Table 5d. Summary Ranking of Rice Genotypes in Mungeshpur, Faizabad District, 1999

Field 2		Males (5)		Females (5)		Breeders (4)	
No	Lines	Ave scores	Rank	Ave scores	Rank	Ave scores	Rank
PVS1	NDR-40032	4.2	3	3.4	3	2.3	1
PVS2	Kamini	11.4	12	14.4	14	14.7	11
PVS3	NDR-973004	8.0	7	6.2	4	4.7	2
PVS4	NDR-973003	8.6	9	8.0	8	8.0	6
PVS5	RAU-1308-9-3-1-10-3-4-3	14	12.0	12	14.3	10	10
PVS6	PSRM-1-16-48-1	12.8	13	11.8	11	12.3	8
PVS7	NDR-9830102	3.6	2	2.4	2	7.0	5
PVS8	NDR-9730002	8.0	7	10.0	9	8.7	7
PVS9	NDR-9730015	5.6	5	6.4	5	5.0	2
PVS10	NDR-9730020	5.2	4	7.0	6	6.0	4
PVS11	Mashuri	10.6	10	13.6	13	7.0	4
PVS12	RAU-1308-10-11-3-1-4-3	8	10.2	10	12.7	9	9
PVS13	NDR-96012	10.8	11	7.2	7	9.3	7
PVS14	RAU-1411-10	7.0	6	10.0	9	9.0	7
PVS15	**NDR-9830103**	**1.6**	**1**	**1.4**	**1**	**5.3**	**3**
PVS16	RAU-1400-13-20	15.0	15	10.0	9	9.7	6
			w=.65**		w=.65**		w=.60**

**Significant at 0.5 and .10 per cent level.

Table 6. Summary Ranking of Preferred Lines by Male and Female Farmers and Plant Breeders, 1999

	Male farmers		Female farmers		Plant breeders	
	Field 1	Field 2	Field 1	Field 2	Field 1	Field 2
Basalatpur						
PVS1	3	2	2	3	2	4
PVS3	5	7	5	5	3	3
PVS7	7	3	7	5	5	5
PVS9	2	1	1	1	4	1
PVS10	1	2	3	4	1	3
Mungeshpur						
PVS1	3	3	2	3	1	1
PVS3	6	7	4	4	2	2
PVS7	1	2	1	2	5	5
PVS9	8	5	5	5	4	2
PVS10	4	4	6	6	6	4
PVS15	3	1	3	1	7	6

Table 7. Farmers' Assessment of New Rice Lines during the 1999 *Kharif* Season

Lines (Location)	Name	Positive traits	Negative traits
PVS1		Good yield Medium plant height Good straw (quantity and quality) Has regeneration capacity (faster recovery after submergence) Short, bold, heavy grains Best for puffed rice, has good	
PVS-3	NDR-973004	Medium plant height Submergence-tolerant Good tillering capacity Long panicles Good eating quality Good milling recovery Remains soft after cooking	
PVS-7	9830102	Short duration (110 d) which makes rice available during the lean period Good yield (4 t/ha) Medium plant height Good straw (quantity and quality) Better for early rabi crops Good taste	
PVS9	NDR9730015	Medium plant height Suitable to land type Submergence-tolerant Good tillering capacity Long, bold grain size Good straw Good for puffed rice	More broken grains after milling Becomes hard after cooking
PVS10	NDR9730020	High yield—more grains per panicle than PVS1 (NDR-40032) Suitable to land type Medium plant height Resistant to lodging (hardy stem) Resistant to pests and diseases Longer panicles Grains are long and cylindrical and finer than PVS9 (NDR9730013) Higher milling recovery Good taste Remains soft after cooking Good for special social occasions Easy to harvest and thresh	

Listening to the voices of male and female farmers

Aside from asking men and women to rank traits and varieties through visual assessment, we conducted informal interviews with men and women farmers, separately. This enabled plant breeders to listen not only to men but also to women. Some of their perceptions of the rice varieties and lines tested are below.

Mrs. Yadav is 53 years old, illiterate, and a full-time farmer. Her husband is a full-time worker in the flour and oil mills. This makes her the *de facto* head of household. She supervises the farm and makes decisions regarding what crops and varieties to grow. Three years ago, she grew mostly local varieties because of a lack of irrigation facilities. We gave her seeds of NDR 97, a new variety, which she planted on 0.10 ha of land. Later she increased the area planted to this variety to 0.5 ha. She told us the positive traits she likes in this variety, such as suitability to her land type, good taste, shorter duration, good milling recovery, ease of threshing, and medium height, and negative traits such as less rice straw:

> *I tried many varieties since the last four to five years such as Saket4 and NDR80, but because they were damaged by drought and disease, I stopped growing them. I shifted back to a local variety [ARI] although it does not taste good, has poor milling recovery and coarse grains. But I like NDR97 because of its suitability to my land, good taste, and shorter duration. The only problem is that it produces less biomass [straw], which is not enough for my two bullocks and five buffaloes. We need more straw for the animals throughout the year. We also grow* curbi *[green fodder] and harvest them green during the* kharif *season. Due to the early duration of NDR97, we can cultivate our land for early* rabi *crops such as oilseed and vegetables before wheat. I also like the taste of NDR97 and I am satisfied with its milling recovery. It is also easy to thresh; it is neither very tall nor short.*

Mrs. Savitri Devi is 45 years old, illiterate, and a full-time farmer of the backward caste. She cultivates 1.1 ha of land in Mungeshpur. She has two types of land, upland and lowland. She grew NDR359, Sarju52, and *Jallahri* in 1998. We gave the new seeds of NDR359 to her in 1996. She prefers this variety because it has a good taste and short duration. She describes their use of NDR359:

> *I don't like the taste of Sarju52. It is coarse and does not remain soft after cooking. It also does not have many broken grains after milling. So we sold Sarju52 and used NDR359 for home consumption. One thing I noticed with the straw of NDR359 is that it is soft, so instead of storing it for a long time, we had to feed it immediately to our animals. If we keep the straw for two to three months, it will not be very easy to cut and the animals will refuse to eat it. Instead of leaving the rice stalks to dry in the field, which is our usual practice, we immediately thresh after harvesting. Its short duration also enables me to grow another crop during the* rabi *season.*

Mrs. T. B Singh, 50 years old, belongs to the upper caste. Due to labor shortages during the peak season and the lack of male labor (her husband is fully engaged in a nonfarm job), she has been forced to provide physical labor in most of the rice operations. She was able to finish five years in school. She is the decision maker in the household and is quite knowledgeable about farming. In 1997, she was one of the collaborators of the project. After testing 13 genotypes on her field, she obtained 5.2 tons per ha from PVS5 (NDRSB9730015), so she decided to continue to grow this variety and expand the area during the 1998 *kharif* season. She expected to get six tons per ha, but because of drought, there were many unfilled grains. She told us about the variety's positive traits aside from its high yield:

> *I prefer PVS5 because of its medium duration; medium bold, cylindrical grain; resistance to pests and diseases; and better milling recovery.*

In 1995, we gave her new seeds of BKP246.

I like this variety too because it is suitable for the lowland rainfed area, has good yields, and is not susceptible to diseases. I like the size and the shape of the grain—medium and bold. It also has the best milling recovery and commands a high price in the market. In 1998, I sold four quintals of paddy at Rs 400 per quintal, while the other varieties are Rs 50 less than BFK246. We use Sarju52 and Saket4 for home consumption. Saket4 has fine grains and matures early, a trait ideal for the uplands. Our agricultural workers prefer coarse grains, which last longer in the stomach than paddy with finer grains. I observed that the quantity of straw of BFP346 is less, but grain quality is more important to us.

Mr. Bansat Lal , 42 years old, an illiterate father from the backward caste, is a full-time farmer. His sons are fully engaged in nonfarm activities and his daughter-in-law supervises farm activities and takes part in decision making. In 1997, he was a collaborator in the plant varietal-selection program and obtained good yields. After threshing and milling, the female members of his household also agreed that the PVS5 (NDRSB9730015) and PVS6 (NDRSB9730020) should be grown the following year. Both Mr. Lal and his daughter-in-law have the same criteria for selection, such as better yield, good quality of straw, medium height, resistance to pests and diseases, longer and fine grains, no broken grains after milling, softness and expansion after cooking.

My daughter-in-law observed that PVS5 is easy to hull through hand pounding after parboiling. It is also good for puffed rice.

Mr. Lal shared the seeds of PVS5 with other farmers. In 1998, he cultivated PVS5 and PVS6 on his 3 *bigha* (0.3 ha) land area. He was able to obtain a yield of six quintals per *bigha* in one plot and four quintals in another plot. These yields were higher than those in nearby fields.

Conclusions

Socioeconomic surveys revealed that a major determinant of varietal choice is the conscious attempt of farmers to match varieties with the land type. Each field position in the topo-sequence corresponds to a risk of drought or submergence. In Mungeshpur (shallow and submergence-prone) farmers' criteria for selecting rice varieties are associated mainly with duration (short to medium), for growing *rabi* crops after rice in the upland fields, and with better yield. A second determining factor is the adaptation to different user needs: food, livestock fodder, thatching, and cash. A third determining factor is related to different postharvest operations like ease of threshing, good taste, high milling recovery (above 65%), good storage capacity, and premium market price. Gender-specific roles and responsibilities also determine varietal preferences. For example, women prefer medium or semi-tall varieties that are easier to thresh, as well as varieties that have a good quantity and quality of rice straw for livestock feed. Moreover, they prefer varieties for the specific rice products that they make. While it may be difficult to combine all their preferred traits into one unique variety because of genetic correlations, it is important that both men and women have a "basket of choices" of varieties suited to their needs and agroecosystems. Clearly, listening to farmers' perceptions and involving both men and women farmers in selecting rice varieties at the early stage of breeding can lead to faster adoption of varieties suited to their specific rice ecosystems and diverse needs.

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Opportunities and Constraints for Participatory Plant Breeding: Farmers' Seed-Management Strategies and Their Effect on Pearl Millet Populations in Rajasthan, India

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Abstract

This paper presents information from a study on farmers' seed-management practices growing pearl millet in Rajasthan, India. It describes farmers' own crop-improvement activities in regard to yield, quality, and diversity of pearl millet, with emphasis on seed-management strategies, such as introgression of modern varieties, selection, storage, processing, exchange, and procurement. It also examines the farmers' definition of "variety" as compared to the definition used by professional plant breeders. For the study, farmers were divided into four groups, based on their seed-management practices. Data were collected on specific traits and correlated with grain yield under different climatic conditions. The potential and constraints of farmers' practices are discussed, with emphasis on areas where researchers could concentrate on specific weaknesses that farmers' own selection practices cannot effectively address.

Introduction

In many regions of the world farmers routinely produce seeds for their staple crops. This is particularly common in regions where agricultural production is affected by frequent and unpredictable droughts, as in most areas where pearl millet (*Pennisetum glaucum* [L.] R.Br.), a cross-pollinating crop, is grown. Under these harsh climatic conditions, farmers have developed landraces that tend to show good levels of tolerance to these environments. The farmers have also evolved strategies for maintaining seed during drought years in order to safeguard food production and animal fodder. Given the fact that formal plant-breeding programs have failed to develop superior varieties for marginal lands and low-input conditions, the main objective of the study presented here is to better understand farmers' own seed-management practices as a basis for planning and implementing participatory strategies that capitalize on farmers' local knowledge. This approach would allow researchers to then concentrate on specific weaknesses that farmers' own selection practices cannot effectively address.

To date, these local strategies, including the farmers' needs and preferences, along with details of their cropping systems, are not familiar to scientists involved in conventional breeding programs.

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The work presented here is part of the project "Enhancing quality, diversity and productivity of farmers' pearl millet genetic resources in Rajasthan, India," which is a collaborative activity of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad, India; its national partner institutions in Rajasthan, including the Central Arid Zone Research Institute (CAZRI), Rajasthan Agriculture University (RAU Mandor), and the National Bureau for Plant Genetic Resources (NBPGR), and the University of Hohenheim in Germany. We thank all scientists and staff members involved for their personal support to this study, particularly Dr. Thomas Presterl and Prof. Dr. H.H. Geiger (University of Hohenheim, Institute of Plant breeding, Seed Science and Population Genetics), Prof. Dr. V. Hoffmann (Agricultural Social Sciences, Department of Communication and Extension), Dr. P. Bramel-Cox (ICRISAT), and Dr. O.P. Yadav (CAZRI). The enthusiastic and most competent participation of farmers from the villages of Aagolai, Udaipur Khurd, Kichiyasar, and Nunwa in the workshops is equally acknowledged. We further thank the German Ministry for Economic Cooperation and Development (BMZ) for funding through the German Society for Technical Co-operation (GTZ).

The objectives of this project are listed below:

1. To describe farmers' own crop-improvement activities in regard to yield, quality, and diversity of pearl millet, with special emphasis on seed-management strategies, such as introgression of modern varieties, selection, storage, processing, exchange, and procurement
2. To quantify the effects of farmer activities on the genetic structure and performance of pearl millet populations

Short description of the study area

Rajasthan is situated in the northwest of India (figure 1). It is a semi-arid region with a mean annual rainfall that ranges from < 250 mm in the western part (*Thar Desert*) to > 650 mm in the southeast (figure 2). In this study, we refer only to the western part of the state, where farmers must make do with less than 350 mm of annual rainfall, with high variability from year to year. Experienced farmers often talk of a 10-year cycle in which two seasons have good rains, two have severe drought with crop failures, and the rest usually have fair to good seasons. Soils are mainly sandy, and sand dunes are common. Villages are typically scattered across wide areas. Pearl millet is grown three to four months during the monsoon season, mostly in mixtures with other crops, such as legumes and cucurbits. Animal husbandry is another important part of the farming system. Social conditions in the villages are governed by the caste system. Even today, the caste system still largely determines people's social status, occupation, income, and access to education and information.

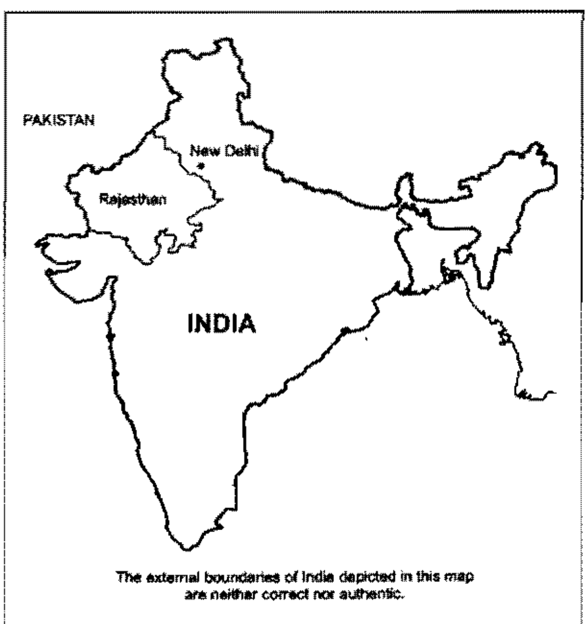

Figure 1. The state of Rajasthan in the northwest of India

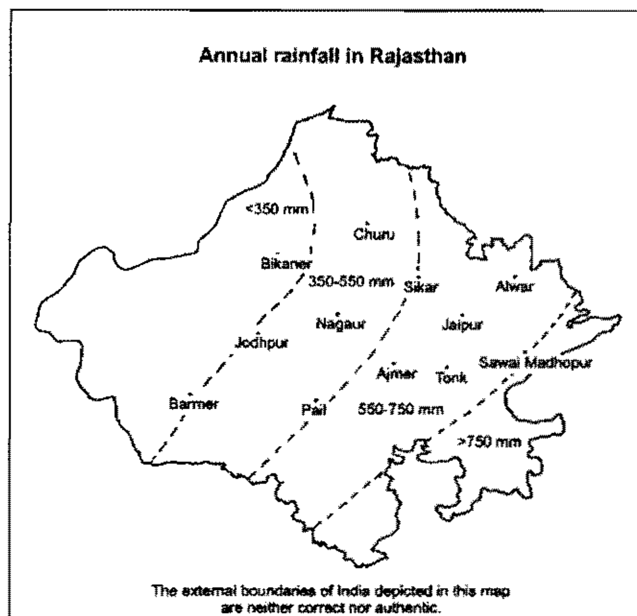

Figure 2. District capitals and zones of mean annual rainfall in the study area

Farmers' seed-management strategies

Farmer's concept of a "variety"

Farmers' seed management can only be evaluated if one fully understands the farmers' concept of a "variety." This term, as understood by plant breeders, does not seem to be fully appropriate for the farmers' pearl millet seed system in west Rajasthan. In order to learn how farmers perceive "varieties," informal interviews as well as classification and ranking exercises were carried out during workshops with farmers from the study villages. Care was taken to include both female and male farmers in the interviewing process. The results demonstrate that environmental adaptation was the main criterion for farmers' classification of pearl millet plants in western Rajasthan. Potential uses and quality aspects further contributed to the farmers' method of grouping different plant types (Christinck and vom Brocke 1998).

Traditional landraces that have adapted to the environment show a high basal and nodal tillering ability, indicating tolerance to drought and low requirements for soil fertility. If these characteristics are combined with thin stems, narrow leaves, and thin, compact panicles with small grains, farmers will conclude that such a plant will grow under low-input conditions (i.e., in their fields) and produce grain and straw of high nutritional quality. In contrast, the characteristics of modern varieties are low basal and nodal tillering ability, thick stems with broad leaves, and large panicles with relatively large grains that are mostly round in shape. From the farmers' experience, this plant type is not tolerant to drought stress, requires higher soil fertility, and has inferior food and fodder qualities. Farmers, however, are aware that pearl millet plants showing such characteristics can produce higher yields under favorable conditions (Christinck and vom Brocke 1998). Farmers are therefore concerned about the composition of their seed stocks, i.e., which plant types and, thus, which properties are present. Farmers expect plant types to change over time, in reaction to environmental conditions such as soil quality and rainfall, so that the seed stock generated in one year cannot be exactly reproduced the next season. They have a strong concept of continuous interactions between plant type and environment, as evidenced by their belief, or experience, that any pearl millet cultivar, including modern varieties, that is grown in their field for some years will eventually become like their local cultivars.

Contrary to the views of professional plant breeders, the farmers' concept of a "variety" is not that of a population with more or less uniform and stable plant characteristics based on its genetic background; the term "variety" is applied to a plant type that is evolving under or adapting to certain environmental conditions. This concept is reflected in the farmers' seed-management strategies.

What is seed management?

Seed management comprises all activities of a farming family that influence their seed stock, including introgression of modern cultivars (open-pollinated varieties or hybrids), seed selection, processing, storage, exchange, and procurement. In this paper, we refer mainly to seed selection and processing, and the ways in which farmers deal with modern varieties from the market.

Ways of selecting or processing seed

Farmers in Rajasthan generally employ two main selection methods. The first is winnowing or grading, which entails cleaning and separating seed grains. The rate of selection can vary greatly. It may be that only 10% of the threshed and stored grain will be rejected (mainly husks and broken

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.

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

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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.

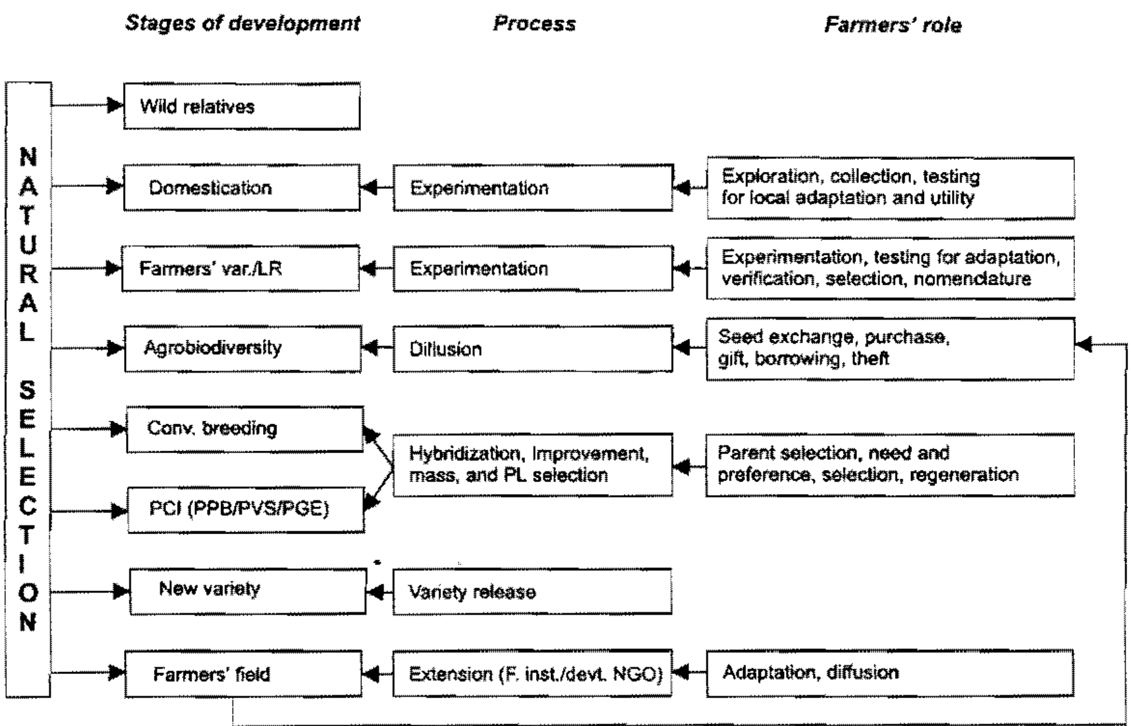

Figure 1. Farmers' roles in the crop-improvement process

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