical methods, plants and animals (other than micro-organisms), and biological processes for the production of plants or animals (other than microbiological processes).

Based on this TRIPS provision, many of

the member countries do not issue patents for plants. However, even if plant varieties may be excluded from patentability, in practise there still may be a way to get patent protection for plants: the European Patent Convention for example does not allow individual plant varieties to be patented, but the Board of Appeals of the European Patent Office ruled in 2000 in Novartis v. Plant Genetic Systems that genetically modified plants may be protected if the invention is not limited to a single variety (Novartis v. Plant Genetic Systems, G1/98 Transgenic Plant/Novartis II OJ EPO 2000). Here, clearly, the interpretation of the law provides patent protection to genetically modified plants. Canadian patent law excludes plants, as higher life forms, from patentability. However, in a recent case, the highest court in Canada found that growing transgenic plants containing a patented gene infringed a patent that claims the chimeric herbicide-resistance inducing gene and cells containing that gene (Monsanto Canada Inc. v. Schmeiser 2004 SCC 34). Therefore, even if Canadian law does not allow patenting of higher life forms, this decision implies that patent protection in Canada is extended to plants if a gene present in the plant's genome is claimed in the patent. The rational behind this is that by growing the plant that expresses a patented gene, one is using the patented invention.

Plant breeders' rights under the TRIPS Agreement

The TRIPS Agreement provides that:

> *members shall provide for the protection of plant varieties either by patents or by an effective sui generis system or by any combination thereof.*
> (Article 27.3 (b)).

The TRIPS agreement does not give any definitions for the term s*ui generis* but leaves us with the translation from Latin being 'specific' or 'of its own kind'. By giving no definition to this essential term means that member countries are left with 'free hands' to fashion their own protection system. The UPOV convention is one interpretation of what a *sui generis* system can be.

Another essential term not defined in the TRIPS Agreement's provision for protection of plants is the term 'effective'. How effective does an 'effective *sui generis* system' need to be? To clarify the meaning of the clause several countries are calling for further discussion on Article 27(3) of the TRIPS Agreement. Among others it has been proposed that the interpretation should extend the protection to traditional and indigenous knowledge. The discussion on Article 27(3) of the TRIPS Agreement is connected to the relationship of the TRIPS and the Convention on Biological Diversity (CBD), and is covered in Section 24.4.3.

WTO member countries have to have their IP laws in line with the TRIPS requirements. When the TRIPS Agreement came into effect in January 1995 it set out transitional periods for implementation for developed, developing and least-developed countries. Developed countries had to comply with TRIPS provisions by 1996, while the least-developed countries had until the beginning of 2006. Developing countries generally had until 2000 for the implementation, but the deadline was later postponed until 2005.

India is an example of a developing country that established its PVP legislation in order to comply with the TRIPS requirement. India enacted its plant variety protection laws in 2001. India has chosen *sui generis* legislation deviating from the norms set by UPOV (see Sahai 2003; Brahmi, Saxena and Dhillon, 2004). The effects of the legislation remain to be seen after it is effectively implemented.

24.4.2 The Convention on Biological Diversity

The Convention on Biological Diversity (CBD) was established in 1992 as an outcome of the United Nations' Conference on Environment and Development (UNCED). Currently the CBD has 168 signatories. Of note is that the United States of America has signed but not ratified the Convention.

The main objectives of the CBD are to ensure conservation of biological diversity, to ensure the sustainable use of biological diversity, and to promote a fair and equitable sharing of the benefits arising from the utilization of genetic resources amongst member countries.

The CBD does not as such elaborate on IPRs, but it makes a clear statement on technology transfer as an important means to reach the goals of the Convention. Because much of the agricultural technology in the developed countries is protected by IPRs, the statement of technology transfer being an essential means to reach the goals of the Convention means that IPRs become an issue as well. Article 16.2 of the Convention states that

> *In the case of technology subject to patents and other intellectual property rights, such access and transfer shall be provided on terms which recognize and are consistent with the adequate and effective protection of intellectual property rights.*

Thereby, CBD clearly recognizes IPRs.

The Convention requires equitable sharing of benefits arising from commercial use of the biological resources and local knowledge of communities. The Convention also requires that access to genetic resources is subject to prior consent of the contracting party providing the recourses. These requirements have induced vast discussion and still unsolved questions of the compatibility of TRIPS and CBD.

24.4.3 Relationship of the TRIPS Agreement and CBD

CBD and the TRIPS Agreement approach the subject of IP protection from different perspectives: CBD has a focus on sustainable management of biodiversity, while TRIPS aims to provide a framework for adequate protection for IPR to reduce distortion of international trade. The relationship of the TRIPS Agreement and CBD has been widely debated in the TRIPS Council. A concern has been raised that implementation of the TRIPS Agreement may affect the ability of the WTO member countries to fulfill their CBD commitments.

Some developing countries have been arguing against granting patent rights for genetic material as is possible under TRIPS, because that might limit access to the resource and equitable benefit sharing, as required by CBD. Some countries have required that patent applications should be accompanied by disclosures regarding source of origin, any related traditional knowledge and evidence of equitable benefit sharing. Counter arguments have included notation that such requirements would limit availability of protection and this again would violate the principles of the TRIPS agreement. Furthermore, additional requirements probably would make the system expensive and complicated to implement.

Due to these concerns, several countries are calling for amendments to be made to the TRIPS Agreement to bring it into the line with CBD. At the same time, both the TRIPS Agreement and CBD are rather flexible in their language, and therefore the member countries have a lot of freedom to find ways to implement both without conflict.

24.4.4 The International Treaty on Plant Genetic Resources for Food and Agriculture

The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) was agreed in June 2004. It provides for a multilateral approach to access and to benefit-sharing of a selected list of plant genetic resources for food and agriculture. The list includes 35 crop genera and 29 forage species. *Ex situ* collections of these crops are held by the International Agricultural Research Centers (IACRs). The species in the list, even if not so many, provide about 80 percent of the world's food calories from plants.

The goals of the Treaty are very similar to the CBD, but ITPGRFA specifically addresses access to and fair sharing of the benefits generated from the commercial utilization of the genetic resources of the listed species in the food and agriculture industries. It thereby leaves utilization of the genetic resources in the pharmaceutical industry out of its scope, while CBD encompasses use of genetic resources in any field of technology. The central mechanism to implement the provisions for access and benefit sharing is a standard material transfer agreement (MTA).

The draft MTA attached to the ITPGRFA contains the language of Article 12.3(d) of the treaty, which has raised a lot of discussion. Article 12.3(d) states that

> *Recipients shall not claim any IP or other rights that limit the facilitated access to the plant genetic resources for food and agriculture, or their genetic parts or components, in the form received from the Multilateral System.*

The language of the article has been regarded as ambiguous as it is not clear whether, for example, isolated and purified compounds or gene sequences are patentable under this provision or not (Lettington, 2004). Currently parties to the treaty can interpret this provision rather freely, which means that the MTA may have different meanings in different countries, depending on the national legislation.

The ITPGRFA recognizes Farmers' Rights to freely access genetic resources, and to use and save seed. However, the implementation of Farmers' Rights is left fully to national governments. An implication of this is that the member countries of the treaty have to consider the relationship of Farmers' Rights to the already existing IP laws. The member countries might, for example, already have provisions for Farmers' Rights in their plant variety legislation. At the same time, member countries may end up protecting some aspects of Farmers' Rights through other legislation, such as laws regulating commerce in seeds.

24.5 CURRENT ISSUES IN IPRS AND PLANT BREEDING

24.5.1 Access to germplasm

Plant and animal breeding is different from any other field of technology in the sense that it is impossible to make progress in terms of inventions without having access to 'prior art'. A mechanic can invent something that provides a huge technical step forward without having the slightest idea of what is already out there. Opposite to this, a plant breeder can breed a better variety only by having access to germplasm. Despite this essential characteristic of the art of breeding, inventions related to plant breeding may still be protected by various forms of IPRs in a way similar to inventions in mechanics.

This is an issue that is raised time after time, because of concern that IPRs might prevent free access to germplasm and thereby affect the capacity to breed, research and provide better varieties for food and feed.

International treaties have provisions that are aimed to ease access to germplasm. As discussed above, ITPGRFA provides for *ex situ* collections of most important food and feed plants. The International Agricultural Research Centers (IARCs) of the Consultative Group on International Agricultural Research (CGIAR) hold over 600 000 accessions of crop, forage and agroforestry genetic resources. ITPGRFA requires a standardized MTA to guarantee that no IPRs shall be claimed for material received from the system. The goal of the treaty is to provide fair exchange of germplasm of the species included in the list.

Wild germplasm, in contrast, is an important part of the art of plant breeding, and wild germplasm might not be represented in genebanks alongside cultivation-based germplasm (Gepts, 2004). This argument would inevitably lead to a very broad and still unsolved issue of compatibility of existing plant IP system with the rights of indigenous people's traditional knowledge which issue has been recently discussed in Fingers and Shuler (2004).

24.5.2 Breeders' exemption in PBRs, and essential derivation

The 1978 UPOV Convention provides that a protected variety can be freely used as an initial source of variation for the purpose of creating other varieties, and that the breeder shall not be required to obtain authorization for marketing such varieties. This provision is known as Breeders' Exemption and it is a fundamentally important part of PVP. Breeders' Exemption guarantees that the germplasm sources remain accessible to the whole community of breeders. This also helps to keep the genetic basis for plant breeding as broad as possible and minimize the threshold for access to germplasm.

The language in the 1978 UPOV Convention has been interpreted to allow cosmetic modifications in breeding new varieties, such as inducement of mutations in ornamental plants. Development of methods for genetic engineering has brought further prospects of rapid modification of existing varieties. In order to prevent protection of new varieties with only minimal changes compared with the original variety without recognition of the breeder of the initial variety, the 1991 UPOV Act amended the concept of 'essential derivation'.

The core of the essential derivation concept is that the scope of the Breeders' Rights is extended to varieties that are essentially derived from the original breed. Essentially derived varieties may be obtained in various ways. The UPOV 1991 Convention gives a list of methods, including selection of natural or induced mutants, selection of a somaclonal variant, selection of variant individual plants in the initial variety, backcrossing and genetic engineering. Through this concept, if a breeder derives a variety essentially from another variety, such as inserting one new gene into the initial variety, the new variety can be protected if it is new, distinct, uniform and stable; but for as long as the initial variety is protected, the essentially derived variety cannot be exploited without authorization from the owner of the initial variety. In practice, this means that the breeder of an essentially derived variety would need a licence from the breeder of the original variety. If the essentially derived variety is derived from a public-sector-bred variety, there is naturally no need for a licence as the original variety was not protected.

The concept of essential derivation does not affect the right of a breeder to choose protected varieties for initial material. However, breeders clearly need to pay more attention to the results of their breeding work when the parents are protected varieties. If the new variety is too close to the protected parents it may be deemed to be essentially derived. The new variety may still be protected if it is distinct, stable and novel, but the breeder may need a licence before they can commercially exploit their essentially derived variety. The difficult question that remains is: "How close is too close?"

The UPOV Act does not provide any guidelines as to how the essential derivation is to be defined. The UPOV 1996 Annex provides that the dependency relations should be handled by the breeders themselves. Obviously, the first step is to define the essential characteristics of the species that is to be inspected further. The criteria for defining whether the characteristics are too close to the parent lines may be phenotypic or genotypic. The threshold determination for essential derivation should be done on a species-by-species basis, and currently there are various academic research programmes to evaluate the threshold values, for example by using separation distances of molecular markers as criteria. Lesser and Mutchler (2004) are of the opinion that the system where the status of the variety is to be worked out solely between the parties will not work, and that some oversight body must be involved to established consistent standards.

24.5.3 Research exemption in patent laws

Most of patent laws contain some kind of provision allowing experimental or research use of patented material or a method without a licence. The definition of experimental and research use may vary from country to country: what is experimental and therefore allowed in one country may not be that in another. Recently, Federal Circuit Court in the United States of America gave a very narrow definition for experimental use. In Madney v. Duke (207 F 3d. 1351 Fed Cir 2002) a university continued to use equipment patented by a professor that was no longer employed by the university. The university relied on its non-profit status and claimed use of the equipment being lawful under research exemption. The court ruled that the non-profit status of the organization is non-determinant and that the experimental use allows use of a patented method solely for amusement, to satisfy idle curiosity or for strictly philosophical inquiry. In Europe, the experimental use exemption seems to be interpreted less narrowly. The Supreme Court in Germany has ruled that clinical trials of a patented compound are non-infringing under the research exemption when the purpose was to find further information (Goddar, 2001).

Regardless of the different views of the United States of America and European courts, the breeder should still know whether the material (e.g. genes) or method they are working with is protected by patents. Even if they might not have thought they were breeding something that would one day become commercially exploitable, they might still be under an obligation to obtain permission from the owner to use the gene for research.

24.5.4 Freedom to operate in developing countries

IPRs are national, and therefore it is totally legal to use the material and methods in countries where the invention is not patented. As an example, various aspects in producing

GoldenRice, the vitamin A–rich transgenic rice, have been patented; a freedom to operate study showed that there are more than 70 patents related to the technology (Kryder, Kowalski and Krattiger, 2000). However, in most of the countries where rice is an important commodity, none or only a few of these patents were in force. In such countries, using or developing the technology further is legally completely correct. Issues may arise only when there is trade in the technology to countries where patents or other forms of protection are in force.

According to Pardey *et al*. (2003) there is still a substantial freedom to operate for most crops of major significance for food security in poor countries. Pardey argues that concern of freedom to conduct research by or on behalf of developing countries is seen as a way to draw attention away from real constraints. Real constraints according to the same authors are lack of investment in developing country research and lack of scientific skill to access modern technology, whether protected or not.

Koo, Nottenburg and Pardey (2004) show that from 2000 to 2002, 54 percent of the variety protection applications filed worldwide were filed in Europe or in the United States of America. The principal reason for the lack of filing activities in the developing countries is a lack of established protection means. At the same time, this data also indicates that a claim that IPRs are limiting the freedom to exploit plant-science-related inventions in the developing countries is an overstatement.

24.5.5 Farmers' Rights

Developing countries are required to introduce some form of plant variety protection under the TRIPS Agreement. However, as the TRIPS Agreement sets the frame very loosely, it remains for the countries to decide how the protection is to be implemented. Some developing countries have chosen to adhere to the UPOV Convention; others, such as India, are going to implement more liberal PVP.

The Farmers' Right provision of India's Plant Variety Protection and Farmers' Rights Act of 2001 has created a lot of discussion, because it seems to differ from anything that has been created under the UPOV Conventions. The Indian law allows farmers to save, use, sow, re-sow, exchange, share or sell the seed, providing that the farmer shall not sell the saved seeds in any packages or containers labelled in a manner indicating that the seeds are protected (Sahai, 2003). It has been argued that Farmers' Rights provisions as liberal as India's does protects only the brand of the breeder. In the Indian Act, there are also provisions for acknowledging the role of rural communities as contributors of landraces and farmers' varieties. A breeder wanting to breed an essentially derived variety needs to have permission of the communities (Sahai, 2003). The Act adopts all the suggestions of the UPOV 1991 Convention as to the methods that may be used to breed essentially derived varieties, in effect almost all the modern means of plant breeding. This leaves the Breeders' Exemption extremely narrow.

The International Association of Plant Breeders for the Protection of Plant Varieties (ASSINSEL) suggests that any national legislation authorizing farm-saved seed without reasonable limit and without safeguarding the legitimate interest of the breeders is not in conformity with the 1991 UPOV Convention. Additionally, ASSINSEL argues that any such legislation would be contrary to the meaning of the TRIPS Agreement, i.e. such a system would not provide effective *sui generis* protection (ASSINSEL, no date).

The consequences of farm-saved seed to the breeder depend also on the contract that the breeder makes with the farmer. If the farmer pays royalties based on the amount of seed originally purchased, then farm-saved seed naturally reduces the earnings of the breeder. Another option for the breeder is to collect royalties as end-point royalties when the harvested crop is sold. By collecting end-point royalties, the breeder would benefit from the farm-saved seed provision provided that the farmer declares that the seeds they sell is of the protected variety. Contracts may also be used to oblige the farmer to keep a record of their practices. Such contracts would help the breeder to monitor the practice of the farmer in end-point royalty cases and would ease collecting royalties.

However, not only the implementation of the law in a country is important but the enforcement is as important, if not even more important. This of course means not only enforcement of Farmers' Rights, but also every aspect of the IP-laws of the country. Lack of enforcement of IP laws may lead to a situation such that of Argentina, where 25–50 percent of Roundup Ready® soybean seeds grown are from black market sources or saved by farmers from the previous year's crop (Robertson, 2000). Similarly Kowalski (2003) is worried about the future of agribiotech in China due to weak enforcement of the IP laws. Lack of enforcement leads to lower prices and eventually leads to unwillingness of companies to invest in countries having weak enforcement of IP laws (Giannakas, 2003). This author suggests that penalties determined under the TRIPS Agreement have to go beyond the norms of GATT, otherwise IPRs remain inefficiently enforced; simply offsetting the value of losses incurred by the innovator is not severe enough a punishment.

24.5.6 Other methods to protect unauthorized use of seeds

Contracts and MTAs

A breeder can control their rights over the material they own by contractual agreements, including MTAs, which are binding legal contracts between the technology provider and the receiver, and the most common legal documents controlling use of research material. The terms of MTAs can go far beyond the rights provided by a patent or other IP legislation. The MTA may include so-called reach-through clauses, whereby the technology provider may get rights to new varieties or other inventions and improvements that have been created by using the material provided through the MTA. The receiving party has to be clear as to what the implications are of signing an MTA before signing.

When selling seeds of a protected or a non-protected variety, a breeder may control the use by various kinds of contract. We discussed earlier how the breeder may control income by choosing the royalty basis defined in the contract with the farmer.

Two specific types of contract of significance in the seed industry are the so called shrink-wrap and brown-bag licences. Typically, a breeder includes in the seed package contractual language limiting the rights of the buyer. The seed bag may for example specify that the material inside the bag may be not be used for further breeding. By opening the package or by planting the seeds the user agrees with the contractual language on the package.

By these contractual means, the breeder can regulate the use of the material, even in countries without no IP legislation.

However, as both MTAs and brown bag licences are interpreted under the contract laws of the country, the enforceability of such means differs between countries.

Biological methods to control re-use of seeds

The modern technologies developed in the plant sciences provide certain methods to protect varieties from unauthorized use. These methods include hybridization and technologies usually called Genetic Use Restriction Technology (GURT).

Hybrid technologies were developed in 1930s and today hybrid varieties have been developed for most of the important cross-pollinated food and feed species. When hybrid seed is used for a second generation, part of the hybrid vigour is lost and therefore saving seed for re-use is not an optimal solution for a farmer. Rather the farmers are each year dependent on seed producer's new seed.

GURT is a biotechnology application of a system providing the breeder control over re-use of the seed. GURTs are not specifically developed for the purpose of enabling plant breeders to prevent re-use of the seed; rather the goal in developing the techniques have been for purposes such as preventing transgene escape into the environment. In any case, GURTs may also be a strong tool for preventing re-use of seed.

Currently it seems that there is quite a lot of discussion of the possible effects of this new technology in relation to farmers, research and the environment (e.g. Budd, 2004). Proponents of GURTS argue that GURTs provide seed companies and plant breeders with stronger control over plant varieties. This would enable greater cost recovery and provide more incentive for the plant breeding industry. GURTs would be a method to protect varieties in countries where only weak IP protection is available or where IP law enforcement is weak. The proponents also argue that transaction costs would be lower if there is no need for IP protection and therefore the benefit would come to consumers and farmers through reduced seed prices. Opponents of GURTs argue that GURTs will harm the farmers by taking away the ability to save and re-use seeds and will have adverse effects on food security and biodiversity.

The GURT technologies are still under development and in many countries genetically modified crops are in any case not yet in cultivation. Therefore there is no data that could prove either the fears of the opponents or the hopes of the proponents to be true. However, there are already indications that countries may not allow GURTs to be used in protectable varieties: the Indian Plant Variety and Farmers' Rights of 2001 does not allow the protectable varieties to include GURT technologies (Sahai, 2003).

24.6. PLANT BREEDERS' RIGHTS AND PARTICIPATORY BREEDING

Farmers have worked as plant breeders for centuries, but have in most cases not sought to protect their new materials through any form of statutory protection. Where a farmer can be identified as a breeder there would be no inherent problem in seeking protection, insofar as what is required for PBR is the identification of a 'breeder', and in the case of a patent an 'inventor'.

There are, however, a number of other elements to the current proprietary IPR protocols, in that farmers and communities are unable to meet some of the other statutory requirements as they relate to novelty, the time of the invention, prior sales, etc. There are also problems that in many locations are associated with the inability to identify a breeder or inventor *per se* since the breeding activity is carried out at the community level—there is no longer a definable breeder or inventor.

A final issue that has been of concern in the literature has been the fact that indigenous materials are often not characterized or published. This may lead to perchance to another person breeding material with the same description, who would be able to gain protection on such material on the basis of claiming 'novelty' for the material in the absence of published information to the contrary.

Let us therefore address each of these issues and indicate arguments that are associated with each side of the issues.

24.6.1 Determination of the 'breeder' or 'inventor'

In modern crop improvement we are accustomed to several people being involved and collaborating on the inventive or breeding step. There would therefore be only limited problems with identification of the inventive steps involved and the persons involved, thus allowing for clear identification of breeders or inventors. In the same way that breeders then assign their material or invention to their institution, it is clearly feasible for a community or tribe to become the title holder to the invention or material bred or invented within that community. What cannot happen is that the community or tribe is deemed as inventor or breeder since they do not fulfil statutory requirements.

24.6.2 Novelty

In order for PBR or a patent to be granted there is a requirement of novelty (or distinctiveness). The challenge there is that the statutes tie caveats to the novelty concept, such as the time the product or invention has been 'in the market' or whether there is prior 'publication' of the information on the invention or material. Clearly, in community-based schemes this approach is hampered by the apparent informality of the system. This situation is clearly crucial to the area of landraces, where over many generations improvement have been made, but such improvements have become public goods basically because of time or sale of seed (even if informal).

24.6.3 Cost of filing

Clearly, in some cases, there are severe constraints on small communities because of the cost of filing applications. This, however, is no different from the problem that faces individual inventors who want to patent an invention. The crucial question to ask here is 'why' the person or community wants to seek protection. If the goal is to licence the materials for income, the answer is to spend the money and seek the protection. If the goal is to prevent appropriation by others of the intellectual knowledge, then simply publish the data in written form, take your credit, and while others can use the invention, they cannot gain any exclusivity or proprietary protection for the material.

24.6.4 Decisions are needed

From the above it follows that what is really needed are educational steps and clear understanding as to the goals and aims of those communities that are improving germplasm. In short, what is it that the communities are seeking? If the key is recognition of input and prevention of proprietary exploitation by others, then publication of the data serves a vital purpose. There are no doubt international agencies that are willing to provide funding, either to communities to protect their new assets, or to assist with documentation and publication.

24.7 CONCLUSIONS

The plant breeding industry has encountered changes during the last decades. New breeding methods have raised issues of IP protection. The menu of the means that a breeder may use to protect their invention is not limited to PVP but includes several other means as well. In addition to various forms of IP, breeders may also use other legal forms to control use of varieties.

There is an increasing amount of legislation and international treaties regulating issues related to IP in plant breeding. Nevertheless, a lot of the decision-making is still left to national governments.

There is certainly no one correct and acceptable system to be implemented in each and every country to provide reasonable rights for farmers, breeders and industry. The international treaties set frames for minimal protection. The individual countries are left with rather a free hand in tailoring their national IP laws.

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CHAPTER 25

The impact of participatory plant breeding

Jacqueline A. Ashby

25.1 INTRODUCTION

Understanding how and when participatory plant breeding (PPB) is a proven complement to non-participatory breeding approaches builds on almost three decades of practical experience with PPB, but also relies on a growing body of impact-assessment research. PPB is a strategy with its own set of methodologies for plant breeding that applies in situations where the demands of producers, traders, industries and consumers for varietal traits are poorly understood and difficult to diagnose with conventional market research methods. This occurs where there is a high degree of risk and uncertainty due, for example, to volatile markets, climate change or very diverse agro-ecologies in the growing environment. PPB may also apply when producers and other stakeholders in a value chain, or even society at large, want to exert a high degree of control over decisions about the use of plant genetic resources and the kinds of plants that are introduced into the food system. The *impact* of PPB refers to the long-run effects of using its strategies, methodologies and tools. As a set of methodologies, PPB influences the agricultural extension and research process, as well as the productivity and welfare of producers, traders and consumers of the end products of PPB.

This chapter lays out the theory of change underpinning the impact of PPB and the evidence of impact from studies and reports of PPB programmes, the majority of which are located in developing countries. The theory of change is an explanation of the causal relationships that link the results of PPB to its impacts. To begin, a short review of definitions of participation is essential because different modes or types of participation in plant breeding can produce different impacts. Once the implications of different modes of participation for impact are clear, then hypotheses and evidence about the impact of PPB can be classified and analysed. This chapter lays out the hypotheses contained in the PPB theory of change in the framework of the impact pathway, a tool for showing the cause and effect linkages among different categories of impacts. Key issues related to research design and the analysis of cause and effect are reviewed, because these influence the extent to which we can confidently attribute certain impacts to PPB. Finally, the chapter examines the evidence that can be brought to bear on the principal components of the PPB impact pathways, using examples to illustrate findings obtained from over twenty years of experience with PPB in crop improvement programmes in more than 15 countries around the world (Walker, 2006; Ashby & Lilja, 2004; Vernooy, 2003). The impact of using PPB is multifaceted and includes changes in the research process as well as in knowledge, technology design and social organization. In developing countries, where markets are inefficient and it is difficult to discern the demand of small-scale farmers for new plant varieties, agricultural researchers use PPB to obtain feedback about farmers' varietal preferences. PPB can enable breeders to incorporate farmer knowledge into breeding strategies, objectives and methodologies: this knowledge refers to local environments, indigenous plant genetic resources, and local organizational capacity for participation in PPB. It can also enable farmers to incorporate advanced scientific knowledge into local practices, such as their customary, back-garden experimentation with plant varieties or seed banks. PPB changes the way the breeding process is organized and its costs when it increases cooperation between breeders and farmers in research.

Key impacts of PPB are to produce plant varieties that are well tailored to poor producers' needs, to shorten the amount of time plant breeding programmes need to get appropriate materials into farmers' fields and so accelerate adoption and seed dissemination. This is an impact on research efficiency related to improving the rate of innovation overall. In some situations, PPB helps to maintain or increase plant genetic diversity in farmers' fields and improves agricultural sustainability. PPB carried out with farmer groups improves farmers' organizational and social capital, as well as individual farmers' knowledge and skills and capacity to learn and experiment: all contribute to more resilient and sustainable farming systems. In addition, PPB is expected to have welfare impacts by increasing poor farmers' access to improved varieties, their productivity, nutrition, marketing and incomes. Given the important role played by women in managing plant genetic resources in many farming communities, PPB can affect gender equity.

PPB has evolved mainly to address the difficulties of poor farmers in developing countries. Widely seen as having advantages for use in low yield potential, high stress environments, PPB is most often applied when specific adaptation is sought. For this reason, a review of plant breeding methodologies in the CGIAR recommended in 2001 that it should form an "organic part of each Center's breeding program"(TAC, 2001: 24). However, some practitioners have results showing that both specific and wide adaptation are possible (see for example, Joshi, Staphit and Witcombe, 2001).

In industrialized agriculture, where wide adaptation is prized and markets drive demand for research, PPB maybe less useful from a research efficiency perspective, although farmers' local knowledge has on occasions proved a vital resource for developing new crop varieties (e.g. Walker, 2006). Nonetheless, in emerging markets, such as organic agriculture, PPB can have advantages. For example, in France, formally including producers in PPB for organic agriculture has proved useful for determining breeding objectives and methodology (Chiffoleau and Desclaux, 2006). This experience illustrates how PPB may prove useful in the debate about the welfare impacts of plant breeding in view of consumer scepticism about genetically-modified (GM) crops, and concern about how plant breeding affects food safety. PPB can promote informed participation and trust in research among consumers and producers.

In summary, impacts of PPB in international crop improvement research are associated with improving research relevance and efficiency via feedback from farmers, traders and consumers, and the welfare impacts of a faster and more relevant supply of new plant varieties to small-scale producers. There is, in addition, the issue of the impact of PPB on the costs of research and innovation. This is a complex issue, which is still relatively under-researched, but for which there is some evidence, discussed later. PPB may increase research costs compared to experiment-station-centred breeding because it is typically decentralized and requires work at multiple sites. At the same time, after 2–3 years of cooperation with a PPB programme, farmers increase their capacity to manage varietal evaluations and trial plots independently, and may assume some of the costs of adaptive research. In this situation, a criticism of PPB is that overall breeding programme costs are reduced but farmers' costs go up. However, the benefits of PPB to farmers include a reduction in the risk of productivity and income losses from planting ill-adapted, poorly performing varieties in their fields (a common experience for poor farmers receiving experiment-station-centred recommendations). Moreover, if PPB places improved varieties and seed in farmers' fields more quickly than other approaches, then farmers' income stream from new varieties will increase sooner. These gains must be factored into the overall cost–benefit assessment of PPB.

Before we can draw conclusions about the impact of PPB it is essential to make some important distinctions among the different types of participation used in plant breeding, and that is the topic of the next section.

25.2 WHAT DOES 'PARTICIPATION' MEAN IN PARTICIPATORY PLANT BREEDING?

The term "participatory plant breeding" (PPB) is used in this discussion to refer to the entire process of setting breeding objectives, making crosses, developing finished varieties and their release up to and including the supply of basic seed to growers. For the purposes of impact assessment, PPB refers to the full spectrum of breeding activities, including participatory varietal selection (PVS), much in the same way that trials evaluating finished varieties are generally understood to form part of a breeding programme. Some PPB specialists distinguish PPB as a breeding programme that includes farmers making crosses, as distinct from one in which breeders use farmers' suggestions or preferred local varieties to make their own crosses. They use the term PVS to refer exclusively to the participation of farmers in the evaluation of finished varieties and have demonstrated that PVS is a rapid way of identifying farmers' preferred cultivars. PPB can then use as parents cultivars identified by PVS (see, for example, Witcombe, Joshi and Staphit, 1996; Witcombe *et al*., 2005). In practice, PPB is a continuum of practices and differences from PVS are not rigid (Morris and Bellon, 2004). Several programmes use a mixture of approaches, often because practice evolves over time as breeders and the participating farmers learn how PPB works.

Discussion of the impacts of PPB requires a clear definition of what is meant by 'participation', because this term is loosely applied to a diversity of approaches for involving farmers in plant breeding, and various types of participation have different impacts. Participation refers to the relationship between producers and breeders, well recognized as a critical factor in many successful breeding programmes (Walker, 2006). One dimension of this relationship can be defined by the use of a functional or an empowering approach to participation. Functional and empowering approaches to PPB can be thought of as opposite ends of a continuum in the degree of participant empowerment. Functional participation in plant breeding improves research efficiency by involving prospective users of the results (farmers, intermediaries, traders, industries and consumers) in prioritizing and evaluating traits important to them, such as plant architecture, market appeal, storage and cooking quality. Functional approaches tend to leave the balance of power in decision-making in the breeding process essentially unchanged, i.e. plant breeders (and their employers) make most of the critically important decisions. Empowering participation changes the balance of power in decision-making in the breeding programme, usually in favour of giving non-research interest groups a more important role in key decisions about the end product, as well as in how the research is carried out. An empowering approach to farmer participation frequently alters breeding objectives and procedures, including the environments and cultural practices used to screen varieties. This leads to different results, as discussed in more detail below (Okali, Sumberg and Farrington, 1994; Ashby, 1996).

A similar distinction is made between PPB carried out in formal plant breeding research programmes versus farmer-led programmes. Farmer-led PPB is typically run by NGOs, and in several cases involves extensive research, but has different objectives from public sector crop improvement research. These may include community empowerment, biodiversity conservation, disaster relief or skills development (McGuire, Manicad and Louise, 2003). By definition, farmer-led programmes aim to empower farmers, but in practice can employ as varied or narrow a mix of types of empowering and functional approaches to participation as formal breeding programmes.

A more important distinction is between participatory research and participatory learning. Participatory *research* in agriculture is conducted to investigate questions for which neither scientists nor producers have an agreed explanation. Like all research, it involves risk and uncertainty about the outcomes of experimental treatments and it combines use of scientific method with native empiricism. The result is new knowledge, usually a blend of scientific and indigenous. The impact of PPB on this co-production of new knowledge may increase as the level of farmer-scientist cooperation and farmer empowerment increases. In contrast, participatory *learning* uses principles of discovery learning to promote sharing of established knowledge. Adult education in particular uses discovery learning because adults learn better when they uncover concepts and facts themselves than when they are told about them. Especially in agriculture, discovery learning involves farmers in running on-farm experiments very similar to the varietal trials used in participatory breeding. The key difference is that the participatory learning facilitator knows ahead of time what the experiments will show and, indeed, has designed the experiments to demonstrate a known practice or principle. Because participatory learning for agriculture uses experiments, it is easily confused with participatory research. PPB demonstration trials use participatory learning to share existing knowledge about varieties. PPB research experiments combine farmers' and breeders' ideas to test jointly conceived hypotheses and co-produce knowledge that is new to all concerned. Indeed, the performance of varieties grown on small farms in marginal environments is often so unpredictable that programmes starting out with a participatory learning focus find themselves drawn inexorably into participatory research, because their varietal demonstration trials did not produce the results expected.

Participation in plant breeding research (and in research generally) is based on the principle that participation of end users in the co-production of knowledge generates a higher level of understanding, ownership and trust in the information, and increases their capacity and willingness to make use of it. All actors involved in PPB research, including the scientists, have hypotheses but no *a priori* certainty of what results will be obtained. The experimental process is undertaken in conditions of mutual uncertainty and shared risk. PPB research typically involves cooperation between farmers and scientists in one or all of the following: establishing breeding objectives; identifying desirable traits so as to design plant ideotypes; selection of parents; selection in early generations; and screening of advanced lines. Scientists and farmers bring very different kinds of complementary knowledge and expertise to PPB research, but they have a common goal of testing hypotheses to answer questions to which neither know the definitive answer. Plant breeding programmes also use participatory learning to demonstrate finished varieties. A different use of participatory learning is when PPB programmes seek to improve farmers' capacity to participate in research in an informed manner, as when farmers are taught basic principles of heritability, techniques for making crosses or how to keep trial records.

In practice, PPB programmes often use a combination of both participatory research and participatory learning at different stages in the plant breeding process. For example, in the PPB methodology called 'Mother-Baby Trial' the Mother varietal trial is a researcher-designed and researcher-managed experiment. This trial is a platform for demonstration and participatory learning by farmers about the varieties that breeders are testing. Farmers then select those varieties they want to try out on their own farms. The farmer-designed and farmer-managed Baby varietal trials are a platform for participatory learning by breeders about farmers' criteria for varietal selection and management. Joint farmer-breeder participation in research and the co-production of new knowledge occurs when the combination of results and recommendations from Mother and Baby trials are made jointly. However, if breeders interpret data, draw conclusions and make recommendations from Mother-Baby trials independently of farmers, then farmers' are limited to a participatory learning role. The important question is: does this difference affect the recommendations and the eventual impact of PPB? The chapter will return to this question when evidence of PPB impact is analysed.

Different types of participation

PPB impacts are likely to vary depending on the type of participation used and whether or not the primary objective of participation is the co-production of new knowledge. The objectives are what differentiate approaches, not the methodologies or tools they use for facilitating participation, whether these involve participatory rapid appraisal (PRA), Mother-Baby trial, farmer field schools (FFS), farmer research committees (CIALs), participatory technology development (PTD) or others (Johnson, Lilja and Ashby, 2003). The key distinctions are:

- whether participation promotes or excludes the co-production of new knowledge between farmers and scientists ; and
- the timing of farmer participation: specifically, how early does participation occur in the breeding cycle?

Lilja and Ashby (1999) constructed a typology for empirical analysis of participation based on the principle that the way decisions are shared at different stages of a plant breeding process will structure the opportunities for co-production of new knowledge. The typology defines two groups of decision-makers: 'scientists' who include research programmes and extension agencies; and 'farmers' who include all the intended users of the PPB varieties such as consumers, traders and processors. These are ideal types of participation along a continuum in which 'farmers' are progressively more empowered, from conventional, in which there is no 'farmer' empowerment, to farmer experimentation, in which there is no 'scientist' empowerment. Different probabilities of co-production of knowledge are embedded in the typology: the most equitable balance of power in shared decision-making and the highest likelihood of shared knowledge generation is defined by the 'collaborative' type. Consultative and collegial participation both decrease the probability of co-production of knowledge.

The five types of participation are as follows:

- ***Conventional*** (no farmer participation). 'Scientists' make the decisions alone without organized communication with 'farmers'.
- ***Consultative.*** Scientists make the decisions alone, but with organized communication with farmers. Scientists know about farmers' opinions, varietal preferences and priorities through systematic one-way communication with them. Scientists may or may not factor this information into their decisions. Decisions are not made with farmers nor delegated to them.
- ***Collaborative.*** Decision-making authority is shared between farmers and scientists based on organized communication between the two groups. Scientists and farmers know about each other's ideas, hypotheses and priorities for the research through organized two-way communication. Plant breeding decisions are made jointly, neither scientists nor farmers make them on their own. Neither party has the right to revoke or override the joint decision.
- ***Collegial.*** Farmers make plant breeding decisions collectively, either in a group process or through individual farmers who are in organized communication with scientists. Farmers obtain information about scientists' priorities and research hypotheses through organized communication between the two groups. Farmers may or may not let this information influence their decisions.
- ***Farmer experimentation*** (no scientist participation). Farmers make the decisions either in a group or as individuals on how to experiment with and introduce new genetic material without organized communication with scientists.

The effect of any one type or combination of types of participation on the probability of co-production of new knowledge and the eventual impacts of PPB depend on how *early* in the breeding process farmer participation is sought (Joshi, Staphit and Witcombe, 2001; Lilja and Aw-Hasaan, 2002). Timing affects the objective and impact of the participation, and, in particular, the likelihood of co-production of new knowledge. To illustrate this point, consider the possible outcomes of one type of participation, collaborative participation, at three different stages of a PPB process: the early planning and design stage, the intermediate testing stage when fixed lines are evaluated, and the final diffusion stage, when seed is multiplied and distributed. The outcomes of collaborative participation will vary depending on the stage in the breeding process at which it is used. Collaborative participation in the early, design stage of PPB enables farmers to contribute genetic materials and actively engage in planning crosses: they can influence overall breeding priorities. Novel parents and crosses often result, affecting the variability on which subsequent stages of the PPB programme will build. In contrast, collaborative participation in the later, testing stage of the breeding process involves farmers in evaluating fixed lines: as a result, the varieties produced and impacts will be different from those developed with farmers involved at the design stage. Collaborative participation at the late, diffusion stage of PPB means farmers can only influence when, where and with whom varieties are demonstrated and multiplied for seed, but not the kinds of varieties available to them.

Early participation that enables farmers to help set breeding goals has the collateral effect of encouraging farmers to engage more actively with the breeding programme and adopt more rapidly. For example, in a community meeting, Nepali women farmers asked for quality improvements in a cold-tolerant rice variety. Farmers and breeders managed and screened jointly from F_5 bulk families and the resultant were superior to the best entries from the conventional breeding programme. Released by the national programme, the new variety spread rapidly to over 30 percent of rice area in the participating villages (Staphit and Subedi, 2000). Witcombe and Virk (2001) argue, based on a number of studies, that when a breeding programme based on a few crosses, the choice of parents is crucial and that farmer participation is highly effective in narrowing this choice made at the early stage in the breeding process. A methodological study of PPB using fixed lines and segregating populations found that farmers used a higher selection pressure than breeders, selecting about half the number of lines on station and about one tenth of the number of lines on farm compared to breeders. Entries selected by farmers yielded as much as those selected by breeders (Ceccarelli *et al*., 2000). This substantial body of research demonstrates the value of integrating farmers' intimate knowledge of their production environments into key breeding decisions.

In the typology described above, Lilja and Ashby (1999) divide the innovation process into three stages: design, testing and diffusion. In PPB (Weltzein *et al.*, 2003) these stages roughly correspond to:

- ***Design***. Setting breeding goals and generating variability. Decisions are made about basic parameters of variety type(s), preferences, and user needs. In most programmes, this stage involves designing and making crosses between diverse parents with complementary trait combinations. It may involve building base populations for cross-pollinating crops or the generation of new progenies for testing.
- ***Testing.*** In plant breeding, decisions are made about how to narrow down the new variability achieved in the design stage from several thousand to a few hundred progenies or clones (in the case of vegetatively propagated crops), and includes selection in segregating generations in self-pollinated crops. In population improvement schemes this is the progeny testing stage. In plant breeding this stage includes the testing of experimental materials on-station and, increasingly, on-farm. This testing looks for desired productivity traits, adaptation and acceptability, usually in replicated plots over a range of locations with increasing plot sizes. Testing continues until varieties are proposed for release.
- ***Diffusion***. This includes varietal release, demonstration under farmer management on farms, and the identification of a seed production and distribution system. Although this stage goes beyond the purely technical breeding process, the seed system may present a bottleneck to eventual impact, especially in poor countries, that needs to be taken into consideration early in the design stage.

Lilja and Ashby (1999, 2007) constructed a matrix in which any one of the five types of participation described earlier can be used in one or more of the three stages of PPB. With data obtained by using this matrix for interviews with 49 PPB programmes and projects about 32 key decisions in the design and testing stages of PPB, multiple correspondence analysis (MCA) was applied to identify types of participation used in PPB. MCA identifies relatively homogenous groups of cases based on selected characteristics, in this case patterns among PPB programmes in the way they use different types of participation at different stages of the PPB process. The results showed that these PPB programmes fall into different clusters based on their participation practice. The cluster with the largest number of PPB projects (61 percent) adheres mainly to collaborative participation.

25.3 IMPACT PATHWAYS FOR DIFFERENT TYPES OF PARTICIPATION

Impact pathways provide a framework for systematically mapping the cause-effect relationships (in the form of a flow chart), whereby a given intervention leads to a set of impacts, either expected or observed (Douthwaite *et al.*, 2003). This section uses the impact pathway framework to compare impact pathways for PPB and PVS, their use of various types of participation and differences in their impacts. Impact pathways can be diagrammed as flow charts, showing products of varietal selection (Figure 25.1, PVS) or making crosses (Figure 25.2, PPB) leading to outputs and finally to impacts. The impact pathway is a tool that a breeding programme can use to clarify its expected or actual outcomes and impacts: for those shown in Figures 25.1 and 25.2 the topmost pathways are generic but they can be changed to reflect specific programme goals.

Products in an impact pathway refer to results over which programmes have a high degree of control and a high probability of achieving. Outcomes in an impact pathway refer to the effects of using the products in the short term (usually about 2 or 3 years).

FIGURE 25.1
Impact pathways for PVS

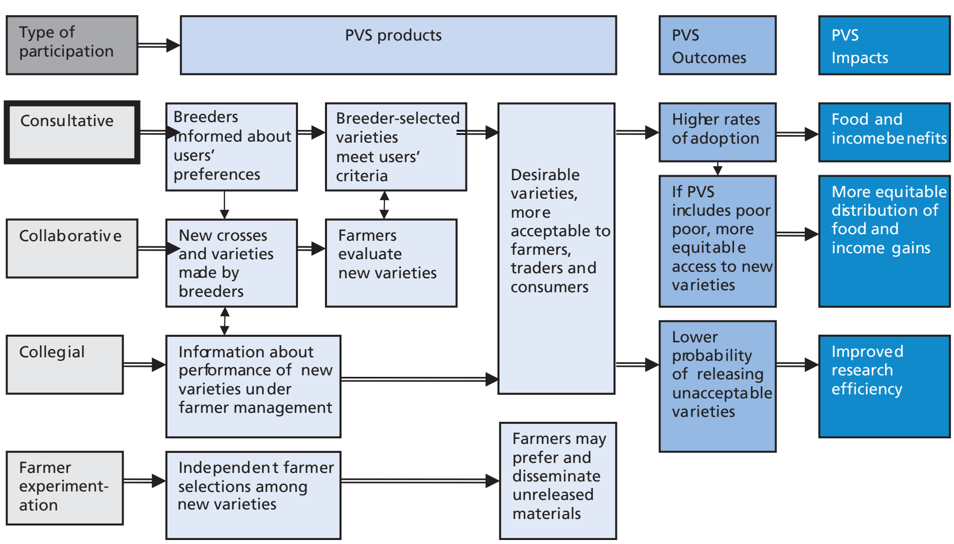
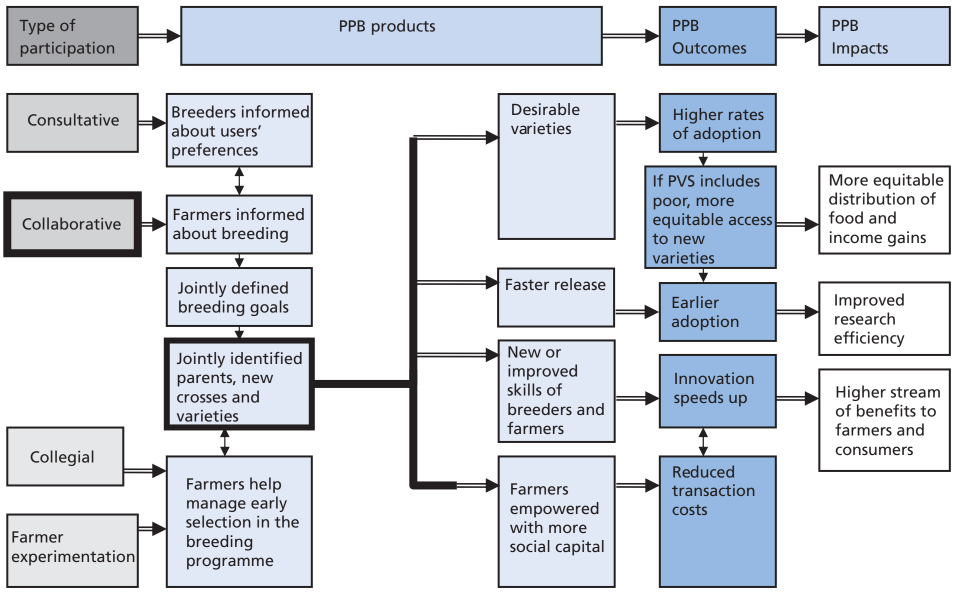


FIGURE 25.2
Impact pathways for PPB



Impacts refer to effects that take more time to achieve. In the category of PVS products, Figure 25.1 shows that consultative participation produces information about farmers' varietal preferences, which breeders then use to identify existing varieties or cultivars that are new and more desirable to the target population of farmers. If existing varieties are not suitable, breeders use information about farmer preferences to produce new varieties that are typically evaluated with farmers. This may involve collaborative participation, in which farmers are involved in decisions about which varieties are advanced or released. Typically, farmers engage in some of their own experimentation, either guided by the breeding programme (as in the Mother-baby trial approach, for example) or independently with escapes from formal trials. The end product of PVS is varieties that are more desirable to producers (and usually also to traders and consumers). The outcome is that more farmers adopt PVS varieties over wider areas, leading to increased food and income benefits. Another impact is increased research efficiency due to more relevant and desirable research products.

The impact pathway for PPB in Figure 25.2 illustrates how impacts change as participation occurs at earlier stages in the breeding process. As in PVS, a product of PPB is information about farmers' varietal preferences. However, in PPB, this exchange takes place early enough for breeding objectives to be defined jointly. In some PPB programmes, parents are also identified and crosses jointly planned. Thus, PPB involves reciprocal learning by farmers of key information about breeding strategies and some basic procedures. Farmers help manage early selection in the breeding programme and this activity harnesses a lot of the energy and resources that farmers otherwise expend on trying new varieties on their own. In addition to more desirable varieties, PPB characteristically produces varietal releases more quickly, reducing the time from first crosses to release by as much as 30 percent. Two other impacts of PPB are, first, the increased skills and knowledge for both farmers and breeders of 'how to' collaborate to co-produce improved crop varieties—this results from collaborative participation early in the breeding process. Second, norms of trust and reciprocity (social capital) developed between breeders and farmers who collaborate, as well as among groups of farmers, lead to observable increases in farmers' self-confidence and leadership (empowerment). One outcome is to reduce the transaction costs for numerous actors involved in developing, releasing and disseminating new varieties, which has a positive effect on the overall speed of innovation in the agricultural R&D system. Increasing the speed not only for making a given variety available to growers but also for the whole process of introducing new varieties, thus dramatically increases the benefit stream.

Evidence of impact

This section draws on a wide range of reported case studies of PPB, both published and unpublished. Fifty cases were included in a survey conducted by the CGIAR Participatory Research and Gender Analysis (PRGA) Program to obtain expert opinion from over 150 participatory research practitioners and form part of the PRGA's inventory of cases .This information is publicly available on the Program's Web site (Ashby and Lilja, 2004). Between 1987 and 2007 the PRGA made a systematic effort to stimulate impact assessment studies, synthesize their findings and promote their publication in peer-reviewed journals. The availability of published studies on the impact of PPB has increased notably in the past five years, including work done by the World Bank for the 2008 World Development Report (Walker, 2006).

Caution is required in using many of the available studies of PPB to make inferences about its impacts. In an impact pathway, outcomes are more difficult to predict or achieve than products, and impacts are even more difficult because of the passage of time and the numerous intervening factors that may change what happens. As one moves across an impact pathway from products to impacts, it is usually increasingly difficult to determine cause and effect. For example, whether higher returns to research on new varieties can be attributed to PPB, to the other types of research involved, or to market or policy changes that stimulate farmer adoption. One approach to this problem of attribution is to design impact assessment studies to include a counterfactual that permits comparison of 'with' and 'without' effects and, in some instances, also comparison of conditions before and after the intervention being assessed. However, most studies of PPB were not designed to provide a formal impact assessment. Although ideally we would compare PPB programmes with breeding programmes that did not use PPB, this is seldom possible. Another difficulty is selection bias, an issue in any analysis where the treatment groups are not randomly selected. PPB programmes may choose to work with specific farmers or communities in a way that biases the observed impacts. For example, they may work with more educated farmers, more organized farmers or more wealthy ones. Then impacts attributed to PPB may in fact be due to farmer education, organization or wealth. Finally, PPB efforts that fail to produce desirable varieties, or any of the other PPB products noted in Figure 25.1, may be under-reported in the literature, so that we tend to have more evidence about success than about failure.

Some PPB impacts are relatively easy to measure using established impact-assessment methodology. Agronomic and economic outcomes can be assessed at the farm level by measuring yield changes, net income over time and externalities such as changes in pest pressure or soil loss. Increases or decreases in costs are also straightforward. However, when empowering participation is used, part of the effects of PPB is on productivity and in particular on accelerating innovation in varietal improvement These impacts that are external to the technology are often referred to as disembodied effects, and pose a greater challenge for impact assessment as they are more difficult to quantify (Lilja and Dixon, 2008).

Impact pathway: PPB and PVS produce more desirable varieties leading to higher rates of adoption

Numerous studies conclude that PPB and PVS improve the acceptability of bred varieties to poor farmers in difficult environments by including their preferences in criteria for developing, testing and release. Small-scale farmers often rank varieties in order of preference differently from breeders. Many examples are available that show how PPB clarifies where there is agreement between breeders and farmers on desirable traits and where they disagree: cassava in Brazil and Colombia (Iglesias, Hernández-R and López, 1990); Hernández, 1993; Fukuda and Saad, 2001); pearl millet in Namibia (Ipinge, Lechner and Monyo, 1996; Monyo *et al.*, 1997a,b) and in India (Weltzein, 2000); maize in Mali (Kamara, Defoer and De Groote, 1996; Defoer, Kamara and De Groote, 1997); beans in Colombia (Ashby, Quiros and Rivers, 1989; Ashby, 1986; Kornegay, Beltrán and Ashby, 1996), in United Republic of Tanzania (Butler *et al.*, 1995), in Ethiopia (Mekbib, 1997), and in Rwanda (Sperling and Scheidegger, 1996; Sperling, Loevinsohn and Ntabomvura, 1993); tree species in Burundi (Franzel, Hitimana and Ekow, 1995); potatoes in Rwanda (Haugerud and Collinson, 1990), in Bolivia (Thiele *et al.*, 1997; Gabriel *et al.*, 2006), in Peru (Ortiz *et al.*, 2004), and in Ecuador (Andrade and Cuesta, 1997); rainfed rice in India (Maurya, Bottrall and Farrington, 1988); rice in Bangladesh, India and Nepal (Joshi and Witcombe, 2003; Joshi *et al.*, 2008), and in East India (Cortois *et al.*, 2001); maize in India (Virk *et al.*, 2003, 2005), in Ethiopia (Negasa, 1991), in Honduras (Gómez and Smith, 1996), and in Brazil (Machado and Fernandes, 2001); and barley in the Syrian Arab Republic, Morocco and Tunisia (Ceccarelli *et al.*, 2001a, 2003). A careful study in Mexico (Bellon *et al.*, 2000) was designed to select a subset of 17 populations for PPB from a set of 152 maize landraces. The suggestions of men and women in farm communities, professional plant breeders, gene bank managers and social scientists were obtained. The results showed that when germplasm choice did not include farmers' ideas, traits and materials important to farm households were often overlooked. The involvement of women farmers in the participatory development of maize seed systems in China resulted in a broadened national maize genetic base and improved maize yields (Song, 1998). This experience, by now so diverse with respect to crops, cultures and production environments, demonstrates the efficacy of participatory selection in producing varieties for poor farmers who are otherwise excluded by conventional crop improvement programmes.

A rigorous study conducted by the ICARDA barley breeding programme compared the number of high-yielding varieties obtained (termed selection efficiency) using different approaches. The breeder was more successful than farmers in selecting on station under high rainfall conditions, but farmers were more successful under stress conditions. A t-test of significant difference showed that farmers' selections were as high yielding as breeders' selections (Ceccarelli *et al.*, 2001a). Subsequently, the same programme conducted an important set of experiments on farmer participation in barley breeding in Morocco, the Syrian Arab Republic and Tunisia, where barley is the main crop for poor farmers in marginal, rainfed areas. Breeders' trials were planted both on research stations and in farmers' fields. Selection was done independently by professional breeders and farmers and data were gathered on their selection criteria and selection efficiency. Farmers used selection criteria not normally used by breeders because of the importance of the crop as source of animal feed. Disease, a major selection criterion used by breeders, was almost entirely neglected by farmers. Farmers successfully selected some of the highest yielding lines in their own fields and also on station. (Ceccarelli *et al.*, 2001b).

By successfully understanding and incorporating farmers' criteria for acceptability, PPB consistently enables breeding programmes to 'break through' adoption bottlenecks. In Ethiopia, for example, over 122 varieties of cereals, legumes, crops and vegetables were released, but only 12 varieties had been adopted by farmers, prompting a start with PPB (Mekbib, 1997). In Brazil, the national agricultural research institute, EMBRAPA, confronted years of non-adoption of new cassava clones. Once PPB was implemented several clones were released which were highly acceptable to farmers (Fukuda and Saad, 2001). Weltzein (2000) explains how learning about farmers' preferences and selection criteria reoriented an international pearl millet breeding programme to identify components for the mixtures of plant types farmers customarily grow. The new materials were well-accepted by farmers who were not adapting modern varieties. A study conducted in Syria provides evidence of higher rates of adoption of PPB barley varieties. Farmers were planting 69 percent more area to PPB than to conventionally bred varieties and were willing to pay more for seed of PPB varieties (Lilja and Aw-Hassan, 2002). On average, farmers reported PPB varieties had a 26 percent yield advantage over conventionally bred varieties. In Ghana, maize breeders released several modern varieties, which had poor acceptance and were not widely adopted. Subsequently, new material was tested in researcher-managed trials and in farmer-managed trials, and the outstanding modern varieties were jointly selected. Overall adoption of modern varieties expanded to over two-thirds of Ghana's maize farmers (Morris, Tripp and Dankyi, 1999). Another study compared matched communities with and without PVS conducted by farmer research committees (CIALs). Communities doing PVS had a much higher rate of adoption than non-PVS communities, who relied on other channels for seed (IPRA, 2008). The WARDA PVS programme conducted in 17 West African countries since 1996 used consultative participation to understand better what farmers need, and to feed back insights to formal research for improving future on-farm productivity: 69 percent of national programme researchers considered that by consulting women and involving them in varietal evaluation, the programme had included varietal traits that women know about, and especially gender-related varietal preferences, leading to higher adoption of the varieties.

Impact pathway: PPB leads to faster varietal release

A study that examines this impact pathway in depth was conducted by the ICARDA Barley Breeding programme in Syria (Ceccarelli *et al.*, 2001a). Using the same breeding population, varieties were developed using participatory and non-participatory breeding. The study found that by introducing farmer participation at an early stage of the breeding process (in Year 3), a three-year reduction was achieved in the time taken from initial crosses to release. PPB made certified varieties available by Year 6 compared to Year 9 in the conventional breeding programme (Lilja and Aw-Hassan, 2002)

PPB in rice and maize in India and Nepal found that farmers were well able to select from large numbers of segregating materials and their most preferred materials were rapidly adopted (Staphit, Joshi and Witcombe, 1996). Based on experience with different crops, the breeders concluded that PPB reduced by 3 to 4 years the time between making a cross and farmers receiving materials for testing. This contrasts with the conventional time of 10 years (Virk *et al.,* 2005, 2003)

In another case, farmer participation in screening the entire pearl millet germplasm accessions from Namibia (numbering about 1 000) proved very efficient in generating some basic information, such as when farmers recognized three major classes of materials with different clusters of desirable traits, and assisted breeders to come up with the desired pearl millet ideotype for Namibia. Breeders introduced material corresponding to the ideotype into farmer trials, and because millet is cross-pollinated, the frequency of the desired traits increased in local germplasm through introgression. Farmers began selecting outcrosses to provide seed for the following season, and after 4 years, breeders selected plants from a farmer's field. These plants were intercrossed with 30 varieties selected on-station by farmers from specially designed elite and morphologically diverse nurseries, to create a PPB composite population named MKC. MKC was far superior to the local germplasm and to another population, NC 90, developed by conventional breeding (Monyo *et al.*, 1997a, b).

PPB carried out in Bolivia addressed the need to develop potato varieties for specific ecological and market niches that need to be similar to those already valued by farmers and consumers, but more productive and more resistant to biotic factors such as Late blight disease (*Phytophthora infestans*) and False root-knot nematode (*Nacobbus aberrans*). Men and women farmers were trained in potato breeding techniques and, jointly with the plant breeders, generated 12 varieties similar to the most widely consumed cultivar in Bolivia, but resistant to late blight, with superior yield (10–25 t/ha, compared with 5 t/ha from the main farmer variety) and possessing agronomic traits and qualities desired by farmers. Three of the varieties showed novel potential for the potato chip industry. The breeders concluded that time was gained and adoption accelerated when farmers engaged early (Gabriel *et al.*, 2006).

Impact pathway: PPB's faster varietal release leading to earlier adoption increases the stream of benefits to farmers

An economic analysis of PPB barley breeding in Syria provides evidence of earlier adoption impact. Over 23 PPB varieties are grown on several thousand hectares. Total estimated discounted research induced benefits to Syrian agriculture were estimated, comparing conventional and three different PPB approaches, based on a rigorous comparison using experimentally-generated data on yields. Benefits from conventional breeding were estimated at US$ 21.9 million. Benefits estimated for the three PPB approaches ranged from US$ 42.7 million to US$ 113.9 million. Most difference is attributed to the way PPB reduced the amount of time it took for improved varieties to get into farmers fields (Lilja and Aw-Hassan, 2002).

Impact pathway: more desirable varieties and higher adoption rates improve research efficiency

New Rice for Africa (NERICA) implemented by WARDA, the African Rice Centre, used PVS to evaluate new varieties with men and women farmers, and helped to identify cost-saving production, grain processing and consumption traits, in addition to yield-related characteristics, valued by men and women. Results from Côte d'Ivoire show that failing to include gender-differentiated production and consumption traits and focusing on the wrong attributes leads to biased and inappropriate varietal promotions. Evaluating new varieties only on yield-related characteristics (often gender-neutral) will cause 19 percent of all varieties to be wrongly categorized as superior, whereas incorporating gender-differentiated traits (labour-related, consumption, post-harvest) reduces the probability of promoting varieties with poor acceptability and instead increases adoption potential (Dalton and Guei, 2003; Dalton, 2004; Lilja and Erenstein, 2002; Lilja and Dalton, 1998).

One of the main concerns related to research efficiency of conventional breeding programmes is that PPB looks very time intensive, and therefore costly. Many aspects of PPB seem likely to increase costs: on-farm testing begins earlier, more seed is needed of experimental varieties, trials are dispersed outside the experiment stations, and different kinds of personnel may be needed to interact effectively with farmers. Farmers need to be transported to experiment stations or regional trials, and a good deal of time is spent interacting with them to involve them in the early stages of the breeding process. In the case of a high altitude rice in Nepal, Staphit and Subedi (1996) considered their combined PVS and PPB approach cost-effective because the parents and segregating products were 'piggybacked' off the ongoing formal breeding process. Farmers were given still segregating (F_5) bulk families harvested from the most promising F_4 rows, for evaluation in their fields. There were important differences in the ways farmers and breeders tested the materials. The preferred cultivars subsequently developed with farmers were widely adopted within three years. In ICARDA's study that compared PPB and conventional approaches the operational costs of the programme increased due to PPB, which included costs of work off station in Syria and in several other countries. However, operational costs are only 23 percent of the total budget. Overall, the total annual budget went up by 3 percent, approximately US$ 26 000. (Lilja and Aw-Hassan, 2002). This cost has to be seen against the savings incurred by getting varieties out to farmers three years earlier using PPB. Clearly more analyses of the way PPB affects costs would help to clarify this debate, but at present we cannot conclude that PPB automatically represents a major increase in cost for a breeding programme.

Impact pathway: PPB fosters new skills, new knowledge and social capital that speed up innovation

PPB involves moving off conveniently-located, well-endowed experiment stations to a more decentralized breeding programme that relies heavily on farmer-managed selection. Numerous studies conclude that selection by farmers offers the greatest yield benefit over experiment station selection in low-yield-potential, marginal environments that differ dramatically from experiment station conditions (Weltzein *et al*., 2001; Smith, Castillo and Gómez, 2001; Cecarelli, 2000, 2001, 2003; TAC, 2001; Virk *et al*., 2003; Morris and Bellon, 2004; Walker, 2006). Decentralization places heavy demands on breeders' time and other resources, unless a significant degree of delegation to farmers takes place. In this situation, farmers need to develop the skills and knowledge required to maintain research quality with minimal supervision. Low rates of varietal turnover or replacement have been proposed as an indicator that farmers are not able to access varieties appropriate to their needs and constraints, signalling that opportunities exist to start PPB (Walker, 2006; Brennan and Byerlee, 1991). Breeders also acquire new skills and knowledge through PPB that improve their capacity to sustain the varietal change needed to increase productivity. However, whether PPB fosters capacity to sustain this innovation remains a research gap in assessment of the impacts of PPB. Whether PPB will gain enough traction to achieve institutionalization in breeding programmes is still an open question: without institutionalization, PPB's wider impact on innovation systems may remain hypothetical. Social analysis of innovation processes involving PPB are therefore an opportunity for further research that could contribute to its wider recognition.

Although not assessments of PPB impact, several studies find that use of participatory research and learning approaches improve skills and knowledge important for innovation (see, for example, Dalton *et al.,* 2005; Classen *et al.,* 2008). For example, social and human capital benefits have been studied for members of farmer research committees (CIALs) in Latin America (Classen *et al.,* 2008). CIAL members indicated that they had gained more knowledge about agriculture and were seen as agricultural experts and advisors in the community. They had also improved their communication and leadership skills, and had increased relationships with neighbours and with other outside institutions. CIAL members experimented more with new crops, had learned other new skills, and had higher levels of commitment to their communities, thereby leading to a higher level of community participation. In communities where the CIAL had identified new technology and converted into commercial seed producers, the communities benefited by having easy access to new technology (e.g. new varieties, such as early maturing maize varieties and new bean varieties). One study specifically examines the argument that improvements in social capital from using a participatory approach reduces transaction costs, leading to better cooperation and coordination and improving the innovation process (Gandarillas Morales, 2007). Thus impact pathway remains poorly documented for PPB, reflecting the focus of most studies on the breeding products and outcomes rather than the social impacts of PPB. This therefore remains an area ripe for further social analysis.

Impact pathway: PPB increases inclusion of the poor and disadvantaged, especially women, in R&D, leading to more equitable distribution of benefits

This impact pathway remains a significant research gap in the assessment of PPB. Only if programmes make a specific strategy of including the poor or other disadvantaged groups in the process, will PPB or PVS lead to more equitable distribution of benefits. It is often wrongly assumed that use of participatory approaches will guarantee inclusion of the poor or women and lead to more equity. While these approaches make it easier to engage with the poor, unless participant selection targets a particular social group, a participatory approach does not automatically lead to benefits for them (Kumar and Corbridge, 2002; Cleaver, 1999). The implications for PPB are illustrated by the findings of a study assessing impacts of participation in potato Integrated Pest Management (IPM) and PPB in Peru (Ortiz *et al*., 2001). Women did not participate in potato IPM because pest management is not part of their traditional responsibilities in the potato crop, and they said they could participate more in other traditional women's crops. However, participatory selection of potato clones was identified as an activity in which women had an essential contribution, because they are responsible for seed management, and so they were 50 percent of the participants in varietal selection. In contrast, a study carried out in Ecuador with two indigenous communities, to determine farmers' preferences for quinoa cultivars and to improve PPB processes, found more women than men participated because quinoa, a primarily subsistence crop, is mainly managed by women (McElhinny *et al.,* 2007). An analysis of economic costs and benefits of participation by farmers in conserving and improving maize landraces in Mexico concluded that farmers as a group earned a high return with a benefit:cost ratio of 3.8-1 although for the private investor the returns were low. This underscores the importance working with groups of farmers to build participation. Participants from richer households captured a larger proportion than they invested so that there was a transfer of wealth to the richer households from the intermediate investors, also the largest sub-group of investors. This reinforced the gender bias in the distribution of benefits (Smale et al., 2003) The lesson here is that participation can lead to the exclusion of important groups of beneficiaries, such as women, depending on prevailing customs and norms, especially if participation is based on self-selection. Inclusion in PPB may be determined *a priori* by the choice of crop, suggesting that if equity is an impact goal, then the decision 'with whom' to do PPB should precede ones about where and which crop to work with.

25.4 CONCLUSIONS

PPB produces more acceptable varieties, increasing adoption. This is its most extensively documented outcome and probably the most compelling incentive for plant breeders to use this approach. While major PPB initiatives, such as ICARDA's, do document yield improvements of 30–50 percent with PPB, there remains a need for more comparative data on yield or other advantages of PPB versus other breeding approaches, data that could be used to assess final impacts. Another consideration is research efficiency: PPB makes research more relevant and the changes in cost it involves do not appear to lower breeding programme cost–benefit ratios, and might even improve these. PPB also affects the speed at which new varieties are developed and get into farmers' fields. The important determinants of this impact are the use and timing of collaborative participation: early involvement of farmers in setting breeding goals encourages the co-production of new knowledge, gives farmers confidence in and ownership of the new varieties, and stimulates their rapid dissemination. To realize its full potential on a large scale, PPB requires organizational, policy and legal changes in both international and national plant breeding which, with few exceptions, represent tenacious obstacles to the institutionalization of PPB because science bureaucracies and the political elites that fund them, resist being accountable to poor farmers as clients. In the long term, one of the most important impacts of PPB may be its effect on the relevance of these agricultural innovation systems to the poor.

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This book provides a comprehensive description and assessment of the use of participatory plant breeding in developing countries. It is aimed at plant breeders, social scientists, students and practitioners interested in learning more about its use with the hope that they all will find a common ground to discuss ways in which plant breeding can be beneficial to all and can contribute to alleviate poverty.

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