Participatory Plant Breeding: Setting Breeding Goals and Choosing Parents for On-Farm Conservation

Bhuwon Sthapit, Krishna Joshi, Sanjay Gyawali, Anil Subedi, Kedar Shrestha, Pasupati Chaudhary, Ram Rana, Deepak Rijal, Madhusudhan Upadhaya, and Devra Jarvis

Abstract

Participatory plant breeding (PPB) is a strategy for strengthening on-farm conservation by encouraging farmers to continue searching, selecting, and managing local crop populations. This paper describes the preliminary results of PPB processes that address the difficulties of setting breeding goals and choosing parents in diverse research areas. Participatory methods were developed to gain an understanding of the extent and distribution of local crop diversity and the processes by which farmers maintain crop diversity on their farms. The study addresses farmers' needs, conservation issues, and diverse users' issues in the process of choosing parents and selecting for variable populations.

Introduction

On-farm conservation can generally be described as the process by which farmers maintain, manage, and improve the traditional crop cultivars that they have developed (Jarvis et al. 2000). Participatory plant breeding (PPB) is a strategy used to strengthen on-farm conservation by encouraging farmers to continue to search, select, and manage local seed supply systems. The PPB process aims to consolidate the farmer's role in setting breeding goals and selecting diverse genetic materials. In so doing it offers skills and opportunities for farmers to search for new diversity and to select and exchange variable populations that match their local preferences and needs (Sthapit and Jarvis 1999).

Participatory plant breeding has been advocated as a strategy for maintaining or enhancing the level of genetic diversity on-farm (Brush 2000) because it can be used to breed divergent cultivars for subtly different environments and for diverse end uses. Also PPB can add value to traditional landraces that would otherwise be lost from the system (Sthapit et al. 2001). On the other hand, the success of PPB products may stem from the addition of just a few major genes, corresponding, for example, to pest resistance or plant height (Brown and Young 1999). It is also commonly assumed that the replacement of farmers' unique varieties with modern cultivars may affect the intraspecies genetic diversity by reducing the genotypic diversity and/or the allelic diversity within the cultivated crop. Both participatory varietal selection (PVS) and PPB may have negative impacts on landrace diversity, because both methods are intended to change the structure of the local crop population to make it more productive and useful to farmers (Joshi et al. 2000b). It has been argued that successful PPB products may swamp a significant fraction of local diversity, leading to a short term gain in productivity, loss of local unimproved populations, and hence increased future vulnerability (Brown and Young 1999). The creation of new varietal diversity by PPB, which has already been successfully used in difficult environments (Sthapit et al. 1996), is a powerful method that can be employed in high potential production systems (Witcombe et al. 2001). However, the impacts of PPB on the extent and distribution of local crop diversity are still poorly monitored and documented.

The PPB program in Nepal was designed to investigate: (1) whether farmers' cultivars are being conserved, (2) whether the PPB process encourages farmers to maintain processes that allow crops to evolve and change over time, (3) whether PPB contributes to the enhancement and conservation of traditional varieties in situ and provides community benefits, and (4) whether landraces can be conserved by improving preferred traits, hence making them more desirable in relation to modern cultivars.

The purpose of this paper is to describe participatory methods that build local capacity to understand the extent and distribution of local crop diversity and the processes by which farmers maintain diversity on their farms. The study addresses farmers' needs, conservation issues, and diverse users' issues in the process of choosing parents and selecting variable populations.

The studies form part of the value-adding activities of the global project "Strengthening the Scientific Basis of In Situ Conservation of Agricultural Biodiversity in Nepal". The study was initiated in 1998 and has been jointly implemented by the Nepal Agricultural Research Council (NARC), Local Initiatives for Biodiversity Research and Development (LI-BIRD), and other local institutions.

Study Sites

Studies are underway in two contrasting villages in Nepal to test if PPB will meet both development and conservation goals. Begnas village is situated in the Pokhara valley in Kaski district (600-1400 meters above sea level), the central mountain ecosystem of Nepal. Pokhara valley, in the western hills of Nepal, is known for high quality rice diversity and harbors more than 69 rice cultivars. Kochorwa is situated in Bara district (54-100 masl) and lies within the fertile Indo-Gangetic plain (100-200 masl) near the southern border with Indian. This eco-site maintains about 35 rice cultivars. Production potentials are high, and farmers have adequate access to inputs and technologies.

The Participatory Plant Breeding Process

A series of brainstorming sessions were organized in Nepal to integrate the PPB approach into the national crop breeding strategy. A primary stakeholder meeting was held in April 1998 to develop a PPB process for on-farm conservation and to agree upon the roles of formal and informal institutions (Joshi et al. 2000a).

There are three essential components to PPB: (1) one parent is a locally adapted cultivar, (2) selection is decentralized in the target environment, and (3) farmers participate in the plant breeding process. Ceccarelli et al. (1996) argued that the most complete decentralization could be achieved when farmers participate in the breeding process in their own fields. Often plant breeders seek functional collaboration with farmers to obtain quick results. Community participation is central to on-farm conservation of agricultural biodiversity. The local capacity to enhance genetic diversity (i.e., to search, select, and exchange) is a key element of sustainable agriculture.

A broad PPB process was used in Nepal to develop local farmers' capacity to assess, select, and share local crop diversity, and to build sustainable partnerships between farming communities and researchers (Sthapit et al. 2000). The process can be divided into the following steps:

- Locate rice agroecosystems and identify interested communities.
- Organize "diversity fairs" for locating rice diversity, and collect germplasm and local knowledge.
- Understand and monitor local crop diversity through a community biodiversity register.
- Analyze options for adding benefits.
- Set breeding goals for PPB and parent selection with representative community participation.
- Agree on roles of farmers and researchers involved in the breeding process.
- Select for diversity.
- Strengthen farmers' seed systems for rapid diffusion.

In 1997 a "diversity fair" was organized at each site to raise community awareness of crop genetic resources, to locate genetic diversity and its custodians, and to promote the value of landrace diversity in the context of local food culture, market forces, and socioeconomic and agroecological considerations. The materials collected from the fairs were grown in farmers' fields as "diversity blocks". The blocks were used to assess field performance and to analyze preferred and undesirable traits through participation from male and female farmers, representing all socioeconomic strata. The diversity block could also be used to select for appropriate parent plants and as a seed source for crossing programs.

Appreciating local crop diversity

Understanding the value of local crop diversity is a key step prior to the initiation of participatory goal setting. After the diversity fair, local communities were motivated to keep a community biodiversity register (CBR). The CBR is a record, kept in a register book by community members, of all landraces in a community, including information on their custodians, passport data, and use value (Rijal et al. 2001). It aims to monitor the level of diversity held by farmers in a community over time, as well as the number of households and area covered by each cultivar within the community. Local communities are encouraged to use CBR information to understand factors influencing farmers' decision making on dynamic changes in local crop diversity and to develop their own on-farm conservation strategies (Sthapit et al. 1999).

We found that farming communities maintained a substantial level of rice diversity at the community level in both the Begnas middle hill eco-site (69 cultivars; 91% local, farmer-named cultivars) and the highly accessible Bara site (53 cultivars; 62% local landraces). More local than modern cultivars were maintained at the household level in both sites. The area of rice landraces in Bara was 17% of the total and in Kaski was 73%. We found that some landraces competed strongly with modern cultivars in certain niches and that these landraces could be promoted in similar areas without further improvement.

Setting breeding goals

The dilemma prior to initiating PPB was deciding which rice varieties to include: all varieties, only those with high market demand, those maintained by only a few farmers in small areas, or those grown by many farmers in larger areas? Since no one knew which group was more important from a conservation perspective, and it was not possible to include all of the traditional cultivars, the team decided to divide the varieties into categories according to certain criteria. There was no literature available to guide this research, so the team elected to divide the landraces into four groups, based on the average planted area and the average number of households growing each landrace (Figure 1). This design ensured that at least one variety from each group, representing a different use value, would be included in the crossing program. The process used is listed as follows:

- List existing local diversity.
- Categorize local crop diversity into four cells according to the planted area of each cultivar and the number of households growing each cultivar.
- Classify local crop diversity by use.
- Perform assessment analysis for preferred and unwanted traits using preference ranking and paired matrix ranking.
- Analyze potential benefits of local diversity and threats of genetic erosion.

Choosing parents

A key element of the PPB program is the choice of the local landrace parent. A consultative participatory process used to assess farmers' needs and the project goal highlighted the conflict of interest between choosing parents and setting breeding goals. The following broad

Figure 1. Conceptual framework for understanding the extent and distribution of local crop diversity (according to farmers' use values) at the community level.

Area planted (columns); Number of farmers (rows)

Large planted area, many farmers (common)	Small planted area, many farmers
Large planted area, few farmers	Small planted area, few farmers (rare)

Source: Sthapit et al. (2000).

criteria were used in the parent selection process to avoid bias from influential groups in the community:

- Community interest and priorities
- Program goal and objectives
- Technical feasibility
- Availability of genetic variability
- Consumer interest

Focus group discussions (FGDs), attended by male and female farmers, were held at Kachorwa and Begnas sites with the objective of identifying the landrace parent for PPB. Both male and female farmers from all socioeconomic strata were consulted in the discussions. Participatory approaches were used to select at least one landrace from each of the four cells. The lists of farmer-named cultivars were analyzed using preference matrix ranking (Guerrero et al. 1993) for preferred and undesirable traits in order to identify traits needing improvement. The next step was to identify the best landraces from each of the four cells using preference matrix ranking. During the discussion, the preferred traits of each landrace parent were documented, while the traits needing improvement were thoroughly analyzed using paired matrix-ranking methods. The landrace parents preferred by farmers for inclusion in the PPB program were short-listed. A relatively large number was selected from the cell representing landraces grown by many farmers over a large area. The exotic parent was then identified by looking at the traits to be improved, the adaptability of the variety in the area, and other farmer preferred traits. Finally, cross combinations for Bara and Kaski sites were finalized by the team.

Distribution of diversity and selection of parents

One of the key steps to success in the PPB project is to understand the distribution of diversity according to farmers' use values in the selection of parents. Participatory rural appraisals (PRAs) were carried out to (1) understand key factors affecting farmers' decisions to maintain local cultivars, including information on market development, and (2) ascertain key limiting factors to production systems reliant on local crop cultivars. As described above, to understand the relative importance of specific landraces, farmers' varieties were grouped into four broad categories using baseline survey data and CBR (Figure 1). This approach could be carried out at the species or variety level.

This type of broad distribution analysis helps us to understand, for example, why some landraces are grown in a small area by many farmers, while others are grown in a small area by few farmers. It is very important for plant breeders to understand such distribution patterns and the underlying decisions made by farmers before starting to design a PPB program to promote on-farm conservation.

The above information can also be accurately collected using participatory methods. Figure 2 presents the traditional rice cultivars, with their perceived desirable and undesirable traits, considered for PPB by the Begnas farming community. Three landraces (Jetho budho, Ekle, and Mansara) from the commonly grown group were selected to address the needs of many households and to ensure that benefits would flow to a diverse range of people. Two landraces from the rare group (Birmaphool and Sano gurdi) were chosen. Aanga was chosen for its unique medicinal value and Gurdi was selected to represent good coarse varieties in each cell.

Results indicated that few culturally important cultivars (e.g., Anadi in Kaski and Sathi in Bara) are grown by many households in small patches for household use. These landraces could be conserved per se; however, the population size of Anadi has increased in recent years with the linking of the project to markets and with sales being made under its brand name in departmental stores.

Table 1 shows the traditional varieties selected in the study area in 1998 using the described participatory process. The exotic parent or local modern variety was selected by plant breeders according to farmers' preferences.

Table 1. Cross combinations selected for participatory plant breeding programs in Kaski and Bara sites, Nepal, 1998.

Begnas, Kaski (600-1400 masl)	Kochorwa, Bara (80-90 masl)
Pusabasmati/**Jetho budho**	**Mansara**/Rampur masuli
Ekle/Khumal-4	**Lajhi**/IR62161-22-1-2-1-1
Biramphul/Himali	**Lalka Basmati**/IR59606-119-3
Thulo gurdi/NR10286	**Dhudhisaro**/BG1442
Sano gurdi/NR10286	**Lajhi**/IR62161-22-1-2-1-1
Mansara/Khumal-4	**Dudhisaro**/BG1442
Aanga/NR10291	

Local seed system

Baniya et al. (2001) found that 96% of farming households in Begnas and Kochorwa villages are dependent upon informal seed sources. Seed flow occurs through farmers' social networks (Subedi et al. 2001). These communities manage their rich rice diversity through bartering, gifts, borrowing seed or seedlings, and purchase (Subedi et al. 2001).

Social networks of germplasm research and exchange

The study found that certain farmers maintain more diversity than other farmers in the community. These farmers are active in searching and selecting for new diversity and in maintaining and sharing it within and outside the

Figure 2. The extent and distribution of local rice diversity in Begnas, Kaski, Nepal, 1998.

Number of farmers / Area planted	(large)	(small)
(many)	**Jetho budho** High market demand for quality traits such as softness, aroma, and taste, but low yielding, and prone to lodging and neck blast disease. **Ekle** Stable yield, good straw, good milling recovery, but high water and input requirements, late maturing, and prone to storage pests. **Mansara** Adapted to rainfed, poor land and low input conditions, early maturing, but poor taste, yield, and milling recovery.	**Gurdi** Good taste, good straw yield, good milling recovery, adapted to irrigated conditions, but low yielding.
(few)	**Aanga** Medicinal value, adapted to very poor soils, but poor yield, taste, and shattering. **Anadi** Valued for sticky rice, but poor milling recovery, high input requirement, and low yielding.	**Biramphool** High quality with good aroma, softness, and medicinal value, but extremely low yielding. **Sano gurdi** Adapted to *tari* rainfed conditions, tolerates shade, good taste, and good milling recovery, but low yielding.

community. These farmers are described as the "nodal" farmers of the community (Subedi et al. 2001). They are perceived to be more knowledgeable than other farmers in relation to seed and production environment matters and as being "diversity minded". Nodal farmers mainly belong to the resource-endowed farmer group, which is characterized by ownership of larger landholdings, more land parcels, and more livestock than less well-off farmer groups (Rana et al. 2000). Moreover, resource endowed farmers generally have a higher education level and participate more frequently in the local market (Gauchan et al. 2001). Some nodal farmers are women. Nodal farmers are spatially distributed within the community; together they can act as a conservation farming network and their farms are used as "field gene banks". They can be involved very effectively in community biodiversity registration and linked to development opportunities. Nodal farmers can enhance farmer to farmer dissemination of genetic materials, be effective as resource persons for farmer to farmer training, and provide information on local crop diversity. Their expertise and knowledge can be effectively utilized in the development of training and extension materials on local cultivars, and they can also be involved in public awareness on agrobiodiversity.

Who should test materials?

The 13 segregating materials selected for PPB were distributed to nodal farmers and a few other interested farmers for growing F_2 or F_3 bulk of their choice. Field performance of the different populations was assessed during farm walks by researchers and farmers. In Begnas village, F_3 segregants of Mansara (locally adapted to marginal, drought prone, rainfed, and low input conditions) and Khumal-4 (good quality modern cultivar with parentage of local variety Pokhereli masino) showed promising results in the upper areas (1000-1300 masl). The breeding goal was to incorporate the good eating quality and yield potential of Khumal-4 into Mansara without losing the latter's adaptive traits. Three distinct population types were selected jointly by farmers and researchers and these were further advanced in farmers' fields. The spread of M x K-4 bulks is being monitored, and the selection history is being documented. The cross between Pusa basmati and Jetho budho (local high quality rice with high market demand) also did well in *Khola-ko-chewn* environments (650-690 masl). In Bara district, six large segregating populations were evaluated in farmers' fields, of which farmers selected the populations of Lajhi and IR62161-22-1-2-1-1 for lodging resistance and post harvest traits.

Discussion and Conclusion

The participatory method used to divide local crop diversity into four categories is useful for understanding the extent and distribution of farmers' classification of local crop diversity. This is a simple method for teaching farmers about the concept of local common and rare traditional cultivars. It is also useful for analyzing options for introducing other benefits such as increased community awareness and motivation, seed networks, new germplasm, market links, and PPB.

Social networks highlight the effectiveness of decentralized selection and informal seed systems. Nodal farmers' expertise in selecting and maintaining genetic materials can be effectively used in PPB. Furthermore, capacity building of nodal farmers in PPB may enhance crop diversity on a large scale.

Participatory methods such as biodiversity fairs, diversity blocks, and community biodiversity registers raise local awareness, strengthen local capacity for understanding the value of local crop diversity, and strengthen the roles of farmers and the informal sector in the process of local crop development. Such community participation helps the benefits of on-farm conservation to reach poor and biodiversity-based livelihoods.

It unlikely that a single product of PPB will outcompete a large proportion of local crop diversity. The diverse agroecology existing in an area, combined with farmers' preferences for different cultivars with varying characteristics, should help to maintain biodiversity.

Acknowledgements

This work is part of the International Plant Genetic Resource Institute's global project "Strengthening the Scientific Basis of In Situ Conservation of Agricultural Biodiversity On-Farm: Nepal Country Component", which is funded by the Directorate-General for International Cooperation, the Netherlands.

References

Baniya, B.K., R.K. Tiwari, D. Pandey, J. Bajracharya, A. Mudwari, B.R. Sthapit, and D.I. Jarvis. 2001. Rice seed supply systems in Terai and high hills of Nepal. Presented at the National Workshop of In Situ Crop Conservation, 24-26 April 2001, Lumle, Nepal.

Brown, A.H., and A. Young. 2000. Participatory plant breeding—does it achieve or does it compromise genetic conservation? Presented at a participatory plant breeding meeting, Mexico.

Brush, S. (ed.). 2000. *Gene in field: on-farm conservation of crop diversity.* IPGRI/IDRC. N.p.: Lewis Publishers.

Ceccarelli, S., S. Grando, and R.H. Booth. 1996. International breeding programmes and resources and resource-poor farmers: Crop improvement in difficult environments. In P. Eyzaguirre and M. Iwanaga (eds.), *Proceedings of a workshop on participatory plant breeding.* Wageningen, The Netherlands: IDRC/FAO/CGN/IPGRI. Pp. 99-116.

Gauchan, D., and P. Chaudhary. 2001. A participatory marketing system research approach to analysing market based incentives and disincentives: a case of rice, Bara, Nepal. Presented at the National Workshop of In Situ Crop Conservation, 24-26 April 2001, Lumle, Nepal.

Guerrero, M.P., J.A. Ashby, and T. Gracia. 1993. Farmer evaluations of technology: preference ranking. Instruction Unit No. 2. Cali, Columbia: CIAT.

Jarvis, D., B. Sthapit, and L. Sears (eds.). 2000. *Conserving agricultural biodiversity in situ: a scientific basis for sustainable agriculture.* Proceedings of a workshop. Rome, Italy: IPGRI.

Joshi, K.D., B.R. Sthapit, and J.R. Witcombe .2000a. How narrowly adapted are the products of decentralised breeding? The spread of rice varieties from participatory plant breeding programme in Nepal. *Euphytica* 122(3):575-588.

Joshi, K.D., D.K. Rijal, R.B. Rana, S.P. Khatiwada, P. Chaudhary, K.P. Shrestha, A. Mudwori, A. Subedi, and B.R. Sthapit. 2000b. Adding benefits: PPB, seed networks and grassroots strengthening. In D. Jarvis, B. Sthapit, and L. Sears (eds.), *Conserving agricultural biodiversity in situ: a scientific basis for sustainable agriculture.* Proceedings of a workshop. Rome, Italy: IPGRI.

Rijal, A., M.P. Subedi, R.B. Upadhyaya, P. Rana, P.R. Chaudhary, R.K. Tiwari, B.R. Tiwari, B. Sthapit, and D. Gauchan. 2001. Community biodiversity register: developing community based database for genetic resources and local knowledge in Nepal. Presented at the National Workshop of In Situ Crop Conservation, 24-26 April 2001, Lumle, Nepal.

Sthapit, B., and D. Jarvis. 1999. PPB for on-farm conservation. ILEIA Newsletter 15(3/4):40-41.

Sthapit, B.R., K.D. Joshi, and J.R. Witcombe. 1996. Farmer participatory crops improvement, III. Participatory plant breeding, a case study for rice in Nepal. *Experimental Agriculture* 32:479-496.

Sthapit, B.R., K.D. Joshi, R.B. Rana, and M.P. Upadhaya. 2001. Enhancing biodiversity and production through PPB. In *An exchange of experiences from South and South East Asia. Proceedings of the International Symposium on Participatory Plant Breeding and Participatory Plant Genetic Resource Enhancement.* CGIAR-PRGA.

Sthapit, B.R., P. Sajise, and D. Jarvis. 2000. Strengthening scientific basis of in situ conservation on-farm: Learning experiences from Nepal and Vietnam. In *Links between cultures and biodiversity. Proceedings of the Cultures and Biodiversity Congress 2000.* Pp. 338-361.

Subedi, A., P. Chaudhary, B.K. Baniya, R.B. Rana, D.K. Rijal, R.K. Tiwari, and B.R. Sthapit. 2001. Who maintains crop genetic diversity and how? Implications for on-farm conservation and participatory plant breeding. Presented at the National Workshop of In situ Crop Conservation, 24-26 April 2001, Lumle, Nepal.

Witcombe, J.R., K.D. Joshi, R.B. Rana, and D.S. Virk. 2001. Increasing genetic diversity by participatory variety selection in high potential production systems in Nepal and India. *Euphytica* 122:575-588.

Discussion Summary

The discussion dealt mainly with a number of questions regarding the presentation. The first question was who decides on the improvement program? The answer was the community, which always looks at new diversity, but keeps old landraces to maintain the gene pool. Currently a PhD student is looking at the genetic variability in the study area with molecular markers, and this should help to identify good landraces to be incorporated into the participatory plant breeding program. A question was raised on the danger of losing vulnerable varieties. It was pointed out that common varieties are most vulnerable to new introductions. The number of different varieties grown by many farmers in small areas seems to be a good predictor of their potential to be maintained. There was a question on how long the farmers in the study have been using their varieties. While there is no exact information to answer this, there is data on how frequently they change materials. The author pointed out that, regardless of varietal value, there is a tendency towards conservation among farmers. In terms of the farmer network analysis, it was noted that there was less movement of materials between some households. The explanation given was that seed exchange among farmers is affected by caste and neighbor relationships. Also it was noted that there seems to be a higher variability in upland areas because of the many agroecological zones and uses of varieties in these areas—factors that promote genetic variability.