Chapter 30

Participatory Plant Breeding for *In Situ* Conservation of Crop Genetic Resources: A Case Study of High Altitude Rice in Nepal

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Nepal is one of the world's richest centres of genetic crop diversity, a result of extreme agro-ecological and socioeconomic variations (Upadhyay and Sthapit 1995). Different production systems have evolved for different crops, trees, and animals to cope with the diversity and complexity of the situation. Food security is the primary objective of maintaining diverse food crops and animals. Farmers and farming communities maintain Genetic Diversity in a continuous process of natural and human selection. The crops and cropping systems depend largely on the available natural resources and are adapted to specific environments. This is in contrast to modern agriculture in which environments are adapted to the crops. Genetic Diversity is maintained as a part of the farming systems to enable biotic and abiotic stresses to be coped with naturally. The most important factors that motivated farmers to maintain wide biodiversity in the past were probably ensuring food security and meeting various qualitative preferences and requirements (Roder 1991, Sperling and Berkowitz 1994).

In mountain farming systems, diversity within and between species provides sustainability and a constant ability to adapt to changing environmental conditions through the natural processes of selection. Approximately 60 per cent of global agriculture is performed by subsistence farmers using traditional methods, and this sector provides between 15 and 20 per cent of the world's food (Francis 1986). Plant diversity is the basis of most traditional farming systems. Farmers in the remote mountains of Nepal still depend on the cultivation of land races for their livelihood. This is evident from the fact that in most of the staple crops that have been studied such as maize, rice, and potato, adoption of modern varieties is still below 50 per cent (NAA 1995). This figure would be even lower if neglected crops were included. Extreme agro-ecological diversity and the specific preferences of farmers mean that a large number of location and purpose specific varieties are needed. Until now, this need has been addressed by cultivating locally adapted land races.

On-farm conservation in farmers' fields needs to be continued in future so that it will still be possible to use recombination of useful genes from wild relatives and cultigens with those from widely-grown land races to develop crops adapted to changed conditions. Diversity is an essential genetic resource for future plant and animal breeding. Gene flow from wild relatives to farmers' land races, and from land races to improved cultivars, is a dynamic process and should be maintained if plant breeding is to meet the growing needs of the world's population (Vaughan and Sitch 1991). New land races will continue to evolve under changing environments as long as genetic variation exists. In fact, modern agriculture is based upon the earlier efforts of farmers to maintain Genetic Diversity and knowledge. Farmer experimentation using the naturally existing genetic variation, produced the present day land races. Food security can only be as good as the genetic base supporting it. Therefore, the maintenance of traditional varieties and land races *in situ* should be an essential component of sustainable agricultural development.

Threats

Crop genetic resources are threatened by population growth, environmental and technological changes, and commercial development, making conservation an imperative. With the introduction of new high-yielding varieties and over-exploitation of natural resources, genetic erosion is also taking place in Nepal. Genetic erosion is reported to be high in staple crops, vegetables, fruit, and medicinal plants at both varietal and species' level. There are many examples in Nepal of crops, such as local vegetables, citrus fruit, and aromatic rices, with genetic potential that was only realised after they were lost from their natural habitats (Shahi and Mathema 1983; Sthapit *et al.* 1996). Until our national research system becomes capable of fully understanding and using the germplasm resources, *in situ* conservation of bio-wealth should receive priority on the national research agenda.

Genetic erosion is largely the result of breeding better varieties in productive environments. Selected cultivars gradually replace land races and better cultivars take over from earlier cultivars, until they in turn are replaced by still better cultivars. This process also occurs at the centres of origin which harbour the maximum genetic variation of one or more species. Genetic erosion also occurs as a result of changes in the land-use system or labour constraints. The potential threat of losing local resources forever has not been considered seriously. This threat will persist if the farming communities who maintain land races do not see any benefit from maintaining biodiversity.

Management Models for Germplasm Conservation

There are two ways of conserving germplasm: *in situ*, in the place of origin; and *ex situ*, outside the place of origin (as in zoos, botanical gardens, and gene banks). According to Brush (1995), *in situ* conservation of land races means maintenance in farmers' fields and home orchards in the place where they originated. *In situ* conservation is currently carried out by farming communities. Unfortunately, *in situ* genetic conservation has been described by various international organizations in reference to the conservation of ecosystems and communities. As a result, the objectives of on-farm conservation have been confused with those of various types of protected reserves. *In situ* conservation is now perceived, however, as a possible complementary method to *ex situ* conservation for land races. In the past it was considered the preferred method of conservation for wild species but was never implemented in the international germplasm system (Frankel 1970).

The Limitations of *Ex Situ* Conservation

Gene banks cannot conserve all types of on-farm species. The faults and merits of gene banks are well recognised. The gene bank cannot conserve the biological and social processes of crop evolution in the way that *in situ* (on-farm) conservation usually does. Furthermore, seeds stored in gene banks are not accessible to local communities. Even researchers have less access to gene banks. *Ex situ* conservation is managed and funded by outsiders (international centres) whereas *in situ* conservation is managed and controlled by local farming communities. Even taking into account the problems associated with *ex situ* conservation of germplasm, *in situ* conservation cannot be regarded as the sole panacea for the loss of land races.

It is important to compare the objectives, methods, and needs of the two approaches to clarify the differences between them and to establish their complementarity. *In situ* conservation can be considered an important conservation strategy and a way of making up for the potential faults of *ex situ* conservation, such as loss of seed viability, smaller population samples, genetic drift, and the static nature of gene flow. However, farmers will not continue to grow local land races or species if they do not see any advantage in them. Materials that farmers are not interested in can still be preserved *ex situ*. Therefore, both *ex situ* and *in situ* genetic conservation of agricultural biodiversity should continue and should be seen as complementary, not exclusive, activities.

Options

Various options can be identified in the literature for managing on-farm conservation of agrobiodiversity in farmers' fields. They are:

- protected reserves,
- subsidies,
- compensation,
- community seed banks,
- incentives - market and non-market oriented,
- awareness,
- education and training,
- policy relief,
- improvement of land races through disease elimination, and
- participatory plant breeding using land races as a parent.

Farmers will continue to search for better varieties than existing ones to meet their needs. This is a natural human instinct and should not be stopped for the sake of a 'protectionist' style of *in situ* conservation. Many conservationists agree that systems that rely on farmers' compensation or subsidies and/or result in low production levels will not be successful in conserving biodiversity and genetic resources at the farm level (Roder 1995). While direct compensation to farmers is not intended, it is important that the global investment in farmer welfare, through participatory plant breeding, farmer training, and community seed banks, be seen as indirect compensation in recognition of their role in on-farm genetic conservation. This kind of indirect compensation may reach more farmers and thus be more equitable than a system of payment to a few farmers (Brush 1992).

Strategy

In situ conservation cannot be achieved through 'subsidy' or 'museum' or 'reserve' strategies (Benz 1988, Roder 1995). The essence of successful *in situ* conservation strategies is to encourage farmers to maintain the special habitats that generated and maintained such diversity in the first place. Strategies for *in situ* conservation of agricultural biodiversity will work if they are:

- beneficial to farming communities,
- complementary to ex *situ* methods,
- politically viable and accepted by scientists, conservationists, farmers, consumers, and government officials, and
- implemented through community-based grassroots' institutions (NGOs).

Community participation will enhance the success of on-farm genetic conservation. The ways in which on-farm genetic conservation can be strengthened are described in the following.

Technical Approaches

- Involving the farming community in a participatory way in variety selection and plant breeding
- Researching the real situation by means of case studies
- Pathogen elimination in local land races (for example, potatoes, citrus fruit trees, and cereal crops)
- Training of farmers in seed selection, storage, and seed health
- Introduction of a flexible seed regulatory system to promote participatory plant breeding (PPB)
- Additing value addition to local plant genetic resources (for example improvements in aroma or in disease and stress resistance)

Non-technical Approaches

- Identifying and developing markets for local products
- Facilitating information and seed exchange
- Analysing agricultural policy to identify the incentives and disincentives that influence farmers' decision-making about variety selection and conservation (for example, policies related to seed, inputs, fertilizers, credit, extension services, and marketing)
- Education in schools through curriculum development
- Raising awareness of consumers
- Networking of grassroots' organizations to improve their capability and promote the exchange of information and materials
- Lobbying

A Case Study of Participatory Plant Breeding (PPB) of High Altitude Rice

The Problem

In Nepal, rice cultivation has been less widely adopted in high altitude areas where cold injury is common. Only limited research resources have been allocated to this problem by national and international programmes (LARC 1995, Chemjong *et al*. 1995). Cold tolerant materials from the International Rice Research Institute (IRRI) and the National Rice Research Programme (NRRP) at Lumle (1450m) and Chhomrong (2000m) failed to produce grain because of incomplete panicle exsertion or spikelet sterility (Sthapit 1992). National and international programmes appear to have failed to meet the needs and requirements of this 'difficult' environment. Many formal breeding programmes tend to focus on developing varieties for wide adaptation and with high yield potential for favourable environments. These materials do not adapt well to Nepalese mountain farming systems because of:

- the limited use of land races in the breeding programmes,
- untargetted screening, and
- lack of involvement of farmers.

The formal research system in developing countries is highly centralized and does not reflect the problems of resource-poor farmers. The low rate of adoption of officially released rice varieties in India (Maurya *et al.* 1988, Joshi and Witcombe 1996) and Nepal (LARC 1995, Chemjong *et al.* 1995) is evidence of this. The slowness of the formal procedures and the fact that only a few new varieties are generated every year when the need of farmers is for a basket of varieties to address diverse and complex farming systems have encouraged us to try alternative, participatory methods.

PPB methods are poorly documented, and there are few examples in the literature. Thakur (1995) screened F_2 material in farmers' fields, but subsequent generations were grown by researchers. In Ethiopia, land races have been enhanced by mass selection by farmers in collaboration with scientists from the Plant Genetic Resources' Centre (Worede and Mekbib 1993). In the Philippines, farmers have been involved in selecting from the progeny of crosses between traditional and improved cultivars, but the methods used have not been described in detail (Salazar 1992). A well-documented example of PPB was described by Sthapit *et al.* (1996) and this is the case study described in the following paragraphs. In all methods plant breeders are the facilitators of the research, since they have the essential understanding of the underlying genetics of parental selection and subsequent genetic segregation.

Concept

A participatory plant breeding (PPB) programme was conducted at Lumle Agricultural Research Centre (LARC) for the high altitude areas of Nepal. The purpose of the programme was to examine the potential of PPB for minimising resource use, utilising farmers' knowledge, developing suitable cold tolerant white-grained rice varieties, and enhancing the biodiversity of rice gene pools.

In the PPB, the land race is chosen as a parent to give genes for adaptation, and a released cultivar is chosen to give genes for other preferred traits, for example, high yield potential. When land race x MV cultivar crosses are used, and selection at the early stage of segregating lines is performed by farmers in the target environment, then the breeding strategy most closely resembles *in situ* genetic conservation of land races. In the past, some curious farmers experimented with naturally existing genetic variation in their own environment to produce the present day land races. Nonetheless, it cannot be ruled out that some 'unidentified but useful' genes present in the land race will be lost in the process of selecting crosses. *Ex situ* conservation will still be necessary to conserve the original unchanged land race. *In situ* PPB conserves and creates Genetic Diversity in farmers' fields, whereas *ex situ* conservation preserves genetic resources (Witcombe *et al.* 1996).

PPB is more likely to be successful in producing farmer-acceptable varieties than a conventional breeding programme because:

- negative genotype/location interactions are greatly reduced as selection is always in the target environment and under farmers' actual management conditions,
- at least one parent is well-adapted to the local (target) environment,
- the impact of genotype/year interactions is also reduced,
- large F_2 and F_3 populations are grown to increase the possibility of identifying transgressive segregants, and
- post-harvest evaluation is used to assess the level of farmers' preference.

The basket of choices available to farmers is likely to be larger when PPB programmes exist than when multi-locational testing programmes are used to produce widely adapted cultivars.

Methodology

The detailed methodology of the PPB programme is described in Sthapit *et al.* (1996). Briefly, PRA was undertaken to identify the characteristics considered important by farmers. Genetic variation was created by crossing a locally adapted land race with a variety with a farmer-preferred trait. Three crosses were used: Fuji 102 x *Chhomrong Dhan* (Machhapuchhre), K 332 x NR10157-2B-2 (Himchuli), and Stejaree 45 x *Chhomrong Dhan* (Nilgiri). In all cases, one of the parents was either a land race or a breeding line involving a local land race. Several sister lines of each cross were given local names to make them easier to identify in discussions with farmers.

Farmer participation began at the F_5 stage, with selection by expert farmers at a village workshop. Wives of cooperating farmers were automatically selected to do post-harvest evaluation. Farmers participated in the selection process by growing the selected rice F_5 bulk seed in the target environment. Actual site selection was left to the farmers, and they were later asked for their reasons for selecting a particular site. The expert farmers were also asked to select management practices of the type followed for their local varieties. Decisions on manure, soil type, and agronomy were left to the farmers. At the beginning of the selection, farmers were informed that when two divergent varieties are crossed the material is segregated for traits such as grain colour, plant height, and maturity, thus selection from the F_5 bulk seed for desired traits should be carried out for two to three years until the trait is fixed. The breeder's knowledge of genetics and heritability was offered to farmers to complement the farmers' indigenous knowledge of diverse environments. When the crop had matured, each participating farmer visited all of the plots during a farm walk, and farmers ranked the varieties from best to worst by assessing visual crop performance. Farmers, with the help of researchers, also recorded the positive and negative characteristics of each variety. Post-harvest evaluations were carried out by women farmers three months after the harvest.

The progress of the PPB programme was followed over three seasons in three villages. Five indicators were used to assess the impact of the PPB programme at farm level.

- The rate of adoption of new varieties and varietal spread
- The level of farmers' awareness
- The measure of Genetic Diversity at the village and household levels
- The basket of choices offered
- The perception of the farming community towards the PPB programme

Result

The strategies used by farmers to select test sites for planting are shown in Table 30.1. There were significant differences between farmers' and researchers' strategies for selecting testing sites. It is common practice in formal research systems to use good, uniform land and uniform growing conditions for trials, rather than to select for the target environment (Sthapit 1995). In contrast, farmers avoided risk by first testing the materials on their worst lands (stressed environments), and then growing the variety in better fields (Table 30.1). The heritability of a selected trait under such stress will usually be very high (Ceccarelli 1989). There is growing evidence that, for selection to be most effective, it must be carried out in the target environment. The farmers' strategies show how difficult it is to represent the heterogeneous environments of farmers' fields in uniform on-station conditions.

Simmonds (1991) also reported that selection for low-yielding environments must be conducted in low-yielding environments, and found that alternative strategies were ineffective. Ceccarelli (1989) suggested that, when the stress environment has a much lower yield potential, direct selection in the environment

Table 30.1: **Farmers' Strategies for Site Selection (1993)**

Farmer	Altitude (m)	F_5 bulk name	Selected site	Decision made
J.N. Devkota	1400	Nilgiri-1	• No rice crop before • Inlet of cold water • High fertility	Confined*
H.B. Gurung	2000	Himchuli-2	• Inlet of cold water • Marginal plot	Rejected
D.J. Devkota	1400	Himchuli-2	• High soil fertility	Promoted
M.K. Gurung	2000	M.puchhre-1	• Upland rainfed conditions	Rejected
R.B. Gurung	2000	M. puchhre-3	• Worst cornered terrace • Cold irrigation water • Shade prevailing	Promoted

* Confined means area not increased cf. to first year planting

is the most efficient breeding strategy. The most effective way of catering to the needs of low resource farmers is to conduct trials on farmers' fields with farmer level inputs.

The farmers were very willing to participate, and some were very skilful in making selections. There are numerous examples in which farmers were able to identify specific varieties for their niches and cold stress conditions (Table 30.1). Farmer methods of plant selection varied with the farmers' own expert knowledge and circumstances. The segregating line of Machhapuchhre-3 was given to three farmers, but only two of them succeeded in selecting superior types (Sthapit et al. 1996). The farmer who failed to identify superior types from the same F_5 seed had simply concentrated on mass selection for grain colour. Women farmers were particularly skilful in assessing post-harvest traits such as milling recovery, cooking, and eating quality of rice. Male farmers showed more skill in the assessment of standing crops for yield potential, management requirements, and threshing criteria. Breeders and field staff need to interact with farmers frequently and stay in the villages for a considerable time in order to identify such gender differences and any differences between groups in the village.

Farmers evaluate new varieties at different stages of crop growth, particularly close to maturity, and also during threshing, milling, and consumption. Monitoring indicated that farmers continually changed their decisions with the availability of new information. At present, farmers' involvement in formal variety testing in Nepal is limited to preference ranking at maturity, but most farmers make their final decision on retaining or rejecting a variety after milling, cooking, and eating. The post-harvest assessment of various tested varieties compared with the local reference variety is shown in Table 30.2. The decisions about retention or rejection were based on different traits. For example, the area under M-4 expanded because of its good milling recovery, whereas M-6 was rejected because of its peculiar

Table 30.2: **Post-harvest Assessment of Various Rice Varieties Measured in Relation to the Local Reference Variety (check variety) Chhomrong Dhan, 1994**

Traits‡	M-2	M-3	M-4	M-6	M-7
Milling %	50.0	45.0	56.0	45.0	40.0
Broken rice %	1.9	5.0	1.3	5.0	5.0
Water-absorbency capacity	+	+	+	-	+
Elongation capacity	+	=	+	-	+
Aroma	+	-	-	-*	-
Dryness	+	+	+	-	+
Stickiness	+	+	+	-	+
Taste	+	+	+	+	+
Appelite delay	+	+	+	-	+

† Better than local reference variety = equivalent to local reference variety, - Inferior to local reference variety

‡ Assessment was done by farmers after cooking in their own way and relative to local reference variety. Asterisk (*) indicates peculiar smell of rice which was not liked by farmers.

smell when cooked. M-3 was preferred at all stages because of its yield potential and straw height. Nilgiri-1 was first selected by a farmer in Lumle village, who later rejected his plan to expand the variety in the remaining good fields because of the high shattering and poor taste. Finally he decided to grow it in only one plot where an inlet of cold stream-water caused high sterility. Himchuli-2 was rejected by farmers at Chhomrong, Ghandruk, and Lumle where rainfall is very high at the time of maturity and causes pre-germination before harvest. In contrast, it was liked by the farmers in Patlekhet village (1,500-1,700m), where rainfall and humidity were less at the time of maturity. In Lumle, the mother of D. Devkota selected non-sprouted panicles and planted the seed from them in a 100 sq. km. area to see whether the problem of sprouting would continue. Such examples support the decentralization of selection. Such information should be disseminated to extension staff.

The most successful material is now being adopted by farmers. Good varieties selected by farmers spread substantially within three years of their introduction (Figure 30.1). M.B. Gurung, who was given half of the seed from his friend, J.B. Gurung, successfully selected from M-3 (his selection is identified as M-3C) and increased the area under this variety from three sq.m. to 150 sq.m. within a year. Similarly, R.B. Gurung also selected from M-3 (variety identified as M-3G) and increased the area grown from six sq.m. to 50 sq.m in 1994 and 1,250 sq.m in 1995 (Figure 30.1). This variety occupied 2.5 per cent of his rice fields after the first year of selection and 62.5 per cent after the second. Thus farmers from two villages from similar ethnic groups and farming backgrounds selected two different varieties, M-3C and M-3G, from the same F_5 bulk seed. The rate at which the area of cultivation of selected cultivars increased has been high in the first three

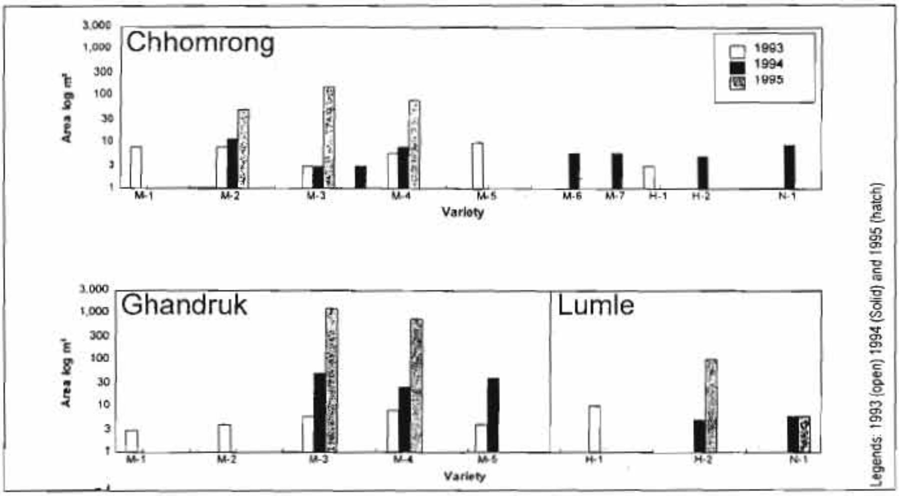

Figure 30.1: The Spread of Farmer-preferred Bulks Measured by Area Increased (log m^3 under New Rice Line Since PPB Was Initiated in Chhomrong and Ghandruk Villages

years. This compares with the conventional system in which there is a long period, typically five to six years, before appreciable adoption occurs (Morris et al. 1992). It has been observed that farmers usually fulfill their own needs first and only then supply seeds to other farmers. Some farmers in the programme have already started distributing seed from their preferred varieties to other farmers. We anticipate that M-3G will be cultivated widely in domains similar to those in Ghandruk and Chhomrong by the time the variety is released through the formal system.

Thus PPB successfully produced excellent cultivars which are spreading in farmers' fields. In a conventional breeding system, material such as M-3G and M-3C (at F_7 stages) would have still been at a very preliminary stage of varietal screening in very small plots, and still at least seven years away from being given to farmers for them to grow in minikit tests (Figure 30.2). Even if time is allowed to select for greater uniformity in a farmers' cultivar to satisfy seed certification requirements, a release proposal can be submitted following PPB three years earlier than in the conventional system.

The varieties developed jointly with farmers were far superior and outperformed the best entries from the conventional system (Figure 30.3). The most preferred material, Machhapuchhre-3, has also performed well in the formal trials' system. There were clear advantages in using locally adapted parents and selection in the target environment, compared to introductions from international nurseries which usually perform poorly (Sthapit 1992).

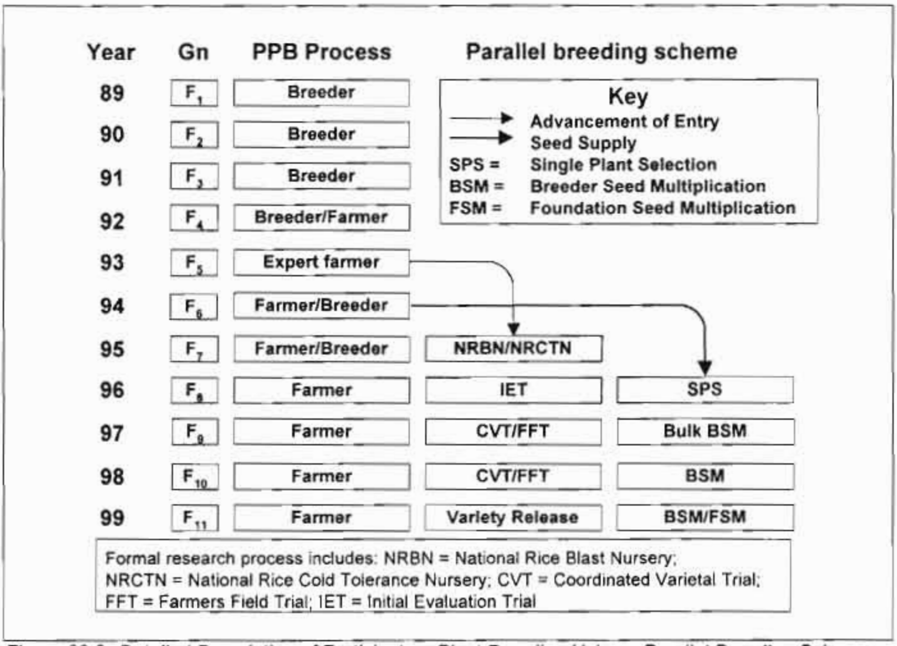

Figure 30.2: Detailed Description of Participatory Plant Breeding Using a Parallel Breeding Scheme

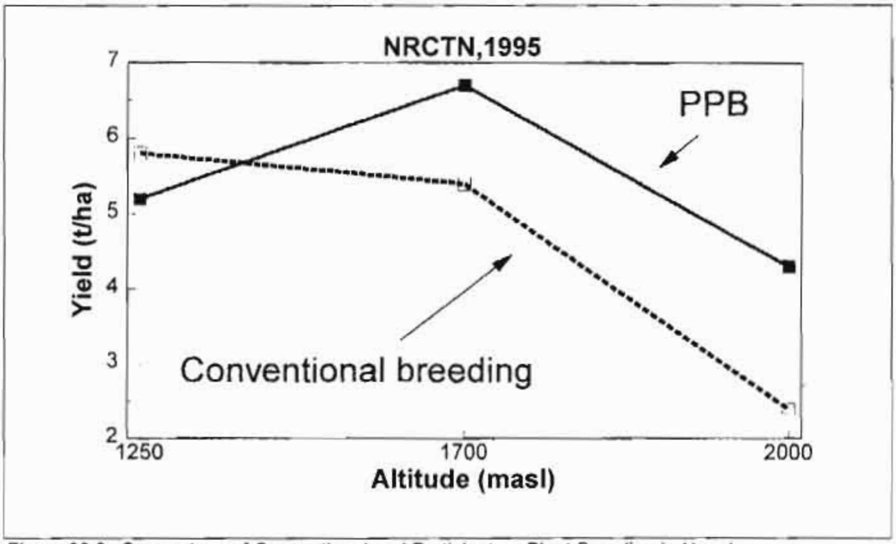

Figure 30.3: Comparison of Conventional and Participatory Plant Breeding in Nepal

This work has shown for the first time that a farmer-selected variety cannot only be farmer acceptable but can also yield well in the formal varietal testing system. This is in part the result of the trials' system having test locations appropriately situated and a trial arrangement that does not differ from farmers' crop management.

PPB will also help to conserve biodiversity as the process leads to the development of different varieties by different farmers. Varietal diversification was achieved within three years, and a dynamic form of Genetic Diversity will persist as farmers select plants for specific niches (Table 30.3). In Chhomrong and Ghandruk villages, two farmers selected two different rice varieties from the same F_5 bulk seed of Machhapuchhre-3 (Fuji 102/Chhomrong) cross (Sthapit *et al.* 1996). They distributed seeds to five more farmers who had selected under their own conditions. These materials might have hidden genetic variation, thus enhancing Genetic Diversity and conserving part of the local gene pool *in situ*. This approach has resulted in a dynamic form of *in situ* genetic conservation of biodiversity by involving farmers and using materials generated from land race x exotic crosses (Witcombe et al. 1996). This system would not necessarily require a formal means of seed supply; seed can be supplied by the same local systems already used by farmers. However, involvement of grassroots' level organizations in the support of a seed supply system would help better dissemination of such varieties.

Table 30.3 : **Varietal Diversity Created by PPB in Selected Villages**

	Chhomrong	Ghandruk	Lumle
Before 1993	1	1	4
1995	5	4	6
1996	7	5	6
1997	9	4	6

Farmer participation in varietal evaluation should be adopted because it allows all of the important farmer-relevant traits to be assessed – including taste, cooking quality, market value, good threshing characteristics, and storability, rather than only the limited sets of characteristics measured in plant breeders' trials. Farmers' perception of the programme was assessed in focus group interviews. At the beginning of the programme, farmers were not very enthusiastic. As farmers realised that PPB was beneficial to them, the quality of participation improved. The comments made during field visits reflect the satisfaction of the participating farmers (Table 30.4).

Policy and Institutional Issues

The mandate of institutional breeding is usually to raise national food

Table 30.4: Farmers' Perceptions of the Participatory Breeding Programme for White-grained Rice in Chhomrong and Ghandruk, 1994

Location	Date	Gender	Size of interview group	Comments
Chhomrong	7 Oct 94	Male	9	"Any rice variety that grows at this altitude is good. We need a variety that yields more and gives more straw. A white grain colour is a bonus. We will further select the plants to grow in larger plots next year."
Chhomrong	7 Oct 94	Female	5	*"If we can change our local rice into white grain rice it will save a lot of our (women's) time. We spend one to two hours' extra time to dehusk rice to get white grain."* *"Machhapuchhre-3 has both more grain and more straw. It has long panicles and plenty of grains. It matures with local varieties and the plant is taller. If it tastes good I would like to continue this variety."*
Ghandruk	9 Oct 94	Male	1	*"In the beginning I was not interested in involving myself, but when LARC scientists told me that the variety has white grain then I became curious. I first tried it on the worst parts of my land. I saw tall plants producing really good panicles. I selected all the best plants with white grain and maturity similar to our local variety. This year it looks really good and better than last year. Now I am happy to grow it on all my plots. I have no plans to share the seeds until I fulfil my requirements."*

production. It is therefore logical that it concentrates its efforts on the main production areas where higher yields are possible through improved crops. A major challenge in plant breeding is how to address the problems of resource-poor farmers in marginal environments who have often contributed important Genetic Diversity to the institutional system and received little benefit in return (Hardon 1995).

It is extremely important for political leaders and decision-makers at different levels to understand both the problem and the means that exist to solve it, as only with their help can appropriate strategies for on-farm conservation be implemented. This will require some fundamental changes in the institutional systems, considering the generally conservative and technological attitude of most formal institutional set-ups for agricultural development.

The major constraints in institutional systems include:

- lack of incentives for and rewards to plant breeders,
- lack of incentives to use local land races and/or involve local communities,
- over-dependence on the Consultative Group on International Agricultural Research (CGIAR) system,
- centralized variety testing and release systems,
- centralized seed production and distribution systems,
- the attitude of conventional plant breeders and pathologists, and
- competition for resource allocation.

As Ashby and Sperling (1994) anticipated, the institutionalisation of decentralized breeding is the most challenging issue. If the success of these initial efforts is to be sustained, research management should ensure a congenial environment for field staff who work in difficult areas. This is often forgotten by policy-makers and research managers when they try to replicate successful and innovative approaches from elsewhere.

Two levels of decentralization are possible: the first is at an international level from CGIAR centres to the National Agricultural Research System (NARS), and the second from NARS to farmers. This second level should be our focus. Farmers should be involved in the selection process from the early stages. A reform of seed regulatory procedure will be required to accommodate decentralized breeding and variety testing, release, and registration procedures. Current seed certification and quality control procedures often do not serve the needs of farmers in developing countries.

Products from PPB could also be entered into the formal trials and official release system (Sthapit *et al.* 1996). The breeder chooses the material most widely accepted by the farmers and introduces the cultivar(s) into a selection scheme parallel to that of the farmers (Figure 30.2). A cultivar release and seed production system is still a very desirable end product to make the results of the PPB more widely available and gain the benefits of large-scale seed multiplication of the successful released cultivars.

Non-government organizations (NGOs) could play a key role in mobilising community support for agricultural development and on-farm conservation activities. Following successful PPB programmes, experienced and expert farmers with motivation from NGOs may wish to select parents and carry out breeding, and seed multiplication and distribution programmes of their own. This would be a more sustainable way of maintaining genetic conservation *in situ*.

The decentralized selection of segregating material from a few carefully chosen crosses draws on the active participation of expert farmers and presents an attractive prospect for fostering a more sustainable and productive agriculture for diverse risk-prone environments. This new approach could be of considerable significance for managing the on-farm conservation of land races. The prerequisite for the method is that the objectives are clearly identified and the breeders flexible enough to learn from and interact with the farmers. Furthermore, community participation is essential for managing *in situ* genetic conservation of land races.

Institutional building of community-based organizations (CBOs) and NGOs should be a part of the strategy to institutionalise on-farm conservation and to deliver benefits to farmers. Strong support to CBOs/NGOs is required to strengthen the management of on-farm conservation There should be a positive policy to support such activities in the longer term. A working partnership should be developed between the international and national agricultural research systems and CBOs/NGOs to implement successful *in situ* programmes on a wider scale.

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