splitting problems. They are generally planted in areas prone to hailstorms. Even wild animals cannot harm them because the ears of the plants bear awns. Some landraces are also of high medicinal value; for example, *kafalya* is used to cure leukorrhea and many other gynecological problems.

The *baranaaja* culture: Diversity is prosperity

A cropping pattern based on intermixing finger millet, locally known as *baranaaja*, is a symbol of prosperity in the region. *Baranaaja* literally means "12 food grains." The adage "diversity is prosperity" holds well from the perspective of mountain agriculture. Finger millet is intercropped with as many as 12, and sometimes even more, other food grains. Amaranth, buckwheat, kidney beans, horse gram, black soybean, black gram, green gram, cowpea, adjuki bean, sorghum, and *cleome* are the main crops intermixed with the base crop of finger millet. *Baranaaja* provides a unique example of how a mountain farmer cultivates diversity. Marginal and small farmers inhabiting the mountains manage agrobiodiversity in such a way that they can harvest the maximum number of food items from the minimum amount of land. The degree of agrobiodiversity is directly proportional to the level of their (food) security, and *baranaaja* is the core of their (agri)culture.

The main result of conventional interventions in agriculture is to replace the unique *baranaaja* culture with monocultures of white-seeded soybeans. Soybeans as a cash crop is projected as a panacea for the land-based economy of the mountains. This crop was introduced recently as one of the packages of the Green Revolution and is said to be a source of protein, milk, and oil. Soybean, in fact, has never been an ingredient of local diets, nor has it fetched more money for the farmers. Farmers who switched to soybean cultivation from *baranaaja* generally barter their produce for salt or rice. Unlike all major mountain crops, soybeans do not provide fodder for livestock, which has contributed to fodder problems in the area.

Realizing the potential dangers to local agrobiodiversity, the majority of local farmers have given up raising soybeans at the expense of the unique *baranaaja*. BBA, with the help of farmers has been successful in reviving the *baranaaja* culture, to the joy of mountain communities.

Ecological regeneration of common property resources

The mountain farming systems typical of Garhwal comprise forests, cropland, livestock, and households as four organically linked components (or subsystems). No input from outside the system is required. This traditional system is "closed," and self-containment is one of its most essential features. Forest biomass flows into cropland (cultivated land) in the form of organic manure via the agency of livestock. Crop biomass is recycled into cropland through livestock and human beings.

This farming system is altogether different from the one operating in the plains under Green-Revolution agricultural practices. In the latter, organic linkages among components are virtually missing. Forests are almost absent. Almost all the necessary inputs are supplied from outside. The forests and grasslands in the mountains, on the other hand, are managed as common property resources, with cropland continuously receiving a subsidy from them. Such a unique farming system could be termed a "nature-subsidized, solar-powered agroecosystem." Green-Revolution agriculture, on the other hand, is a "fossil-fuel–subsidized, solar-powered agroecosystem" in which petroleum-based inputs (chemical fertilizers, pesticides, and machines powered by fossil fuels) are inevitably used.

Common property resources play the most vital role in providing ecological integrity to mountain agriculture. Biodiversity in these areas has enormous bearing on agrobiodiversity. Ecological regeneration and enrichment of diversity in these areas is also a focal point of BBA. Plentiful biomass harvests, especially of fodder and fuel wood, from common property resources have strengthened organic linkages among the components of farming system, infusing health into the whole farming system. Cropping systems are more fragile than forest ecosystems. If there is crop failure due to an erratic weather cycle, for example, common property resources can fill much of the requirement for food. They also ease pressure on croplands. In their absence, more and more areas would have to be cultivated, which would exact a heavy cost from the ecological balance in the region.

Common property resources also play a significant role in enhancing food security. Villagers in Garhwal have access to at least 127 different food-providing plants. Many of these food plants occur in areas that are common property resources. People incorporate 23 wild fruits, flowers, and buds and 14 wild vegetables in their diets. These uncultivated foods complement the cultivated ones. Foods obtainable from uncultivated common property resource areas often have very high nutritive value. Many of these have medicinal value as well. At least 100 more plant varieties that occur naturally in uncultivated areas are exploited as fodder for livestock and thus become part of human nutrition through milk and milk products.

When looking at the food spectrum of prehistoric humans, we come to know that they embraced at least 1500 species of plants, while over 500 vegetables were utilized by ancient civilizations. However, in contemporary times, human nutrition is based on no more than 30 plants, with three crops—wheat, rice, and maize—accounting for 75 percent of our cereal consumption (SAM 1984).

It can clearly be inferred from this that human societies have been moving steadily towards a state of food poverty based on the decline of food diversity. The state of food diversity is grimmer in agriculturally transformed areas deluged by high-yielding, fertilizer-dependent varieties of food grains. In these Green-Revolution areas only a few species of plants with a limited number of varieties remain the sole source of human nutrition. There is no mention of and no debate about uncultivated foods. In urban mountain areas, where the public distribution system is the only way to feed people, most of nutritional requirements are met by *dal-bhat* (pulses and rice). But the plates of rural mountain people are piled with delicious and diverse foods thanks to the enormous biodiversity flourishing in their forests and agroecosystems.

Because of the continued neglect of common property resources in policies and planning, however, considerable ecological damage has been witnessed in these areas over the last few decades. BBA took stock of this situation and designed concrete strategies for ecological regeneration. *Van suraksha samiti* (forest protection committees) have been formed. Inspired by the Chipko Movement, the village youths involved in these committees have taken on the task of regenerating the rapidly depleted forests. Overgrazing of the common property resources by cattle and ovine species is not allowed. Only hand-lopping (no cutting with sickles) of oak leaves is permitted. Oak forests represent the natural climax vegetation of the Middle Himalayas, playing a very specific role in soil and water conservation and microclimate maintenance. These forests are especially protected from overexploitation. Only dry branches and twigs can be removed for firewood. The committee's sanctions are to be followed by all. BBA has enhanced the biodiversity of the common property resources through massive plantings of food-yielding trees. These trees have begun bearing fruit and contributing to food security.

As a result of this community management, village residents in the Henwal Valley of Garhwal are now obtaining fuel, fodder, and several kinds of wild foods (fruits, flowers, buds, vegetables, seeds, honey, etc.), along with cultivated fruits, from the common property resource areas—free of cost on sustained basis. Water springs have been rescued and these supply clean drinking water to villagers. The reappearance of several wild animals—boars, bears, leopards, etc.—indicates that the ecological balance is being restored. Farmers are getting plentiful natural subsidies in the form of forest biomass, water for irrigation, etc., for agriculture, and the impact on agronomic yields in cropland is visible.

Farmers' Experimentation

BBA keeps records of the performance of all the landraces. BBA farmers also do their own informal experimentation on the landraces. The performance of all the landraces is compared with the so-called HYVs demonstrated by external development agencies. All the traits of vital socioeconomic importance, rather than just grain yields, are taken into consideration. The results of one such experiment conducted in Jardhargaon of the Henwal Valley are presented in table 1. In their experimentation, farmers do not apply any statistical design, but they do take into consideration more traits and factors than an agricultural scientist would conventionally do. Some of the interesting observations are listed below.

- The average yield of 27 landraces (40.00 q per ha) was significantly higher than the yields of five HYVs (28.00 q per ha).
- *Thapachini*, a widely adopted landrace, gave the highest grain yield (54.00 q per ha).
- *Jhumkya, khushboo, agariya, lathmar, kali mukhri, basmati nagni, lalmati, congressi, nailchamya, rekhalya,* and *rikhwa* also gave impressive yields.
- Most of the landraces attain maturity earlier than HYVs.
- The average recovery percentage of landraces (72 percent) was significantly higher than that of HYVs (60 percent).
- The average grain-husk ratio of landraces (2.6:1.0) was wider than that of HYVs (1.5:1.0).
- Straw-grain ratios of most of the landraces (1.4:1.0 to 2.3:1.0) are higher than those of HYVs (1.1: to 1.6:1.0), thus supplying more fodder, a critical produce, no less important for livestock production in the region.
- Yields of the landraces are fairly sustainable. This has been observed for more than a decade in the Henwal Valley of Garhwal.
- More yields with low inputs (zero external input) indicate the high-energy efficiency in landraces.
- Landraces show considerable tolerance to diseases and pest infestation, and some of them can thrive well under rain-fed conditions, thus exhibiting the unique trait of drought tolerance. HYVs, on the other hand, are vulnerable to several sorts of pests and cannot grow under rain-fed conditions.
- In addition to organic manure, HYVs usually require external inputs (chemical fertilizers and dreaded pesticides); hence, their cultivation contributes to environmental pollution and

Table 1. Performance of Some Landraces and High-Yielding Varieties of Rice in a Village of the Garhwal Himalayas, India

Name of Landrace/ HYV	*Production (q per ha)*		Straw-Grain Ratio	*Plant Height, (cm)*	Days of Maturity
	Grain	*Straw*			
Landraces					
Thapachini	54.00	96.00	1.8	140	140
Khushboo	49.00	80.00	1.6	125	145
Kali Mukhri	46.00	80.00	1.7	122	145
Agaria	49.00	78.00	1.6	125	145
Kanguri	38.00	54.00	1.4	115	120
Lalmati	45.00	64.00	1.4	120	140
Rikhwa	43.00	64.00	1.5	125	130
Jhumkya	50.00	80.00	1.6	130	140
palphaBasmati Nagni	45.00	88.00	2.0	135	150
Utauli	36.00	64.00	1.8	118	145
Bangoi	40.00	65.00	1.6	125	140
Congressi	45.00	104.00	2.3	126	145
Anjana	29.00	48.00	1.7	125	145
Gajraj	33.00	48.00	1.5	126	150
Ghyasu	37.00	72.00	1.9	135	150
Lathmar	47.00	65.00	1.4	115	150
Rekhlya	43.00	70.00	1.6	120	140
Gorakhpuri	36.00	65.00	1.8	135	120
Hansraj	33.00	75.00	2.3	130	160
Bhagwandas	33.00	58.00	1.8	125	135
Nyuri	35.00	60.00	1.7	110	120
Palyopar	36.00	66.00	1.8	120	140
Basmati Doon	32.00	55.00	1.7	125	150
Nailchamya	43.00	72.00	1.7	120	145
Chawarya	32.00	60.00	1.9	122	135
Luakat	37.00	60.00	1.6	130	145
Ramjawan	33.00	57.00	1.7	125	130
High-Yielding Varieties					
Kasturi	24.00	34.00	1.4	85	150
Pant Dhan – 6	30.00	40.00	1.3	72	155
Saket – 4	41.00	64.00	1.6	72	165
Pant Dhan –11	30.00	40.00	1.3	80	160
Govind	17.00	18.00	1.1	85	155

Note. Landraces were grown at the farm of a BBA farmer, while HYVs were the demonstrations of an agricultural university near the same farm. Organic manure was applied to all the plots at the rate of 250 q per ha. HYVs, in addition, were also provided with recommended doses of chemical fertilizers and pesticides.

health hazards, whereas the landraces thrive under organic culture, ensuring environmental quality.

- Landraces not only satisfy people's hunger and contribute to food security, but they are also used in many rituals. All through the history of Indian civilization, these landraces have been used as symbols of religion and culture.
- The social acceptability of landraces is very high.

Regular features of the movement include organizing meetings to review the progress of the BBA and occasional walking trips, along with seed fairs and participation in museums, fairs, etc., in urban areas. These have been considered necessary for creating awareness in the community. The relentless search in remote and poorly accessible areas for the collection of more and more seeds of landrace varieties exhibiting unique characteristics goes along with the awareness-raising activities. An inventory of the unique traits of landraces is made with the help of farmers in remote areas, and oral histories relating to their cultivation are recorded. BBA has also prepared a biodiversity register for elaborating the characteristics of individual landraces.

Seeds of the local varieties of crops, such as rice, kidney beans, black soybeans, several local pulses, amaranth, etc., can now be found for sale in urban markets, indicating their increasing economic value in the market. Landraces, in fact, are fetching handsome returns for some of the families in the area. Many varieties of the crops grown only in the mountain areas are known for their special food and medicinal values and have great export potential.

Future Implications

Traditional systems of management and ecological knowledge have been the vital means by which mountain communities have evolved richly diverse food-production and livelihood systems. Traditional knowledge develops from the natural process of adaptation and, unlike conventional scientific knowledge, it is moral, ethical, aesthetic, intuitive, theosophical, compassionate, and holistic, resulting in a diverse local and bioregional economy.

One thing that seems certain is that in the historical process of agricultural development, farmers have always sought to enhance the level of biodiversity. When they opt out of following the biodiversity-destructive ways of the Green Revolution, they return to the biodiversity-based agriculture they have tested over millennia. Farmers in the Garhwal Himalayas, through BBA, are doing this.

Diversity in agricultural crops, landraces, and their wild relatives in the Indian Himalayas have been maintained by farmers for centuries. In India, the endemic species inhabit two areas for the most part: approximately 4,200 species are found in the Himalayas and 2,600 in the peninsular region. In the Indian Himalayas, crop diversity is related to eight groups of crops and 71 species. As a result of the selection pressure exercised within the species by locals over the millennia, enormous diversity has evolved in the form of local landraces (Pant 1998). Too much emphasis on HYVs has led to the extinction of several landraces during recent decades. People's movements, like the BBA, would help remove such extinction scenarios from the mountains.

The efforts of BBA are noteworthy in that they have revived the cultivation of unique landraces and cropping systems, promoted on-farm conservation of genetic resources, enhanced biodiversity in forests and agroecosystems, and encouraged the growth of organic farming based on the principles

of a living soil, biodiversity-complexity, and cyclic flow patterns. The success of BBA suggests that it is possible to combine diversity, productivity, and livelihood security in future agricultural policy.

Since many of the local landraces exhibit unique properties—like taste, aroma, essential amino acids, high calcium content, medicinal (Ayurvedic) value, and the like—they can have very high market value in the plains and can bring in handsome returns to local farmers. A mountain-friendly agricultural policy can play a pivotal role in this regard. Prices should be decided on the basis of the characteristic properties the produce possesses. Mountain agriculture, in fact, should be dictated by the principle of value, rather than volume. Value rather than volume should also be the main concern of the agrarian economy of the mountains and other marginal areas harboring unique biodiversity in their ecological niches.

When agrobiodiversity is managed and controlled by farming communities, it is virtually regarded as a common property resource. Conservation of plant and animal genes should be seen as an aspect of management of the common property resource. It should, therefore, be seen as a fundamental duty of both institutions and farmers to conserve biological and genetic resources. BBA reminds us this moral obligation.

A farmers' movement, rather than just farmers' participation or farmers' involvement, is the most radical approach towards realizing the most desirable change in a system. This approach itself takes care of any bias and lack of institutional mechanisms for change. It also reverses negative change into positive. By creating local gene pools through large-scale farmers' movements, on-farm management (conservation and sustainable use) of genetic resources will also help marginal farming communities, like those of the mountains, to remain impervious to the global politics surrounding control of the world's gene pools.

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Empowering Farmers through Participatory Plant Breeding: An Initiative of the Green Foundation

Vanaja Ramprasad and Shibu M P

Abstract

In the so-called *difficult environments*, institutional plant breeding appears to be a failure, mainly because breeding is directed at increasing yields in more favorable environments. Although the improved varieties have broad adaptability, under varied marginal environments, they do not express their yield potential or they do not satisfy other user requirements. In any environment, the potential of a plant is controlled by the interaction of its genetic composition with the environment. This involves adaptation of the plant to both physical environments (climate, soil, abiotic and biotic stress) and the socioeconomic environment (user concerns, consumers' preferences, economic status, markets, etc.). After the introduction of high-yielding varieties and hybrids during the Green Revolution in India, hundreds of landraces and indigenous varieties have become extinct or on the verge of extinction, largely because they have not been considered economical to grow under the present market economy.

Despite this, small-scale farmers in marginal environments continue to grow a mixture of crops and varieties as a buffer against temporal and spatial variation to cope with stress factors. It has been a time-tested practice by farmers to continue to select their next generation of seeds, thereby modifying the genetic characteristics of the crops. Tapping into this practice and empowering farmers to improve their crops has now come to be referred to as "participatory plant breeding."

Conservation of plant genetic resources has been initiated by the Green Foundation, working in the dryland regions of South India. As a means of empowering farmers, the Green Foundation has conserved several varieties of staple food crops, like finger millet and rice, on-farm. Using the genepool available to them, farmers have selected varieties, based on a set of criteria, for varietal purification, as a first step towards participatory plant breeding. This paper describes the process of varietal selection for improvement of local cultivars and the upgrading of farmers' skills as independent seed producers.

Introduction

Indigenous seed practices encompass practically all aspects of crop production, since seed saving is an integral part of cropping activities in indigenous systems. Farmers engaged in the production and multiplication of quality seeds deal with asexual propagation, land preparation and soil management, seed and seedling preparation and care, crop and pest management, flowering induction, the enhancement of seed quantity and quality, crop improvement, harvesting or collection, seed processing, storage, and genetic conservation (Fernandez 1994).

The holistic understanding of cropping in semi-arid areas has lent support to the conservation of diversity in various parts of the country. In the last few decades, there have been dramatic changes in Indian agriculture. The advent of the Green Revolution in the mid-1960s has been a major threat to India's vast genetic diversity. Intercropping has been replaced by monocropping, and as a result, food production is perched on narrow genetic diversity. The erosion of agricultural biodiversity threatens the long-term stability and sustainability of Indian agriculture in the following ways:

- It erodes the genetic base on which scientists are dependant for crop breeding.
- A monocrop of high-yielding varieties (HYVs) does not provide adequate insurance against failures caused by natural calamities.

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Need to revive biodiversity

A considerable amount of the genetic material that has been maintained by farmers over several years is now no longer available to the farmers. The ex situ collections play an important role in preserving germplasm under freezing conditions but they have their own limitations, like cost and loss of viability during storage. This limits the natural course of evolution, since the environmental conditions to which crops are constantly adapting cannot be recreated in a refrigerated gene bank.

It is in this context that a plant-genetic-resources conservation program was introduced in 1992, to ultimately create a village-based community seed bank. Since then, the program has gone through the stages of collection, multiplication, monitoring, evaluation, and farmers' participation in selection, rating, and distribution of varieties.

The profile of the area

Thally block, in the State of Tamil Nadu, and Kanakapura, in the state of Karnataka, are semiarid, with an annual rainfall of 700–900 mm. The Green Foundation works in the dry-land regions lying between these two administrative regions—Tamil Nadu and Karnataka. Seed conservation work extends across 85 villages, involving more than 500 farmers. The agricultural scene paints a bleak picture. The combination of illiteracy, poor infrastructure, poverty, and small land holdings on the one hand and changing agricultural practices and market pressures on the other have rendered agriculture very vulnerable for the farmers of the area. More than 85 percent of the cultivated area comes under rain-fed dry-land. Changing rainfall patterns have affected the improved varieties introduced in the area. Yet the area also represents a rich source of biodiversity, which is on the verge of extinction. It is against this backdrop that the Green Foundation has initiated a genetic resource conservation program.

The major food crops of this region are finger millet and dryland paddy, followed by wetland paddy, pulses, sorghum, maize, oilseeds, vegetables, and other minor millets. Many of the indigenous varieties have been reintroduced with low-input agriculture since 1993, when the foundation started its work in the area. Table1 gives the details of the collections between 1995 and 1999. In 1998 an attempt was made to upgrade local varieties through a process of participatory varietal selection, and as an initial step, *ragi* (finger millet) and rice crops were selected.

Earlier practices recall cultivation of four seasonal crops such as *gingelly* in the pre-monsoon season; groundnuts, paddy during early monsoon; *ragi*, pulses in the monsoon season; and horse gram in the post-monsoon period.

Changes in climatic variations have had an impact on the rainfall pattern and, as a consequence, have affected different crops in different ways. Intercropping has been popular as a traditional practice, although many farmers have shifted to the improved varieties of finger millet, leading to erosion of traditional ones. The program of seed conservation has widened the choice of finger millet varieties for farmers (figure 1).

The focus of the program was not only to widen the choice of varieties but also to increase yields by improving the quality of seeds. The on-farm conservation program, with nearly 34 indigenous varieties of finger millet and 38 varieties of wetland and dry-land paddies provides the basic materials for the participatory plant breeding (PPB) process.

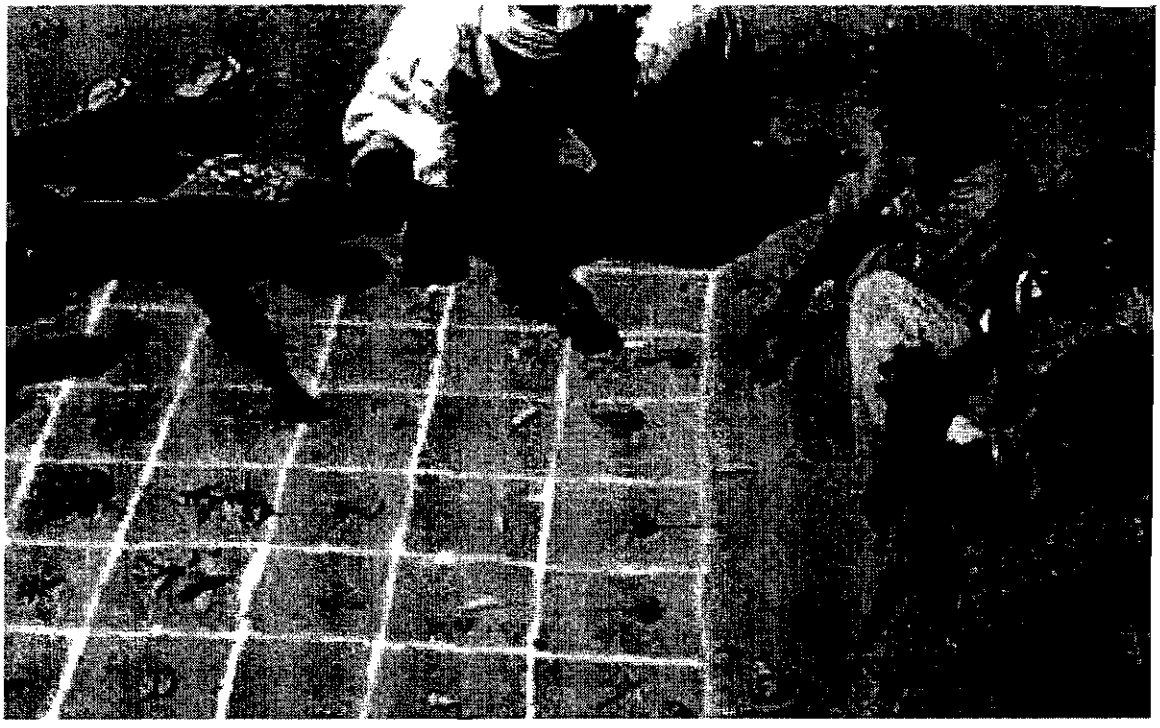

Figure 1. Participatory varietal selection of finger millet

Table 1. Collections of Indigenous Varieties and On-Farm Conservation between 1995 and 1999

	No. of varieties at conservation center		No. of varieties with farmers	
CROPS	**1995**	**1999**	**1995**	**1999**
Finger millet	21	68	6	34
Upland paddy	20	36	5	22
Wetland paddy	12	46	5	16
Pearl millet	3	13	3	5
Sorghum	4	15	3	5
Maize	3	8	1	3
Little millet	4	11	2	5
Foxtail millet	4	12	2	6
Kodo millet	1	1	0	1
Proso millet	1	2	1	2
Vegetables	24	68	23	53
Oil seeds	7	14	4	13
Pulses	12	38	8	26

The concept of PPB

To ensure household food security and optimize productivity under available conditions, which are highly resource-constrained farming environments, the farming community continuously relies on diversity of crops and crop species. The efficiency of formal breeding lines or improved cultivars has remained largely confined to favorable environments and high-input conditions. Decentralized breeding approaches have been started in Western Asia and the Near East (Ceccarelli et al. 1994),

Central Africa (Sperling, Loevinsohn, and Ntabomurra 1993; Voss 1992), and West Africa (Jusu 1995). Farmer-based breeding is an important strategy for maintaining and using genetic diversity in agriculture as part of a multilateral system for conserving plant genetic resources (PGR) by making a wider range of genetic material available to farmers, directly as well as through the use of a broader genetic base in formal breeding (Eyzaguirre and Iwanaga 1995), by developing plant varieties suitable for resource-poor farmers in marginal areas, and by creating incentives for in situ conservation of PGR (Cooper, Engels, and Frison 1994).

Although agricultural universities and private-sector organizations are releasing a number of varieties, the farming community has continued to maintain their own varieties. Although advances are being made to decentralize the varietal evaluation process for incorporated traits, breeders have not risked making selections under the non-uniform conditions typical of a small and marginal farmer. Even today a number of farmers prefer their varieties and reject modern varieties because of the probability of low yields and crop failures in unfavorable environments. Besides it is also realized that the use of inputs such as fertilizers, pesticides, and chemicals for weed control is uneconomical and risky for resource-poor farmers.

As a process of decentralizing the formal and conventional breeding system, PPB approaches were developed with the involvement of farmers. PPB is more likely to produce farmer-acceptable products or varieties, particularly for marginal environments, as in our context. It also has a greater effect on increasing biodiversity, though its impact may be limited to smaller areas as acknowledged by authors like Witcombe et al. (1966).

The approach

There are many improvement programs that involve farmer participation, with different degrees of participation for breeding, identifying improved cultivars, or upgrading landraces. One participatory approach is being varietal selection, which broadly aims at purifying the seed material—a precursor to the plant-breeding program.

In the initiatives of our program, the concept of PPB has been employed in three broad areas: (1) crop improvement, (2) conservation of biodiversity, and (3) empowerment of farmers. Here, crop improvement involves informal varietal breeding under variable environments using traditional varieties. As described by Witcombe et al. (1996), the first phase of PPB starts with the identification of farmer-preferred traits in a particular variety.

Identification of farmer-preferred traits and cultivars

Alternative approaches for identifying cultivars that are acceptable to resource-poor farmers have been suggested and tried by a number of researchers. Maurya, Bottrall, and Farrington (1998) tested advanced lines of rice cultivars in villages in Uttar Pradesh, India, and successfully identified superior material that was preferred by farmers. The first step in a successful participatory varietal-selection program involves identifying farmers' needs in a variety of crops. The farmers' requirements can be identified using several methods (Joshi and Witcombe 1996), such as participatory rural appraisals, examination of farmers' crops around harvest time by providing a pool of genetic materials in a demonstration plot, and comparative evaluation on the farm.

A similar set of methodologies was adopted to identify farmers' needs over a variety. With an on-farm conservation program around, farmers had a number of choices to select some varieties