Decentralized-Participatory Plant Breeding

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A fundamental problem in plant breeding is the relationship between selection environment and target environment. As Falconer (1952) pointed out, direct selection in the target environment is always the most efficient. The selection efficiency decreases as the selection environment becomes increasingly different from the target environment.

Therefore, it is not surprising that plant breeding has been much more successful in those environments with the greatest similarity to those where most selection is usually conducted, i.e. the research stations where breeding material is customarily grown in near-optimum conditions. It is also not surprising that the most poverty-stricken farmers, living in unfavorable environments without the means to modify them through the application of water, fertilizers, herbicides and pesticides, are also those who continue to suffer from chronically low yields, crop failures and, in the worse situations, malnutrition and famine (Byerlee and Husain, 1993; Eyzaguirre and Iwanaga, 1996; Trutmann, 1996).

Plant breeders have notable successes in favorable environments, but they are often addressing the problems of poor farmers living in unfavorable environments by simply extending the same methodologies and philosophies applied to favorable, high-potential environments. They are counting on the so-called spill-over effect without considering the limitations associated with the presence of large Genotype x Environment (GE) interactions.

GE interactions are almost unanimously considered by plant breeders to be among the main factors limiting response to selection and, in general, the efficiency of breeding programs. When the sample from the population of selection environments is very different from the population of target environments, GE interactions usually gain in importance because they change the ranking of breeding lines. This change in ranking has been defined as crossover GE interaction (Baker, 1988).

Plant breeders distinguish between those interactions that change the ranking of genotypes in the same locations (or in the same population of target environments) over time causing large temporal variability, and those which consistently change the ranking of genotypes between different populations of target environments causing large spatial (or geographical) variability. We argue that farmers are mostly interested in avoiding or reducing temporal variability, while the majority of plant breeders (and obviously the seed companies) are mostly interested in avoiding geographical variability.

In the case of temporal variability, the objective should be to avoid GE interactions by stabilizing crop yields; this can be achieved by breeding heterogeneous populations (genetically similar to the old landraces) rather than uniform cultivars, such as pure lines or hybrids, or by growing different varieties at the same location. In the case of geographical variability, the objective should be to exploit GE interactions by breeding for specific adaptation within each population of target environments. This can be achieved by selecting directly in the target environments, a type of selection defined by Simmonds (1984) as decentralized selection. In such cases the breeding program has a number of selection sites, some representing one type of target environment, others representing a different type of target environment, and so on. Decentralized selection becomes selection for specific adaptation when it is based on the performance within each population of target environments rather than on the average performance across all sites and all years.

This strategy has two important consequences. Firstly, it adapts crops and cultivars to the environment, rather than changing the environment to fit the crops, and hence does not have harmful effects on the environment. Secondly, it leads to a reassessment of the importance of landraces in plant breeding: these old cultivars usually do not perform well under the high-input conditions of the research stations, but are very difficult to beat in low-input, marginal conditions (Ceccarelli, 1994).

Although decentralized selection is a powerful methodology to fit crops to the physical (climate and management) environment, crop breeding based on decentralized selection can still miss its objectives if it does not consider the farmers' knowledge of the crops and the environment. Unless it becomes participatory, such crop breeding may fail to fit crops to the specific needs and uses of farming communities.

In the very initial stages of breeding the large genetic variability created by the breeders is virtually untapped. By adding farmers' perceptions of their own needs and their knowledge of the crop at this point, it is possible to exploit fully the potential gains from breeding for specific adaptation through decentralized selection. The participation of farmers in the very early stages of selection offers a solution to the problem of fitting the crop to a multitude of both target environments and users' preferences (Ceccarelli et al., 1996; Kornegay et al., 1996).

Although decentralized selection and farmers' participation are conceptually unrelated, the acceptance of the former as a breeding strategy almost inevitably leads to the acceptance of the latter as a tactical necessity. Thus, there are sound scientific and practical reasons for farmer participation to increase the efficiency and the effectiveness of the breeding program (functional participation), even though farmer participation is often advocated mainly on the basis of equity (Ashby, 1997).

These concepts have been recently implemented in a participatory breeding project conducted in Syria and supported by BMZ (Der Bundesminister für Wirtschaftliche Zusammenarbeit, Germany). The objective of the project is to test an alternative way to produce improved varieties of crops grown in marginal environments such as barley.

The project operates in nine villages (Figure 1) chosen to represent differing amounts of annual rainfall (from less than 200 mm to nearly 350 mm), soil types, management practices, farm sizes, types of livestock ownership and formal education levels of the farmers.

The area encompasses a range of agroecological conditions, from high to low-potential environments for cereal production. Barley is the main winter cereal. It is planted in the fall, usually after the first rain (mid-October to mid-December) and harvested in May-June. It covers over 2 million hectares with little use of modern or improved varieties. At the wettest end of the area (350 mm of annual rainfall) and on fertile soils, farmers can obtain up to 5 t ha-1 of grain in a good season by using fertilizer. In contrast, at the driest end (less than 200 mm of annual rainfall), soils are generally poor, input levels are low, and grain yields vary from nothing to around 1.5 t ha-1. National average barley grain yields are stagnant at a low of 0.65 t ha-1.

Barley is the principal feed crop for sheep in Syria, being used as: a) grain, chopped straw and stubble grazing in years with adequate rainfall for harvest; b) grazing of the standing crop at maturity in dry years when low yields do not justify harvesting; and c) winter green grazing before stem elongation, under all conditions.

Landraces are predominant (99% of the area), they are exclusively two-row types, and known as either Arabi Abiad (white-seeded), common in slightly better environments (250 to 350 mm) or Arabi Aswad (black-seeded), common in harsher environments (< 250 mm).

Considerable phenotypic and genotypic heterogeneity exists both among landraces collected in different farmers' fields (even if designated by the same name) and among individual plants within the same farmer's field (Ceccarelli and Grando, 1998). Farmers in dry areas consider that grain and straw quality of the black-seeded landrace is better that the white-seeded one.

In 1997 we planted 208 barley lines in the field of one farmer in each village. The lines were a random sample of those representing the early stages of the breeding process (lines that are normally planted only at the research station). The lines represented different types of germplasm such as two and six-row, modern and landraces, uniform lines and segregating (heterogeneous) populations and black and white seed color. The lines were also planted at two research stations, representing a favorable and an unfavorable environment, respectively.

Selection in each village was done by the host farmer as well as by the national breeder from the Syrian Directorate of Agriculture and Scientific Research. Each farmer and the breeder also selected in the two research stations. In five of the nine villages we also conducted group selection in which a group of about nine farmers scored each plot and indicated reasons for selecting or discarding specific plots. In this way the project compares the following four strategies of selection:

1. selection by farmers in their own fields (decentralized-participatory selection),
2. selection by farmers in the research station (centralized-participatory selection),
3. selection by the breeder in farmers fields (decentralized-non participatory selection),
4. selection by the breeder in the research station (centralized-non participatory selection).

In the second year (1998) each of the nine participating farmers planted the lines selected under the four strategies, and a second cycle of selection was conducted with the same procedures as in 1997. This is being repeated in 1999.

The most important findings are the following (Ceccarelli et al., 1999):

1. The host farmers were able to handle the large population of entries and to take a number of

observations (Figure 2) during the cropping season using different scoring methods;

2. Farmers did not use the performance of entries on-station for their final selection;
3. In the first year, when the same lines were planted in the nine farmers fields and the two research stations, in their own fields farmers selected about one-tenth of the number of entries selected by the breeder, while on-station the farmers selected, on average, about half the number of lines selected by the breeder. The difference was presumably a consequence of a different selection procedure. The farmers' selection was based only on the performance of the lines in their respective fields (they did not use their observations on station, although these were available to them) The breeder's selection was based on the performance of the lines in all the eleven environments. Eventually, he selected two groups of entries, one for high-rainfall and one for low-rainfall areas. The first group was based on the scores given in Tel Hadya and in locations 1, 2 and 9, the second on the scores given in Breda and in locations 3, 4, 5, 6, 7 and 8. In the second year, when the lines planted at each site were different, the breeder could not select for performance across locations and the selection pressure of the breeder and the farmers were the same.
4. For some broad attributes, such as modern germplasm versus landraces, selection was mostly driven by environmental effects. Landraces were selected more often in the dry sites, and the modern cultivars more often in the wet sites. Other attributes were partly environmentally driven and partly based on individual farmers' preferences. There were no preferences between fixed or segregating populations;
5. There was more diversity among farmers' selections in their own fields than among farmers' selections on research stations and among breeder's selections, irrespective of where the selection was conducted;
6. Kernel size, grain yield, and total biomass were the most frequently selected characteristics by both the breeder and the farmers. Taller entries were also selected by both the breeder and the farmers, particularly in environmentally stressed locations;
7. In their own fields, farmers were slightly more efficient than the breeder in identifying the highest yielding entries. The one exception was a farmer who did not select any of the highest yielding entries in his own field. The breeder was more efficient than the farmers in selecting in the research station located in a high-rainfall area, but less efficient than the farmers in the other research station located in a low-rainfall area;
8. There were significant changes in selection preferences (both by farmers and breeders) under two different rotations, indicating an important (yet unplanned) advantage of decentralized breeding, namely the possibility of adapting the breeding material to the changes occurring in the farming systems and agronomic practices in the target environments;
9. Decentralization had a more important role than participation in maintaining/enhancing genetic diversity. The total number of entries left after two cycles of decentralized-participatory selection was double the number of entries left after two cycles of centralized-non participatory selection in Breda and three times higher than the number of entries left after two cycles of centralized-non participatory selection in Tel Hadya. However, the reduction in the total number of entries does not give a full picture of the decrease in diversity associated with centralized selection. In fact, both in Tel Hadya and in Breda, some type of germplasm disappeared after two cycles of selection. This was the case of landraces and black-seeded types in Tel Hadya, and of the six-row types in Breda. The same phenomenon, i.e. the disappearance of some germplasm types, does occur also in decentralized-participatory selection, but different germplasm types disappear in different locations. The frequency of landraces, which changed in opposite directions depending on whether centralized-non participatory selection was conducted in Tel Hadya or in Breda, also changed in opposite directions in decentralized-participatory

Fig. 2. Change in the frequency of modern and landraces after two cycles of centralized-non participatory selection in Tel Hadya (wet research station) and two cycles of decentralized-participatory selection in Ebla (site #2, wet) and Melabya (site # 7, dry).

selection depending on whether the location was dry or wet. Figure 3 shows the case of Ebla, a wet site, where two cycles of decentralized-participatory selection led to the disappearance of landraces, like in the centralized-participatory selection in the wet research station, while in Melabya, a dry site, two cycles of decentralized-participatory selection led to the disappearance of modern germplasm.

Farmers' skills and self confidence increased considerably as indicated by their ability to conduct the trials with no supervision, their suggestions about potential parents for crosses, and their ability to illustrate the project to other farmers.

Farmers' reactions were very interesting. One asked why the same approach was not used with bread wheat and durum wheat. Another, realizing for the first time that there could be many different types of barley, asked for lines with a darker seed than the black-seeded landrace.

While visiting the research station and seeing several thousand different types of barley, most farmers were interested to know how we made them. We showed them how crosses were made, and the different types of barley generated by a single cross. In the second year we found a farmer standing in the middle of his field staring at two lines and wondering what would come from making a cross between the two. Indeed, at the end of the second year, one farmer wanted to design the trials himself for the following year.

During the first two years of the project some of the human relationships changed. For example, in one of the villages, a farmer's wife suddenly started sitting in the same room with us 'foreigners' and participating in the discussion. Such a change obviously makes it much easier to find out directly the preferences of women that would be otherwise 'filtered' through the males of the family.

These reactions and changes may seem small, but they indicate the potential for making a major impact by this approach, not merely in terms of variety adoption, but also by skill building, increased female participation, and the increased capacity of farmers to actually redirect plant breeding and shape agricultural research towards their needs.

The project had a major impact on National Agricultural Research Systems. All the national scientists who visit ICARDA are exposed to the activities of this project, and many of them at the end of their visit ask ICARDA to help in developing similar activities in their own countries. As a result, there are now participatory barley breeding projects in Tunisia and Morocco (funded by the International Development Research Center, Canada), in Yemen (funded by the System Wide Program for Participatory Research and Gender Analysis), in Ethiopia (funded by the Government of the Netherlands), and in Eritrea, partially supported with core funds from ICARDA. Participatory barley breeding projects are in preparation in Jordan, in collaboration with the University of Jordan in Amman, the National Center for Agricultural Research and Transfer of Technology, the Jordan University of Science and Technology, and the Jordanian Hashemite Fund for Human Development, and in Egypt, in collaboration with the Agricultural Research Center.

In May 1999, ICARDA organized a 'Farmer Participatory Workshop' for nearly 50 scientists from 16 different countries. Sponsored by the Islamic Development Bank, FAO and the System Wide Program on Participatory Research and Gender Analysis (SWP PRGA), the workshop generated considerable interest towards farmer participatory research and promoted its use as a new research strategy. A number of recommendations were made by the workshop members whose presentations and discussions will be published in a publication for practitioners and policy makers.

This work demonstrates that it is possible to organize a plant breeding program so that farmers become major actors in selection, testing and multiplication of new cultivars. Participatory plant breeding recognizes that, regardless of whether the breeder likes it or not, it is the farmers who ultimately decide whether or not to adopt a new variety. It reduces the chances of developing cultivars that, for reasons unknown or overlooked by the breeder, are not acceptable to farmers. Participatory plant breeding may be the only possible type of breeding for crops grown in remote regions, for crops for which a high level of diversity is required within the same farm, or for those considered as minor crops and therefore neglected by formal breeding.

Although we are still moving the first steps in participatory plant breeding, some general features have started to emerge. Firstly, the main obstacle to participatory plant breeding is neither the interest of the farmers, nor their ability to handle breeding material, but perhaps the reluctance of breeders to share with others the paternity of new varieties. Secondly, a critical step in participatory research seems to be the first contact with farmers when the scientists should be able to establish a relationships where partners have equal rights; this is achieved by listening to the farmers (and not only talking to them – a too often quoted definition of farmers participation), and even more to be prepared to accept their opinions, suggestions and criticisms. During the first year of the project in Syria we found that ill-adapted varieties play an important role in conveying the message that breeders can make mistakes, and therefore make them more acceptable to farmers. Thirdly, participatory plant breeding, and probably participatory research in general, improves with time, in the sense that through their continuous interaction, scientists and farmers know each other better and better, and the increased understandings of each other's skills, interests, motivations, problems, limitations translate into a gradually more equitable collaboration. Another level of improvement, specific to participatory plant breeding, is the increase amount and quality of demands that farmers poses to the formal breeding program as a consequence of their increase awareness of what plant breeding can do.

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