- When an appropriate cultivar is selected, adoption is much faster through non-market methods of seed distribution (Grisley 1993).
- When farmers are involved in the selection process, their selection criteria may be very different from those of the breeder (Hardon and de Boef 1993; Sperling, Loevinsohn, and Ntabomura 1993). Typical examples are crops used for animal feed, such as barley, where breeders often use grain yield as the sole selection criterion, while farmers are usually equally concerned with forage yield and the palatability of both grain and straw (Saade et al. 1993).

Because the concepts of conventional plant breeding are rarely questioned, the blame for the nonadoption of new cultivars is variously attributed to the ignorance of farmers, the inefficiency of extension services, and the lack of availability of seed of improved cultivars. Thus, an impressive amount of human and financial resources continue to be invested in a model that has not been, and most likely will not be, successful in unfavorable agroclimatic conditions.

We base our approach on the following four assumptions:

1. Farmers have accumulated experience and know their specific environment better than breeders.
2. Farmers operate according to specific needs and objectives, which may not conform to breeders' research objectives.
3. Farmers will determine the success of a new variety, not breeders.
4. It is possible to integrate the scientific knowledge of breeders (in areas such as genetics, breeding, physiology, agronomy), as well as their broader experience across environments and their ability to create and manipulate genetic variability, with the knowledge and experience of farmers.

The concepts of the project are not new. Farmers have been participating to a greater or lesser extent in the pigeon-pea and pearl-millet programs of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), in the breeding program carried out by the Centro Internacional de Agricultura Tropical (CIAT) in Rwanda, and in a number of projects implemented by ICARDA and national agricultural research systems (NARS) in Syria, Tunisia, Morocco, Eritrea, and Yemen (Ceccarelli et al. 2000, 2001). These projects, however, were only experiments in participatory plant breeding, since they did not incorporate the cyclical nature of plant breeding. The project presented here represents a step forward because it will transfer to farmers' fields various steps of a formal breeding program. Although we will document farmers' selection criteria, and whether selection criteria differ between men and women, through descriptive indigenous-knowledge studies, emphasis will be given to (1) measuring and quantifying the effect of using farmers' selection criteria on the performance and adoption of improved barley and (2) developing an approach that can be readily utilized by other NARS in developing countries.

The project area

The geographical scope of this research is the dry areas of Jordan where drought stress is the major biotic stress and where barley is often the only possible crop for resource-poor farmers. This area encompasses a range of agroecological conditions, all of which may be considered as low-potential environments for cereal production. Arable land is predominantly cultivated with barley landraces.

In Jordan, the popularity of barley among farmers, despite the failure to improve yields, lies in its use as feed for small ruminants (sheep and goats); meat, milk, and milk products represent the prin-

cipal source of income for rural households in marginal areas. Barley grain and straw constitute the most important source of feed for the small ruminants throughout much of the year when grazing is in short supply. In the driest areas, a grain yield is obtained only one year in 10. And yet barley is sown every year, essentially as a forage crop whose value depends on biomass yield rather than grain yield (figure 1, table 1).

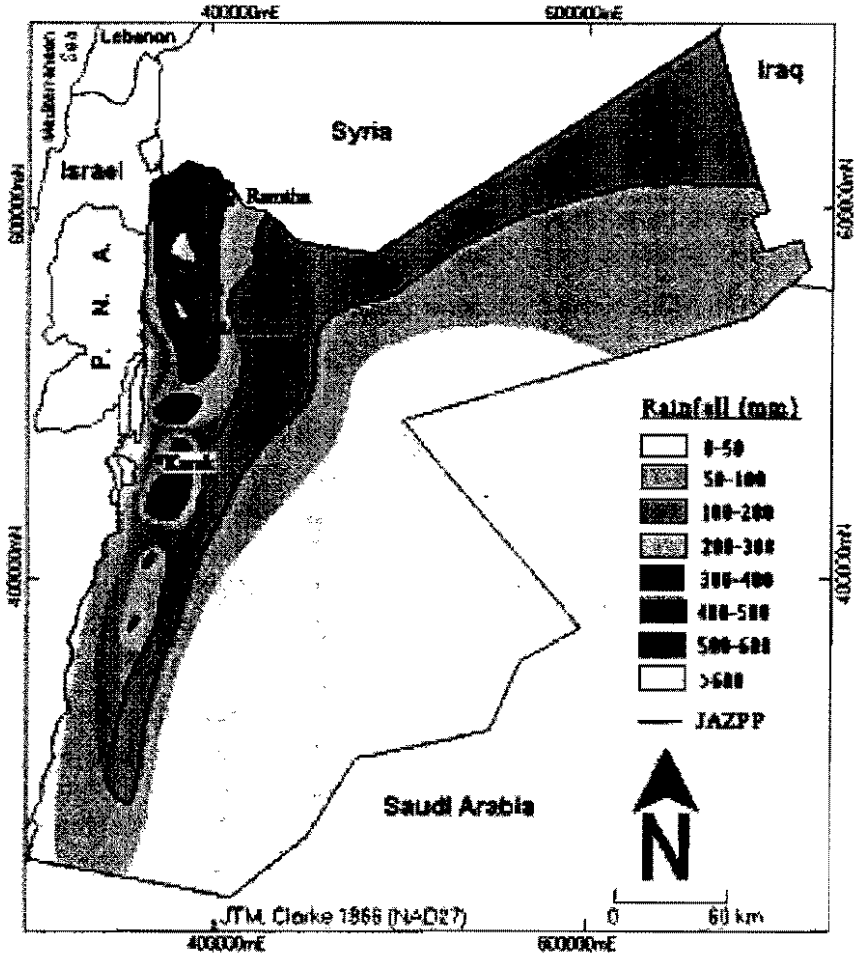

Figure 1. The rainfall zones of Jordan

Barley is mainly cultivated in the dryland areas that cover part of east Jordan. These areas are characterized by low rainfall, irregularly distributed, with most of the rain falling during the winter. Temperatures vary widely, with frequent frost in early spring and in late spring, resulting in head sterility, low yields (table 2) and often in crop failure. The unpredictable environmental conditions, along with poor soils and crop management, have made it difficult to introduce new cultivars and obtain yield increases.

Table 1. Planted Ares, Production, and Productivity of Barley in Jordan (1990–1997)

Year	Area thousand dunum	Production thousand ton	Productivity (kg/dunum)
90	34.44	36.4	1060
91	25.58	26.8	1190
92	83.63	103.2	1230
93	69.19	44.2	640
94	62.56	34.3	550
95	83.83	57.7	690
96	52.22	44.9	860
97	50.29	42.8	850
Average	57.34	48.8	883

Table 2. Mean Grain Yield, Biological Yield, Straw Yield, Plant Height, Harvest Index, Days to Heading, Days to Maturity, and Grain Filling Period at Four Locations in Jordan

	Locations				
Traits	Rabba	Khanasri	Ghweer	Ramtha	Mean
Grain yield (g/plot)	289.58	95.90	154.02	129.48	167.3
Biological yield (g/plot)	994.90	423.0	807.1	639.2	716.0
Straw yield (g/plot)	705.32	327.1	653.08	509.72	548.7
Plant height (cm)	59.50	33.1	47.9	56.6	49.3
Harvest index (%)	29.30	22.5	19.3	21.1	23.1
Days to heading (days)	118.50	110.8	85.6	128.7	110.9
Days to maturity (days)	152.0	137.8	113.2	155.9	139.7
Filling period (days)	31.50	24.0	26.5	24.2	26.5

Note: Data are the means of 84 barley lines during the 1996/1997 growing season.

Project objectives and expected outputs

The long-term goal of the project is the improvement of the welfare of small, resource-poor farmers by increasing and stabilizing barley and livestock production.

The immediate objectives of the project are

- to develop a participatory approach to breeding barley for stress conditions
- to improve barley varieties that fulfill the needs of poor farmers in the marginal rainfed environments of Jordan
- to enhance the rate of adoption of new varieties through farmers' participation in selection and testing

- to identify differences in selection criteria used by different types of farmers (according to gender, enterprise mix, and other farm characteristics)

At the end of the project we expect the following outputs:

- documented and validated information on farmers' objectives, knowledge, and field conditions
- the performance and quality, under both farmers' and station conditions, of barley lines selected by farmers in their fields, compared with the performance and quality of lines selected on the experiment station using breeders' selection criteria
- documentation of the selection criteria used by different types of farmers and/or different members of farm households
- a number of lines selected and developed through this participatory breeding program multiplied by farmers and tested by neighboring farmers
- the importance of the interactions between selection criteria and selection environment assessed
- incorporation of participatory approaches by the two national breeding programs

Methodology

Orientation and targeting

At each of the locations included in the project area, cooperating farmers ("host farmers"), who will host breeding plots and make individual selections, will be recruited from the pool of participants in previous on-farm research and cooperative research programs in ongoing research-and-development projects. A rapid-appraisal exercise will be conducted within the agricultural community associated with each of the selected agroecological locations, and a group of local "expert farmers" will be identified and recruited on the basis of reputation, key farming contacts, past performance, gender representation, producer and consumer categories, and self-selection. The expert farmer groups, together with the host farmers, will participate as key informants in the indigenous-knowledge study and will perform group selections from their respective host farmers' germplasm collections.

Indigenous knowledge

This component has several crucial outputs for developing the participatory-breeding approach. First, there will be an enquiry into farmers' objectives, reasons for producing barley, and different end-uses of the crop. This will include their perceptions of the difficulties they experience in reaching these objectives. Household economic security and risk considerations will also be considered in the context of production objectives and genotype evaluation.

The indigenous-knowledge study will provide the information needed for the analysis of concepts such as how farmers, both men and women, value various characteristics of the barley crop and how much they understand adaptation for specific environments and uses. The methodology for data collection and analysis will rely primarily on formal ethnographic techniques used in sociocultural anthropology, including participant observation, structured interviews, and taxonomic and componential analysis of labeled traits. As much as possible, barley characteristics recognized by

farmers will be classified hierarchically to enable selection procedures to be applied one after the other according to priorities reported by farmers. Indigenous methods for recognizing desirable characteristics within populations of barley cultivars will be documented, and activities of farmers applying these methods will be recorded in detail.

An important aspect of this component is the identification of women's selection criteria, particularly, but not only, at those locations where barley is used for human consumption.

Specific outputs for this component include the following:

- evaluation of the innovative capacity of farmers and insight into their potential for direct participation in formal breeding programs
- lists of desirable characteristics, prioritized and cross-referenced to environment and utilization
- indigenous knowledge and perceptions of environment-genotype interactions in barley landraces
- the theory, objectives, and implementation of the participatory-breeding program will be discussed thoroughly with the host farmers and expert farmer groups in order to obtain their input into the design of the breeding scheme, including selection procedures, such as the proper time for selection, how often selection is done, etc.

From centralized nonparticipatory to decentralized participatory barley breeding

This component represents the major empirical thrust of the project and will quantify the effects of the selection environment (experiment station vs. farmer's field), of who does the selection (breeder vs. farmer), and whether these effects interact or vary from year to year.

The traits that farmers select for, and the criteria they use in their selection, will be recorded by the breeders and social scientists, and compared with objective measures of traits used by barley breeders, including the yield and quality of grain and straw.

A common set of lines and populations (including the farmers' cultivars) will be grown on a typically well-managed experiment station field and on one farmer's field at each of six locations in Jordan under farmers' management practices (fertilizer use, rotations, date and method of sowing, land preparation, etc.). The locations will be as follows:

Al-Mohay	60 km southeast of Karak and about 130 km south of Amman, with an annual rainfall of about 130–150 mm
Al-Muaqure	55 km east of Amman, in the arid areas, with an annual rainfall of 150 mm
Ramtha	160 km north of Amman, with an annual rainfall of 250 mm
Khanasri	135 km north of Amman, with an annual rainfall of 200 mm
Rabba	140 km south of Amman, with an annual rainfall of 340 mm
Ghwer	160 km south of Amman, with an annual rainfall of 280 mm

By including locations with less than 200 mm average annual rainfall, there will be opportunities to investigate the performance of breeding material in environments where barley is a forage crop rather than a grain crop. In addition, small grain-producing areas occur within the < 200 mm zone. These are seasonally flooded *wadi* floors (*marrabs*), where high grain yields are normal within a generally arid environment. Because of their importance locally, and the uniqueness of the agroecosystem, these locations are included in the project.

In the project area, the majority of farmers still grow barley landraces that are heterogeneous populations composed of a large number of individual genotypes. Although the population buffering of such heterogeneous populations—and, hence, their role in reducing the risk of crop failures—is well documented, we do not know whether farmers perceive this type of diversity as important and if this is the reason for the popularity of landraces. To gain information on this specific point, the genetic material will include high-yielding fixed or nearly fixed lines, segregation populations, and farmers' cultivars. The use of both pure lines and heterogeneous populations will provide a means for testing the attitude of farmers towards heterogeneity, as opposed to the conventional breeders' propensity for homogeneity.

The farmers' cultivars, which are likely to be different at each location, will be collected from each farmer during the harvest of the previous year, and all farmers' cultivars will be grown at each site. Selection will be conducted on the experiment station by breeders, and in each host farmer's field, selection will be conducted by both the breeders and the host farmers, their spouses, and/or other household members. Whenever possible, neighboring farmers will also participate in the selection process.

The collaborating farm householders will make selections from their fields. Following a group selection procedure similar to that used by ICRISAT in Rajasthan (ICRISAT 1996:98–100), the expert farmer groups will be asked to select material from that grown by their host farmers, material that they think would be useful for them and other farmers in their area. The selection will be conducted in such a way as to reveal the criteria being used by the farmers and others when they make their choices. There will be detailed discussions regarding the cultivars selected and the criteria used in selection. Farmers' observations, expected performance, and crop-management practices will be recorded.

At the end of the first year, in addition to the breeders' selections from the experiment stations, for each participating farmer, the following groups of selected lines will be available:

1. lines selected by the breeder
2. lines selected by the farmer
3. lines selected by other household members
4. lines selected by the farmer's neighbors

In the second year, each host farmer will grow all the lines selected in his/her field in the first year, regardless of who made the selection, i.e., groups 1 to 4 above, as well as the lines selected by the breeder in the experiment station. The selections will be grown as one population of lines without obvious distinctions between the groups to avoid any possible bias in the second cycle of selection. All the lines selected in the first year will also be grown on the experiment station in the second year to provide enough seed for the third year. Data on grain and straw yield will be collected at each host farmer's field and at the experiment station. Response to selection will be evaluated using the farmer's cultivar as reference. In the second and third year, selection will be done, as in the first year—on the lines resulting from the first and second cycle of selection. Thus, during the second and third cycle (year) of selection, the farmers and the breeders will be exposed to the material selected by each other. By the third year, the project will have involved a total of 36 households in the target area and will have simulated three cycles of selection of the same type of cyclical processes that take place in conventional breeding programs (figure 2).

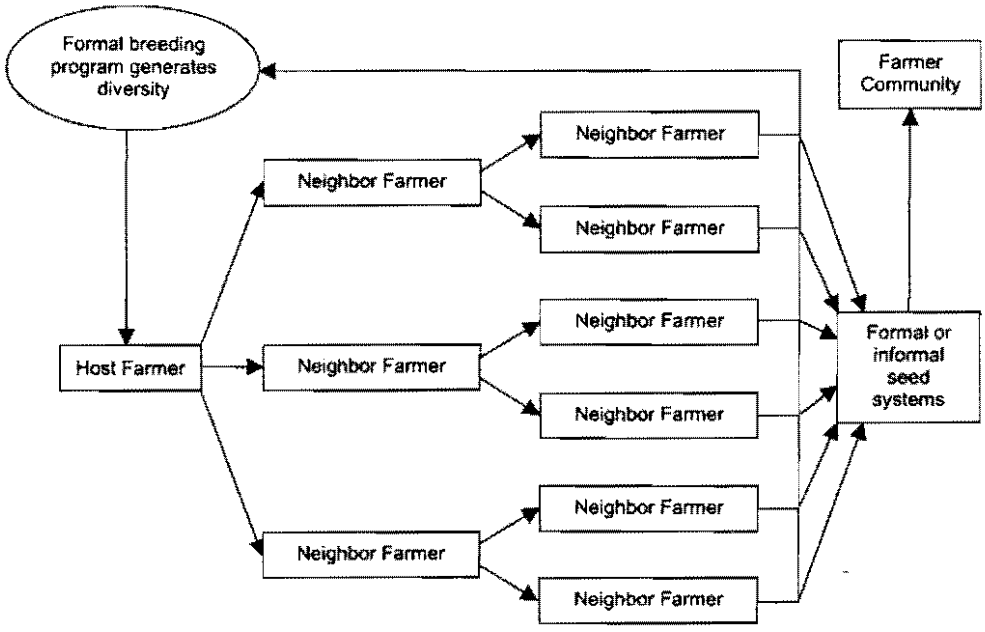

Figure 2. Scheme of the decentralized participatory barley-breeding program for one location (The number of farmers is arbitrary. The same scheme is repeated in six locations.)

During the selection process, the criteria of both farmers and breeders will be monitored and compared. Of particular interest will be the frequency with which the farmers, in the second and third year, select from the material they selected themselves in the first year and from among the material selected in the first year by the breeders. This will give not only an indication of the consistency of farmers' selection criteria, but also an indication of the possible effects of fluctuations in environment over years on genotype performance and farmers' perceptions of these effects.

This component is designed to quantify the following effects:

- the effect of the selection environment (experiment station vs. farmer's field) by comparing, both on the experiment station and on the farmer's field, the superiority over the farmer's cultivar of the lines selected by the breeder on-station with the superiority of those selected by the breeder in the farmer's field
- the effect of selection criteria (breeder vs. farmer) by comparing, in the farmer's field, the superiority over the farmer's cultivar of the lines selected by the breeder with the superiority of those selected by the farmer (this comparison will be extended to cover selections done by others, i.e., farm household members and/or neighbors.)

At the end of the first three years, it is expected that the number of selected lines will be small enough to stimulate the interest of the participating farmers, and possibly of some neighboring farmers, to grow one or more of them as commercial crops. The experimental material will be assembled and distributed by the barley breeders to ensure a uniform seed source.

References

Binswanger, H.P. and B.C. Barah. 1980. *Yield risk, risk aversion, and genotype selection: Conceptual issues and approaches.* Research Bulletin No. 3. Hyderabad, India: International Crops Research Institute for the Semi-Arid Tropics.

Byerlee, D. and T. Husain. 1993. Agricultural research strategies for favored and marginal areas: The experience of farming system research in Pakistan. *Experimental Agriculture* 29:155–171.

Ceccarelli, S. 1994. Specific adaptation and breeding for marginal conditions. *Euphytica* 77(3):205–219.

Ceccarelli, S. 1996. Positive interpretation of genotype by environment interactions in relation to sustainability and biodiversity. In *Plant adaptation and crop improvement*, edited by M. Cooper and G.L. Hammers. Wallingford, UK: CAB International.

Ceccarelli, S., S. Grando, R. Tutwiler, J. Baha, A.M Martini, H. Salahieh, A. Goodchild, and M. Michael. 2000. A methodological study on participatory barley breeding. I: Selection phase. *Euphytica* 111: 91–104.

Ceccarelli, S., S. Grando, A. Amri, F.A. Asaad, A. Benbelkacem, M. Harrabi, M. Maatougui, M.S. Mekni, H. Mimoun, R.A. El-Einen, M. El-Felah, A.F. El-Sayed, A.S. Shreidi, and A. Yahyaoui. 2001. Decentralized and participatory plant breeding for marginal environments. In *Broadening the genetic base of crop production*, edited by H.D. Cooper, C. Spillane, and T. Hodgink. Wallingford, UK: CAB International.

Galt, D. 1989. *Joining FSR to commodity programme breeding efforts earlier: Increasing plant breeding efficiency in Nepal.* Network Paper 8. London: Overseas Development Institute.

Grisley, W. 1993. Seed for bean production in sub-Saharan Africa: Issues, problems, and possible solutions. *Agricultural Systems* 43:19–33.

Hardon, J.J. and W.S. de Boef. 1993. Linking farmers and breeders in local crop development. In *Cultivating knowledge, genetic diversity, farmer experimentation and crop research*, edited by W. de Boef, K. Amnor, K. Wellard, and A. Bebbington. London: Intermediate Technology Publications, Ltd.

ICRISAT. 1996. *ICRISAT Asia region annual report 1995.* Semi-formal publication. Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Saade, M., F. Nassif, A. Amri, and H. El Baghati. 1993. *Constraints to the adoption of barley varieties in Morocco.* ICARDA Expert Report (Semi-formal publication). Aleppo, Syria: International Center for Agricultural Research in the Dry Areas.

Simmonds, N.W. 1991. Selection for local adaptation in a plant breeding programme. *Theoretical and Applied Genetics* 82:363–367.

Sperling, L., M.E. Loevinsohn, and B. Ntabomura. 1993. Rethinking the farmer's role in plant breeding: Local bean experts and on-station selection in Rwanda. *Experimental Agriculture* 29:509–519.