Involving Farmers in the Development Process to Improve Adoption of Varieties Developed by National Maize-Breeding Programs

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Abstract

Developing maize varieties that will be readily adopted by subsistence farmers is challenging as there are numerous characteristics in addition to agronomic performance that are important to these farmers. Furthermore, these preferences vary from location to location. It may be logical to conclude that because of these location-specific requirements, maize breeding that targets subsistence farmers should be done at a localized level. National maize-improvement programs have an important role to play in developing improved maize genotypes for these farmers because they have access to a wide range of genetic materials that allows for the identification of genes for disease resistance and high yield that may not be available in local germplasm. Furthermore, they have the expertise required to incorporate these genes efficiently into genotypes that meet the farmers' other requirements. To increase the impact of genotypes developed by national maize-improvement programs, however, farmer input into their activities is essential. A balance between on-station breeding activities and interactions with farmers is needed in order for the process to be efficient. Therefore, the National Maize Research Program within Nepal's National Agricultural Council (NARC) has developed the following procedures for developing maize genotypes for subsistence farmers with their input. First, through on-farm surveys, the required grain (i.e., flint, dent, yellow, or white) and plant (i.e., tall, leafy, early, or late, etc.) types are determined. Second, exotic and locally developed genotypes are screened for the desired characteristics and general adaptation on-station using local varieties from the targeted environment as checks to ensure that maturity duration matches that already used by farmers. Promising materials are initially tested on-station for yield and disease resistance. Elite materials (approximately six to eight genotypes) are then tested in on-farm trials under farmers' conditions. Farmers who grow these materials observe their agronomic performance and provide input about which entries they prefer. Only those varieties that have proven to be high yielding and stable, and which have the characteristics preferred by farmers, will be released and made available on a more national scale. Maintenance of released genotypes and seed multiplication is a resource-intensive activity that must be limited to genotypes that are the most likely to have an impact. We believe that this varietal-development scheme will efficiently provide new and desirable options to small-scale subsistence maize farmers in Nepal.

Introduction

Maize is one of the three most important cereal crops in the world. Global annual maize production now exceeds 550 million tons. Of that, approximately 100 million tons are used directly for human food (CIMMYT 1999). Maize is growing in importance in Asia, primarily as a feed for animals. Nevertheless, there are significant areas of the region where maize is still the dominant cereal in the human diet. In Nepal, for example, of the 1.4 million tons produced annually, it is estimated that 86% is used directly as human food (CIMMYT 1999). The development of hybrids is one of the main reasons for the phenomenal advances in maize productivity throughout the world in the past few decades. In most developed countries, the area planted to hybrids approaches 100% of all land planted to corn. Growth in the use of hybrids has been impressive in areas of the developing world as well. For example, 60% and 46% of the area planted to maize is sown to hybrids in Thailand and

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Vietnam, respectively. Both within Asia and globally, there is a significant negative correlation between the percent utilization of maize for human food and the use of improved varieties (CIMMYT 1999). This can partially be explained by the fact that subsistence farmers have limited cash and are reluctant to pay the premium price associated with improved seeds, particularly hybrid seed, which must be purchased each year. Single-cross hybrid seed in Asia costs on average US $3.12 per kg, in comparison to US $0.69 per kg for open-pollinated varieties (OPVs) (Gerpacio 1999).

The development of OPVs for areas of the world where maize is grown as a subsistence crop makes good sense. Compared to hybrids, OPV seed is more readily produced, it can be made available to farmers at a lower cost, and it can be generated by farmers themselves. Nevertheless, in large areas of the world where maize is a subsistence food crop, a large percentage of the area is not planted to improved varieties (OPVs or hybrids) even though modern varieties with excellent adaptation are available from both the public and private sectors. The poor adoption of improved maize varieties can be attributed to many factors, primary among which may be the lack of viable seed enterprises. Other factors, such as the varieties' lacking the characteristics that are important to farmers, also constrain adoption. Farmers in Nepal for example, prefer their own varieties because they are earlier, have better husk cover and culinary characteristics than improved OPVs. In order to improve adoption of modern varieties, there is a need for greater farmer input into the development of genotypes that take these preferences into account. This paper discusses issues relative to developing and providing improved maize genotypes to farmers and describes a germplasm-improvement scheme adopted by the National Maize Research Program in Nepal to ensure that the products they develop are better targeted to the requirements of farmers.

Fixing favorable alleles—the numbers game

Maize is cross-pollinated under normal circumstances. Therefore, a crop or plot of a desired genotype must be carefully managed if the seed it produces is to be genetically pure. Furthermore, in relation to participatory approaches to plant breeding it means that seed of genotypes that are tested or demonstrated in farmers' fields in a typical small plot are likely to be contaminated or genetically altered through the inflow of foreign pollen. Saved seed will, therefore, not produce a phenotype identical to that observed the previous season. In a varietal-improvement program, be it through informal farmer selection or through a formally organized plant-breeding program, success is determined by the ability of the breeder to find desirable characteristics and fix them in the population so that they can be expressed in subsequent generations. For traits that do not exist or that have little expression in an otherwise desirable population, conventional breeding programs have a substantial competitive advantage over farmer-led approaches. In order to find favorable alleles for stress tolerance, for example, many thousands of lines and populations might need to be screened in order to identify a few genotypes with the desired characteristics. Similarly, for alleles that are found in a very low frequency in a population, breeding techniques that include selfing and extensive testing with recombination of best lines can be used to increase their expression relatively quickly.

Developing OPVs through conventional methods requires both time and land resources. As an example, the following steps are required to develop a superior experimental variety using full-sibs developed from an improved population (which itself may have been improved through many cycles of selection). First, 250 full-sib progenies are generated by hand-pollination. These are tested in up to six locations, including sites where a stress of interest is present. Next, eight to 10

superior families are selected and recombined using remnant seed. The progeny of these crosses are then allowed to intermate for one further cycle. The favorable alleles in these EVTs are now more or less fixed and these varieties are ready for testing.

In order to maintain these materials (produce breeder seed), at least 1500 plants need to be grown if they are hand-pollinated (bulked pollen). Foundation and certified seed can be produced from this breeder seed. Using these procedures, the greater the number of materials tested and the lower the experimental error of the experiments, the greater the likelihood that superior materials can be identified. Seed production requires isolation, and minimum standards of isolation are set for different classes of seed. As mentioned, this process is expensive and requires substantial areas of uniform land to ensure adequate testing. Nevertheless, it is very effective in identifying and fixing favorable alleles for the traits of interest. It is very effective in identifying resistance or tolerance to stresses that are prevalent in the testing environments and in developing materials with high yield potential. High yield potential and stress tolerance in OPVs, however, does not mean that they will be acceptable to farmers or will be adopted by them.

Adding farmer participation to the conventional breeding program

The rates of adoption of improved genotypes developed through the conventional methods described above have not been high in many areas of the world. Including traits that farmers prefer in OPVs may help improve rates of adoption in some of these regions. We propose that (1) input in the beginning of the development process, (2) coupled with more intensive on-farm testing of the materials that are developed, are two ways to improve the rates of adoption of newly developed genotypes that farmers desire. Moreover, we believe that identifying and fixing farmer-desired traits is most effectively carried out through conventional, tried-and-tested breeding methods, like those briefly referred to above.

Input at the beginning of the development process

Before a breeding program begins, the target environment and the basic requirements of the farmers in that particular environment must be clearly understood. In Nepal, the National Maize Research Program is currently developing materials that target the mid-hills, the high hills, the *terai*, and areas in both the *terai* and valley bottoms that require early-maturing varieties. Generally speaking, the biotic stresses differ significantly between the various agroecologies—enough that material developed for one ecology will not do well in another, and vice versa. Some extremely important farmer characteristics that must be ascertained at the beginning stages are length of growing period and grain type. This input can be obtained through farmer interviews (rapid rural appraisals [RRAs] and more formal surveys) and by soliciting farmers' reactions to on-going trials either on-farm or on-station. In Nepal, using an RRA approach, we found that farmers in different areas of the country preferred different characteristics (table 1). Furthermore, by having farmers view trials, they provided valuable feedback on the length of maturity they desired.

Farmer feedback during testing

After the on-station work of identifying and the fixing favorable alleles has been concluded, the experimental varieties need to be tested widely. Multilocational testing, usually on-station where experimental error can be controlled, allows researchers to identify high-yielding genotypes that are stable and adapted across environments (including having resistance to the prevalent diseases).

Table 1. Grain Characteristics Desired by Farmers in Maize Varieties in Various Regions of Nepal, Based on Results of Rapid Rural Appraisals Conducted by the National Maize Research Program, October 1999

Region	Grain type	Reason for preference
Eastern	White flint	Good storage, high grit yield
Central	Yellow flint	Good storage, taste, grit yield
Far western	White dent	High flour yield—used in *rotis*
Terai	Yellow dent or flint	Used for animal feed

Farmer input into the selection of experimental varieties can be obtained by allowing them to visit trials being conducted on-station. Generally, however, on-station yield trials contain a relatively large number of entries. Furthermore, a single visit to the research station would not allow farmers to select entries for grain type, unless farmers visited trials at the time of harvest. In the Hill Maize Research Project, the top four to six entries of the coordinated varietal trial are tested further on-farm, in what is termed a farmer field trial (FFT). These trials are conducted as widely as resources allow, and in addition to yield, feedback from farmers on varieties that they prefer is obtained and used in determining which varieties are released. This process allows farmers to evaluate fewer materials, and since plots are larger, a good evaluation of seed characteristics can be obtained.

A novel approach to allow farmers' input at an earlier stage of testing is being used by Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT) in southern Africa (CIMMYT 2000:12–14). It is called the mother-daughter testing scheme. Within a given agroecology, a complete set of experimental varieties is tested on an experiment station, on a substation, or on-farm (with researcher management). The complete set can contain as many entries as desired by the breeder. These are grown in a lattice design with replications. The complete set is referred to as the "mother." In farms in the area represented by the mother trials, four to six entries that represent a block within a rep of the lattice are grown. These smaller on-farm trials are referred to as "daughters" and these daughter trials may be managed by nongovernmental organizations (NGOs), extension programs, community-based organizations, or farmers themselves.

Yield and farmer preferences are obtained from each of these on-farm trials. The results from all of these daughter trials can be combined and statistically analyzed as components of the complete trial. Although each farmer only sees a subset of the complete mother trial on his or her own farm, with sufficient replication, this approach should allow researchers to obtain yield data that can be analyzed statistically, as well as information from the farmers as to which materials are preferred. The approach allows for more effective farmer input at an earlier stage of testing. With the assistance of extension officers and NGOs, nearly 300 on-farm daughter trials were conducted in 1999/2000 in Zimbabwe.

A note on seed production and maintenance

Developing improved varieties is only part of the process of getting them into production in farmers' fields. Distinct from the cases of rice and wheat, seed production in maize is more complicated. Plots must be isolated to eliminate genetic contamination from foreign pollen. Furthermore, the

number of plants grown must be sufficiently large to ensure that the genetic variability of the population is well represented and inbreeding effects are reduced. Seed enterprises rely on a good source of foundation seed, which is usually produced from breeder seed maintained by the organization that develops the genotype. A lack of resources universally limits the number of varieties that can be maintained by public institutions. Due to the lack of involvement of the public and private sectors in seed production (certified seed) within Nepal, the Hill Maize Research Project supports seed production at the community level. This should allow quality seed of improved varieties to be available to farmers at a reasonable cost, even in relatively inaccessible areas.

Furthermore, farmers who use improved seed and retain their own seed for subsequent plantings must be trained in how to select seed if they are to continue to benefit from the "fixed favorable alleles" in the improved varieties. This training should emphasize that seed should be from plants in the field and not cobs in the store, that it should be selected from the center of their larger fields so as to avoid contamination from pollen from adjacent fields, and that it should be dried well and stored in such a way that it is protected from insect pests and will maintain a high level of germination.

Conclusion—the strategy of the Hill Maize Project

Based on the need to have greater input from farmers in the variety-development process and the efficiencies in finding and fixing favorable alleles inherent in station-based breeding programs, the following breeding strategy has been adopted by the Hill Maize Project for the development of OPVs for the hill areas of Nepal.

1. Based on information from RRAs and other survey instruments and feedback obtained from farmers from on-farm and on-station trials, breeding activities will focus on incorporating traits desired by farmers (i.e., grain texture and color, maturity length, plant stature, etc.) into new varieties.
2. Exotic and locally generated germplasm will be evaluated to determine source populations with which to work.
3. Tried-and-tested breeding procedures will be used to identify desirable traits and fix them into experimental varieties.
4. Promising genotypes will be identified through multilocational on-station testing.
5. Elite material will be evaluated in farmers' fields for both agronomic performance and farmers' preferences in either FFTs or mother-daughter trials.
6. Only varieties that are desired by farmers will be released.
7. Community-based seed production will be used as one mechanism for making seeds available to farmers at a reasonable price.
8. Farmers will be trained in techniques that can be used to ensure the maintenance of genetically pure seed.