Decentralized-Participatory Plant Breeding: a Link between Formal Plant Breeding and Small Farmers.

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Summary

Participatory plant breeding is discussed not only for its advantages in exploiting specific adaptation and hence in fitting crops to the environment, but also as the only possible type of breeding which is possible for crops grown in unfavorable conditions and/or remote regions, and in areas not sufficiently large to justify the interest of large breeding programs.

The paper describes the evolution of a typically centralized international breeding program towards non-participatory decentralization, and eventually to a decentralized and participatory approach. A number of methodological issues C such as the choice of participating farmers, number of lines to use, and comparison between decentralization and participation C are discussed while illustrating a project on participatory barley breeding in Syria which began in 1996.

Participatory plant breeding C i.e. farmers= participation in selection of early segregating populations C should become a permanent feature of formal breeding programs. It should be linked both with the formal breeding system which can provide a continuous flow of novel genetic variability, and with the informal seed supply system which can spread new varieties in the farmers= communities without the unnecessary requirements of the formal seed system.

Introduction

Formal plant breeding has been beneficial to farmers who either enjoy favorable environments, or could profitably modify their environment to suit new cultivars. It has not been so beneficial to those farmers (the poorest) who can not afford to modify their environment through the application of additional inputs (Byerlee and Husain, 1993). Poor farmers in marginal environments continue to suffer from chronically low yields, crop failures and, in the worse situations, malnutrition and famine. Because of the past successes, conventional plant breeders have tried to solve the problems of poor farmers living in unfavorable environments by simply extending the same methodologies and philosophies applied earlier to favorable, high potential environments. Moreover, farmers in favorable environments who use high quantities of inputs are now concerned with the adverse environmental effects and the loss of genetic diversity.

The essential concepts of conventional or classical plant breeding can be summarized as follows:

(a) Selection is highly centralized and is conducted under the high-yielding conditions of experiment stations;

(b) Cultivars must be uniform (e.g. in self-pollinated species must be pure lines), and must be widely adapted over large geographical areas; this is obtained by selecting for average performance in multi-location testing;

(c) Locally adapted landraces must be replaced because they are low yielding and disease susceptible;

(d) Disseminating seed of improved cultivars must take place through mechanisms and institutions such as variety release committees, seed certification schemes and governmental seed production organizations. The requirements of these mechanisms and institutions are so strict that one wonders whether breeders are more concerned about the requirements of the formal seed systems than those of the farmers;

(e) The end users of new varieties are not involved in selection and testing; they are only involved at the end of the consolidated routine (breeding, researcher managed trials, verification trials), to verify if the choices made for them by others are appropriate or not.

In situations where the objectives are to improve yield and yield stability for poor farmers in difficult environments, plant breeding programs rarely question the efficacy of this conventional approach. The implicit assumption is that what has worked well in favorable conditions must also be appropriate to unfavorable conditions, and very little attention has been given to developing new breeding strategies for low-input agriculture in less favorable environments. There is mounting evidence that this assumption is not valid, and that, in fact, the special problems of marginal environments and their farming systems must be addressed in new and innovative ways.

In those few cases where applying conventional breeding strategies to marginal environments has been questioned, it has been found that:

(a) Selection in well managed experiment stations tends to produce cultivars which are superior to local landraces only under improved management and not under the low-input conditions characteristic of the farming systems (Galt, 1989; Simmonds, 1991; Ceccarelli, 1994, 1996). The result is that many new varieties are released but few, if any, are grown by farmers in difficult environments;

(b) Poor farmers in difficult environments tend to maintain genetic diversity in the form of different crops, different cultivars within the same crop, and/or heterogeneous cultivars to maximize adaptation **over time** (stability), rather than adaptation **over space** (Binswanger and Barah, 1980). Adaptation over time can be improved by breeding for specific adaptation, i.e. by adapting cultivars to their environment (in broad sense) rather than modifying the environment to fit new cultivars. Since diversity and heterogeneity serve to reduce risk of total crop failure due to environmental variation, farmers may not abandon traditional cultivars;

(c) When the appropriate cultivar is selected, adoption is much faster through non-market methods of seed distribution (Grisley, 1993), and indeed for many crops in difficult environments the informal seed supply system is the main if not the only source of seed, particularly for small farmers; and

(d) 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 *et al.*, 1993). Typical examples are crops used as 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.

Because the concepts of conventional plant breeding are not questioned, the blame for the non-adoption of new cultivars is variously attributed to the ignorance of farmers, the inefficiency of extension services, and the unavailability of seed of improved cultivars. Thus, enormous resources continue to be invested in a model of breeding which is unlikely to succeed in unfavorable agroclimatic conditions.

The contrast between the reality of the farming systems and the plant breeding philosophies is particularly striking in developing countries. This is not surprising. Most of the breeders from developing countries have received their training in those rarely-questioned breeding principles enshrined in developed countries.

Specific Adaptation and Decentralization

Interactions between genotype and environment (GxE) are almost universally accepted as being among the major factors limiting response to selection and, hence, the efficiency of breeding programs (Ceccarelli, 1989). GxE interactions become important when the rank of genotypes changes in different environments. This change in rank has been defined as a crossover GxE interaction. When there is G x E interaction of crossover type between experiment stations and farmers= fields, it is not surprising that selection in high-input experiment stations does not allow the identification of the best genotypes for poorer conditions, and promotes genotypes which are in fact inferior in stressful conditions.

Formal breeding has taken a negative attitude towards GxE interactions of crossover type, in the sense that only breeding lines with low G x E interaction (that is high average grain yield *across* locations and years) 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. What this implies is that specific adaptation to difficult conditions must be found through direct selection in the target environments C not just on experiment stations.

To accommodate the concept of specific adaptation in a breeding program with an international mandate, we have started to decentralize **selection** to NARS in specific geographic areas in 1991. The first geographic area to be chosen was North Africa because of its importance (it grows nearly 5 million hectares of barley), and because in the entire area only six rows barley are grown. In the five North African countries the scheme shown in Fig. 1 is now fully implemented.

This decentralized selection of early segregating populations in the target environment largely avoids the danger of useful lines being discarded because of their relatively poor performance at the experiment station (Ceccarelli *et al*., 1994). It will be noticed from Fig. 1 that decentralization begins as early as the F_3 bulks (when enough seed is available), without any selection at ICARDA headquarters in the F_2.

Decentralization from international to national breeders is also much Agreener@ because it adapts crops to an environment, rather than viceversa, fewer chemical inputs are needed and biodiversity benefits because it favors the deployment of more varieties. Decentralization from international to national programs is in fact a drastic departure from the traditional one-way, "top-down" interaction between international and national programs (Simmonds and Talbot, 1992).

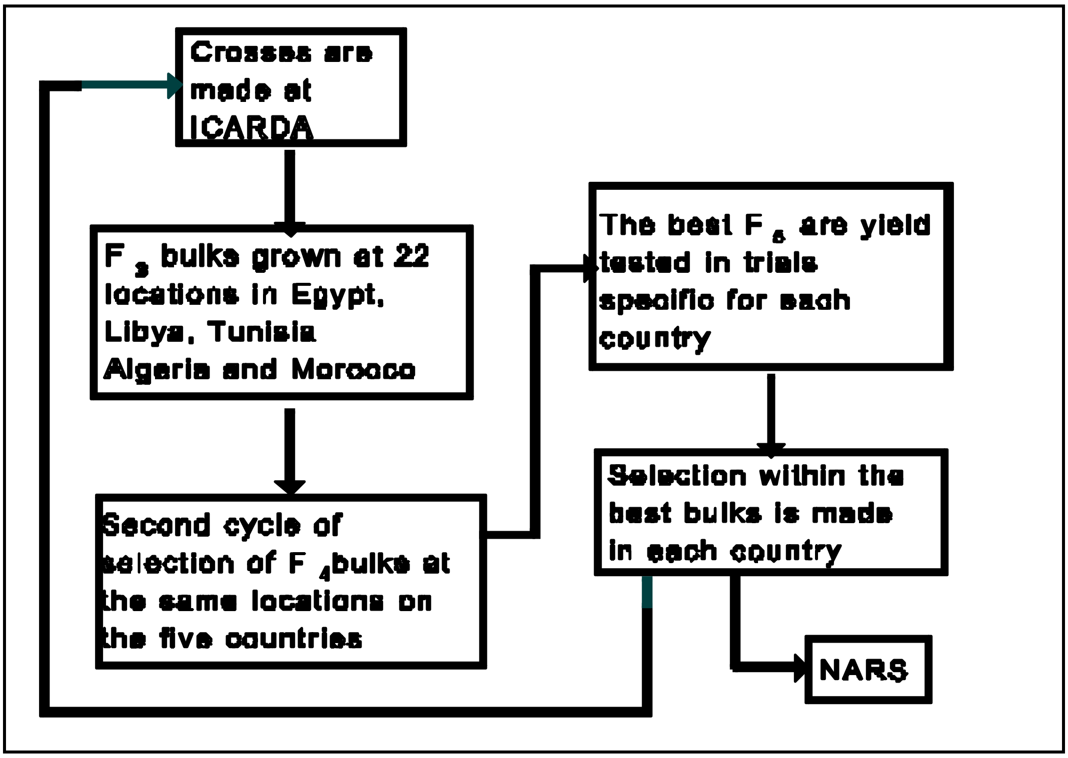

Fig. 1. Scheme of Decentralized Barley Breeding between ICARDA and five NARS in North Africa.

However, our decentralized barley breeding for North Africa, although achieving NARS participation, does not necessarily involve farmers. Therefore, this type of decentralization may not respond to the needs of resource-poor farmers if it is only a decentralization from the experiment station of the IARC to the experiment station of the NARS; the latter is often no more representative of the difficult environments where the crop is grown. If we are to exploit the potential gains from specific adaptation, selection needs to involve farmers under their own conditions. Therefore, at ICARDA farmers= participation is viewed as necessary to achieve all the potential advantages of decentralization.

From G x E Interaction to Farmers= Participation

Farmers' participation in the ICARDA barley breeding program to date has been occasional and has consisted of discussions during field visits and occasional inspection and selection by farmers of breeding lines. The most significant outcome so far has been the inclusion by the breeders of plant height under drought and softness of the straw as selection criteria in breeding barley for dry areas.

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. It is obvious that these two characteristics represent a drastic departure from the typical selection criteria used in breeding high-yielding cereal crops - short plants with stiff straw and high harvest index. Cultivars possessing the two characteristics considered important by farmers in dry areas would be unsuitable for high-yielding environments because of their lodging susceptibility, and in a traditional breeding program will not be made available to farmers C a further indication of the importance of specific adaptation.

Barley Breeding by Syrian Farmers

In 1996 we began testing the possibility of incorporating farmers= participation as a permanent feature of a breeding program addressing difficult environments and low-input agriculture. We are doing this through a three years research project supported by the Der Bundesminister für Wirtschaftliche Zusammenarbeit (BMZ).

This research is conducted in the northern part of the Fertile Crescent lying in the Syrian Arab Republic. The area has average annual precipitation between 350 mm and 200 mm and encompasses a range of agroecological conditions, all of which may be considered as low-yielding environments for cereal production. Arable land is predominantly cultivated with barley landraces. The landrace barley cultivars are two-row, and known locally as *Arabi Abiad* (white-seeded) and *Arabi Aswad* (black-seeded). The first is common in slightly better environments (between 250 and 350 mm rainfall) and the second in harsher environments (less than 250 mm rainfall). 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 secret to barley's popularity among farmers and its continuing spread across the agricultural landscape, despite the failure to improve yields, lies in its adaptation to very harsh conditions and in its use as feed for small ruminants, essentially sheep and goats. Barley grain and straw are the most important source of feed for the small ruminants, which are the main source of meat, milk, and milk products, particularly for the rural populations.

Farmers consider that the quality of both the grain and the straw of the black-seeded landrace is better than that of the white-seeded. However, this has never been tested either in the field or under laboratory conditions, and the linkages between desirable qualities and specific uses are not clear.

The adoption of new, improved barley varieties has been virtually nil in Syrian rainfed agriculture. So this crop and this environment seem to be a good model to test the efficiency of decentralized and participatory breeding in comparison with decentralized but non participatory, centralized and participatory and centralized and non-participatory models.

A common set of 208 lines and populations (200 breeding lines representing an extremely wide range of germplasm plus eight farmers' cultivars) will be grown as unreplicated nursery with plots of 12 m^2 (8 rows at 20 cm distance, 7.5 m long) in three types of locations: a typically well-managed experiment station (Tel Hadya, ICARDA headquarters), an experimental site managed as a farmer=s field and used in the past for decentralized non-participatory breeding (Breda), and eight farmers' fields under farmer's management practices.

The number of breeding lines used in this research is much higher that the one used in previous studies of this type. This is due to the need to include as much diversity as possible for traits such as row type (two- *vs*. six-row), phenology (early, medium and late-maturing types), plant height (tall vs. dwarf), lodging resistance (susceptible vs. resistant), disease resistance (susceptible vs. resistant), seed color (from white to black), stem size (from thin to thick), and others. Also, there was the need to include both landraces and modern varieties with sufficient diversity within each group. The breeding lines include both pure lines and heterogeneous populations to test the attitude of farmers towards heterogeneity, as opposed to the conventional breeders' propensity for homogeneity.

Discussions with farmers, as well as previous occasional participation of farmers in selection of breeding lines in the experiment stations, would indicate that the number of lines used in participatory work does not necessarily have to be small. Probably the optimum number varies in different environments/countries and can not be standardized.

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 will host the breeding plots and will make individual selections, have been recruited from the pool of participants in previous on-farm research as part of the long-standing Syria-ICARDA bilateral cooperative research program. Before selection, groups of local **"expert farmers"** will be identified and recruited on the basis of reputation, key farming contacts, past performance, representativeness of producer and consumer categories, and self-selection. The expert-farmer groups, together with the host farmers, will perform group selections from their respective host farmer's germplasm collections.

During selection, the traits that farmers select for (and the criteria they use in their selection) will be recorded by the breeders, economists and anthropologists and compared with objective measures of traits, including the yield and quality of grain and straw, by barley breeders and by animal nutritionists.

There will be four types of selection (see Fig. 2):

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 field).

The timing and the frequency of selection will be based on the information obtained in a parallel study of indigenous knowledge. Following a group selection procedure similar to that used by ICRISAT in Rajasthan, the expert farmer groups will be asked to select material from amongst those grown by their host farmers 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 members of the groups when they make their choices. There will be detailed discussions, including both the expert farmer groups and the host farmer and breeders, regarding the cultivars selected and the criteria used in selection, farmer observations, expected performance, and crop management practices.

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. 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.

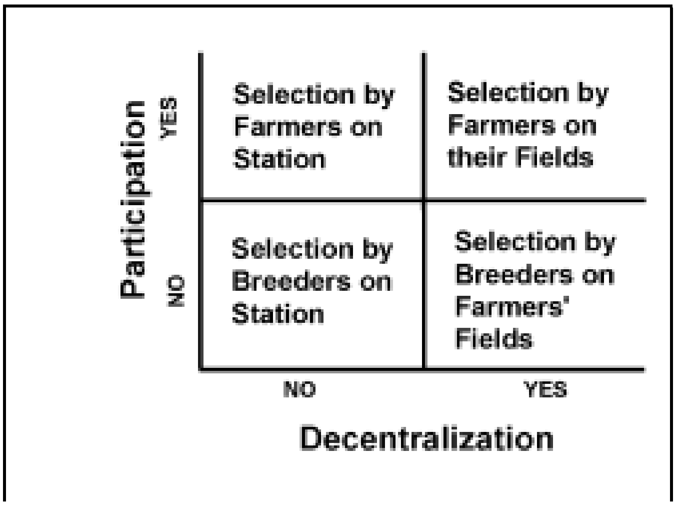

Fig. 2. Decentralization and Participation.

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.

Conclusions

The research project described in the paper will help to clarify some of the methodological issues in relation to participatory plant breeding, intended as participation of farmers in the selection of early segregating populations. From a breeding point of view some of the most important questions that will be answered are:

1. Do farmers and breeders use similar or different selection criteria?
2. Which is more important C the environment where the material is grown or 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 breeder, with his/her capacity to generate, on experiment stations, large amounts of variability, and the farmer, with his/her comparative advantage in exploiting that variability in his/her own farming system and for his/her specific needs (Fig. 3).

Fig. 3. Links between formal plant breeding, farmers and informal seed system.

Figure 3 illustrates that participatory plant breeding can not be limited to *ad hoc* studies conducted for a limited period to document indigenous knowledge and farmers= preferences. To be completely effective, participation should become a permanent feature of plant breeding programs addressing crops grown in agriculturally difficult and climatically challenging environments. 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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