and insect-infested grains), or more than 50% if the grains, for example, are small and not fully developed. Generally, the smaller grains are be used for food.

The second method, which is also very common, is the selection of panicles that show preferred traits. Farmers usually select for panicles on the threshing ground after the panicles have been separated from the straw, although some farmers prefer to select for panicles in the field before harvesting, taking the entire plant into consideration, e.g., number of tillers, height. Even by inspecting the panicle, farmers can envisage what the plant's other characteristics looked like (or would look like when regrown). Many farmers do not perform panicle selection every year, but only in the better seasons, which usually occur every two to four years. In harsher years, they are most likely to use the winnowing/grading method. A third, less common, form of selection is to use the harvest of a preferred field—a field considered to be more fertile than others—for sowing the following year.

Using "improved varieties" or hybrids from the market

If a farming family does use pearl millet seed from the market, in most cases it will be mixed into the family's own seed stock. In western Rajasthan, farmers without access to irrigation facilities generally do not grow improved varieties or hybrids in pure stands. Market seed is mostly certified or "truthfully labeled" seed. Further advanced generations of such seed can be optioned from the market or from other farmers. This grain is not labeled and its origin is often unknown. There are two ways in which farmers use seed from the market:

1. Occasional introgression of new seed from the market into the previous year's seed stock: the resulting crop consists of many different plant types (traditional landrace, market variety, and several generations of progeny). Mixing ratio and frequency can vary widely, ranging from 1:10 up to 50:50.
2. Regular introgression of new seed from the market into the previous year's seed stock, selecting for desired plant types among outcrosses: One or more new plant types will become dominant, and the variability of plant types is less than in the first example. The amount and frequency of mixing new seed, as well as selection intensity, can differ greatly from farmer to farmer and from year to year.

It is important to understand that most farmers do not use improved varieties to replace their own seed, as is often assumed. Rather, they use new seed to increase the variability of plant types in their fields, thereby creating new options for their strategies of selecting for preferred plant characteristics, including grain and straw yield, food and fodder quality, storability, drought tolerance, early maturity, tolerance to adverse weather conditions (heat, sandstorms, thunderstorms), and resistance to bird or locust damage.

Social aspects of seed management

The availability of seed grain at the onset of rains is very important for farmers in western Rajasthan. The success of a crop depends very much on sowing immediately after the first rains of the monsoon. For centuries, farmers have had to deal with crop failures due to severe drought conditions. Therefore, "taking care of the seed" is considered to be of great importance. Farmers who can successfully maintain their own seed, or be in a position to provide other villagers with seed in times of scarcity, are considered to be good farmers and are respected by all. There is a special caste in most villages for whom maintaining seed and sharing it with others is considered to be a traditional obligation. Nevertheless, other farmers can also build up a reputation for owning good seed,

and "lending" or selling it to others. Seed management is, therefore, related to aspects of caste and status in village life. Furthermore, it is a gender-related activity. Selecting the seed, storing it, and processing it before sowing is traditionally done by women, whereas soil preparation and sowing is usually done by men. Men also often participate in harvesting, and depending on the family, they can be equally involved in selecting seed. Buying seed from the market and obtaining information about market varieties is done almost exclusively by men.

Diverse seed-management strategies co-exist in villages in western Rajasthan, reflecting the diversity of socioeconomic conditions: farmers who grow traditional landraces with or without selection; families who mix, sometimes or regularly, seed from the market into the landrace seed with or without selection; and families who sow the pure seed of market varieties. All these seed-management strategies can be found in one village. Even though pearl millet is a cross-pollinating crop, it seems to be possible for a village community to maintain a diversity of plant types. The reasons for a farming family using a certain strategy can only be partly explained by soil conditions and climatic factors. Other important factors seem to be the size of the landholding (market-oriented or subsistence-oriented), the number and species of animals and their fodder requirements, the access to cash income or loans to buy seed, the family tradition and knowledge, and access to information on new varieties, e.g., literacy and mobility. Most of these socioeconomic conditions are related to the caste system in Rajasthani villages.

Quantification of the effects of farmers' seed-management strategies

Material and methods

To quantify the effects of farmers' seed management, 69 grain stock samples were collected from 16 farmers located in four different villages in western and central Rajasthan during 1995–1997. Samples were characterized by the farmer, e.g., as separated seed grain and food grain, and were classified into four main seed-management strategies (table 1). These grain samples from farmers, along with 12 modern varieties known to be grown in these villages, were evaluated under varying drought-stress conditions at three research stations in western Rajasthan (Mandor, Jodhpur, Pali) between 1997 and 1998. Climatic conditions in 1997 were generally favorable, whereas in 1998 severe drought affected the plant growth, especially at Mandor. The field trials comprised 81 entries and were laid out in lattice designs with five replications. The different plant traits that are used by farmers and scientists to describe the performance of pearl millet were recorded in order to assess productivity and characteristics of entries. These plant traits included nodal tillering, leaf shape, stem diameter, panicle girth, number of productive tillers, grain weight, straw and grain yield, as well as diversity of plant types within one entry.

Table 1. Farmers' Seed-Management Strategies as Represented in Field Trials

LR	Maintains only local landrace seed without introgression of modern material Selection method mainly winnowing
IGR1	Occasionally introgresses modern varieties into landrace Selection method mainly winnowing
IGR2	Introgresses modern material more regularly than strategy IGR1 Selects regularly/frequently for panicles
MV	Modern varieties

Separate analysis of the five test environments revealed a significant phenotypic relationship between grain yield and plant characteristics (table 2). The number of panicles and basal tillers, plus nodal tillering and phenotypic diversity of plant types within one entry, were all positively associated with grain yield in the stress environments and negatively associated in the non-stress environments. Conversely, entries with large stems, large leaves and panicles, and bold grains showed negative correlation coefficients with grain yield under stress conditions and positive coefficients in the non-stress environments.

Table 2. Phenotypic Correlation of Observed Traits with Grain Yield

	Environments				
	Favorable		Mild terminal drought	Early drought	
Traits	MAN97	JOD97	PAL97	MAN98	JOD98
Grain weight	0.69**	0.75**	0.42**	0.08	–0.25*
Panicle girth	0.70**	0.83**	0.42**	–0.60**	–0.24*
Leaf width	0.38**	—	0.33**	–0.62**	–0.24*
Stem diameter	0.62**	0.69**	0.41**	–0.65**	–0.14
No. of panicles	–0.54**	–0.46**	–0.41	0.90**	0.48**
Tillers	–0.54**	–0.58**	0.01	0.67**	0.36**
Nodal tillering	–0.65**	—	–0.41**	0.56**	0.27*
Plant type diversity	–0.57**	—	–0.36**	0.32**	0.11

*$p < .05$.
**$p < .01$.

A genotype × environment (GE) analysis based on grain-yield data was carried out in order to gain an overall view of the effects of these strategies on the adaptation of farmers' seed stocks to different environments. For this purpose pattern analysis was used to classify environments and to assess relationships between the entries and between environments, as well as to analyze the interrelation between entries and environments. To generate the analysis, the statistical packet GEBEI was used (Watson et al. 1996). The details of this calculation will be published elsewhere.

Results and discussion

The phenotypic relationship described in table 2 shows the effectiveness of farmers' seed-management strategies. Entries with plant characteristics that farmers associated with adaptation to stress proved to be more productive under stress conditions than other entries. These findings were supported by the results of the pattern analysis. The analysis indicated that most of the entries classified as LR showed close interaction with the preflowering drought stress at Mandor and Jodhpur. Compared to the LR entries, entries classified as IGR1 tended to show a less specific interaction with the stress environments. In contrast to the management groups LR and IGR1, a change in the adaptation pattern seemed to be obvious in entries derived from IGR2. The positive interaction of the samples exclusively with the preflowering drought environments was mostly eliminated. Entries also tended to show relatively high productivity in more favorable environments. Samples grouped in IGR2 thus tended to perform fairly well in all the test environments. Entries labeled as modern varieties (MV), indicated almost no positive association with the preflowering drought

environments. The exceptions were some modern varieties with pedigrees based on landrace material from western Rajasthan.

Farmers who practice IGR2, which includes introgression and selection for contrasting plant types, are generally successful with this method. In the one seed stock, the IGR2 method produced traits indicating adaptation to stress as well as potential for high yield under favorable conditions. In terms of potential grain yield, this method appears to be effective. Some of the farmers' grain stocks generated by this strategy even yielded better with increased rainfall compared to the "pure" landraces (LR). It was the farmers' aim to introgress modern varieties so as to produce seed stocks that "take advantage" of good rains and it appears they have met their objective.

Although "pure" landraces are not as productive under favorable conditions, they are more resilient under conditions of stress. For centuries they have been grown in heterogeneous environments. They therefore have the capacity to adjust to the erratic climatic conditions that occur in this region. Seed samples from farmers practicing introgression, in combination with regular panicle selection, seem to indicate that it is possible to improve a landrace population through newly introgressed variability. It also appears that if farmers use panicle selection to separate seed from food grain, they can improve their control over seed-stock performance.

Summary and conclusions

Potentials and constraints of farmers' own crop improvement

The present study has revealed opportunities, as well as constraints, for farmers' own crop improvement. Other studies have assumed that landraces are mainly a product of natural adaptation and that farmers often do not, or only "unconsciously," select landrace seed (Damania 1996). However, direct observation and interview data from this study have revealed that this view does not apply to the case of pearl millet in western Rajasthan. The results of this study confirm that different seed-management strategies are practiced in the one village. Some farmers maintain the local landrace with superior quality and yield stability, while others create variability through introgression of modern varieties. Furthermore, previous studies carried out in western Rajasthan also show that farmers use their own sophisticated strategies for seed management and crop improvement (Dhamotharan et al. 1997; Weltzien et al. 1998). Quantitative data from field trials proves that these farmer strategies lead to populations with diverse plant types. This diversity offers possibilities of recombination in the population and natural selection, and also increases the gains of farmers' selections.

Seed selection, especially intensive selection of plant type or panicle, enables farmers to exert control over the negative effects of introgression. Farmers select according to their various breeding goals, such as yield stability under stress conditions and higher productivity in regard to straw and grain yield in the target environment. These selection strategies are largely guided by their concept of a variety. Mainly farmers who practice introgression along with panicle or plant type selection are able to improve the productivity of their landraces without losing yield stability. However, other results show that traditional methods of seed selection practiced before the introduction of exotic material, such as winnowing/grading, can lead to a decrease in the expression of adaptive traits and characteristics in the typical landrace phenotype. This is due to seed winnowing and the use of the bolder grain for seed purposes. Smaller grains (representing adapted landrace types) are rejected, whereas bigger grains (representing less adapted modern material) remain in the seed stock.

It should also be taken into consideration that the farmers who benefit from the higher yield potential of the introgressed cultivars are mainly those who have relatively good land and resources. These farmers are traditionally those who distribute seed material to other, poorer, farmers in times of scarcity. As poor farmers usually have less fertile land and less manure, the properties of the original landrace pearl millet are ideal for them. If better-off farmers continue to use introgressed seed, which requires better land and continuous selection to assure yield stability, the availability of landrace seed may decrease for poor farmers with marginal lands unless measures are taken to maintain the original landrace plant type. Finally, farmers often show a lack of technical knowledge concerning the genetic material that is available on the market. For instance, most farmers are not aware of the differences between hybrid varieties and open-pollinated varieties, nor are they aware of the consequences of using hybrids in seed production.

Role of researchers

These constraints point to several possible ways in which researchers can help to improve farmers' seed stocks in western Rajasthan. Researchers could take on an advisory role and support farmers in their own crop-improvement strategies, for example, with technical knowledge or explanations of the effects of different management strategies. The plant breeder could recommend material that has the ability to combine with local material and has the potential to achieve genetic gains in farmers' preferred traits. Material should not merely be handed out to the farmer by the breeders. A material exchange between farmer and breeder should also be supported. Breeders could help to improve those traits that farmers have difficulty working with, e.g., specific resistance or seed-set improvement. Where farmer and breeder both provide material and resources, intellectual property rights should be respected.

Results from this study show that farmers in western Rajasthan are actively working on developing and improving their seed stocks, and that many opportunities exist for fruitful collaboration between farmers, plant breeders, and other scientists.

References

Christinck, A. and K. vom Brocke. 1998. Evaluating pearl millet cultivars with farmers. In *Participatory Plant Improvement*. Proceedings of MSSRF-ICRISAT Workshop, edited by V. Arunachalam. Chennai, India: M.S. Swaminathan Research Foundation.

Dhamotharan, M., R.E. Weltzien, M.L. Whitaker, H.F.W. Rattunde, M.M. Anders, L.C. Tiagi, V.K. Manga, and K.L. Vyas. 1997. *Seed management strategies of farmers in western Rajasthan in their social and environmental contexts: Results from a workshop using new communication techniques for a dialogue between farmers and scientists, 5-8 February 1996, Digadi village, Jodhpur district, Rajasthan, India.* Integrated Systems Project Progress Report No. 9. Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Damania, A.B. 1996. Biodiversity conservation: A review of options complementary to standard ex situ methods. *Plant Genetic Resources Newsletter* 107:1–18.

Weltzien R.E., M.L. Whitaker, H.F.W. Rattunde, M. Dhamotharan, and M.M. Anders. 1998. Participatory approaches in pearl millet breeding. In *Seeds of choice: Making the most of new varieties for small farmers*, edited by J.R. Witcombe, D.S. Virk, and J. Farrington. New Delhi: Oxford & IBH Publishing Co.

Watson S.H., I.H. DeLacy, D.W. Podlich, and K.E. Basford. 1996. *GEBEI: An analysis package using agglomerative hierarchical classificatory and SVD ordination procedures for genotype x environment data.* Research Report No.57. Brisbane: Department of Mathematics, The University of Queensland.

Strength of Farmers' Knowledge and Participation in Crop Improvement and Managing Agrobiodiversity On-Farm

P. Chaudhary, S.P. Khatiwada, and K.D. Joshi

Abstract

This paper highlights the role of farmers in crop improvement and managing agrobiodiversity. The findings are mostly based on focus-group discussions and field observations. Documentation of farmers' knowledge and experiences in crop improvement and managing agrobiodiversity may serve as a reference for individual breeders or institutions involved in participatory crop improvement through different strategies like participatory plant breeding, participatory varietal selection, or participatory germplasm enhancement. The strength of participatory crop improvement is that there is multistage involvement of farmers, from parent selection through to cultivation and selection of planting materials, because farmers have a wide range of knowledge and experience, and they are the end-users as well. Since ancient times, farmers have been dependent upon the traditional seed-supply system, which still accounts for over 90% of the seed requirement in Nepal. A variety of mechanisms like varietal selection, seed selection, seed processing and storage, and the seed-flow system have contributed to crop development, creating agrobiodiversity on-farm. More recently, participatory germplasm enhancement has arisen as a new strategy to enhance the germplasm of local landraces, which will not only empower farmers in improving their landraces but also strengthen in situ conservation of such landraces on-farm. The current need is to incorporate farmers' relevant knowledge and use it in the overall crop-improvement process.

Key words: Participatory, crop improvement, agrobiodiversity, germplasm, on-farm, and knowledge

Background

In many developing countries, farmers play a pivotal role in the conservation of genetic resources, thus maintaining biodiversity, since they hold the bulk of these resources (Worede 1992). From time immemorial, farmers have experimented with naturally existing genetic variations in their own environments to produce present-day landraces (Sthapit and Joshi 1998). Farmers have grown, tested, utilized, developed, and finally, selected new varieties and crop combinations to suit particular ecosystems. The role of farmers in creating agrobiodiversity is also evident from their involvement in seed storage and seed exchange. Of course, the need and preferences of individual farm families have driven them in the selection of crop species. For this reason, they have acquired a profound knowledge about landraces and niche-specific placement.

Given the inherent advantages of traditional practices, on-farm landrace conservation and enhancement provides a valuable option for observing genetic diversity (Worede 1992). A large number of subsistence farmers still use traditional methods. Those using modern technology account for approximately 40% of global agriculture, while rest is under traditional agriculture, which provides between 15% and 20% of the world's food (Francis 1986; Sthapit and Joshi 1998). The most important factors that motivated farmers to diversify crop and livestock in the past were probably ensuring livelihood and meeting qualitative preferences and requirements (Roder 1995; Sperling and Berkowitz 1994; Sthapit and Joshi 1998). Roder (1995), has reiterated the factors motivating farmers in maintaining diversity as follows:

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- the need for high self-sufficiency due to communication problems
- reduction of risk factors
- labor considerations
- lack of availability of suitable improved varieties
- market fluctuations
- traditional food preferences
- special requirements for ceremonies and rituals

One of the commitments made in Leipzig in 1996 during the NGO conference on the access and control of agricultural biodiversity was to enable the formal sectors, through training, to recognize the value of farmers' and indigenous peoples' knowledge and practices in conserving and strengthening agricultural diversity. The following statements further stress that the documentation of farmers' knowledge and participation in crop improvement is essential.

- To be able to define precisely the objectives, limits and means for implementing in situ conservation, it is necessary to obtain a better understanding of the structure of polymorphism within farmers' varieties, ways it evolves with farmers' practices and the methods and mechanism for managing this source of diversity. (FAO 1989; Brush 1992; Louette and Smale 1996)
- Recognizing farmers' knowledge and the farmers' role in developing landraces and maintaining their genetic diversity through the partnership of farmers with formal science institutes is an important step in enhancing the maintenance of biological diversity, agricultural sustainability and food security at the farm, regional and global levels. (Teshome 1997)

This paper highlights the role of farmers in crop improvement and agrobiodiversity management. The different stages of crop development and different approaches applied to bring about current agrobiodiversity are explicated in the following chapters. The examples are mainly from one of the sites of the project "Strengthening the Scientific Basis of in situ Conservation of Agrobiodiversity On-Farm" being implemented in Nepal jointly by the Nepal Agricultural Research Council (NARC), Local Initiatives for Biodiversity Research and Development (LI-BIRD), and the International Plant Genetic Resources Institute (IPGRI).

Farmers' role in crop improvement

Crops have traveled through different stages of natural evolution and systematic crop breeding. Breeding by different groups, such as routine seed selection by farmers and formal breeding in public and private institutions, has played an important role in bringing crops and varieties to their present status. Crop species have been adapted to different agroecological conditions while evolving from a wild to a cultivated form through more refined landraces because of farmers' selections. Farmers' landraces have been extensively used to develop improved varieties through breeders' efforts and again through diffusion through formal and informal institutions. Gene flow from wild relatives to farmers' landraces and from landraces 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 Stich 1991; Sthapit and Joshi 1998). This is why the conservation of plant genetic resources in situ has very recently been widely accepted by several formal and informal institutions

worldwide. The inclusion of a landrace as one of the parents in participatory plant breeding and the involvement of farmers in several stages of its development is imperative if the needs of farmers are to be accurately met, leading to a successful conservation strategy. The figure below outlines the stages and the processes through which crops have traveled and the important role played by farmers to make the story successful.

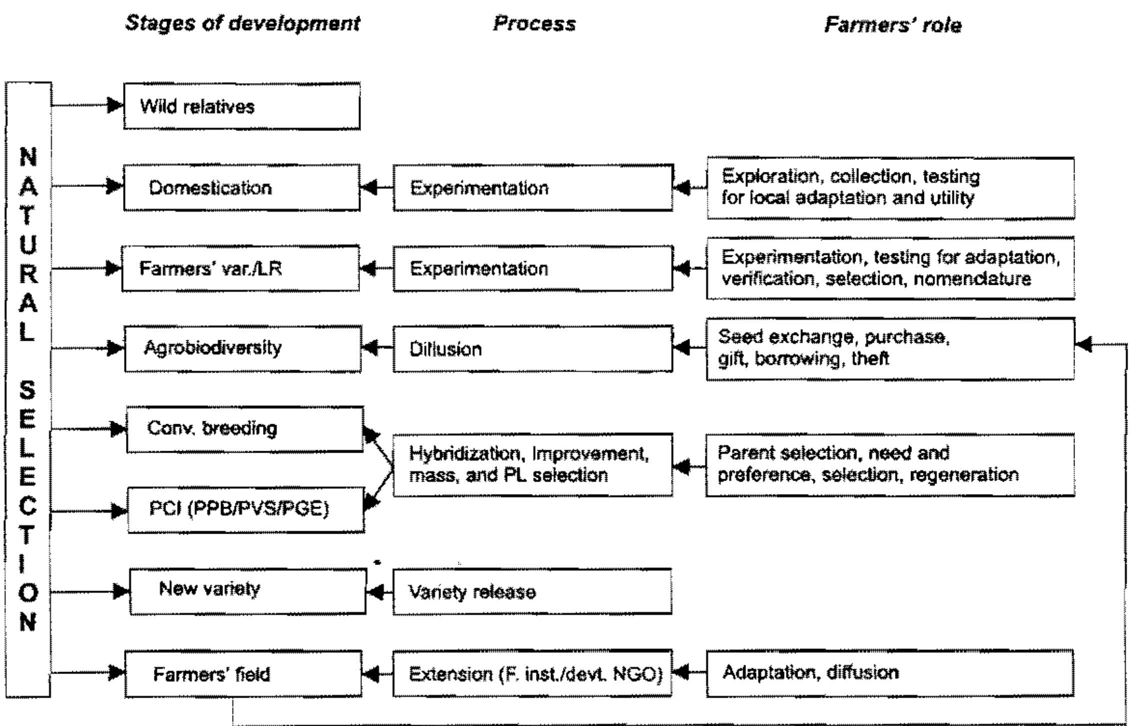

Figure 1. Farmers' roles in the crop-improvement process

Nomenclature of traditional varieties

Farmers have given names to their traditional varieties of different crop species based on their identifying characteristics, which can either be external appearance or internal quality. For some of the landraces, one can easily distinguish one from another on the basis of their names. Farmers' nomenclature has a scientific basis since words that constitute the name have an important meaning that reflects the characteristics of that variety. For instance, *lal tengan* is one landrace; it has been named for its red (*lal*) lemma and palea color and a long, stout tentacle/spur (a type of fish called a *tengar* has spur like this). A few examples of the names of farmers' varieties and their meanings are presented in table 1.

On-farm varietal diversification

Varietal replacement has been taking place with the introduction of modern varieties for several years, starting from the Green Revolution in Asia during the early 1970s. In many regions of the world, farmers have economic incentives to replace the varieties that have evolved within their own ecosystems with improved, introduced varieties (Louette and Smale 1996). Landraces seem so

Table 1. Name and Meaning of a Few Selected Landraces

S.No.	LR Name	Type	Name & meaning	Easy way to identify/distinguish
1	*Nakhi saro*	*Bhadaiya*	Nakhi=awn, Saro=bhadaiya type	Long awn; yellowish lemma and palea (L/P)
2	Bhadaiya basmati	"	Bhadaiya= early seasoned, Bas=aroma	Slightly rango-like color; fine grained
3	*Basmati*	*Aghani*	Bas=aroma	Like B. basmati; long panicle length; fine grain; aroma; awn on a few grains
4	*Lal tengar*	"	Lal=red, Tengar= type of fish with stout spur	Reddish L/P color; bold grain with long stout awn; grown in shallow water
5	*Amaghauj*	"	Ama=guava, Ghauj=cluster	Yellowish grain; two to four grains originating from a single point giving cluster-like look; long and strong stalk
6	*Dudhraj*	"	Dudh=milk	Whitish L/P color; milky-white grain
7	*Lalka faram*	"	Lal=red, Faram= research institution	Yellowish L/P color with minute reddish stripes
8	*Harinker*	"	Harin=spotted deer	L/P during milking and dough stage looks like spotted deer; small round grain,
9	*Parewa pankh*	"	Parewa= pigeon, Pankh=feather	The sterile lemma is long, covering the grain from both sides
10	*Kariya kamodh*	"	Kariya=black	Very fine grain; blackish in color; aromatic

fragile to maintain that farmers easily adopt improved varieties—they have a higher yield potentiality than farmers' traditional varieties. As a result, the number of farmers growing local landraces and the area covered by those landraces is declining. To counteract this trend, there has been a big contribution to varietal diversification through the varietal choices made by different institutions, and on-farm varietal diversity has further been enhanced by farmer-to-farmer dissemination of new rice varieties (Joshi et al. 1997).

Figure 2 gives examples of diversity created by different factors. For instance, rice varieties grown in *ucha khet* (upland) are different from those in *nicha khet* (low wetland) and *man/pokhari* (water-logged areas). Similarly, *basmati, sathi,* and *khera* fulfil cultural and religious requirements, while *sokan* and *sotwa* are valued for their medicinal qualities. *Bhathi* is grown for its unique characteristic of adapting in deep water, and *sathi, mutmur,* and *sokan* are grown in marginal uplands where no other landraces or modern varieties can be cultivated satisfactorily. In contrast, farmers generally confine their sources of planting materials to neighbors, relatives, and whatever is available in a new environment.

Conventional breeding

The farmers' role in conventional breeding generally starts after the variety has been released, particularly for adoption and diffusion if the released varieties are preferred by the farmers. Once a variety is released through the breeding system, it is made available to a few farmers for assessing acceptance and rejection. The farmers' role is still as a passive partner and as an end user. Farmers' responses about new technologies are collected through farmers' days, farmers' field observations, and demonstrations.

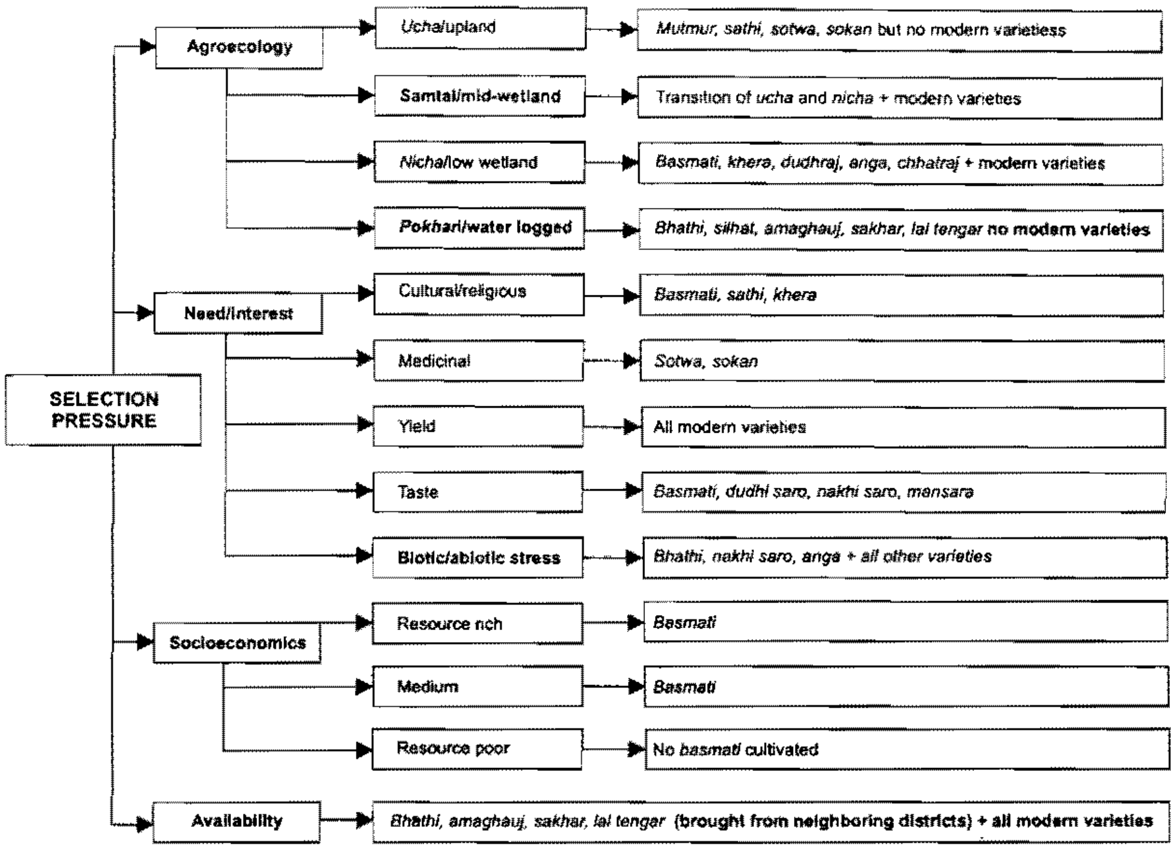

Figure 2. Agroecology and human-induced selection pressures on crop genetic resources

Participatory plant breeding

Participatory plant breeding (PPB) is widely used by different institutions, both government organizations and nongovernment organizations, and even by farmers. However, farmers' participation in PPB varies. The approach and methods of PPB are described in detail by IPGRI (1996: 57–65), Sthapit, Joshi, and Witcombe (1996), and Witcombe et al. (1996). However, the stages where farmers' involvement is most important are plant selection, germplasm enhancement, seed selection, and management (Joshi et al. 2000). Table 2 summarizes the range of farmers' participation in the PPB process.

Prospects for germplasm enhancement with farmers' empowerment

The germplasm of local landraces can be improved through pure-line or mass selection with the active participation of farmers and modest technical backstopping from formal institutions for most of the processes. This can be achieved through farmers' active participation, with minimum costs and little effort for breeders. At the same time, the genetic potential of local landraces can be conserved by encouraging in situ conservation.

Farmers at Begnas, Kaski and Kachorwa Bara have recently taken the initiative for participatory germplasm enhancement (PGE) through pure-line selection. In these areas, farmers' knowledge about seed selection and storage were first documented. On the basis of this information, the farm-

Table 2. Level of Participation in Different PPB Processes

Citation	Modes of participation	Level of participation by farmers
Witcombe (1996)	Consultative	Researcher consults farmers to assess needs, set breeding goals, and choose testing sites, but researcher retains key decision making
	Collaborative	Expert farmers grow early, variable generations and select best plants on their own fields
McGuire, Manicad, and Sperling (1999)	Farmer-led PPB	External agents support farmers' own system of crop development
	Formal-led PPB	Farmers join in formally initiated process of crop development

ers were next given an orientation on seed selection and germplasm improvement. Finally, an agreement was made to follow a pure-line selection process in which farmers' participation in the process was assured. This process was designed to help impart a selection of skills to farmers and improve their cop varieties through pure-line selection if they wished. They would also feel empowered through their own participation in the process. This process may be proven to be a holistic, less time-consuming, and more cost-effective approach to improve the quality of landraces, thus making them competitive with improved varieties and, eventually, invigorating in situ conservation on-farm.

The traditional seed-supply system

The role of farmers in crop improvement and managing agrobiodiversity can best be explained by the traditional seed-supply system (figure 3). Approximately, 60% of global agriculture is performed by subsistence farmers using traditional methods—providing between 15% to 20% of the world's food (Francis 1986; Sthapit and Joshi 1998). Diffusion in most parts of Nepal happens through the informal seed-supply system; the contribution of the formal seed sector is less than 5% in major staple crops (Baniya et al. 2000). The traditional seed-flow system includes variety selection and adoption, seed selection, seed exchange, processing, and storage (Shrestha 1998), and all of these processes are responsible for local crop improvement and creating agrobiodiversity. A review of case studies from Bangladesh (Mazhar 1997), Indonesia (Winarto 1997), Nepal (Joshi et al. 1997; Sthapit et al. 1998), and Ethiopia (Worede 1992) shows a wide range of examples in different countries where farmers—either independently or in collaboration with formal or informal institutions—have played an important role in crop improvement through seed production and dissemination (see also figure 1).

Variety selection and adaptation

From time immemorial, farmers have been observing and selecting their crops and crop varieties, saving and maintaining the seeds for next season, and experimenting with new seeds exchanged with neighbors and relatives (Shrestha 1998). It is noteworthy that farmers have tried to select the best available portion of the harvest for growing the subsequent year and also to meet the requirements of food and tradition. Farmers introduce new varieties in their localities to suit the different needs of soil fertility, moisture, family, and society, and to spread labor and reduce risk. Hardon (1995) and Joshi et al. (1997) reported that farmers possess the ability and knowledge to select crops and species that suit their environment and meet quality and other consumer requirements.

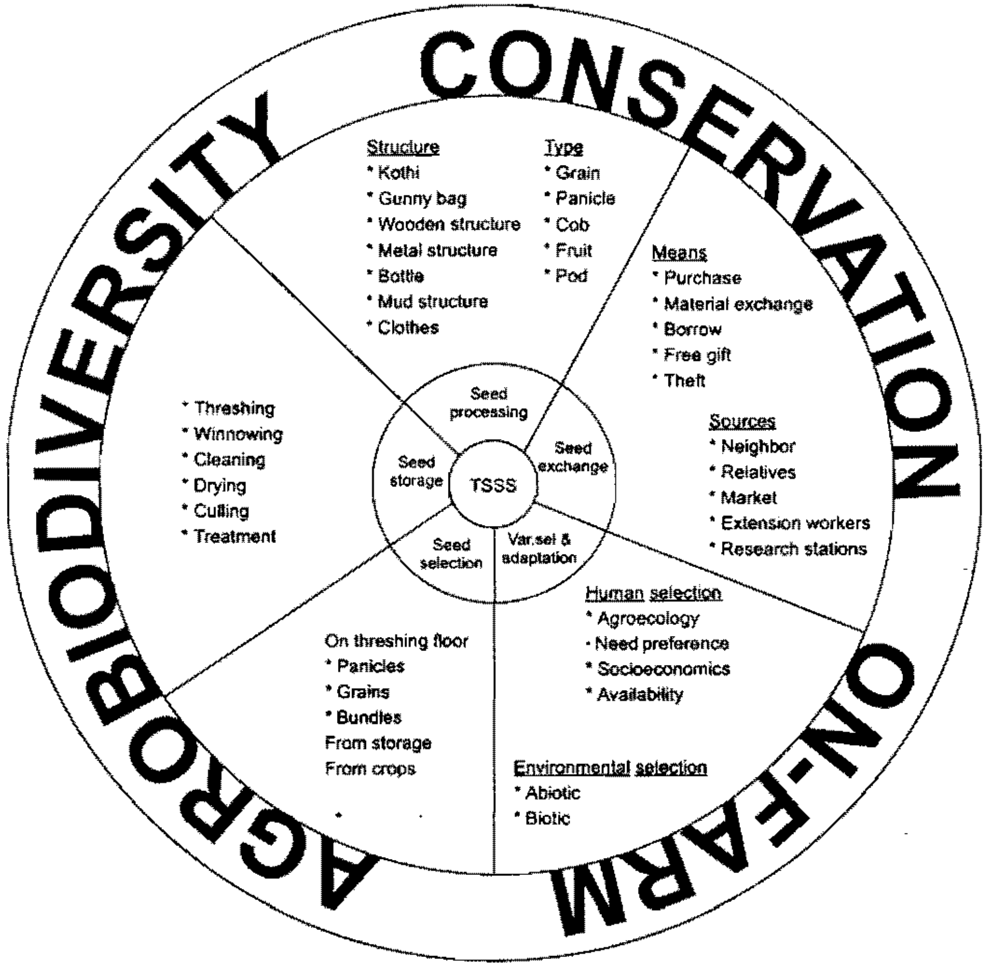

Figure 3. Farmers' role in the traditional seed-supply system

This process has created a diversity of crops and crop species, and thus, present-day landraces are no doubt the outcome of farmers' knowledge about and activities in crop improvement. Formal breeders in the name of "PPB" have lately consolidated the role of farmers in crop improvement through regular seed selection and exchange.

There is a wide range of information about the participatory methods practiced by scientists and breeders in several countries. Informal research and development (IRD), a type of participatory varietal selection (PVS) is reported to be 43% more cost effective compared to the formal system (Joshi et al. 1996 and Joshi et al. 1997).

Seed flow

The sources and directions of seed flow are vital to creating the diversity of both landraces and improved varieties. All the means through which seeds flow from one farmer to another contribute to diversity in totality. Seed flow includes purchasing, exchanging, giving as a free gift, borrowing, and stealing. Sources of new seeds might be markets, neighbors, relatives, agriculture extension, and research stations (see figure 1). In these ways, plant genetic materials drift from one place to another, creating new diversity in each community. This creates opportunities for farmers to meet

different needs, which they could not do with a single variety (Joshi et al. 1997). In one of the studies in Begnas, Kaski, Baniya et al. (1999) reported that rich farmers generally initiate variety introduction. Most farmers (85%) change seed lots or cultivars regularly, and about 49% follow this practice every one or two years. Ex situ conservation in gene banks being unaffordable, the fate of crop diversity in many mountain areas is largely governed by the fate of the traditional seed-supply system that exists within local communities (Shrestha 1998).

Seed selection

For generations, farmers have been involved in seed selection, testing crop varieties to address single or multiple household needs such as food security, economic benefits, and religious and cultural requirements, as well as finding varieties that suit their land type depending upon the access or availability of planting materials (see figure 2).

The choices or preferences for varieties of a crop may, however, differ with differences in socio-economic status. Religious and cultural considerations, level of education, and gender dimension are equally important in influencing the choices and preferences for different crops and varieties. Traditional methods of seed selection in one of the rural areas in terai region of the country are presented in box 1.

Box 1. Traditional Methods of Seed Selection at Kachorwa, Bara

Seed-selection practices	Rank
• At threshing floor, off -type panicles are removing, grains are removed by beating against hard surface to get seeds	I
• At the threshing floor, selected panicles are threshed by bullock and kept separately	II
• Panicles are selected at the threshing floor, keeping bundle of panicles and grains separated	III
• Seeds used directly from grain storage without prior selection	IV

Source: Chaudhary and Joshi (1999).

In traditional farming systems, varietal mixtures either emerge through the deliberate action of farmers, or seeds get mixed at several stages from seed sowing through harvesting, threshing, drying, and storage. Box 2 gives examples of the reasons for seed mixtures in rice, as mentioned by the farmers at Kachorwa, Bara.

Seed processing and storage

Farmers have developed different seed-processing and storage practices for different crops and crop species, which help the seeds stay viable. The practices that are followed by seed-storage companies and research stations today are the results of farmers' experiments in seed storage, transferred from generation to generation. Where seed processing is concerned, farmers keep the bare seeds of some crops, such as rice and wheat, or the cobs of maize or panicles or bunches or the fruit of some crop species, especially vegetables. For some crops, grains are cleaned and then dried well after threshing, while others require no such processing. Farmers store the seeds of some vegetable crops in the kitchen, where they are exposed to a continuous flow of smoke and heat. They dry the seeds of some other crops in the sun, some others (such as potatoes) in the shade. Some are kept in

Box 2. Traditional Methods of Seed Selection in the *Terai* Region of Nepal

Reasons for mixture in rice seeds

- *Jharan*: shattered seeds in the rice fields
- *Kheraha*: volunteer plants that emerge from jharan
- mixed in threshing floor because of a common floor used for a number of cultivars
- mixed because of using compost manure containing the seeds of other cultivars
- blown by air and getting mixed
- intermixed during planking
- mixed in seed bed because of flooding
- mixed by birds in the seed beds
- intermixed during transplanting
- careful seed selection process not performed in the mixed population by the farmer
- only a few farmers mix intentionally for monitory profit or to reduce the risk of failure

Source: Chaudhary and Joshi (1999).

airtight conditions, and some are spread on the floor. Baniya et al. (1999) reported on the different seed-storage practices followed by farmers in Begnas, Kaski, where there is a wide range of crop diversity even today. If farmers did not save seeds under proper storage condition, we would not have the diversity in both crops and crop species that we have today.

Limitations of participatory approaches

Participation

In the commercial world, there may be a lack of interest in participatory methods because resource-poor farmers might not appreciate immediate benefits from participation in research. They have a restricted time for contribution and limited resources to support research. On the other hand, resource-rich farmers, especially in a high production-potential system (HPPS) are likely to migrate to urban areas, thereby discontinuing active participation after a year or more. Urbanization and commercialization might have a negative impact on the participation since absentee landlords may have less time to think about all these participatory approaches, their being capable of supporting land for research purposes. Moreover, without compensation, long-term participation of farmers can not be assured, since the time for research activities can cause conflicts with farmers' field activities.

Knowledge

Confining farmers to traditional cultivation systems has made them focus on traditional selection practices; they are less aware of advances in agricultural science for seed selection and varietal selection based on agroecology. Searching and procuring seeds becomes cumbersome and time consuming for individual farmer. Traditional ways of procuring seeds without adequate information about new varieties might in some cases adversely affect the farmers' yield. Lacking adequate knowledge about seed selection, farmers keep mixtures in their selections to ensure adequate yields, but this also creates high diversity. Furthermore, in most of the participatory approaches to crop improvement, gathering postharvest information from rich people does not provide useful

insights—they are not actually the end users, since they are likely sell a large portion of their produce in the market (Witcombe 1999).

Farmers' knowledge threatened

Several areas of knowledge are associated with landraces, and with the elimination of landraces, we not only lose genetic resources from our farming system or community but also the knowledge associated with them. With the ever-increasing dependence of farmers on modern technologies, accompanied by the use of chemical fertilizers and hazardous pesticides, farmers are being handicapped in several ways, including the area of indigenous knowledge. Farmers are, therefore, not only losing benefits from plant genetic resources, but more important, they are losing the right to save, exchange, and improve their seeds (Mazhar 1997).

Despite several efforts, it has been observed that no "steady state" is possible in populations of primitive cultivars because of technological changes in the farming systems that once produced them (Frankel 1970; Brush 1995). It is, therefore, certain that genetic erosion is pervasive and may accelerate if no proper action is taken on time to check it. It is also true that gradually the habitats of the landraces will be changed, the strength of the planting materials will be weakened, development and revolutionary options for various species may be shut off in the process, diversity will be skewed, and farmers' decision-making and indigenous knowledge systems will be diluted. The hardest hit by this will be small and marginal farmers, whose situations will be further worsened by concomitant increases in uniformity and expensive market seeds, fertilizers, insecticides, and pesticides, irrespective of their quality. As a result, food deficiency will become more widespread and the lives of people will be threatened. Thus, there is an urgent need to look for a solution that helps cope with food deficiency through the management of agrobiodiversity.

Coping strategies

The threat to farmers' knowledge, as well as to agrobiodiversity, can be addressed through the following strategies.

- Research should emphasize the process of responding to farmers' needs rather than designing fixed options in standardized trials. Research-managed on-station and on-farm trials need to be combined with trials designed and run by farmers. Researchers therefore need to expand their focus and learn about the complex adaptations made by farmers.
- Agricultural research needs to reflect farmers' own diverse conditions. It needs to be adapted to different settings (e.g., both dry-field and wetland agriculture), to different field conditions (e.g., a variety of soil types), and to different cropping patterns (e.g., multiple and intercropping patterns), rather than focusing on standardized, uniform trial plots, so that the processes of local adaptation and the technology developed are understood and can be supported.
- Farmers can be successfully empowered through training in the process of germplasm enhancement through pure-line and mass selection of their traditional varieties (Chaudhary and Joshi 1999), enhancing in situ conservation on-farm.
- The seed-supply system can be strengthened for self-reliance and cost effectiveness through the use of farmers' networks of information and seed exchange, involving grass-roots institutions (Joshi et al. 1997).

Conclusions

Farmers' knowledge (skills) and routine involvement in the crop-improvement process is crucial to the management of agrobiodiversity on-farm. Farmers are key players, bringing a wild species through generations, creating diversity to suit to their different agroecologies and traditions. However, farmers' knowledge is being eroded and plant genetic materials are being lost forever. Our current need is to document agrobiodiversity and the knowledge associated with it to use in crop improvement in the future. It is essential to have an adequate scientific explanation of farmers' knowledge in order to better and or improve this knowledge for efficient and sustainable agriculture. This can be achieved through different strategies such as diversity fairs, community biodiversity registers, poetry journeys (Rijal, et al. 2000), censuses, and field observations or transect walks. It requires the commitment of farmers and strong linkages with formal science institutes to enhance the maintenance of biological diversity, agricultural sustainability, and food security at the farm, regional, and global level.

References

Baniya, B.K., A. Subedi, R.B. Rana, C.L. Poudel, S.P. Khatiwada, D.K. Rijal, and B.R. Sthapit. 2000. Informal rice seed supply and storage system in mid-hill of Nepal. In *Conserving agricultural biodiversity in situ: A scientific basis for sustainable agriculture. Proceedings of a workshop, 5-12 July 1999, Pokhara, Nepal*, edited by D. Jarvis, B. Sthapit, and L. Sears. Rome: International Plant Genetic Resources Institute.

Brush, S.B. 1995. In situ conservation of landraces in centre of crop diversity. *Crop Science* 35:346–354.

Brush, S.B. 1992. Farmers' rights and genetic conservation in traditional farming systems. *World Development* 20(11):1617–1630.

Chaudhary, P. and K.D. Joshi. 1999. Summary of orientation workshop on seed selection and germplasm enhancement. A project document of the project "Strengthening the scientific basis of in situ conservation of agrobiodiversity on-farm." Unpublished document.

FAO. 1989. *Resources phytogenetique: Leur conservation in situ an service des besoins humains.* Rome: Food and Agriculture Organization of the United Nations.

Francis, C.A. (Ed.) 1986. *Multiple cropping systems.* New York: MacMillan.

Frankel, O.H. 1970. Genetic conservation in perspective. In *Genetic resources in plants: Their exploration and conservation,* edited by O.H. Frankel and Bennet. IBP Handbook II. Oxford: Blaskwell Scientific Publications.

Hardon, J. 1995. The outcome of a workshop on PPB, sponsored by IDRC, IPGRI, FAO and CGN at Wageningen, the Netherlands on 26–29 July 1995. *PPB issues in genetic resources* No. 3, October 1995.

IPGRI. 1996. *Participatory plant breeding: Proceedings of a workshop on participatory plant breeding, 26-29th July 1995, Wageningen, The Netherlands,* edited by P. Eyzaguirre and M. Iwanaga. Rome: IPGRI.

Joshi, K.D., M. Subedi, K.B. Kadayat, and B.R. Sthapit. 1996. Genetic diversity and erosion in indigenous arable crops and green manuring species in the mountains of Nepal: Some conservation issues. In *Proceeding of the working seminar on managing agricultural biodiversity for sustainable mountain agriculture: Issues and experiences,* edited by B.R. Sthapit. Pokhara, Nepal: Local Initiatives for Biodiversity Research and Development.

Joshi, K.D., M. Subedi, R.B. Rana, K.B. Kadayat, and B.R. Sthapit. 1997. Enhancing on-farm varietal diversity through participatory varietal selection: A case study for *chaite* rice in Nepal. *Experimental Agriculture* 33:29–37.

Joshi, K.D., D.K. Rijal, R.B. Rana, S.P. Khatiwada, P. Chaudhary, K.P. Shrestha, A. Mudwari, A. Subedi, and B.R. Sthapit. 2000. Summary of presentation of working group recommendations from Nepal: PPB, seed networks, and grassroots strengthening. In *Conserving agricultural biodiversity in situ: A scientific basis for sustainable*

agriculture. Proceedings of a workshop, 5-12 July 1999, Pokhara, Nepal, edited by D. Jarvis, B. Sthapit, and L. Sears. Rome: International Plant Genetic Resources Institute.

Louette, D. and M. Smale. 1996. *Genetic diversity and maize seed management in a traditional Mexican community: Implications for in situ conservation of maize*. NGR Paper 96-03. Mexico, DF: Centro Internacional de Mejoramiento de Maíz y Trigo.

Mazhar, F. 1997. *Nayakrishi andoland*: An initiative of the Bangladesh peasants for a better living. In *Using diversity: Enhancing and maintaining genetic resources on-farm*, edited by L. Sperling and M. Loevinsohn. Ottawa: International Development Research Centre.

McGuire, S., G. Manicad, and L. Sperling. 1999. *Technical and Institutional issues in participatory plant breeding: Done from a perspective of farmer plant breeding. A Global analysis of issues and current experience*. Cali, Colombia: CGIAR Systemwide Program on Participatory Research and Gender Analysis for Technology Development and Institutional Innovation, Centro Internacional de Agricultura Tropical.

Rijal, D.K., B.R. Sthapit, R.B. Rana, P.R. Tiwari, P. Chaudhary, Y.R. Pandey, C.L. Poudel, and A. Subedi. 2000. Summary of presentation of working group recommendations from Nepal: PPB, seed networks, and grassroots strengthening. In *Conserving agricultural biodiversity in situ: A scientific basis for sustainable agriculture. Proceedings of a workshop, 5-12 July 1999, Pokhara, Nepal*, edited by D. Jarvis, B. Sthapit, and L. Sears. Rome: International Plant Genetic Resources Institute.

Roder, W. 1995. *On farm management of biodiversity and genetic resources*. MFS Series No. 95/3 (ISSN 1024-7548). Kathmandu, Nepal: International Centre for Integrated Mountain Development.

Shrestha, P.K. 1998. Gene, gender and generation: Role of traditional seed supply system in the maintenance of agrobiodiversity in Nepal. In *Managing agrobiodiversity: Farmers' changing perspectives and institutional responses in the HKH region*, edited by T. Pratap and B. Sthapit. Kathmandu, Nepal: ICIMOD.

Sperling, L. and P. Berkowitz. 1994. *Partners in selection: Bean breeders and women bean experts in Rwanda*. Washington, DC: CGIAR Gender Program, Consultative Group on International Agricultural Research.

Sthapit, B.R. and K.D. Joshi. 1998. Participatory plant breeding for in situ conservation of crop genetic resources: A case study of high altitude rice in Nepal. In *Managing agrobiodiversity: Farmers' changing perspectives and institutional responses in the HKH region*, edited by T. Pratap and B. Sthapit. Kathmandu, Nepal: ICIMOD.

Sthapit, B.R., K.D. Joshi, and J.R. Witcombe. 1996. Farmer participatory crop improvement III: Participatory plant breeding: A case of high altitude rice from Nepal. *Experimental Agriculture* 32:479–496.

Sthapit, B.R., K.D. Joshi, R.B. Rana, and A. Subedi. 1998. *Spread of varieties from participatory plant breeding in high altitude villages of Nepal*. LI-BIRD Technical Paper No. 1 (ISSN 1561-1558). Pokhara, Nepal: Local Initiatives for Biodiversity Research and Development.

Teshome, A. 1997. Sorghum landraces, farmers' knowledge and agricultural sustainability. In *Proceeding of a workshop to develop tools and procedures for in situ conservation on-farm, 25–29 August*, edited by D.I. Jarvis and T. Hodgkin. Rome: International Plant Genetic Resources Institute.

Vaughan, D.A. and L.A. Stich. 1991. Gene flow from the jungle to the farmer: Wild rice genetic resources and their uses. *Bioscience* 41(1):22–28.

Winarto, Y.T. 1997. Maintaining seed diversity during the Green Revolution. *Indigenous Knowledge and Development Monitor* 3(5):3–6.

Witcombe, J.R. 1999. Do farmer participatory methods apply more to high potential areas than to marginal ones? *Outlook on Agriculture* vol.28(1):43–49.

Witcombe, J.R. 1996. Participatory approaches to plant breeding and selection. *Biotechnology and Development Monitor* No 29, December 1996.

Witcombe, J.R., A. Joshi, K.D. Joshi, and B.R. Sthapit. 1996. Farmer participatory cultivar improvement. I: Varietal selection and breeding methods and their impact on biodiversity. *Experimental Agriculture* 32:445–460.

Worede, M. 1992. Ethiopia: A gene bank working with farmers. In *Growing diversity: Genetic resources and local food security*, edited by D. Cooper and R. Vellve. London: Intermediate Technology Publication.

Need for Advocacy for Effective Participatory Crop Improvement and Plant Genetic Resource Enhancement: Case Studies on Rice-Breeding Processes from Khotang and Jajarkot Districts, Nepal

Yamuna Ghale

Abstract

This paper deals with advocacy for effective participatory crop improvement and plant genetic resource enhancement. First, the need for advocacy is highlighted; second, cases on the community-managed process of managing plant genetic resources is discussed. *Advocacy* is public action directed towards wider social change. It is about changing the policies, practices, attitudes, positions or programs of governing institutions within the public and private sectors that have a negative impact. In the age of globalization, multinational/transnational corporations (MNCs/TNCs) increasingly influence policies, but these organizations are not bound by rights-related laws and regulations. The trade-related intellectual property rights (TRIPs) agreement under the World Trade Organisation (WTO) is a major threat to crop and variety development and genetic resource enhancement. Advancements in genetic engineering promoted by profit-oriented MNCs/TNCs is gradually taking over the classical research-and-development process. If we are concerned about participatory crop improvement, we have to pinpoint the issue now. We need to enforce favorable policies and effective implementation for the conservation of our genetic resources and participatory development of crops and varieties. Therefore, to have influence at the policy level, we have to develop links between operational work and advocacy. In this context, advocacy can support communities demanding their rights in germplasm conservation. It is about having an input when government is formulating relevant policies, considering the voice of the powerless in developing plant- breeding program or plans, and bringing about the realization of favorable promises or policies for the benefit of farmers. The case studies show that farmers have selected and maintained their rice crops for generations with their own experience. The role of women farmer is vital to the process of seed selection, preservation, and maintenance. However, the cases indicate that men are still ignoring the role of women in the plant-breeding process. We argue that farmers are the owners of genetic resources, and they should have right to select, develop, conserve, and multiply them as they wish. Therefore, advocacy should be one of the major activities of all development organizations if they are to have any spillover effect for challenging sustained inequality and injustice to farmers.

Introduction

This paper basically deals with two issues: the first is the issue of advocacy and the need for advocacy in participatory crop improvement (PCI) and plant genetic resource enhancement (PGRE). It also analyzes the trend of global mechanisms to develop crops and or varieties without the participation of real stakeholders and the threat to developing countries. The second part highlights the major processes of seed production and saving rice in the mid-hills of Nepal. The cases elaborate these processes along with gender dimensions and the exclusion of farmers from breeding processes. Further to this, it highlights some of the advocacy and operational work of the development organization taking place in the Jajarkot area. The cases we highlight are from Khotang, in the eastern hills of Nepal for farmer-managed seed production, and Jajarkot, in the western hills of Nepal.

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