PARTICIPATORY APPROACH FOR VARIETAL IMPROVEMENT - A REVIEW

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ABSTRACT

The G x E interactions is the main reasons for the failure of formal breeding programmes to several small, resource poor farmers. Farmers' participation in selection under their own environmental and agronomic conditions also will speed up the transfer and adoption of new varieties without the involvement of complex and often inefficient mechanisms of variety release, seed certification and production. Farmers involvement in the early stages of a plant breeding programme involves eliciting farmers criteria for ranking alternative materials or contrasting plant characteristics in order of preference, and then searching for parents which order some of the desired traits. However, as farmer participation in the later stages of varietal selection tends to coincide with seed multiplication of the most promising material, it can be very advantageous for farmers to take over responsibility for adaptive varietal testing, multiplication of the locally adopted materials and dissemination of seed.

The Green Revolution provides the most dramatic case for illustrating the general trend of the relationship between productivity, technology and biodiversity in the recent past. Science and technology were systematically applied to the goal of raising yield in rice and wheat in order to meet the challenge of feeding a rapidly growing global population. The technologies developed to increase the productivity of the worlds major food grains combined with high external input agriculture and commercial pressures favored a very narrow range of the most productive, input responsive, new varieties of rice and wheat. Although this was very successful in staving off widespread famine in India, it had the consequence of greatly reducing the tremendous diversity found within and between the landraces developed as a result of centuries of farmer breeding and selection (Frankel, 1970).

In modern agricultural systems, the traditional varieties of principal crops have been replaced by improved high yielding varieties produced by specialized breeding enterprises. Most of the cultivars grown by farmers are old and that a few of the released cultivars are widely grown.

Farmers participation research can help to reduce the time involved in post development testing of new breeding lines, and can reduce the number of unacceptable varieties being released. Farmers, like breeders, have their own criteria by which they evaluated new varieties. The success of a new variety depends on how many of the farmers criteria are incorporated in to the breeding lines and how great is the variety by environment interaction. These mechanisms, like the breeding methodologies and philosophies of formal breeding programmes are not used by most resource poor farmers as their main seed supply. Most of the seed used by these farmers is either produced on the farm, acquired from neighbors or purchased from local markets. These informal sources of seed must be fully understood and exploited if resource poor farmers have to benefit from plant breeding.

The advantage of farmers participation are non requirement of research station land and the insurance that all farmers relevant traits, including post harvest traits, are

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appropriately evaluated.

Improved seed is of basic importance in agriculture. It is the key to optimum use of natural resources and according to its provenance and the breeding goal, seed determine the requirements for inputs such as pesticides, fertilizer and agricultural technology. The interaction between international and national programmes has been largely a one way, “top down” process (Simmonds and Talbot, 1992) where international programmes develop germplasm, distribute it as “international nurseries”, and national programmes test and eventually release it as varieties. Formal, or institutional, breeding has been highly efficient in improving yield levels of several crops. However, its efficiency has remained largely confined to favourable environments, or to environments which could be made favourable by adding fertilizer and irrigation, and by chemical control of weeds, pests and diseases.

CHARACTERISTICS OF FORMAL BREEDING PROGRAMMES

1. They generally produce genetically uniform cultivars (pure lines, clones, hybrids)
2. They do not involve the farmers in any of the steps which will eventually lead to new cultivars, except perhaps in the final field testing of a few promising lines.
3. They promote cultivars which can be grown over large areas (widely adapted in a geographical sense).
4. They are largely conducted either in good environments or in well managed experiment stations where growing conditions are optimum or near optimum.
5. In most grain crop selection is almost exclusively for grain yield and disease resistance.

ASSUMPTIONS OF FORMAL BREEDING PROGRAMMES

1. Selection must be conducted under good growing conditions where heritability is higher and therefore response to selection is also higher.
2. Yield increases can only be obtained through replacement of locally adapted landraces (Brush 1991) which are low yielding and disease susceptible.
3. Breeders know better than farmers the characteristics of a successful cultivar.
4. When farmers do not adopt improved cultivars it is because of ineffective extension and/or insufficient seed production capabilities; the hypothesis that the breeder might have bred the wrong varieties is rarely considered.

INVolVEMENT OF FARMERS IN BREEDING PROGRAMME

Farmer participation in formal plant breeding spans a very broad set of activities along a continuum ranging from the involvement of farmers in helping plant breeders to develop the plant ideotype, to decision making about the release of varieties and seed production. The development of the plant ideotype with farmers can be accomplished by involving farmers in a dialogue about desirable plant characteristics, their presence and absence in known landraces, and the kinds of traits farmers would like to introduce.

Farmers involvement in the early stages of a plant breeding programme involves eliciting farmers criteria for ranking alternative materials or contrasting plant characteristics in order of preference, and then searching for parents which order some of the desired traits. Then farmers can take part in active selection among the progeny. Active farmer participation in evaluating segregating populations in still unusual, but involving farmers in the evolution of advanced lines, whether in breeder’s nurseries on station, or in multilocational varietal traits on farm, is
increasingly recognized as a useful way to generate timely feedback to breeding programmes about the potential acceptability of new materials.

However, as farmer participation in the later stages of varietal selection tends to coincide with seed multiplication of the most promising material, it can be very advantageous for farmers to take over responsibility for adaptive varietal testing, multiplication of the locally adopted materials and dissemination of seed. Experience with this approach shows that new varieties selected with farmers participation methods are better adopted locally than those recommended by researchers working on their own, and that significant widespread adoption and impact can be achieved by varieties selected together with farmers (Sperling et al., 1993). The implications of farmer participation, especially in the early stages of selection (e.g. before the F₄ or F₅ generations), for plant breeding methods are less well understood, but there are a growing number of practical experiences with the approach which lend themselves to systematic assessment of the relative advantages of different methods. It is well understood that participatory breeding requires a significant degree of decentralization of the breeding effort, but the organizational implications for national breeding programmes, for example, of this type of decentralization have yet to be identified.

Participatory breeding, combined with decentralized selection, has at least two advantages. It allows the individual farmers to (i) meet their needs for a diversified portfolio of varieties in order to manage risk, and (ii) satisfy different end uses. Also, it allows a diverse set of farmers to meet individual needs which are themselves diverse because of differences in wealth and agronomic conditions on their farms. Participatory approaches can be grouped in to (a) Participatory plant breeding and (b) Participatory varietal selection. (a) Participatory plant breeding (PPB)

Participatory plant breeding (PPB) is the decentralized breeding controlled by plant breeders to various degrees of farmer involvement in the breeding process. The fundamental differences between the two forms of breeding were clarified and considered as a continuum from breeder controlled to farmer controlled systems of breeding and selection.

The methods used in PPB are poorly documented, since there are no reports in the literature of a completed participatory plant breeding programme. PPB can benefit greatly by linking local plant genetic resource management institutions. The release of well adopted varieties, developed in cooperation with farmers, may result in serious genetic erosion, similar to the release of conventional modern varieties, if distributed without complementary action.

The two types of PPB programmes are recognized, one consultative type and another is collaborative type. In consultative PPB, farmers are consulted at every stage in order to set relevant goals and choose appropriate parents, and in collaborative PPB, farmers grow the early, variable generations and select the best plants amongst them on their own fields (Chopra, 2000).

PPB is a logical extension of participatory varietal selection (PVS). If it is desirable to involve farmers in selection of cultivars then there is no need to wait until there are finished products. Farmers can be involved in selecting among segregating material. However, the first recourse should be to PVS since PPB is more resource consuming. PPB has to be used when PVS has been tried and failed, or when the search process has failed to identify any suitable candidate cultivars.

The major target of PPB efforts has been on (Chopra, 2000)-
1. Self pollinated species.
3. Local races as the parents in programme.
4. Selection for specific adaptation under target environments.
5. Decentralization of testing procedures.

Advantages of PPB are (Chopra, 2000):
1. At least one parents of any attempted cross in well adapted to local environment.
2. Interaction between genotype and location are greatly reduced because selection is done in the target environment.
3. Local parent is already stable in performance against year to year environmental variations.
4. Fewer crosses need to be made. This allows for larger F2 and F3 populations to be screened leading to greater probability of identifying the desired recombinations.

(b) Participatory varietal selection (PVS)

Participatory varietal selection involves the selection by farmers of material under test in the plant breeding programme. PVS is move to accommodate non conventional approach to varietal selection because it is not very demanding on resources and technical expertise. It is to identify preferred cultivars has three phases: identifying farmer's needs, searching for suitable material to test with farmers and experimentation of farmers fields. PVS involves the selection by farmers of non-segregating, characterized products from plant breeding programmes. Such material includes released cultivars, varieties in advanced stages of testing and advanced non-segregating lines. In contrast, PPB involves farmers selecting genotypes from genetically variable, segregating material.

The difference between PVS and PPB may not appear to be great at first sight. However, PPB requires more resources than PVS, and PVS identified material that can be adopted more rapidly by the formal seed sector (Witcombe and Joshi 1995). Participatory research for varietal breeding and selection can best be defined as participatory varietal selection, since farmers were given near finished or finished products to test in their field (Maurya et al., 1988 and Sperling et al., 1993). Assumption in the PVS of released cultivars is that cultivar replacement rates are lower than optimal because farmers have never seen a range of new cultivars.

METHODS OF PARTICIPATORY PLANT BREEDING

Participatory research methods must be adapted to the need of plant breeding, breeding methods must be modified for the participatory approach, and communities must be organized and motivated for their participation. All of these three preconditions are now sufficiently developed for the wider adoption of participatory methods in plant breeding. Participatory research methods provide a rapidly evolving framework for fruitful involvement of farmers in technology development.

Farmers have definite requirements for the varieties they choose, and can work together successfully with breeders, starting at a very early stage in the breeding process, to select mutually acceptable materials. By involving farmers in an earlier stage of the breeding process than is usual, it may be possible to incorporate their preferences and expertise in a more systematic manner. Experience involving farmers early in the evaluation and screening of advanced lines has shown that bean varieties selected with farmer participation are better adapted locally than those selected by breeders working on their own (Sperling et al., 1993). Although the advantages of decentralizing the variety testing process are well understood by plant breeders, it is still unusual to involve farmers in determining desirable traits to be incorporated into the breeding programme before crossing actually taken place, for example. In spite of
the advances made in decentralization the variety testing process, plant breeders have not risked making selections under the non uniform conditions typical of small farmers. Nor have plant breeders studied the possibility of having farmers make selections within segregating populations that conform to their needs.

Farmers can be involved at various places in the chain of events that leads to the generation of new germplasm for use in agriculture-

(i) in the final stage of variety testing, or screening of breeders lines (Maurya et al., 1988 and Witcombe and Joshi 1995).

(ii) in line selection from bulk populations provided by breeders (Witcombe and Joshi, 1995).

(iii) in planning and decision of what to cross (i.e. Sperling et al., 1993).

According to Kornegay et al. (1996), farmers participating able to follow the breeding methodology recommended by the researchers and successfully developed advanced lines from early segregating population. Differences were found between breeder selected and farmer selected lines. The breeders concentrated more on yield and stress tolerance while farmers were concerned with quality traits related to local markets. The farmer selected lines tended to have more attractive seed colour and patterns and medium to large seed size. The breeders permitted lines to be developed whose seed characteristics were not as well appreciated by the farmers. Farmers also made trade off between commercial quality and yield in their selections, which demonstrates the great importance of quality characteristics in the farmers ideotype of an improved variety. The high level of disease resistance was not of top priority to farmers, nor was yield, but the participation by farmers catalyzed the inclusion in the breeding strategy of other traits deemed important by them.

A range of PPB methods is possible with predominantly self pollinating crops, and they have been ordered by degree of farmer’s participation in Table 1. The methods very according to which, generations are grown by farmers and by the extent of researcher participation. The method with the greatest farmer participation and the greatest number of generations requires little breeder input during the selection stages. However, PPB is not intended to make plant breeders redundant, and in all of the methods the plant breeder is the facilitator of the research. Only the plant breeder can make the crossing between the parents and have the essential understanding of the underlying genetics in the segregating generations (Witcombe and Joshi 1996).

For predominantly open pollinating crops, plant breeders can create composites in isolation and give the third or fourth random mating to farmers for mass selection. Large plants of the composite have to be grown by farmers, or small plots need to be isolated from other plots of the same crop by time of flowering or by space between schemes in many locations. Mass selection can be done by farmers with or without an off season generation controlled by plant breeder. The off season can be used to breed for wider adaptation by plant breeders recombining selections from different farmers. Although it is likely to reduce the progress made by selection over the best farmers selections, it avoids the risk of continuing a population from a poor section by one farmer, or from a population where out crossing with crops in surrounding fields happened to be higher than expected. Plant breeders can produce progeny before giving material to farmers, and can produce progeny between generations of farmers selection. In the most extremely breeder oriented system, the farmers grow
Table 1. Methods of PPB in predominantly self pollinated crops

<table>
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<tr>
<th>S No</th>
<th>Methods of farmers participation (in increasing order)</th>
<th>Site specificity</th>
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<tbody>
<tr>
<td>1.</td>
<td>Early generation (F_2) in farmers fields, all other generations and procedures with plant breeder</td>
<td>Single location</td>
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<tr>
<td>2.</td>
<td>Best advanced lines at F_3 or F_4 given to farmers for testing, closest method to PVS since farmers given nearly finished product</td>
<td>Easy to use across location</td>
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<td>3.</td>
<td>From F_3 onwards farmers and plant breeders work together to select and identify the best material. Farmers are the selectors. Plant breeders facilitate the process by giving advice on which characters are heritable, and on selection methods. Pre release multiplication can be taken place in parallel to the participatory plant breeding. Release proposal prepared by plant breeder</td>
<td>Possible to run selection procedures in more than one location</td>
</tr>
<tr>
<td>4.</td>
<td>Breeders give F_3 or F_4 material to farmers. All selection and advancement of generations left to farmers. At F_3, to F_4 or later, stage breeders monitor diversity in farmers fields. They identify, by phenotypic appearance and farmers perceptions, best material to enter in conventional trails and pre release multiplications</td>
<td>Extremely easy to run selection schemes in many locations</td>
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(Source-Witcombe and Joshi 1996).

progeny trails of full-sib or S_1 families, and the breeder recombinations from remnant seed the farmer preferred progeny.

**GENOTYPE \times ENVIRONMENT INTERACTIONS**

Genotype by environment (G \times E) interaction are of the main reasons for the failure of formal breeding to several small, resource poor farmers. Formal breeding has frequently adopted a negative interpretation of G \times E interaction. This has implied selection for broad adaptation, and consequently replacement of landraces with input responsive cultivars ill adapted to low input and stress conditions. By contrast, a positive interpretation of G \times E interaction implies the exploitation of specific adaptation by direct selection in the target environment. This requires the use of different breeding methodologies, use of locally adopted germplasm and farmers participation in selection to take full advantage of their knowledge of the crop and the environment (Ceccarelli *et al.*, 1996).

The G \times E interaction among farms for yield was just as great as G \times E interaction between research stations and farms. There is no guarantee that one farmers selection will perform well on a neighbors farm. Lines selected under high fertility, performed well on farmer under high fertility, but performed poorly in trials under low fertility. Baker (1988) observed the G \times E interaction is almost unanimously considered to be among the major factors limiting response to selection and, in general, the efficiency of breeding programmes. G \times E interaction becomes important when the rank of genotypes changes in different environments. This change in rank has been defined as a crossover G \times E interaction. "Crossover effect" meaning that varieties selected under good conditions generally are not the best performing under marginal conditions and vice versa.

G \times E interaction in general, and G \times E interactions of a crossover type in particular, are considered to have a negative impact on the success of breeding programmes, because breeders tends to search for a few widely adapted cultivars while this is probably the best strategy in the case of breeding programmes targeted at favorable environments, it has been suggested (Ceccarelli 1989 and 1994) that, in the case of less favorable environments, breeders may need to look at G \times E interaction in a different way.
The reason for failure of the conventional breeding approach in evolving suitable for harsh environment lines in the handling of the interaction between genotype and environment (G x E). Lines with high average grain yield across location and years are selected while lines with good performance at some locations and poor performance at other are discarded. Lines with good performance in some locations and poor response to favorable conditions get rejected because they have low average yields (Chopra, 2000).

**SELECTION IN UNFAVOURABLE ENVIRONMENTS**

Unfavourable environments are defined as those where crop yields are commonly low due to the concomitant effects of several abiotic and biotic stress. Breeding for unfavourable environments based on selection (not merely testing) in the target environments is undoubtedly more complex than selection for favorable environments largely because of the year to year variation. In general, when different genotypes of a given crop are evaluated in a sufficiently wide range of environments, G x E interactions of a crossover type seem to be very common. This indicates that, as a general phenomenon, genotypes selected under optimum growing conditions do not perform well under poor growing conditions, and vice versa. This is hardly supervising as physiologists have long recognized, with specific reference to drought, that high yield in favorable conditions and high yield in unfavorable conditions are associated with different physiological mechanisms and different phonologies (Hsiao, 1982 and Blum, 1993).

Selection in high yielding sites, such as well managed experiment stations, does not allow the identification of the best genotypes for poorer conditions, and promotes genotypes which are not superior in stressful conditions.

**MAXIMIZING SPECIFIC ADAPTATION**

The idea of farmers participation in the development of new technology is not new. It was introduced in 1982 (Rhoades and Booth, 1982) as “the farmer back to farmer model”, later modified in to the “farmer first and last model” (Chambers and Ghildyal, 1985) and more recently discussed by Sperling et al. (1993) and Stroup et al. (1993). Using Sperlings technology “formal breeding programmes” can be described as a sequential and cyclical process in which-

(i) An extremely large amount of genetic variability is continuously created.
(ii) This variability is drastically reduced through selection (we have seen that this is often done in conditions which have little in common with those of resource poor farmers).

It is possible that the plant characteristics which are used as selection criteria in a high yielding environment, such as an experiment station, are those which give the future variety an advantage when grown by a resource poor farmer. When breeders and farmers select in the same environment, farmers selection can be effective implying that farmers possess considerable knowledge which is almost totally neglected in formal plant breeding programmes.

Breeding for specific adaptation not only offers a solution to how to improve agricultural production in marginal environments but also can do so in a sustainable way. This breeding philosophy, based on a positive interpretation of G x E interaction, is in contrast with the common belief that the introduction of inputs, such as fertilizer and irrigation, to raise the yield potential is an essential prerequisite for successful breeding work. Breeding for an agronomically improved environment dictates the type of germplasm which will best exploit it, and is based on genetic uniformity, the reverse of the biological diversity.
requisite for minimizing risk in most natural systems (Wilkes, 1989).

Breeding for specific adaptation of unfavorable environments implies a reevaluation of the role of genetic resources such as landraces, which can play an important role because they possess adaptive features to these environments. This is the first consequence on biodiversity of breeding for specific adaptation. A second consequence of exploiting specific adaptation on biodiversity is that the number of varieties (not necessarily homogeneous) of a given crop grown at any time will be large.

CONCLUSIONS

Breeding for sustainability has been defined as a process of fitting cultivars to an environment instead of altering the environment (by adding, fertilizer, water, pesticides etc.) to fit cultivars (Coffman and Smith, 1991). In most conventional breeding programmes, only at the end of the development process is the farmer allowed access to the new lines. Access usually involves adaptation/validation of the genetic material to edaphoclimatic, biotic and abiotic stress encountered on farm. However, even at this late stage it is not usual to solicit feedback from future users or adopters of the varieties about the extent to which the new materials are acceptable. Even if such feedback were to be obtained, knowing whether and why farmers are likely to adopt the new varieties, as a late stage in their development, leaves little scope for plant breeders to make changes in the bred traits. As a result, new varieties are often released with disappointing results in terms of the rate and extent of adoption by farmers, even in areas where the varieties have been targeted.

Participatory approaches in a highly market oriented context are very effective at identifying varieties that will be adopted by farmers, but the farmers selection criteria include a very narrow set of market oriented characteristics. In large part, participatory breeding, combined with decentralized selection under high stress conditions, has arisen as a breeding strategy to attempt to improve the performance of formal breeding for difficult environments.

REFERENCES

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