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Farmers' seed management strategies and their effect on pearl millet populations – examples from Rajasthan, India

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Abstract

Farmers' seed management strategies in pearl millet - such as introgression of modern varieties, plant type selection and seed grading – were evaluated in Rajasthan/India by combining social science and population genetic research. The diversity of socio-economic conditions in the semi-arid environment leads to various seed management strategies, which co-exist in the one village. Consequently, the farmers' seed stocks show differences in adaptation patterns and productivity. Better land and continuos selection are required to benefit from the high yield potential of the introgressed modern cultivars, thus only a limited number of farmers have advantages from the newly introduced variability.

Figure 1: The state of Rajasthan in the north- west of India

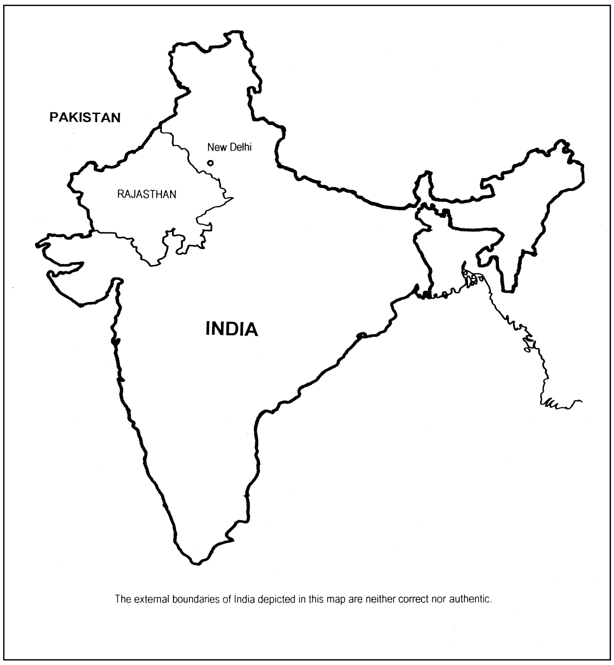
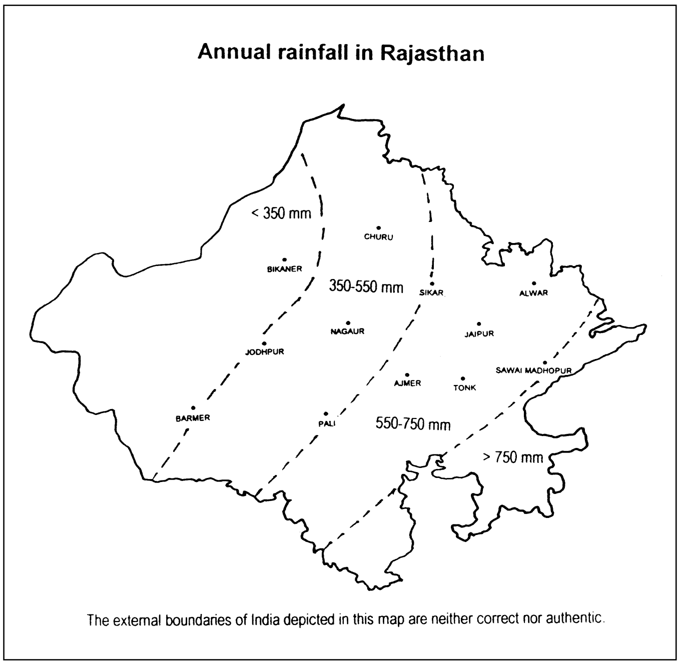


Figure 2: District capitals and zones of mean annual rainfall in the study area



Keywords: pearl millet, seed management, traditional knowledge, GxE interactions, adaptation

Introduction to the project

"Enhancing quality, diversity and productivity of farmers' pearl millet genetic resources in Rajasthan, India" is a collaborative project between the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT, Hyderabad, India), its national partner institutions in Rajasthan and the University of Hohenheim in Germany. Local Indian NGOs were also involved in the project in an informal capacity. This GTZ coordinated project is being funded by the German Ministry for Economic Cooperation and Development (BMZ).

A special feature of the project is that an agricultural social scientist (A. Christinck) and a population geneticist (K. vom Brocke) are working closely together. The two project scientists are supported by Prof. Dr. V. Hoffmann (Agricultural Social Sciences, Department of Communication and Extension), Prof. Dr. H.H. Geiger and Dr. T. Presterl (University of Hohenheim, Institute of Plant breeding, Seed Science and Population Genetics). ICRISAT scientists involved are Dr. E. Weltzien (plant breeder) and Dr. P. Bramel-Cox (germplasm specialist).

The background for initiating the project in Rajasthan lies in the fact that the adoption of modern pearl millet varieties has been very limited in many parts of this semi-arid state. Previous studies reveal that farmers have their own sophisticated strategies of seed management and crop improvement (Dhamotharan et al., 1997). These strategies, along with farmers' needs and preferences, and details about the cropping systems, were not well known to scientists involved in conventional breeding programs.

Therefore, the main aims of the project are: to help breeders develop locally acceptable, improved cultivars through structured intervention, such as participatory plant breeding; to improve the dissemination of such germplasm; and to explore possibilities for *in-situ conservation* of traditional cultivars with the active involvement of farmers.

Direct objectives are:

- To describe farmers' own crop-improvement activities with 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.
- To quantify the effects which these farmer activities have on the genetic structure and performance of pearl millet populations.

The methods used by the social scientist were interviews, workshops, participatory rural appraisal (PRA), observation, and action research. The methods used by the population geneticist comprised field and laboratory trials as well as molecular marker studies.

Short description of the study area

Rajasthan is situated in the North-West of India (Map 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
south-east of the state (Map 2). In this report we are referring to the western part of the state only, where farmers must deal with less than 400 mm of annual rainfall that has a high variability from year to year. Experienced farmers say that out of ten years, two seasons will be good, two will be severe drought years with crop failures, while the rest of the years will be more or less good or bad seasons. Soils are mainly sandy, sometimes sand dunes, and villages are typically scattered across wide areas. Pearl millet (*Pennisetum glaucum* [L.]R.Br.) is the staple food and fodder crop, grown during 3 to 4 months in 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 qualified by the caste system. Even nowadays the caste system to a large extent determines people's social status, occupation, income, and access to education and information.

Description of farmers' seed management strategies in western Rajasthan

Varieties used
Traditional pearl millet landraces are still in wide use in the western part of Rajasthan. Improved varieties are usually only used in pure stand when irrigation is possible. The reasons given by farmers are the higher risks of crop failure, higher production costs and inferior food and fodder quality. Nevertheless, farmers are aware of the higher yield potential of modern varieties under favourable conditions. They try to benefit from the higher yield potential by mixing modern seed material into their own populations, while at the same time eliminating the negative effects of this introgression with further seed management strategies. Pearl millet being a cross-pollinating crop, the mixing strategy leads to a diversification of the genetic base.

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 article we mainly refer to seed selection and processing, and the ways in which farmers deal with modern varieties from the market.

Ways of selecting or processing seed

There are two general selection methods. The first is winnowing or grading, which entails cleaning and separation of seed grain. The selection rate can vary greatly. It can be that only 10 % of the threshed and stored grain will be rejected (mainly husk, broken and insect infested grains), or more than 50% if the grains are generally small and not fully developed. Generally though, the separated smaller grains will be used as food grain. The second method is the selection of panicles, which is very common. The method involves selecting panicles which show preferred traits. Some farmers select panicles in the field before harvesting and take the entire plant into consideration (number of tillers, height etc.). It is more common, however, to select the panicles on the threshing ground after they have been separated from the straw. By inspecting the panicles, farmers associate other plant-type characters as well. Another, though 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. Many farmers do not perform panicle selection every year, but only in the better seasons, which usually occur every 2 to 4 years. In harsher years they would most likely use the winnowing/grading method.

Using "improved varieties" or hybrids from the market
In the western part of Rajasthan, those farmers without access to irrigation facilities generally do not grow improved varieties or hybrids in pure stand. There are, however, some exceptions: some farmers have fields in special water catchment areas which have a higher soil moisture availability; other farmers sow hybrid seed if they expect extraordinarily good rainfall for a cropping season even though it carries risks; and farmers buy seed from the market if they cannot obtain local seed i.e. after several years of drought when farmers lose the seed grain of their local cultivar.
When a farming family is actually using pearl millet seed from the market, in most cases it will be mixed into the farmer's own seed stock. Two general ways of this practice should be presented:

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

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 this seed for increasing the variability of plant types in their fields, thereby creating new options for their selection strategies for preferred plant characters such as: food and fodder quality, storability, drought tolerance, early maturity, tolerance to adverse weather conditions (heat, sandstorms, thunderstorms), and insusceptibility 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 caste and status aspects of 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 nearly exclusively by men.

Diverse seed management strategies co-exist in villages in western Rajasthan, reflecting the diversity of socio-economic conditions: farmers who grow traditional landrace seed 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 the 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, climatic factors etc. Further 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 about new varieties (literacy, mobility) as well as many other factors. Most of the aforementioned socio-economic conditions are related to the caste system in Rajasthani villages.

Quantification of the effects of farmers' seed management strategies

Material and Methods

On-station field trials were conducted at five locations under varying drought stress conditions in western Rajasthan during 1997 and 1998, using 81 entries, with the aim of quantifying the effects of farmers' seed management. Sixty-nine of these entries were collected between 1995 and 1997 from 16 farmers located in four different villages in western and central Rajasthan. Samples were characterised by the farmer i.e. as separated seed grain and food grain. Samples were classified into four main seed management strategies.

Table 1: Seed management strategies as represented in field trials

Strategy 1:	Maintains only local landrace seed without introgression of modern material; selection method mainly winnowing
Strategy 2:	Occasionally introgresses modern varieties into landrace; seed selection method mainly winnowing
Strategy 3:	Introgresses modern material more regularly than strategy 2; selects regularly to frequently for plant types
Strategy 4:	Maintains modern varieties obtained from market on own farm

In the following we concentrate on strategy1-3 – strategies typical for western Rajasthan. A genotype×environment (GE) analysis 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. The pattern analysis (Williams 1976) was used to (1) classify the environment and (2) to assess the relationships among different genotypes and among different environments, and to assess the interaction between genotypes and environments (Fig. 3). In order to gain a more detailed impression of the effects of farmers' management strategies, an individual analysis of three farmers' seed stocks (seed and food grain) was conducted (Fig. 4).

Figure 3: Biplot for principal component 1 and 2 from the ordination of environment and standardized grain yield

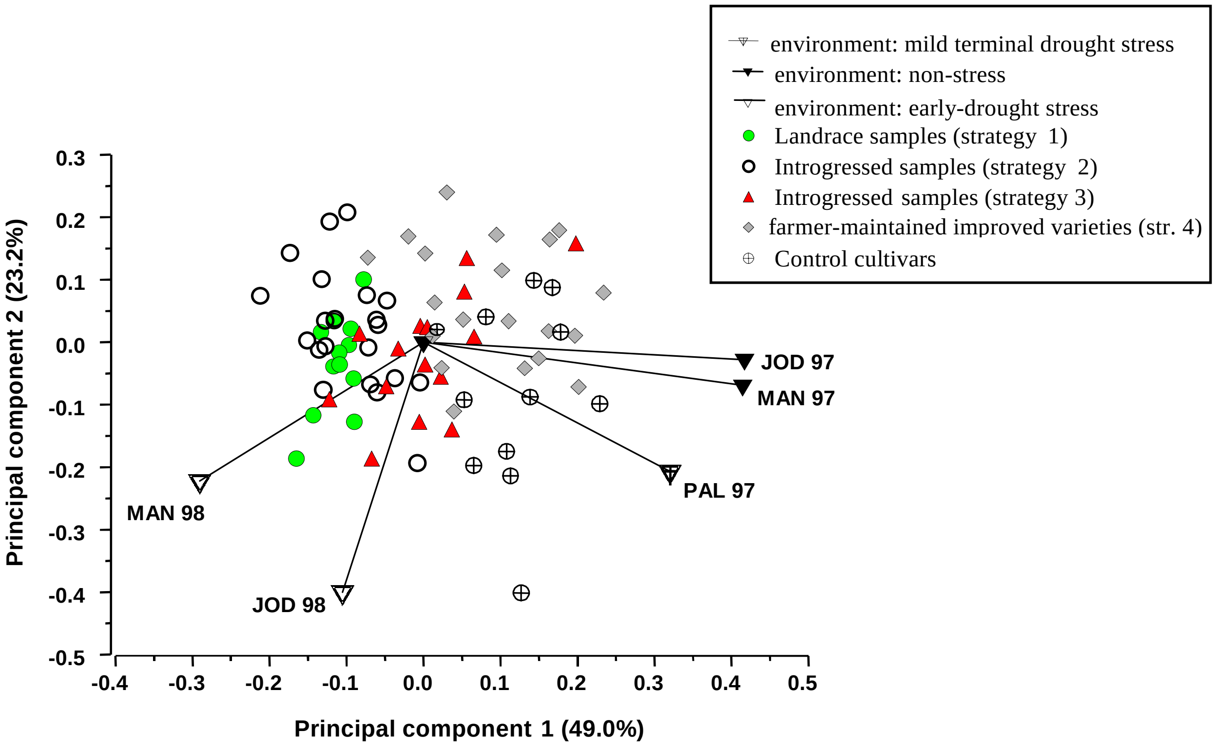
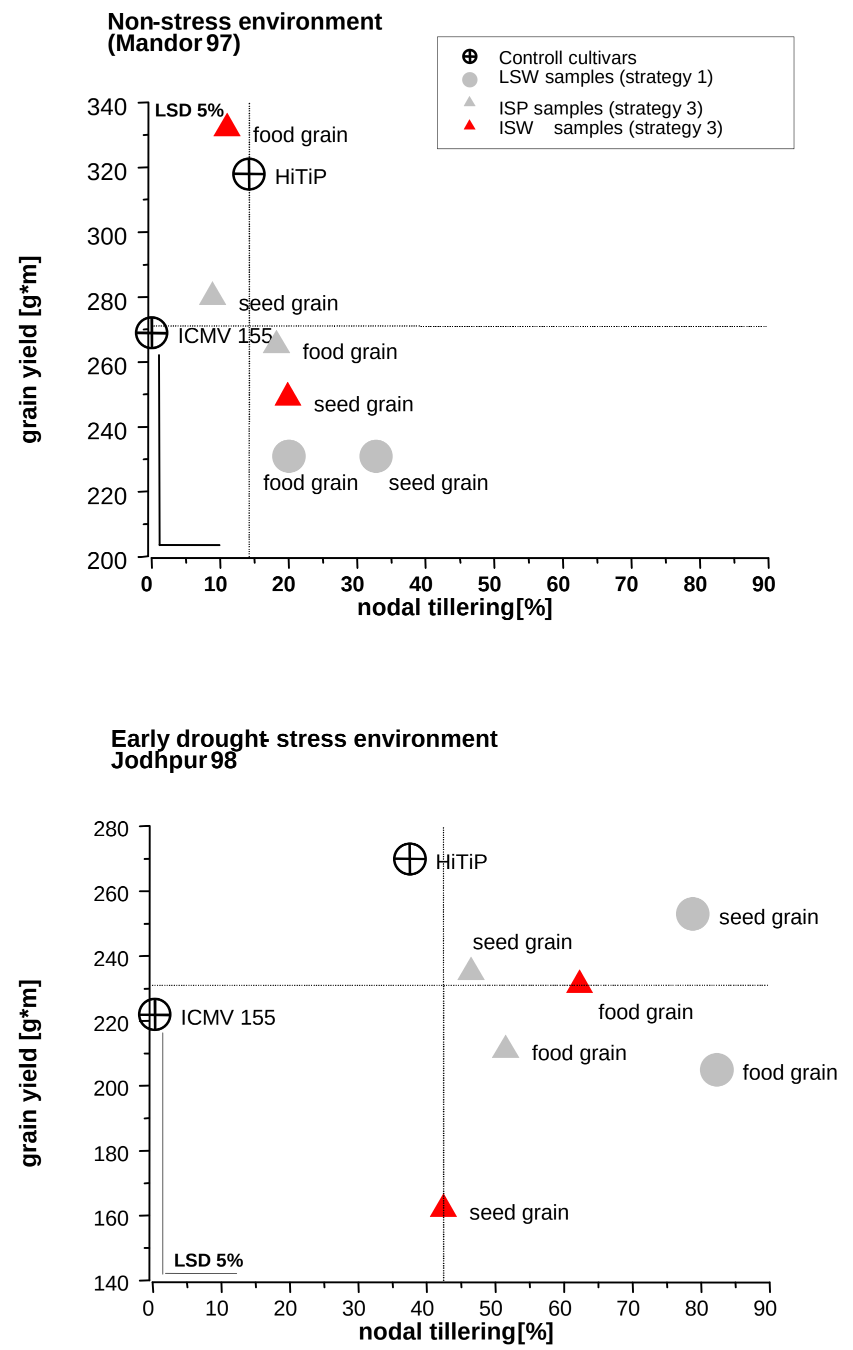


Figure 4: Individual analysis of three farmers' seed stocks and two improved cultivars under non-stress conditions (A.) and early drought conditions (B.)



Results

The stress environments and the favourable environments are clearly divided by the first principal component, which explains 49.0% of the GE variation. Even though the proximity of the test locations were relatively close (15 to 70 km), the environment vectors in the biplot (Fig. 3) covered a wide range of Euclidean space, which indicates the strong influence of the climatic conditions found at the experimental sites in 1997 and 1998. In Figure 3 the relative favourable environments Mandor 1997 (MAN97) and Jodhpur 1997(JOD97) tend to discriminate genotypes in a similar fashion while others(MAN97 and MAN98, JOD97 and JOD98) show an almost opposite association. Genotypes that are close to the origin of the environmental vectors tend to have average performance across all environments, while genotypes and environments close to each other may be similar. Genotypes plotted in the increasing direction of an environment vector are positively associated with this environment. Furthermore, genotypes plotted in the opposite direction may not be adapted to this environment.

Samples collected from farmers who are practising strategy 1 indicate a close association with the extreme stress environment, for they cluster close to the environment vector MAN98. Seed stock samples of strategy 2 are also associated with the environment MAN98, but display wider dispersion. This dispersion indicates two trends: on the one hand, a tendency towards a wider adaptation, and, on the other hand, that samples are losing their specific adaptation without associating positively with any other test environment. The change in the adaptation pattern seems to be obvious in material derived from strategy 3, as the association of the samples with the stress environments MAN98 and JOD98 is mostly eliminated. Some of these samples grouped in strategy 3 are clustering close to the origin of the biplot and tend to have an average performance across all environments, while others are clearly associating with the favourable environments (JOD/MAN97). Farmer-maintained improved varieties and improved cultivars indicate nearly no positive association with the stress environments (Fig. 3).

For a more detailed impression of the effects of farmers' management strategies, an individual analysis of three farmers' seed stocks (seed and food grain) is shown in Figure 4. The seed samples from strategy 1 represent the food and seed grain stock of a farmer growing only landrace and without conscious introgression. His selection method for separating food and seed grain is winnowing; in the following refered to as LSW samples. The two other samples were collected from farmers who practice strategy 3, but in combination with different selection methods. Those labeled as ISP sample were obtained from a farmer who practised regular plant type selection, whereas those labeled ISW were obtained from a farmer who used the winnowing method to separate his food and seed grain. Also included were the results of two released open-pollinated varieties, HiTiP and ICMV 155.

The graphs in Figure 4 display the relationship of grain yield performance with nodal tillering ability. Nodal tillering is a plant's ability to produce productive nodal branches. It is one of the landrace's key traits for adapting to harsh and erratic weather conditions. Nodal tillering is also positively correlated with various plant traits preferred by farmers, such as food and fodder quality.

Performance under non-stress conditions:

The first graph of figure 4 shows that grain yield was negatively correlated with nodal tillering. Out of the presented samples and improved cultivars, those labeled ISW tended to be the most productive in respect to grain yield. The selection method of winnowing was successful, as grain yield from the separated seed grain was markedly higher. The ISP samples had average yield performance. The selection method (plant selection in field) was also successful, as the seed grain sample tended to be more productive than the food grain sample. The LSW samples indicate the lowest yield performance in this environment and no selection effect was observed concerning the grain yield. The food grain samples derived from the three various strategies showed only minor differences in yield. If farmers introgressed modern material into their seed stock the seed grain samples had less nodal tillering than the food grain samples. The opposite trend can be observed in the LSWsamples, which shows 15% more nodal tillering in the selected seed grain. Food grain samples from the three various strategies showed almost no differences in nodal tillering. Regarding the improved cultivars, the HiTi Population had average nodal tillering, while the variety ICMV 155 had no nodal tillering ability at all.

Performance under early drought stress conditions:
Under early drought stress conditions the two selected traits were slightly positively correlated. The highest grain yield could be observed in the seed sample of the landraces. In contradiction to the aforementioned case, selection had an effect on grain yield under drought stress. No significant decline in yield in the LSW seed sample and the ISP seed sample was observable in this environment compared to the non-stress environment, whereas a sharp decrease in grain yield (50%) was observed in the ISW seed sample. The improved population HiTiP seems also to be adapted to the stress environment, whereas ICMV 155 had slightly lower yields than the LSW and ISP samples.

Regarding the three management strategy-groups of western Rajasthan, Figure 3 indicates a change in the adaptation pattern of the typical landrace material through the increasing intensity of introgression. Taking only grain yield into consideration, two trends could be observed during the relatively short time of this project: Introgressed samples, derived mainly from strategy 2, seemed to lose their tight, positive association with the stress environment without showing any positive association with another test environment; and those samples mainly collected from farmers using strategy 3 showed a trend towards wider adaptation.

Although the landraces (strategy 1) are not as productive under optimal conditions, they are more resilient and constant under stress conditions. They have been growing in heterogeneous environments for centuries and therefore have the ability to adjust to the erratic climatic conditions found in this area. The seed sample of the farmer who is practising introgression combined with regular plant type selection among the outcrosses appears to demonstrate that it is possible to use newly introgressed variability for the improvement of a landrace population. On the other hand, drought stress had a severe effect on the yield of the samples derived from introgression combined with the selection method of winnowing. Because the winnowing method separates the bigger from the smaller grains, most of the landrace material (small shaped grains) can be winnowed out as food grain. The danger of losing a crop therefore seems higher if farmers mix market varieties into their seed stocks while following this particular traditional practice. As expected, the food grain – which may contain the separated adapted landrace seed – had a markedly higher yield performance. The control over population properties and performance thus seems greater if a farmer uses plant type selection to separate seed from food grain.

Conclusions

Role of plant breeders

The presented results point to two possibilities of how breeders could improve farmers' seed stocks in western Rajasthan:

1. The plant breeder could take on an advisory role to support farmers in their crop improvement strategies. The plant breeder could suggest material that has the ability to combine with the local material and which also has a potential for achieving genetic gains in farmers' preferred traits. Hybrid cultivars would, however, be a disadvantage if the farmer prefered to produce his own seed.
2. Developing improved cultivars together with farmers: Farmer participation in breeding programs could prove to be a more efficient way of allocating resources, targeting potential needs and developing locally acceptable improved cultivars. Adequate test sites and trial management would need to be chosen in order to ensure that varieties have yield advantages over the local material – also under stress conditions.

Who benefits from new variability through seed introgression?

The farmers who would 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 landrace pearl millet are ideal for them. If better-off farmers use introgressed seed, which requires better land and continuos selection to assure yield stability, the availability of landrace seed may decrease for poor farmers with marginal lands.

In-situ conservation of landraces or other farmer cultivars

So far our results indicate that even in villages where some farmers are using the mixing strategy, other farmers who only grow populations described as typical landrace cultivars are able to maintain these populations under certain conditions. Factors such as situation of the fields, size of landholdings and intensity of natural as well as human selection, may aid success. If traditional ways of seed distribution in villages are disturbed – if, for example, farmers who traditionally distributed seed have started growing different material than what poorer farmers need – it could be an option to support those farmers who depend on the traditional landrace seed to maintain their own seed. Successful *in-situ* conservation programs thus require detailed knowledge of the socio-economic structures, including changes regarding traditional roles and relationships between villagers.

References

Dhamotharan, M., Weltzien, E., Whitaker, M.L., Rattunde, H.F.W., Anders, M.M., Tiagi, L.C., Manga, V.K., 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, ICRISAT, Patancheru 502324, Andhra Pradesh, India.

Williams, W.T ., (1976). Pattern analysis in agricultural science. Elsevier Scientific Publisher Company, Amsterdam.