Increasing the Efficiency of Breeding through Farmer Participation

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Summary

Participatory plant breeding (PPB) -- defined as farmers' participation in selection of early segregating populations -- should become a component of formal plant breeding programs to exploit more efficiently specific adaptation, and therefore to mach more precisely crops to their environment, particularly in the case of marginal, difficult, stressful environments. PPB is the only possible approach to breed crops grown in unfavorable conditions and/or remote regions, in areas not sufficiently large to justify the interest of large breeding programs, and to breed for minor crops neglected by both private and public plant breeding programs.

The paper describes decentralized and participatory selection and the relationships between them. A number of methodological issues -- such as the choice of participating farmers, the number of farmers doing the selection, the gender of who does the selection, the number of lines to use, and comparison between decentralization and participation -- are discussed as aspects of a true partnership between breeders and farmers.

Participatory plant breeding should be linked not only with formal breeding programs -- providing a continuous flow of novel genetic variability -- but also with the informal seed supply system which can spread new varieties in the farmers' communities without the unnecessary requirements of the formal seed system.

Specific Adaptation and Participatory Breeding

The idea of farmers participation -- not necessarily only in breeding -- is neither new nor revolutionary (Rhoades and Booth, 1982; Sperling, *et al*., 1993; Farrington, 1996). In the case of breeding, we must remember that for 10,000 years women and men consciously have been molding the phenotype (and so the genotype) of hundreds of annual and perennial plant species, as one of their many routine activities in the normal course of making a living (Harlan, 1992). All the adaptation -- plant breeding -- was done by unschooled peasant farmers in the form of hundreds of distinct varieties (Duvick, 1996), presumably specifically adapted to the conditions of a particular farmer or farmers' group.

One of most debated issues in plant breeding is how to deal with interactions between genotype and environment (GxE). These are almost universally accepted as being among the major factors limiting the efficiency of breeding programs particularly when they are of crossover type -- that is when the rank of genotypes changes in different environments. We argued that breeding for favorable conditions has been successful because it is based on selection done in the equally favorable conditions of experiment stations. Breeding for favorable conditions also has usually a wide impact because favorable environments tend to be similar even when geographically distant. On the other hand, breeding for unfavorable conditions has been much less successful because of the G x E interactions of crossover type between experiment stations and farmers' fields (Ceccarelli, 1989) and because unfavorable environments can be very different from each other.

In general, modern plant breeding (or formal plant breeding) takes a negative attitude towards GxE interactions of crossover type, in the sense that only breeding lines with high average grain yield *across* locations -- widely adapted in space -- are selected, while lines with good performance at some sites and poor performance at others are discarded. Because lines with good performance in unfavorable sites and poor response to favorable conditions have a low average grain yield, they are systematically discarded. Yet they would be the ideal lines for farmers in unfavorable locations. This implies that improving specific adaptation to difficult conditions requires direct selection in the target environments, i.e. decentralized selection.

Decentralized selection is a term first used by Simmonds (1984) and defined as selection in the target environment (s). In the case of self-pollinated crops it consists in selection of early segregating populations (such as F_2) in a number of locations representing the target environment(s) (climate, soil, farming system and management) the breeding program aims to serve. Decentralized selection becomes selection for specific adaptation when the selection criterion is the performance in specific environments rather than the mean performance across environments.

Decentralized selection is different from **decentralized testing**, which is a common feature of breeding programs and takes place, usually in the form of multilocation trials and on-farm trials, after a number of cycles of selection in one or few environments (usually under high inputs). The last stages of decentralized testing have been improperly indicated as participatory only because farmers are allowed to visit the on-farm trials and express their opinion on the varieties being tested.

Decentralized selection of early segregating populations in the target environments using a bulk-pedigree method has been used by international breeding programs to avoid the danger of useful lines being discarded because of their relatively poor performance at the experiment station (s) (Ceccarelli *et al*., 1994).

Decentralized selection is expected to be a powerful methodology to fit crops to the physical (climate and management) environment. However, it does not benefit from the farmers' knowledge of the crops and the environment, and it may fail to fit crops to the specific needs and uses of farmers communities unless it becomes participatory. Participation of farmers in the very initial stages of the breeding process, when the large genetic variability created by the breeders is virtually untapped, is expected to exploit fully the potential gains from breeding for specific adaptation through decentralized selection by adding farmer's perception of their own needs and farmers' knowledge of the crop.

At ICARDA, farmers' participation has been therefore the ultimate conceptual consequence of a positive interpretation of genotype x environment interactions, i.e. of breeding for specific adaptation, rather than a social or political choice.

Issues in Farmers' Participation

Till 1996, farmers' participation in the ICARDA barley breeding program has consisted of informal discussions during field visits and occasional inspections and selection by farmers of breeding lines grown at ICARDA's experiment stations. During this stage, the most significant contribution of farmers to barley breeding for dry areas has been the formulation of a barley ideotype for dry areas characterized by tall plants and soft straw.

A crop which remains tall even in very dry years is important to farmers, because it reduces their dependence on costly hand harvesting; while soft straw is considered important in relation to palatability -- barley, both as grain and as straw, is the main animal feed in the area. It is obvious that these two characteristics represent a drastic departure from the selection criteria used in breeding high-yielding cereal crops -- short plants with stiff straw and high harvest index. Tall cultivars with soft straw are unsuitable for high-yielding environments because of their lodging susceptibility, and in a traditional breeding program would be discarded under the high-input conditions of the experiment stations.

This shows not only that farmers can significantly contribute to the success of a breeding program, but also that in farmers' participation breeders should be open to unexpected and unplanned contributions of ideas.

We began incorporating farmers' participation as a permanent component of a breeding program addressing difficult environments and low-input agriculture through a project supported by the Der Bundesminister für Wirtschaftliche Zusammenarbeit (BMZ).

The project area has an average annual precipitation between 200 mm and 450 mm. Barley is the main arable crop and farmers are still using landraces. Considerable phenotypic and genotypic heterogeneity exists both between landraces collected in different farmers' fields (even if designated by the same name) and between individual plants within the same farmer's field (Ceccarelli *et al*., 1987, 1995).

The adoption of new, improved barley varieties has been virtually nil in Syrian rainfed agriculture. Therefore, this crop and this environment provide a good test-bed to compare the efficiency of the following selection model: 1) decentralized and participatory, 2) decentralized non participatory, 3) centralized participatory, and 4) centralized non-participatory.

The preparation for the project started with informal discussions with farmers to make sure that they were willing to participate. It is essential in this stage that farmers are treated as true partners which implies that farmers' opinions have the same weight as breeders' opinions. It was in this framework that issues such as number of lines, plot size, frequency of selection, whether neighboring farmers can do selection in their field, scoring methods, access to quantitative data such as weight of straw and grain, were discussed. The emphasis was on the freedom of farmers to do what they believe it is important to do, to do it in way that makes sense to them and when they thinks it is appropriate. In this way a participatory project quickly becomes a farmers project in which breeders are participating.

A set of 208 lines and populations (200 lines representing a wide range of germplasm plus eight farmers' cultivars) are grown in (1) a high-input experiment station (Tel Hadya, ICARDA headquarters), (2) an experimental site managed as a farmer's field and used in the past for decentralized, non-participatory selection (Breda), and (3) nine farmers' fields under farmer's management practices in environments receiving between 200 and 450 mm annual rainfall.

The number and type of breeding lines was dictated by the objective of this research which is to test a number of hypothesis in relation to farmers' preferences. In the actual participatory breeding the number of lines will depend on the size of the breeding program and will be similar to the number used by the breeders in that stage of the breeding program.

Field locations represent a wide range of environments, in terms of both physical (soil type and fertility, elevation, rainfall, etc,) and farmers practices (fertilizer use, rotations, date and method of sowing, land preparation, etc.). The cooperating farmers, **"host farmers"**, who host the breeding plots and make individual selections, have been identified from the pool of participants in previous on-farm research as part of the long-standing Syria-ICARDA bilateral cooperative research program. Groups of local **"expert farmers"**, identified by the host farmers, will also perform group selections from their respective host farmer's fields.

During selection, the traits that farmers select for (and the criteria they use in their selection), as well as traits they select against, will be recorded and compared with objective measures of traits, including the yield and quality of grain and straw.

There will be four types of selection:

Centralized Non-participatory:	done by the breeder at Tel Hadya.
Decentralized Non-Participatory:	done by the breeder at Breda and at each of the eight farmers' fields.
Centralized-Participatory:	done by each of the eight farmers at Tel Hadya.
Decentralized-Participatory:	done by each farmer at Breda and in their own field (each farmer only selects in his/her field).

In the second year all host farmers will grow the lines selected by the breeder in Tel Hadya and in Breda. In addition each farmer will grow the lines he/she selected in Tel Hadya, those he/she selected in Breda, those he/she selected in his/her field, and those selected by the breeder in his/her field. Grain and straw yield data will be collected at each host farmer's field and at the experiment stations. The data collected in farmer fields as well as the seed will be made available to farmers to allow final selection based on yield and on seed characteristics. 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. However, in the experiment station, each host farmer will only select from the material grown at his site.

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. During the selection process, the criteria of both the farmers and the 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 among the material they selected themselves in the first year and from among the material selected in the first year by the breeder. 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.

Eventually, during the course of the project, we will monitor initial adoption of some of the lines and their use by the informal seed system, which is very active and efficient in the project area in the case of barley.

Role of women

In a number of countries, such as Ethiopia and Nepal, women regularly select barley spikes specifically to provide seed for the following year's crop.

One of the special nurseries distributed to Tunisia as part of the decentralized barley breeding described by Ceccarelli *et al*. (1997), was planted near Tejerouine, a village in southern Tunisia close to the border with Algeria. The nursery included 207 barleys types, mostly early segregating populations (F_4), together with check varieties. These were both the landraces grown in North Africa, such as Martin from Tunisia, Saida and Tichedrette from Algeria, Arig 8 from Morocco, and California Mariout and Athenais from Libya, some improved varieties (Rihane-03 and

ER/Apm), and one promising Tunisian variety, Manal 92. A check variety was planted every 10 entries, therefore each check variety was present more than once.

Visual selection was conducted by Dr. A. Yahyaoui, barley breeder at l'Ecole Superieure d'Agricolture de Kef, and by the host farming family with the results indicated in Table 1. Farmers were more selective than breeders. This is expected since breeders usually select not only lines that could become varieties, but also those which some useful specific traits, while farmers are presumably only interested in lines which could become cultivars.

The type of material selected was of interest. Martin, the local landrace, was present once among the 40 lines selected by the breeder, twice among the 13 lines selected by the farmer, and was never selected by the farmer's wife. She was the only one to select twice one of the two Algerian landraces, Tichedrette and once the other Algerian landrace, Saida. The farmer also selected Saida twice, but from the two plots not selected by his wife (Saida was present three times in the nursery). Therefore, although chosen from different plots, the farmer and his wife eventually agreed on at least one cultivar. Neither the farmer nor his wife selected improved cultivars. There were no attempts to select *within* segregating population.

Table 1. Number and % of lines selected by a breeder, a farmer and the farmer's wife, from a nursery of 207 barley breeding lines (Tejerouine, Tunisia, 1996)

Selected by	Nr. (%)	In common with:	
		Farmer	Farmer's wife
Breeder	40 (19.3)	2	3
Farmer	13 (6.3)	-	0
farmer's wife	14 (6.8)	-	-

Conclusions

A number of methodological issues in participatory plant breeding still need to be clarified. From a breeding point of view some of the most important questions to be answered are:

1. Do farmers and breeders use similar or different selection criteria?
2. How important is the environment where the material is selected and the person who does the selection? In other words, what is the key factor in increasing breeding efficiency: decentralization or participation?
3. Does participation increase the number of varieties adopted and the rate and the speed of adoption more than decentralization?

The answer to these questions would provide the basis for a very different type of breeding, characterized by a continuum between the formal breeders, with their comparative advantage in generating, on experiment stations, large amounts of variability, and the farmers, with their comparative advantage in exploiting that variability in their own farming systems and for their specific needs. In this continuum some of the key decisions, such as the choice of the parental material for further cycles of crosses and, to some an extent, the choice of breeding methods, will be made by the farmers.

In several crops and in many developing countries, only a very small percent of the total seed supply, particularly in the less favorable environments, is certified seed, i.e. coming from the formal seed system. The bulk of the seed comes from the so called informal seed systems, namely (1) purchased from markets, (2) obtained from other farmers, and (3) own seed saved from the previous year. The informal system deals with small quantities of seed, is semi-structured, operates at community level, and uses a wide range of traditional seed exchange mechanisms. A major advantage of participatory plant breeding is its ability to feed several new cultivars directly into the informal seed system bypassing the unnecessary and inefficient variety release-seed productionseed certification schemes able to accommodate only few cultivars.

Participatory plant breeding can not be limited to *ad hoc* studies conducted for a limited period of time to document indigenous knowledge and farmers' preferences. To be effective, participation should become a permanent feature of plant breeding programs addressing crops grown in agriculturally difficult and climatically challenging environments. To achieve this it is essential that farmers are considered as true partners and that they have access to the same type of information usually available to breeders.

For crops grown in remote regions, or for those considered as minor crops and therefore neglected by formal breeding, this could be the only possible type of breeding.

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