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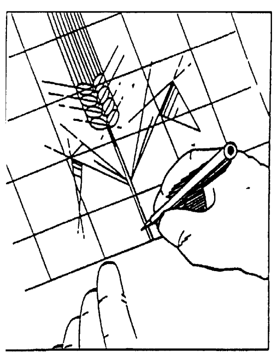

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Farmer Participation in Pearl Millet Breeding for Marginal Environments[3]

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Introduction

One of the goals of the Consultative Group on International Agricultural Research (CGIAR) is to develop strategies and research methods to cope with increasing demand for food production in light of degrading environments. This commitment to integrate growth and poverty alleviation with environmental protection was reinforced by Agenda 21 (CGIAR, 1993). A large proportion of the world's poor live in the harsh environments of the arid and semi-arid tropics. It is one of ICRISAT's goals to develop innovative techniques to improve the impact of its research on the nutritional and economic well being of low-income people in these environments. Developing methods to bring farmers and scientists closer together has been one of the approaches used to achieve research results with more relevance to specific farming communities. Understanding farmer's priorities helps to target research efforts. Giving farmers oppurtunities to choose, improvise and adapt from a range of choices will create more useful technologies (Farrington and Martin. 1988).

New varieties, breeding population and improved genetic materials are among the major outputs of ICRISAT's research efforts. Farmer's involvement in this process has traditionally been limited to that of a donor of germplasm and of a recipient of a final product. Opportunities for farmer participation in the various stages of this process will be explored in this paper, based on research with pearl millet (Pennisetum glaucum) in the state of Rajasthan in northwestern India. This paper describes the interaction between scientists and farmers during individual stages of the breeding cycle of a cross pollinated crop and summarizes key results obtained to date.

Pearl millet in Rajasthan

Pearl millet ist the major cereal crop and staple food of Rajasthan. It is grown annually on 4-6 million ha. predominantly in the drier western part of the state. The area under pearl millet varies greatly from year to year, depending on the yearly rainfall and ist distribution. There has been a slight increase in area cultivated with pearl millet over the past thirty years (Jansen, 1989). The average productivity of the crop varies greatly from year to year, and rarely 500 kg/ha. In the western districts of Barmer, Jodhpur and Bikaner average yield levels frequently are below 100 kg/ha.

Adoption of modern varieties (MV) of pearl millet is low in this state, in contrast to other millet growing areas in India where both improved open-pollinated varieties and single-cross hybrids are widely used (Jansen, 1989). Local varieties of pearl millet from the western part of Rajasthan tend to outperform the standard MVs for grain yield under stress conditions (Weltzien and Witcombe, 1989). Pearl millet is normally cropped in mixtures with short season legumes. Livestock are an important component of the farming system. Crop residues of pearl millet and legumes are important sources of livestock fees and farm yard manure is the primary fertility amendment used by farmers.

The cycle of plant breeding activities

Breeding new cultivars of any crop involves a series of activities common to all crops. Schnell (1982) defined these major stages as „generation of variability", „selection" and „testing of experimental cultivars". This classification facilitates the analysis of the technical process of variety

[3] leicht gekürzte Fassung eines Beitrags für den Workshop „Participatory breeding approaches" in Wageningen vom 26.-28. Juni 1995

development, the domain of classical plant breeding research. A successful breeding program however needs two additional stages: the setting of goals or the definition of a target for the breeding program and an efficient system for varietal release and dissemination. These two stages need to be integrated with the technical variety development process, to allow for feedback between these stages and for a dynamic optimization of the whole breeding cycle.

Opportunities and experiences with farmer's participation

Defining goals

Setting goals is usually the first step in developing an effective breeding program. Appropriateness of goals set determines the effectiveness of a breeding program to a large extend. The goals have a large influence on the choice of breeding method, composition of the germplasm base and diversity that is required. Formulating goals is crucial to any breeding program. It is surprising that very little research has been reported on methodologies for the identifying appropriate goals in breeding programs. Reasons for this could be historical. Seed improvement, variety development and plant breeding as an enterprise and a research discipline have evolved out of crop improvement in general (Kuckuck, 1988; Gäde, 1993). Thus the intricate understanding of farmer's production goals, their preferences for certain traits as well as a familiarity with future trends in production conditions formed the basis for genetic crop improvement. With the rapid scientific development in genetics and its application to crop improvement the linkage between genetic, agronomic and farming system improvements has loosened and plant breeders are frequently in a position where appropriate goals are not obviously set. This is particularly the case in marginal environments where farming is frequently subsistence rather than market oriented, and farmer's strategies for coping with large seasonal variations are not well understood (Matlon, 1987).
Pearl millet cultivation in Rajasthan is such a case. We have therefore initiated research with farmer's participation on the following issues relating to the setting of goals for the breeding program:

-identification of farmer's preferences for individual traits of pearl millet
-identification of major production constraints
-identification of major trends and anticipated changes in the production environment for pearl millet in Rajasthan.

Methods

In an initial study we used formal, structured-pretested questionnaires to ellicit farmers' perceptions of the relative importance of grain versus stover yield (Kelley et al., 1995). The results of this survey were mainly limited by the fact that farmers in marginal areas of pearl millet cultivation had not been exposed to the wide range of variability available among newly released pearl millet cultivars and pre-release advanced experimental cultivars. Farmers could thus not consider the whole range of available variability while expressing their preferences and concerns.

On-farm trials

To expose farmers to a wide range of these options we decided to encourage them to grow trials with new cultivars under their normal crop management conditions. We organized the on-farm trials with the support of local non-government and government organizations, working with farmers in the target areas.

The on-farm trials were managed by farmers. Each farmer compared one experimental variety with his/her own variety. Farmers obtained assistance for the organization and layout of these trials from village investigators employed in each village. These investigators werde trained to understand the trial objectives, the methods to monitor them and to administer interview schedules to collect background information on key features of the production system. Details of the process we used for selecting target regions, study villages and participating farmers are described in Weltzien et al. (1995) and Whitaker et al. (1995).
The varieties used for these trials were chosen by the researchers. The new varieties were chosen to meet the following criteria:
-to cover a maximum span of variability for the trait time to maturity
-to cover a maximum span for tillering potential and panicle types
-the varieties should have been widely tested for yield, preferably released or near release
-the varieties should preferably be open-pollinated varieties and not single-cross hybrids, permitting farmers to produce their own seed.
We changed some varieties from year to year in response to farmers' evaluations and interests.

Using these trials as the basis for discussions we used several methods to understand farmers' criteria for differentiating between cultivars and farmers' preferences for individual traits and trait complexes: 1. Individual comparisons of experimental varieties with farmer's own variety. 2. Group interviews to compare a range of cultivars. 3. Farmers' descriptions of an ideal variety.

Characterization of the cropping system and ist main constraints

The expression of individual traits of a crop variety depends not only in the variety's genetic composition but also on the environmental conditions where the variety is grown. Growing conditions have important direct effects on a variety's growth and performance, but more importantly the expression of many productivity related traits depends on interactions between genetic and environmental factors. These interactions are usually unpredictable. An important part of formulating goals for a breeding program is thus the identification of key environmental factors and production constraints This allows the breeder to adapt on-station testing conditions to prevalent target growing conditions.
One complicating element is the time lag between the initial steps of variety development and its possible release and extensive adoption by farmers. This time lag spans normally five to ten years. During this period production conditions, both economic as well as environmental, can change. The description of target growing conditions thus contains an important predictive element. Discussions with farmers about their management practices, production goals, occurring changes, and factors that cause them can be important sources of information for defining target production environments for a breeding program. We focussed our discussions on crop management issues and livestock-crop interactions through individual structured interviews and informal group discussions on specific topics, such as crop rotations, fallowing practices or crop mixtures.

Results

Farmers used a wide variety of traits to distinguish between the experimental varieties and their own cultivars. The traits can be slassified into three groups: growth and productivity, grain and fodder quality, and adaptation to the environmental conditions and needs. Farmers in the three districts mentioned grain and stover yield during varietal comparisons in about half the cases. Grain yield was consistently mentioned more often. These two traits were the most important for varietals comparisons in all three districts.

Percentage of farmers using productivity related traits to distinguish the expereimental variety from their own variety, 1992 and 1994 results combined, across all experimental varieties

Trait	Ajmer 1992	Jodhpur 1992/94	Bikaner 1992/94
No. of farmers surveyes	27	44	49
Grain yield	68	50	65
Stover yield	52	36	53
Earliness	72	48	37
Large panicles	59	34	57
Large grain size	44	40	45
High tillering	20	23	65

The most important difference in farmers' preferences between the higher rainfall district (Ajmer) and the drier western part of Rajasthan was the different attention paid to the tillering. Tillering is of importance to farmers of western Rajasthan as a component of both grain and fodder yield. They associate better adaptation to low water availability and poor fertility conditions with this trait, and consider it as a component of stover feed quality. Nodal tillers frequently do not mature before harvest and thus contribute to the stover feed quality. Higher tillering varieties commonly have thinner stems, which result in higher intake by animals, wihout the need to chop the stover. The local landraces tiller profusely from both basal and aerial nodes. They are extremely thin stemmed with small panicles and very small grain size.

Adaptive traits which farmers in Jodhpur and Bikaner district observed during three years of on-farm variety comparisons (**bold** = mentioned very frequently)

Trait	*Reason*
Plant type **early maturity**	associated with low water requirements
high tillering, nodal tillering, many leaves	associated with high productivity under stress conditions
tall plant height	associated with high fodder yield under stress conditions
large panicle large grain	
Overall adaptation **good and fast germination**	stand establishment is essential
low seedling death low water requirements good growth in early drought, dark leaves, less drying, less leaf firing low soil fertility requirements	
good seed set	flowering, pollination and early grain development are very sensitive to stress
reduced bird damage bristles, glumes	in poor years bird damage causes severe losses, bristles and glumes contribute to nonpreference for birds
uniformity **disease resistance**	

The frequency with which earliness was mentioned differed markedly between all three districts. In Ajmer, the district with the highest seasonal rainfall and the longest rainy season, earliness was mentioned most often. This is unexpected, because earliness would seem to be of most benefit in the drier areas. However, in Ajmer district the differences in earliness between the experimental varieties and farmers' own varieties were most pronounced. In Ajmer district two of the experimental varieties flowered and matured distinctly earlier than the commonly grown cultivars. Farmers in this area had no previous experiences with the degree of earliness, and perceived it as advantageous in both years of on-farm testing. In 1992, the early maturity of these cultivars gave many farmers the oppurtunity to plant a postrainy season crop with the late rains of that year. Contrastingly, 1993 was a dry year and this earliness was the key to a higher grain yield for many farmers in this district. In both Jodhpur and Bikaner districts the local varieties flower early, thus the difference between local and experimental cultivars is smaller. Confounding this is the effect of poor soil fertility and other stresses on flowering behaviour. It appears that the flowering of improved cultivars under stress is delayed more than in the local varieties of western Rajasthan, thus further reducing the potential differences between the two types of breeding material.

Adaptive traits and adaptation were mentioned by farmers from western Rajasthan as criteria for which the varieties differed. Farmers' criteria for assessing adaptation fall into two groups: plant type or plant architecture and specific adaptations to identifiable stress situations. Farmers commonly associate early maturity with low water requirements. Tall plant height is at times associated with high fodder yield under stress conditions. Specific adaptations that farmers regularly observed were speed of germination, early growth and other responses to early season drought, the ability to set seed and fill grains, and attributes that contribute to reduced bird damage, which is particularly important under drought conditions.

Farmers had specific preferences for grain and stover quality characteristics. In western Rajasthan farmers preferred the thin stemmed stover of the local varieties, possibly because choppers are generally not available in this region. There is also a stronger preference for grain quality characteristics of the local varieties. In Ajmer district this preference appeared to have changed perhaps through the wider availability and adoption of modern varieties.

Percentage of farmers preferring their own cultivar for traits contributing to grain and stover quality, as observed during 1992

Trait	Ajmer	Bikaner	Jodhpur
No. of farmers	19	21	19
Grain size	5	0	0
Grain color	26	53	95
Cooking quality	11	5	0
Chapati taste	21	74	57
Chapati keeping quality	21	58	67
Overall grain quality	16	74	71
Stover appearance	13	16	43
Chopped quality	62	63	43
Animal preference	11	42	28
Overall stover quality	21	74	33

Traits of an ideal variety

The most frequently mentioned traits of an ideal variety are large panicle size and tillering, with grain yield and earliness not lagging far behind. The differences between Ajmer district and western Rajasthan are similar to those obtained from discussions on trait preferences. High tillering is clearly of much more importance to farmers in western Rajasthan. Similarly, farmers in Bikaner district include low water requirement in their list of traits for an ideal cultivar. These same farmers placed less emphasis on large panicle size and large grain size then did farmers in Jodhpur and Ajmer districts. In all districts at least 50% of the farmers mentioned earliness in their list of ideal traits. Earliness is relative to the length of the growing season in the three distiricts, and to the crop duration of the prevalent varieties in a district.

Evaluations of the on-farm trials by farmer groups

At the end of the season five groups of farmers in Ajmer district compared the three experimental cultivars, including groups of participant and non-participant men and women farmers. These discussions were held 2-3 weeks prior to harvest. Farmers used differences in earliness as one of the first criteria to differentiate between varieties. Differences in rankings of relative earliness reflected land quality as well as differences in genetic potential. Farmers generally felt that their own cultivars were later than all three experimental cultivars. All groups noted differences in fodder or grain yield among the three cultivars. They expected all three cultivars to yield well relative to their own cultivars in 1992. Relative yield rankings differed across groups, reflecting the quality of the land where the experimental cultivars were grown as well as the genetic potential of each cultivar.
Most groups noted strong differences in yield component structure between cultivars. The ranking of head size, grain size, plant height, and tillering ability was consistent across groups and was congruent with previous on-station comparisons. Perceptions of grain size also seemed related to land quality.
In addition, farmers included quality-related characteristics, like fodder and grain quality or water requirements as criteria to differentiate among the three experimental cultivars. They evaluated these qualities visually. Fodder quality for chopped fodder was related to thick stems, whereas thinner stems were beneficial in direct feeding. Grain quality appeared to be mostly related to large grain size, lighter, yellowish grain color, and sometimes the sweet taste of raw grain. Water requirements, often considered together with fertility requirements, were judged mostly by considering earliness, tillering, and thinness of stems and leaves. Farmer appeared interested in having a cultivar that will give some amount of assured grain yield in a poor year, rather than just fodder. They seemed willing to sacrifice grain yield in a good year.

Generating variability

Choosing breeding material, developing the germplasm base for a breeding program, choosing parents, making crosses, and random mating populations are major and crucial activities of every breeding program. It is generally assumed that breeders have a major comparative advantage over farmers in the choice of germplasm and in carrying out the processes leading to recombination and thus new combinations of traits and gene complexes for quantitive traits. However, a role for farmers in this process could be envisaged for cross-pollinated crops where crossing occurs naturally.
In the villages in western Rajasthan, where none of the experimental varieties satisfied farmers needs per se, the farmers nevertheless used seed harvested from the on-farm trials, for their own efforts in seed selection. This seed was most often planted in a mixture with their own variety, mainly to reduce the risk of crop failure from the new seed source. This resulted in intermating of the two

groups of material, and farmers observed frequently an increase in variability in their seed stocks. We observed intense discussions among farmers about selection in these more variable seed stocks. For the breeders it may be worthwhile to consider using population crosses and random matings made in this way by farmers, under farmers' field conditions, with a large population size and selection for the most preferred trait combinations as base material. Rather than making similar population crosses, often under non-representative off-season conditions, and with severe limitations on the number of plants that can be handled per population cross. Breeders could use farmer-generated population-crosses for targeted improvement of specific traits, which farmers can not easily select for on a single-plant basis (e.g. grain yield, stover yield or disease resistance) possibly without having to spend much effort on yield components and adaptive or quality traits.
The role of the breeder in this process would thus become one of making useful new variability available to enable farmers to generate new population crosses with a good potential for achieving genetic gains for the key traits. For farmer - breeder interactions to be successful at this stage of the breeding cycle, farmers would need to be involved in evaluating a much larger range of material and genetic variability. It would also be beneficial if there was a better understanding of the combining ability of farmers' local cultivars with different sources of germplasm that farmers may want to use. We are presently evaluating farmer-generated seed stocks for their comparative performance and variability.

Farmers' Participation in selection

In any breeding program selection is a key activity which can occur at any of the following stages: in the composition of the base material, in the selection of parents for crossing, in the selection among progenies, in the selection among experimental varieties and in the maintenance of Breeder Seed stocks. Selection among segregating progenies as well as selection during the testing of experimental cultivars requires the balancing between the different traits that vary within the material. Understanding of the mode of inheritance is beneficial for complex traits, such as grain yield or disease resistance. Selection in all these stages of a breeding program is normally carried out under experiment station conditions. Farmer visits to experiment stations are usually limited to the viewing of demonstration plots of a few highly selected advanced varieties. Options for them are thus limited, and feedback from farmers on these displayed options is usually not sought. Possibilities for farmers'participation in selection could be as diverse as the oppurtunities for selection itself.

Methods

We have experimented with farmers' participation in the selection among experimental varieties, with the aim to complement variety evaluation with their opinions, and to confirm previous results on trait preferences by exposing farmers to a wider range of genotypes. Groups of farmers, men, women, participants and non-participants from different villages were invited to the research station at Jodhpur during 1992, 1993 and 1994. They were asked to make selections from this trial which would be beneficial for farmers in their area. After they completed their selections we held discussions on the range of variability they saw and its usefulness as well as on their reasons for making these choices. Farmers were given the opportunity to select one of the entries in the demonstrations for their on-farm trial the following season.
This method could easily be modified to involve farmers in selection among progeny rows or for selection among single plants for mass selection in a population bulk in on-station conditions. Crucial to the success of these efforts is identifying farmers who have a keen interest in seed issues

and selection for their own local area and social group. These visits are time consuming for the farmers and not necessarily of immediate benefit.

Results

1992 was a rather wet year with uneven rainfall distribution, short drought spells occured in the vegetative growth stage, and towards harvest. In 1993 the trial was exposed to a severe early season drought, and received moderate rainfall for the remainder of the season. In 1994 no periods of drought occurred, growing conditions were excellent for pearl millet. At the time of the farmers' visit to the research station in 1992 the differentiation between early and later maturing genotypes was very clear, whereas in 1993 and 1994 these differences were not so obvious, because the farmers' visits occurred later in the crop cycle.
Results from 1992 showed that farmers from different pearl millet production areas selected very different types of plants. Farmers from Jodhpur selected earlier maturing and higher tillering material than farmers from the higher rainfall area in Ajmer district.

In 1993 farmers from Bikaner district selected mostly high tillering, tall material which were predominantly landrace accessions from another low rainfall district in Rajasthan. From Aagolaie village in Jodhpur district a group of men and women made separate selections in the trials. Women tended to select material with large panicles and lower tillering more frequently; whereas the men appeared to be divided, with about half of their selections made for large panicle types with high grain yield potential and the other half for higher tillering with better stover yield and quality.

In 1994, men and women from the same village (with relatively poor soil conditions) and from a new study village (with better soil conditions) visited the on-station trial. Farmers from the village with poorer soil conditions, who also had experience with some of the cultivars in their own fields, appeared to prefer a new type of material derived from combining high tillering local varieties with large panicle modern varieties. This type was equally preferred by men and women from this village. However, man from the new village with better soil conditions preferred this type of material much more than did women from the same village. These women selected mostly material with large panicles, and high grain yield potential. For women from these villages grain yield, early availability of grain and the ease of harvesting by hand (lower panicle number and lower plant height) were their main considerations for making selections. For the men, stover yield and quality appeared to be a stronger concern.

Advanced variety testing, variety release and seed dissemination

It is not uncommon to have some level of farmer involvement in the final stages of variety testing, mostly through researcher managed on-farm trials, on-farm demonstrations and large-scale minikit testing. Similar types of trials are commonly organized by the extension services to expose a large number of farmers to newly available varieties and other technologies. Generally these trials are managed with the full range of recommended external inputs, which may be atypical of the predominant growing conditions in the target regions. Farmers often have little input into the management of these trials. Based on our experience of the usefulness of careful evaluations of on-farm trials with farmers using their criteria, it appears that the biggest draw back of such on-farm trials ist that only standard yield data are recorded. Farmers' evaluations of the test-genotypes are not sought, and farmers' evaluation criteria are not regularly used, or if so, they do not enter final reporting and play no role in the decision making process for varietal releases and recommendations (Farrington and Martin, 1988). It is our experience that the type of on-farm trials we described in the first section and an attitude towards learning and understanding from farmer reveal new information which allows a more precise assessment of the overall usefulness of a new genotype, based on the judgement of a large number of farmers. Such participatory evaluation and selection of existing released varieties has not only great potential for identifying locally acceptable varieties but also for exposing a large number of farmers to new varieties.

In Ajmer district, one of the varieties (RCB-IC 911) included in the on-farm trials yielded better in two very contrasting years, 1992 and 1993. A large number of farmers had visual exposure to this variety and it was widely accepted as being better than other options. There was a strong interest by farmers in obtaining seed for the next season. We indicated that because this variety was an open-pollinated variety, farmers could maintain relatively pure seed stocks in the village. Pamphlets and posters were provided illustrating how fields might be isolated and pure seed selected. Farmers indicated a strong interest in obtaining sufficient quantities of seed to provide the community with its requirements. They were willing to pay Rs 10/kg for seed of this variety, which is slightly more than the cost for seed of local varieties in this area.

Availability of seed of improved genetic material is often a primary reason for lack of adoption, even if well-adapted, acceptable varieties are available, and released. On the background that farmers had stated a strong interes for seed of RCB-IC 911 the issue of seed availability could be addressed in our study area in Ajmer district. It was agreed that ICRISAT would produce a larger quantity of seed, which would be distributed by the local NGO. A total of 2500 kg of seed was supplied to the NGO and was made available to 14 villages in the area. Included were villages where earlier work had been conducted as well as villages which had limited or no exposure to RCB-IC 911. All the available seed was sold rapidly and not all the demand for it could be met.

Rainfall in 1994 was excellent and visits to the area indicated that this variety performed well and local seed production by farmers was seriously pursued. ICRISAT will be conducting an early adoption study in 1995 to determine farmers' perceptions of their 1994 production, and to assess how the seed was produced and stored, and to evaluate its spread in 1995. It will be possible to determine the impact of farmer involvement in variety evaluation and of seed availability on early adoption.

Conclusions

We have outlined in this paper opportunities for and results from farmer involvement and participation in the main stages of a formal variety development program. Our results and observations indicate that farmer input into all these stages can be very meaningful and helpful to make such programs more cost-effective. There is no doubt that appropriate targeting will help to maximize the gains that can be expected from a breeding program. The use of farmer-generated population crosses may help to increase potential gains from a formal breeding program by relieving breeders from selecting for adaptive and quality traits, and thus allowing more focus and intensity for selection on disease resistance or productivity related traits. Planning for farmer-generated population crosses may involve more detailed analyses of the available genetic diversity, and its relationship with adaptation to and productivity under specific growing conditions.

Farmers participation in selection was mainly discussed with respect to farmers' involvement in on-station evaluation of progeny trials, or variety trials. In the system of pearl millet cultivation as it is found in Rajasthan, it is difficult to envisage, how a large number of progenies, or varieties could be effectively tested by farmers in their own fields. There is, however, no difficulty to foresee farmers' involvement in the selection among single plants in a population bulk grown in farmers' fields, especially if simple methods for pollination control can be implemented.

It is well established that farmers can evaluate a smaller number of experimental varieties in on-farm trials under their own management. If farmers' active involvement in the evaluation and ranking of these varieties is sought, the most acceptable varieties can be rapidly identified, and the time span between variety testing, release and seed dissemination shortened dramatically, particularly if farmers have the option to multiply their own seed.

The presented analyses are based on the assumption that a full fledged formal breeding program is desirable and its effectiveness could be supported by input and involvement from farmers in and from the target region. The different options for farmer participation described here could be combined in a breeding program in many different ways, depending on needs and opportunities.

In contrast to the described scenario, there may also be situations, in which it is not economical to operate full scale formal breeding programs. A thorough understanding of the traditional system of seed selection, production and storage may open avenues for specifically targeted support by breeding research of such a traditional, indigenous seed system (Hardon, 1995; Lenne´ et al., 1995).

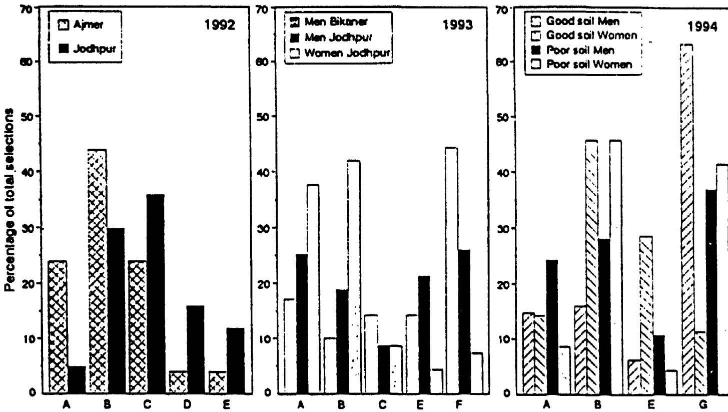

Abb. 1: Selections made by farmers from different districts in Rajasthan among groups of pearl millet varieties differing in plant type, as percentage of total selections made by each group of farmers, made in 1992, 1993, and 1994

Legend: A: medium maturity, low tillering, large panicle
B. early maturity, low tillering, large panicle
C: medium maturity, basal tillering, medium panicle
D: extra early maturity, high tillering, small panicle
E: early maturity, high tillering, small panicle
F: early maturity, high tillering, medium panicle
G: early maturity, medium tillering, medium panicle

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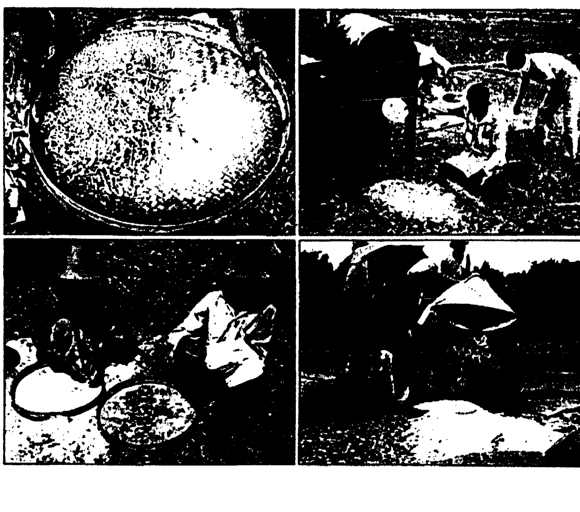

The CGPRT Centre

The CGPRT Centre

The Regional Co-ordination Centre for Research and Development of Coarse Grains, Pulses, Roots and Tuber Crops in the Humid Tropics of Asia and the Pacific (CGPRT Centre) was established in 1981 as a subsidiary body of UN/ESCAP.

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In co-operation with ESCAP member countries, the Centre will initiate and promote research, training and dissemination of information on socio-economic and related aspects of CGPRT crops in Asia and the Pacific. In its activities, the Centre aims to serve the needs of institutions concerned with planning, research, extension and development in relation to CGPRT crop production, marketing and use.

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1. Research and development which entails the preparation and implementation of projects and studies covering production, utilization and trade of CGPRT crops in the countries of Asia and the South Pacific.
2. Human resource development and collection, processing and dissemination of relevant information for use by researchers, policy makers and extension workers.

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Breeding Varieties with Farmers' Participation: Pearl Millet Improvement in Rajasthan, India

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Introduction

Participatory approaches have become widely used, applied and modified in rural development work. Much of the methodology used and being developed is action oriented. Farmers' participation in the research process may have similar merits. It is one of ICRISAT's goals to develop innovative techniques to improve the impact of its research on the nutritional and economic well-being of low-income people in these environments. Developing methods to bring farmers and scientists closer together has been one of the approaches used to achieve research results with more relevance to specific farming communities. Understanding farmers' priorities helps to target research efforts. Giving farmers opportunities to choose, improvise and adapt from a range of choices will create more useful technologies (Farrington and Martin 1988).

New varieties, breeding populations, and improved genetic materials are among the major outputs of ICRISAT's research efforts. Farmers' involvement in this process has traditionally been limited to that of a donor germplasm and of a recipient of a final product. Opportunities for farmer participation in the various stages of this process will be explored in this paper, based on research with pearl millet (*Pennisetum glaucum* (L) R. Br.) in the state of Rajasthan in northwestern India. This paper describes the interaction between scientists and farmers during individual stages of the breeding cycle of a cross pollinated crop and summarizes key results obtained to date.

Pearl millet in Rajasthan

Pearl millet is the major cereal crop and staple food of Rajasthan. It is grown annually on 4-6 million ha, predominantly in the drier western part of the state. The area under pearl millet varies greatly from year to year, depending on the rainfall and its distribution. There has been a slight increase in area cultivated with pearl millet over the past thirty years, probably due to increased demand for food and feed by a rapidly increasing population (Jansen 1989). The average productivity of the crop varies greatly from year to year, and rarely exceeds 500 kg/ha. In the western districts of Barmer, Jodhpur, and Bikaner, average yield levels are frequently below 100 kg/ha.

Adoption of modern varieties (MVs) of pearl millet is low in this state, in contrast to other millet growing areas in India where both improved open-pollinated varieties and single-cross hybrids are widely used (Jansen 1989). Local varieties of pearl millet from the western part of Rajasthan tend to outperform the standard MVs for grain yield under stress conditions (Weltzien and Witcombe 1989). Pearl millet is normally cropped in mixtures with short season

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legumes, and livestock are an important component of the farming system since crop residues of pearl millet and legumes are important sources of livestock feed and farm yard manure is the primary fertility amendment used by farmers.

The cycle of plant breeding activities

Breeding new cultivars of any crop involves a series of activities common to all crops. Schnell (1982) defined these major stages as generation of variability, selection and testing of experimental cultivars. This classification facilitates the analysis of the technical process of variety development, the domain of classical plant breeding research.

A successful breeding program however, needs two additional stages: the setting of goals or the definition of a target for the breeding program and an efficient system for varietal release and dissemination. These two stages need to be integrated with the technical variety development process, to allow for feedback between these stages and for a dynamic optimization of the whole breeding cycle.

Opportunities and experiences with farmers' participation: defining goals

Setting goals is usually the first step in developing an effective breeding program. Appropriateness of the goals set determines the effectiveness of a breeding program to a large extent. The goals have a large influence on the choice of breeding method, composition of the germplasm base and diversity that is required. Formulating goals is crucial to any breeding program. It is thus surprising that very little research has been reported on methodologies for identifying appropriate goals in breeding programs. Reasons for this could be historical. Seed improvement, variety development and plant breeding as an enterprise and a research discipline have evolved out of crop improvement in general (Kuckuck 1988; Gade 1993). Thus the intricate understanding of farmers' production goals, their preferences for certain traits as well as a familiarity with future trends in production conditions formed the basis for genetic crop improvement. With the rapid scientific development in genetics and its application to crop improvement, the linkage between genetic, agronomic and farming system improvements has loosened and plant breeders are frequently in a position where appropriate goals are not obviously set. This is particularly the case in marginal environments where farming is frequently subsistence rather than market oriented, and farmers' strategies for coping with large seasonal variations are not well understood (Matlon 1987).

Pearl millet cultivation in Rajasthan is such a case. We have therefore initiated research with farmers' participation on the following issues relating to the setting of goals for the breeding program:

- identification of farmers' preferences for individual traits of pearl millet;
- identification of major production constraints; and
- identification of major trends and anticipated changes in the production environment for pearl millet in Rajasthan.

Methods

In an initial study we used formal, structured, pretested questionnaires to elicit farmers' perceptions of the relative importance of grain versus clover yield (Kelley et al. 1996). The results of this survey were mainly limited by the fact that farmers in marginal areas of pearl millet cultivation had not been exposed to the wide range of variability available among newly released pearl millet cultivars and pre-release advanced experimental cultivars. Farmers could thus not consider the whole range of available variability while expressing their preferences and concerns.

On-farm trials

To expose farmers to a wide range of these options, we decided to encourage them to grow trials with new cultivars under their normal crop management conditions. We organized the on-farm trials with the support of local non-government and government organizations, working with farmers in the target areas (Table 1).

Table 1 Location and number of on-farm trials organized each year with the support of local organizations.

Year	District	Village	Number of trials	Supporting organization
1991	Ajmer	Kotri	12	Social Work and Research
		Singla	12	Centre (SWRC)
		Brijpura	12	SWRC
		Nallu	12	SWRC
1992/ 1993	Ajmer	Nunwa	15	Swiss Integrated Goat Development Project (IGDP)
		Udaipur Khurd	15	SWRC
	Jodhpur	Aagolale30		Department of Soil and Conservation and Watershed Development of the Government of Rajasthan: Central Arid Zone Research Institute (DSSWSD, CAZRI)
	Bikaner	Kichiyasar	30	Urmul Trust
1994	Jodhpur	Aagolale20		DSSWD, CAZRI
		Malunga20		Grameen Vikas Vigyan Samiti (GVVS)
	Bikaner	Kichiyasar	20	Urmul Trust
	Churu	Krejada	20	Urmul Trust
	Barmer	Bhadka	20	Society for Uplift of Rural Economy SURE
		Mangla	20	SURE

The on-farm trials were managed by farmers. Each farmer compared one experimental variety with his/her own variety. Farmers obtained assistance for the organization and layout of these trials from village investigators employed in each village. These investigators were trained to understand the trial objectives, the methods to monitor them and to administer interview schedules to collect background information on key features of the production system. Details of the process we used for selecting target regions, study villages and participating farmers are described in Weltzien et al. (1995) and Whitaker et al. (1995).

The varieties used for these trials were chosen by the researchers, and we changed some varieties from year to year in response to farmers' evaluations and interests. The varieties were chosen to meet the following criteria:

- to cover a maximum span of variability for the trait time to maturity;
- to cover a maximum span for tillering potential and panicle types;
- the varieties should have been widely tested for yield, preferably released or near release;

the varieties should preferably be open-pollinated varieties and not single-cross hybrids, permitting farmers to produce their own seed.

Evaluation of on-farm trials

Using these trials as the basis for discussions, we used several methods to understand farmers' criteria for differentiating between cultivars and farmers' preferences for individual traits and trait complexes: i) individual comparisons of experimental varieties with farmers' own variety; ii) group interviews to compare a range of cultivars; and iii) farmers' descriptions of an ideal variety.

Individual comparisons: project scientists visited the on-farm trials twice a season to hold discussions with farmers. The first visit took place before flowering to discuss field management and early growth of the experimental variety relative to the farmers own variety. Prior to harvest, plots were visited again to discuss in detail farmers' perceptions of differences between the experimental variety and their own. Individual assessments, while viewing the standing crop, indicated what characteristics farmers use to distinguish between varieties. For each distinguishing trait, farmers were asked to rank the two varieties. Farmers also ranked the varieties over all traits. After harvest, farmers were asked to measure grain and fodder yields and to evaluate grain and fodder quality of the experimental varieties compared to their own.

Group assessments: with different groups of 3-6 farmers each, representing farmers participating in the experiments, non-participating farmers, and women farmers, we conducted group interviews to compare all experimental varieties with each other and with the local variety. Groups toured a cluster of fields to see all three experimental varieties under similar growing conditions. Farmers collected 3-4 representative plants from each variety to have specimens available during the discussions.

Discussions were structured so that farmers were first encouraged to talk about differences between the local varieties and the experimental varieties. For each trait they mentioned, a picture was drawn on a card. The cards were then used to construct a matrix ranking table. Farmers ranked the three experimental varieties for each of the characteristics they had mentioned. Usually these discussions led to other topics, such as crop management, crop utilization and seed selection.

Ideal variety: during the individual and the group assessments, farmers were asked to describe the characteristics of an ideal variety, thus ranking and combining the individual traits that they had mentioned before. This was followed by discussion on the reasons for this ranking and the preferred trait combinations.

Characterization of the cropping system and its main constraints

The expression of individual traits of a crop variety depends not only on the variety's genetic composition but also on the environmental conditions where the variety is grown. Growing conditions have important direct effects on a variety's growth and performance, but more importantly the expression of many productivity related traits depends on interactions between genetic and environmental factors. These interactions are usually unpredictable. An important part of formulating goals for a breeding program is thus the identification of key environmental factors and production constraints. This allows the breeder to adapt on-station testing conditions to prevalent target growing conditions.

One complicating element is the time lag between the initial steps of variety development and its possible release and extensive adoption by farmers. This time lag normally spans five to ten years. During this period production conditions, both economic as well as environmental, can change. The description of target growing conditions thus contains an important predictive element. Discussions with farmers about their management practices, production goals, changes occurring, and factors that cause them can be important sources of information for defining target production environments for a breeding program. We focused our discussions on crop management issues and livestock-crop interactions through individual structured interviews and informal group discussions on specific topics, such as crop rotations, following practices or crop mixtures.

Results

Farmers' preferences for individual traits

Farmers used a wide variety of traits to distinguish between the experimental varieties and their own cultivars. The traits can be classified into three groups: growth and productivity, grain and fodder quality and adaptation to the environmental conditions and needs. Farmers in the three districts mentioned grain and stover yield during varietal comparisons in about half the cases. Grain yield and fodder quality were consistently mentioned more often. These two traits were the most important for varietal comparisons in all three districts (Table 2).

Table 2 Percentage of farmers using productivity related traits to distinguish the experimental variety from their own variety, 1992 and 1994 results combined, across all experimental varieties.

Trait	Ajmer 1992	Jodhpur 1992/94	Bikaner 1992/94
Number of farmers surveyed	27	44	49
Grain yield	68	59	65
Stover yield	52	36	53
Earliness	72	48	37
Large panicles	59	34	57
Large grain size	44	40	45
High tillering	20	23	65

The most important difference in farmers' preferences between the higher rainfall district (Ajmer) and the drier western part of Rajasthan was the different attention paid to tillering. Tillering is of importance to farmers of western Rajasthan as a component of both grain and fodder yield. They associate better adaptation to low water availability and poor fertility conditions with this trait (Table 3), and consider it as a component of stover quality. Nodal tillers frequently do not mature before harvest and thus contribute to the stover feed quality. Higher tillering varieties commonly have thinner stems, which result in higher intake by the animals, without the need to chop the stover. The local landraces of western Rajasthan tiller profusely from both basal and aerial nodes. They are extremely thin stemmed with small panicles and very small grain size.

The frequency with which earliness was mentioned differed markedly among all three districts. In Ajmer, the district with the highest seasonal rainfall and the longest rainy season (van Oosterom et al. 1995), earliness was mentioned most often. This is unexpected, because earliness would seem to be of most benefit in the drier areas of western Rajasthan. However, in Ajmer district the differences in earliness between the experimental varieties and farmers' own varieties were most pronounced. In Ajmer district two of the experimental varieties, HHB 67 and RCB-IC911, flowered and matured distinctly earlier than the commonly grown cultivars.

Farmers in this area had no previous experiences with this degree of earliness, and perceived it as advantageous in both years of on-farm testing. In 1992, the early maturity of these cultivars gave many farmers the opportunity to plant a post-rainy season crop with the late rains of that year. In contrast, 1993 was a dry year and this earliness was the key to a higher grain yield for many farmers in this district. In both Jodhpur and Bikaner districts, the local varieties flower early, thus the difference between local and early experimental cultivars is smaller. Confounding this is the effect of poor soil fertility and other stresses on flowering behavior. It appears that the flowering of improved cultivars under stress is delayed more than in the local varieties of western Rajasthan, thus further reducing the potential differences between the two types of breeding material.

Table 3 Adaptive traits which farmers in Jodhpur and Bikaner districts observed during three years of on-farm variety comparisons.

Trait	Reason
Plant type :	
early maturity	associated with low water requirements
high tillering*, nodal tillering, many leaves	associated with high productivity under stress conditions
tall plant height	associated with high fodder yield under stress conditions
large panicle, large grain	
Overall adaptation	
good germination, **fast germination**	stand establishment is essential
low seedling death	
low water requirements good growth in early drought, dark leaves, less drying, less leaf firing	
low soil fertility requirements	
good seed set	flowering, pollination and early grain development are very sensitive to stress
reduced bird damage **bristles, glumes**	in poor years bird damage causes severe losses; bristles and glumes contribute to non-preference for birds
uniformity **disease resistance**	

* Traits in bold type were mentioned very frequently.

Adaptive traits and adaptation where mentioned by farmers from western Rajasthan (Bikaner and Jodhpur) as criteria for which the varieties differed. Farmers' criteria for assessing adaptation of cultivars fall into two groups: i) plant type or plant architecture and ii) specific adaptations to identifiable stress situations. Farmers commonly associate early maturity with low water requirements (Table 3). The relevance of high tillering was already discussed. Tall plant height is at times associated with high fodder yield under stress conditions. Specific adaptations that farmers regularly observed were speed of germination, early growth and other responses to early season drought, the ability to set seed and fill grains and attributes that contribute to reduced bird damage, which is particularly important under drought conditions.

Farmers had specific preferences for grain and stover quality characteristics. In western Rajasthan farmers preferred the thin stemmed stover of the local varieties, possibly because choppers are generally not available in this region. Animals take in the fine straw better than the thick stemmed hard straw of many improved cultivars. In western Rajasthan there is a stronger preference for grain quality characteristics of the local varieties. In Ajmer district, this preference appeared to have changed perhaps through the wider availability and adoption of modern varieties (Table 4).

Table 4 Percentage of farmers preferring their own cultivar for traits contributing to grain and stover quality, as observed during 1992.

Trait	Ajmer	Bikaner	Jodhpur
Number of farmers	19	21	19
Grain size	5	0	0
Grain color	26	53	95
Cooking quality	11	5	0
Chapati taste	21	74	57
Chapati keeping quality	21	58	67
Overall grain quality	16	74	71
Stover appearance	16	16	43
Chopper quality	32	63	43
Animal preference	11	42	28
Overall stover quality	21	74	33

Table 5 Percentage of farmers using a trait to describe an ideal pearl millet variety based on surveys conducted in 1992 and 1994 in Ajmer, Jodhpur and Bikaner districts.

Trait	Ajmer 1992	Jodhpur 1992/94	Bikaner 1992/94
Number of farmers	22	32	33
High grain yield	32	56	67
High stover yield	23	28	42
Earliness	55	50	61
Large panicle size	77	75	45
Large grain size	45	34	30
High tillering	27	72	70
Low water needs	0	6	42
Good grain filling	32	9	42

Traits of an ideal variety

The most frequently mentioned traits of an ideal variety are large panicle size and tillering, with grain yield and earliness not lagging far behind (Table 5). The differences between Ajmer district and western Rajasthan are similar to those obtained from the discussions on trait preferences. High tillering is clearly of much more importance to farmers in western Rajasthan. Similarly, farmers in Bikaner district include low water requirements in their list of traits for an ideal cultivar. These same farmers placed less emphasis on large panicle size and large grain size then did farmers in Jodhpur and Ajmer district. In all districts at least 50% of the farmers mentioned earliness in their list of ideal traits. Earliness is relative to the length of the growing season in the three districts, and to the crop duration of the prevalent varieties in a district.

Evaluation of the on-farm trials by farmer groups

At the end of the season, five groups of farmers in Ajmer district compared the three experimental cultivars, including two groups of non-participant men farmers, one group of participant men farmers, one group of non-participant women farmers and one group of participant women farmers.

These discussions were held 2-3 weeks prior to harvest, when HHB 67, the earliest maturing cultivar, had completed grain filling of the main panicle in most locations. Under good fertility conditions, it continued to produce tillers which were later maturing. RCB-IC 911 had completed grain filling in most cases, except under poor fertility conditions. ICMV 155 and their own cultivars had mostly not completed the grain filling stage, depending on the fertility of the land. Thus most groups used differences in earliness as one of the first criteria to differentiate between the varieties.

Differences in rankings of relative earliness reflected land quality as well as differences in genetic potential. Farmers generally felt that their own cultivars were later than all three experimental cultivars. All groups noted differences in fodder or grain yield among the three cultivars. They expected all three cultivars to yield well relative to their own cultivars in 1992. Relative yield rankings differed across groups, reflecting the quality of the land where the experimental cultivars were grown as well as the genetic potential of each cultivar.

Most groups noted strong differences in yield component structure between cultivars. The ranking of head size, grain size, plant height, and tillering ability was consistent across groups and was congruent with previous on-station comparisons. Perceptions of grain size also seemed related to land quality. Under better conditions RCB-IC 911 produced larger grains. Under poorer conditions the advantage of RCB-IC911 in grain size disappeared, as it had not yet completed grain filling at the time the discussions were held.

In addition, farmers included quality related characteristics, like fodder and grain quality or water requirements, as criteria to differentiate among the three experimental cultivars. They evaluated these qualities visually. Fodder quality for chopped fodder was related to thicker stems, whereas thinner stems were beneficial in direct feeding. Grain quality appeared to be mostly related to grain size, lighter, yellowish grain color, and sometimes the sweet taste of raw grain.

Water requirements, often considered together with fertility requirements, were judged mostly by considering earliness, tillering, and thinness of stems and leaves. Farmers appeared interested in having a cultivar that will give some amount or assured grain yield in a poor year, rather than just fodder. They seemed willing to sacrifice grain yield in a good year for a more assured grain yield in a poor year.

Production constraints

As described earlier, adaptation to the climatic and edaphic conditions is a major requirement for success of any new variety in the harsh environments of western Rajasthan. To improve our understanding of the growing conditions for pearl millet in western Rajasthan, we held group discussions with farmers in all study villages about the major factors contributing to crop failures and severe yield losses. Crop establishment is often problematic. Pearl millet seeds are small (5-14 g 1000 grain mass) so emergence under adverse conditions (deep planting, crust formation) is problematic. The seedlings are tender and fragile during the first days after emergence. Losses occur due to dry hot winds, sandblasting, and heavy rains that fill the furrows in which millet is normally sown. Thus plants are covered with soil. However, in some years emergence conditions are excellent and yields appear to be reduced by excessively high stands. Farmers are of the opinion that the available tractor drawn sowing equipment is producing a poorer seed bed than the traditional animal drawn equipment. It appears that improved sowing equipment, which would allow more precise placement of the seed, could contribute substantially to more reliable stand establishment.

Poor soil fertility is probably the main yield reducing factor in the western part of Rajasthan. The traditional farming system relied on long fallow periods to restore soil organic matter content and general soil fertility. However, farmers from all over Rajasthan report that during the past 20-30 years a decrease in the duration of fallow periods has occurred due to increased population pressure. Farmers with small landholdings fallow their land only in severe drought years. Farmers in the western part of Rajasthan do not have much experience with mineral fertilizers. With the decline in fallow periods, farmers associate a loss of organic matter and a loss of soil structure. They consider this also one of the causes for more severe crust formation.

Farmers in western Rajasthan perceive drought as the main cause for crop failures and yield losses. However, there appears to be a strong interaction with soil fertility. Comparisons of high and low fertility plots over the past four years in three districts of Rajasthan lead us to assume that water utilization could be improved greatly in many fields, if a more adequate supply of nutrients were available.

Generating variability

Choosing breeding material, developing the germplasm base for a breeding program, choosing parents, making crosses, and random mating populations are major and crucial activities of every breeding program. It is generally assumed that breeders have a major advantage over farmers in the choice of germplasm and in carrying out the processes leading to recombination and thus new combinations of traits and gene complexes for quantitative traits. However, a role for farmers in this process could be envisaged for cross pollinated crops where crossing occurs naturally.

In the villages in western Rajasthan, where none of the experimental varieties satisfied farmers needs per se, the farmers nevertheless used seed harvested from the on-farm trials for their own efforts in seed selection. This seed was most often planted in a mixture with their own variety, mainly to reduce the risk of crop failure from the new seed source. This resulted in intermating of the two groups of material, and farmers observed frequently an increase in variability in their seed stocks. We observed intense discussions among farmers about selection in these more variable seed stocks.

For the breeders it may be worthwhile to consider using population crosses and random matings made in this way by farmers, under farmers' field conditions, with a large population size and selection for the most preferred trait combinations as base material rather than making similar population crosses, often under non-representative, off-season conditions, and with severe limitations on the number of plants that can be handled per population cross. Breeders could use farmer-generated population crosses for targeted improvement of specific traits, which farmers cannot easily select for on a single-plant basis (e.g. grain yield, stover yield or disease resistance), possibly without having to spend much more effort on yield components and adaptive or quality traits.

The role of the breeder in this process would thus become more one of making useful new variability available to enable farmers to generate new population crosses with a good potential for achieving genetic gains for the key traits. For farmer-breeder interactions to be successful at this stage of the breeding cycle, farmers would need to be involved in evaluating a much larger range of material and genetic variability. It would also be beneficial if there were a better understanding of the combining ability of farmers' local cultivars with different sources of germplasm that farmers may want to use. We are presently evaluating farmer-generated seed stocks for their comparative performance and variability.

Farmers' participation in selection

In any breeding program, selection is a key activity which can occur at any of the following stages: in the composition of the base material, in the selection of parents for crossing, in the selection among progeny, in the selection among experimental varieties and in the maintenance of breeder seed stocks. Selection among segregating progeny as well as selection during the testing of experimental cultivars requires balancing between the different traits that vary within the material. Understanding of the mode of inheritance is beneficial for complex traits, such as grain yield or disease resistance. Selection in all these stages of a breeding program is normally carried out under experiment station conditions. Farmer visits to experiment stations are usually limited to the viewing of demonstration plots of a few highly selected advanced varieties. Options for them are thus limited, and feedback from farmers on these displayed options is usually not sought. Possibilities for farmers' participation in selection could be as diverse as the opportunities for selection itself.

Methods

We have experimented with farmers' participation in the selection among experimental varieties, with the aim of complementing variety evaluation with their opinions, and of confirming previous results on trait preferences and preferences for trait complexes by exposing farmers to a wider range of genotypes.

Groups of farmers, men, women, participants in the on-farm trials and non-participants from different villages were invited to the research station at Jodhpur during 1992, 1993 and 1994. At the beginning of each group visit, we discussed the crop management of our trials in detail. Groups of 5-6 farmers were then led through the portion of the trial (usually one replication with 40-60 entries), from which they would make their selections. They were asked to make selections of single rows from this trial which would be beneficial for farmers in their area. Each farmer could make up to ten selections, by tying numbered labels to the ends of selected rows. After they completed their selections we held discussions on the range of variability they saw and its usefulness as well as on their reasons for making these choices. Farmers were then given the opportunity to select one of the entries in the demonstration for their on-farm trial the following season.

The method could easily be modified to involve farmers in selection among progeny rows or for selection among single plants for mass selection in a population bulk in on-station conditions. Crucial to the success of these efforts is identifying farmers who have a keen interest in seed issues and selection for their own local area and social group. These visits are time consuming for the farmers and not necessarily of immediate benefit. Institutional issues such as formation and/or identification of representative farmers' groups become more important, not only the actual process of farmers' selection (Sperling and Scheidegger 1995).

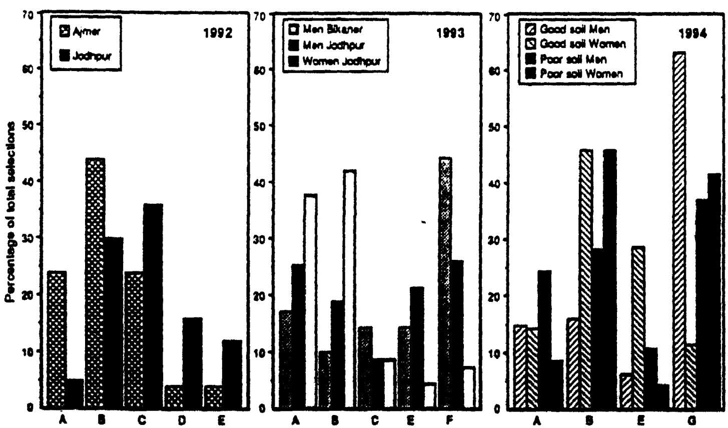
We analyzed the selections by grouping the varieties in the trial according to plant type based on time to flowering, tillering behaviour and panicle size, and recording the frequencies with which different farmers and farmer groups selected these types of material. The composition of the trial (Rajasthan Varieties and Population Trial, RVPT) changed from year to year, thus not all groups are represented each year, and the genotypes within each group are not always the same.

Results

1992 was a rather wet year with uneven rainfall distribution; short drought spells occurred in the vegetative growth stage, and towards harvest. In 1993 the trial was exposed to a severe early season drought, and received moderate rainfall for the remainder of the season. In 1994 no periods of drought occurred, and growing conditions were excellent for pearl millet. At the time of the farmers' visit to the research station in 1992, the differentiation between early and later maturing genotypes was very clear, whereas in 1993 and 1994 these differences were not so obvious, because the farmers' visits occurred later in the crop cycle.

Results from 1992 showed that farmers from different pearl millet production areas selected very different types of plants (Figure 1). Farmers from Jodhpur selected earlier maturing and higher tillering material than farmers from the higher rainfall area in Ajmer district.

Figure 1 Selections made by farmers from different districts in Rajasthan among groups of pearl millet varieties differing in plant type, as percentage of total selection made by each group of farmers, made in 1992, 1993, and 1994.



Legend: A: medium maturity, low tillering, large panicle
B: early maturity, low tillering, large panicle
C: medium maturity, basal tillering, medium panicle
D: extra early maturity, high tillering, small panicle
E: early maturity, high tillering, small panicle
F: early maturity, high tillering, medium panicle
G: early maturity, medium tillering, medium panicle.

In 1993 farmers from Bikaner district selected mostly high tillering, tall material which were predominantly landrace accessions from another low rainfall district in Rajasthan, Barnr. From Aagolaie village in Jodhpur district, a group of men and women made separate selections in the trial. Women tended to select material with large panicles and lower tillering more frequently, whereas the men appeared to be divided, with about half of their selections made for large panicle types with high grain yield potential and the other half for higher tillering with better stover yield and quality.

In 1994, men and women from the same village in Jodhpur district (with relatively poor soil conditions) and from a new study village (with better soil conditions) visited the on-station trial. Farmers from the village with poorer soil conditions, who also had experience with some of the cultivars in their own fields, appeared to prefer a new type of material derived from combining high tillering local varieties with large panicle modern varieties. This type was equally preferred by men and women from this village. However, men from the new village with better soil conditions preferred this type of material much more than did women from the same village. These women selected mostly material with large panicles, and high grain yield potential.

The follow-up discussions indicated that grain yield, early availability of grain and the ease of harvesting by hand (lower panicle number and lower plant height) were, for women from these villages, the main considerations for making selections. For the men, stover yield and quality appeared to be a stronger concern.

Advanced variety testing, variety release and seed dissemination

It is not uncommon to have some level of farmer involvement in the final stages of variety testing, mostly through researcher managed on-farm trials, on-farm démonstrations and large-scale minikit testing. Similar types of trials are commonly organized by the extension services to expose a large number of farmers to newly available varieties and other technologies. Generally these trials are managed with the full range of recommended external inputs, which may be atypical of the predominant growing conditions in the target region. Farmers often have little input into the management of these trials. Based on our experience of the usefulness of careful evaluations of on-farm trials with farmers using their criteria, it appears that the biggest drawback of such on-farm trials is that only standard yield data are recorded. Farmers' evaluation of the test-genotypes are not sought, and farmers' evaluation criteria are not regularly used, or if so, they do not enter final reporting and play no role in the decision making process for varietal releases and recommendations (Farrington and Martin 1988). It is our experience that the type of on-farm trials we described in the first section and an attitude towards learning and understanding from the farmer reveal new information which allows a more precise assessment of the overall usefulness of a new genotype, based on the judgment of a large number of farmers. Some methods for discussions with individual farmers and farmer groups were described in the first section of this paper. Similar approaches have been used by Joshi and Witcombe (1995) to identify locally well adapted cultivars from the often wide range of already released cultivars of different crops. Such participatory evaluation and selection of existing released varieties has not only great potential for identifying locally acceptable varieties but also for exposing a large number of farmers to new varieties. Seed of already released varieties can be made available to farmers relatively easily through collaboration with existing seed multiplication and distribution agencies. This is a very effective way to utilize already existing research products.

In Ajmer district, one of the varieties (RCB-IC 911) included in the on-farm trials yielded better in two very contrasting years, 1992 and 1993. The structure of our studies resulted in a large number of farmers having had visual exposure to this variety and it was widely accepted as being better than other options. In our discussions with individuals and groups, there was a strong interest by farmers in obtaining seed for the next season. We indicated that because this variety was an open pollinated variety, farmers could maintain relatively pure seed stocks in the village. Pamphlets and posters were provided illustrating how fields might be isolated and pure seed selected. Farmers indicated a strong interest in obtaining sufficient quantities of seed to provide the community with its requirements. Farmers indicated a willingness to pay Rs 10 per kg for seed of this variety, which is slightly more than the cost for seed of local varieties in this area.

Limited availability of seed of improved genetic material is often a primary reason for lack of adoption, even if well-adapted, acceptable varieties are available, and released. Since farmers had stated a strong interest for seed of RCB-IC911, the issue of seed availability could be addressed in our study area in Ajmer district. It was agreed that ICRISAT would produce a large quantity of seed, which would be distributed by the local NGO (SWRC, see Table 1). A total of 2,500 kg of RCB-IC911 seed was supplied to SWRC in May 1994. This seed was made available to 14 villages in the area. Included were villages where earlier work had been conducted, as well as villages which had limited or no exposure to RCB-IC911. All the available seed was sold rapidly and not all the demand for it could be met.

Rainfall in 1994 was excellent and visits to the area indicated that this variety performed well and local seed production by farmers was seriously pursued. ICRISAT will be conducting an early-adoption study in 1995 to determine farmers' perceptions of their 1994 production, to assess how the seed was produced and stored, and to evaluate its spread in 1995. It will be possible to determine the impact of farmer involvement in variety evaluation and of good seed availability on early adoption.

Conclusions

We have outlined in this paper opportunities for and results from farmer involvement and participation in the main stages of a formal variety development program. Our results and observations indicate that farmer input into all these stages can be very meaningful and helpful in making such programs more cost-effective. There is no doubt that appropriate targeting will help to maximize the gains that can be expected from a breeding program. The use of farmer-generated population crosses may help to increase potential gains from a formal breeding program by relieving breeders from selecting for adaptive and quality traits, and thus allowing more focus and intensity for selection on disease resistance or productivity related traits. Planning for farmer-generated population crosses may involve more detailed analyses of the available genetic diversity, and its relationship with adaptation to and productivity under specific growing conditions.

Farmers' participation in selection was mainly discussed with respect to farmers' involvement in on-station evaluation of progeny trials, or variety trials. In the system of pearl millet cultivation as it is found in Rajasthan, it is difficult to envisage how a large number of progenies, or varieties, could be effectively tested by farmers in their own fields. There is, however, no difficulty in foreseeing farmers' involvement in the selection among single plants in a population bulk grown in farmers' fields, especially if simple methods for pollination control can be implemented.

It is well established that farmers can evaluate a small number of experimental varieties in on-farm trials under their own management (Farrington and Martin 1988). If farmers' active involvement in the evaluation and ranking of these varieties is sought, the most acceptable varieties can be rapidly identified, and the time span between variety testing, release and seed dissemination shortened dramatically, particularly if farmers have the option to multiply their own seed.

The analyses presented here are based on the assumption that a full fledged formal breeding program is desirable and its effectiveness could be supported by input and involvement from farmers in and from the target region. The different options for farmer participation described here could be combined in a breeding program in many ways, depending on needs and opportunities.

In contrast to the scenario described, there may also be situations in which it is not economical to operate full scale formal breeding programs. A thorough understanding of the traditional system of seed selection, production and storage may open avenues for specifically targeted support by breeding research of such a traditional, indigenous seed system (Hardon 1995; Lenn et al. 1995).

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