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Discussion

Malawi delegate: We feel that in-country training programs are more useful than courses at CIMMYT headquarters in Mexico that emphasize some techniques, such as minimum tillage, that are not applicable to the local situation in our country.

Dr. Gelaw: I encourage in-country training, but not to the exclusion of training in Mexico. Those courses can expose your people to to a broader spectrum of field techniques and course materials.

Dr. Khadr: You mention that the real indication of success in a germplasm program is not in the number of releases from breeding programs, but the extent to which farmers have adopted those varieties. Do you know how much area is covered by varieties which include CIMMYT materials?

Dr. Gelaw: National programs would be in a better position to answer that question, but as an example, 75% of the farmers in the highlands of Lesotho have adopted new varieties which are based on CIMMYT germplasm.

Question: We used to get the East African Maize Variety Trial. Wouldn't it be a good idea to revive this?

Dr. Gelaw: In many countries, seed companies and government research are doing a good job with trial work. I believe there are better ways of accomplishing the same purpose and avoid duplication.

Mr. Mpabanzi: Central Africa is not identified as a separate ecological region. The result is that CIMMYT and IITA materials are unadapted to the highlands of Rwanda and Burundi.

Dr. Gelaw: The fact that Rwanda and Burundi are included in this workshop, even though they are not MULPOC countries, shows that we have an interest in their situation. It is true that our materials are not well adapted to your highlands; they need to be selected for adaptation in a similar environments in the region.

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III. Agronomy

On-Farm Research with a Systems Perspective: Its Role in Servicing Technical Component Research in Maize, with Examples from Eastern and Southern Africa

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Abstract

On-farm research with a farming-systems perspective (OFR/FSP) is a new tool for agricultural research in the eastern and southern African region. Focusing on local farming situations, OFS/FSP can modify the findings of technical research, pinpoint farmers' technical problems and bring together researchers, farmers and extension in the selection and adoption of technology for local situations. Three case studies in which OFR/FSP has shown merit are discussed, one concerning the low power resources which are available to small farmers and which affect their varietal choice and management, another showing how more intensive cropping patterns have come about as a result of increasing population pressure on the land, and a third case study describing the circumstances which cause farmers to use specialized varietal types. The three cases illustrate how a systems perspective is used in OFR/FSP to understand local farming situations, and how the output of technical component research can be mobilized by identifying the techniques appropriate to those situations. This approach can feed information back to researchers that will help them to evaluate selection blocks, yield trials and cultural practices, using the same criteria that farmers use in assessing recommended varieties and practices. This can make the products of research more pertinent to the needs and capabilities of the small farmers who constitute the market for those products.

There is an increasing commitment to on-farm research with a farming-systems perspective (OFR/FSP) as a new tool for agricultural research among countries of the eastern and southern African region (ESA). OFR/FSP is relatively well developed in Zambia (1982) and Malawi (1984), where regionally deployed teams of on-farm researchers, including both technical and social scientists, have been restructured into their research services. Botswana, Ethiopia, Kenya, Lesotho, Sudan, Swaziland, Tanzania and Zimbabwe have OFR/FSP-type programs, and are actively debating how they can best be integrated with technical component research (TCR) and the extension services. Burundi, Mozambique, Rwanda, Somalia and Uganda also have, or soon will have, pilot programs in OFR/FSP.

There is interest in OFR/FSP in three areas:

- Mobilizing timely and appropriate findings of technical research in identified local farming situations;
- Identifying, in those local situations, unsolved, technical problems important to farmer development, and feeding them back to the relevant specialist researchers (TCR), and

- Allowing a participatory approach to the selection and adaptation of technology in local situations, involving researchers, farmers and extension staff.

The roles fill gaps and complement deficiencies, which in the traditional research process have inhibited the wide utilization of research results and recommendations by farmers, especially small farmers. Agricultural researchers have always realized that blanket recommendations represent a compromise, and have sought to handle differences in climate and soil by multilocation trials, adapting their materials to local agroecological circumstances. Adaptive research and on-farm experimentation *per se* are not new, but OFR/FSP brings to them three new perspectives:

- Awareness that social and economic, rather than agroecological, circumstances dictate farmers' final decision making; technologies, like other products, need to be tailored to the peculiarities of local markets;

- Understanding that farmers, to meet their diverse objectives, operate multiactivity systems which demand compromises on technical perfection in any one activity in the interests of the system as a whole, and

- Recognition that innovations must be exposed to farmers and extension staff as part of the technology development process, with nonviable options eliminated before recommendations are made. This is clearly preferable to finding out about nonviability after recommendation, when considerable resources have already been invested in extension training, input and credit servicing of the technology, and often related infrastructural development.

In the urge to realize biological potential, agricultural scientists have often exploited interactions by developing comprehensive "packages" of components. Recommendations and the credit packages which accompany them represent the "best way" to grow maize within the present state of the art. The gap between current practice and these "final solutions" to maize growing is often so wide that it cannot be bridged by the smaller farmer for such reasons as:

- Their cash surplus is so low that these compound packages are out of reach economically;
- The management repercussions of these compound packages on their current activities are highly complex, and often imply the sacrifice of other objectives, which may have a high priority with the farm family, and
- The risks in making these changes, even in accepting credit beyond their annual spending levels, go against family security, which is often central to the priorities of the small farmer.

There is nothing wrong with packages *per se*; farmers, like agricultural scientists, are interested in exploiting interactions. What is important is that the selection of components for packages be made with a knowledge of specific farmer situations. OFR/FSP supplies this knowledge. Brought into the planning of adaptive research, these additional perspectives enable the matching of emerging technologies to the needs and capabilities of local, specific farmer groups, raising the rate of technology adoption.

Although there is a growing commitment to OFR/FSP, it is still in its beginning stages in the ESA region; capacity for OFR/FSP is limited. Probably less than 3% of the professional personnel of the national agricultural research service (NARS) in the region are working with OFR/FSP. It seems likely that the participation of 15 to 25% of national researchers, depending on the complexity and diversity of farmer circumstances in a particular country, is a cost-effective proportion, leaving 75 to 85% of the research professionals in specialized technical component research. This estimate may be modified for very small countries, which have large, agroecologically similar neighbors with greater resource bases to support a critical TCR mass. Where a regional spirit of cooperation allows ready access to research information across national boundaries, it makes sense for small countries to opt more heavily for OFR/FSP and to concentrate on adaptation. The capacity of a country for OFR/FSP cannot be counted by the number of researchers allocated to it. Professional competence in diagnosis, planning, implementation and interpretation of on-farm experiments, and in eliciting farmer and extension participation in the OFR/FSP process, requires high levels of skill and commitment. Few of the national researchers allocated to OFR/FSP have master's degrees, and perhaps only half a dozen have PhDs; very few have been exposed to the concepts, and fewer still the practice, for more than five years. It will take time to build effective capacity in an approach which is itself evolving rapidly, and which because of the added social and economic dimensions is complex in its different dimensions as compared to technical research.

The Use of OFR/FSP in Small-Farm Situations

Despite the infancy of OFR/FSP, it has begun to show its merits. Three cases where the application of OFR/FSP has provided new insights into the needs of local small-farm situations will be discussed here. They have been chosen to illustrate situations which are widely relevant in small-farm agriculture. Some show how technical results have been immediately available to meet identified farmer needs. Others show how needs have influenced, or will influence, the orientation of specialist research programs. The majority are in maize in the interests of the audience here, but other situations are mentioned to illustrate circumstances which may also be applicable to maize. All of the cases are designed to show how OFR/FSP assists specialized technical component researchers, both by mobilizing their results to meet observed farmer needs and by identifying technical problems, which are important to farmer development and which need their attention.

The three cases are concerned primarily with varietal selection. They illustrate how the use of a farming-systems perspective for understanding the situations of small farmers can be brought to bear in the choice of appropriate varieties. Aspects of maize agronomy are added where relevant to the particular case.

Case 1. The low power resources available to small farmers, and implications for varietal choice and management

Small farmers in the ESA region have limited power resources. Land preparation and planting of a hectare of maize with a hoe takes up to 50 man-days, depending on the previous crop cover and soil type. Even with a team of oxen, often weakened after the dry season, a family needs up to a week to prepare and plant less than a hectare. Studies from Tanzania, Zambia, Zimbabwe and Malawi, as well as across the region, show that small-farmer communities are still planting several months after the start of the rains. Characteristically, for much of the ESA region, cultivation begins in late October and ends in mid-January, a three-month period. Land preparation and planting are not the farmers' sole occupation during this period; they also weed and fertilize their earlier plantings. The decision as to when to stop planting more area and weed the early plantings is economically complex. The use of a farming-systems perspective to examine such situations has promoted research interest in a range of disciplines. Among these are plant breeding and selection.

Variability between and within species for tolerance to delayed planting—The planting date effect *per se* is perhaps not yet fully understood, and is different in different agroecological situations. It is clear throughout the region that there is a strong time-of-planting effect, that independent of late plantings being immature at the end of the rains, reduces yield radically. Figures of 50 to 150 kg/ha yield loss per day of delay after the onset of the rains have been quoted for maize in Kenya (1). Research results show that planting date for optimum yields, often of a wide variety of crops, is immediately after the onset of the rains. However, an economic analysis of the situation shows that where these findings are reflected in the same recommended planting date for a variety of crops grown by the farmer, he might reduce his production for food and cash by up to 70% by following the recommendations faithfully. Given evidence of the severe power limitations of small farmers and the relative land abundance in many small-farm situations, interest has increased in the relative tolerance of both crop species and varieties within species to delays in planting. This is particularly relevant to maize, which occupies between 50 and 80% of the cultivated area in farming systems of the region, and which is both the staple food for the household and a profitable cash crop.

Changes in varietal superiority as planting time is delayed—This same limited power characteristic of small-farm communities has prompted interest in cross-over points in maize varietal performance with delays in planting. Work is being done in both Zambia and Zimbabwe to formulate recommendations of maize varieties more suitable for delayed planting. Most of this work is currently centered around the use of early maturing varieties to avoid the end of the rains, rather than of tolerance in the maize varieties to the direct effects of late planting.

Some agronomic aspects of the power limitations of small farmers—Contrary to the conventional belief that proper time of planting is virtually costless to the farmer, there is increasing recognition that power limitations can restrict the farmers' ability to achieve optimal time of planting. This has led to increased interest in the management of late-planted varieties. As a result of agronomically significant interactions between planting date, plant density and fertilizer levels, it is becoming accepted that different management regimes are necessary for late-planted crops. On-farm research in both Zambia and Zimbabwe is working towards management recommendations for late-planted maize.

In the draft-animal systems, which are widely found in the ESA region, power limitations are increasing in severity. As population density increases, the demand for new arable land encroaches on grazing areas, reducing the number of animals which can be maintained and consequently the draft-power pool. Well-documented cases from the International Livestock Center in Africa (ILCA) in Ethiopia and from Zimbabwe (Research and Specialist Services) show that a decreasing draft-power pool has to prepare the land for an increasing farm population. Delays in land preparation, and consequently maize planting, are exacerbated across the community as the draft-power pool decreases. Similar situations can be identified in parts of Kenya, Tanzania, Lesotho, and probably Zambia and Uganda.

In both Ethiopia and Zimbabwe, on-farm research has resulted in initiatives for stabilizing the draft-power herd, both by improving feed resources and by reducing draft requirements. At ILCA, harnessing experiments have resulted in a single draft animal giving some 70% of the power output of the traditional pair. In Zimbabwe, it has been found that the use of a tine for opening the planting row can reduce the number of passes in plowing to one-third. Because the tine can be pulled by a two-animal team, rather than the four-animal team traditionally used for plowing, the rate of land preparation increases five to sixfold. Combined with the use of Atrazine to control the early weed flush, this higher work rate will allow for earlier planting of a significant proportion of the farming community's maize; it will also lower the stress level for the draft herd. The appropriateness of different approaches to the solution of this widespread problem of animal draft power can only be assessed from an understanding of the particular farming system in which the problem occurs.

These facets of an examination of the implications of the low power resources of small farmers for maize variety choice and management are important. They reflect an increasing awareness that the best way to grow maize changes radically with local circumstances, both agroecological and economic. Technically optimal maize growing, identified in isolation from a farming situation, can reduce the farmer's flexibility to manage. For enhancing his flexibility to handle the circumstances within which he has to operate, such as low power resources, the problem must be seen and met from his perspective.

Case 2. More intensive cropping patterns

Extreme population pressures for rain-fed agriculture are being experienced in some well-watered (1500 mm rainfall) parts of the East African highlands. There a population of up to 600 people per square kilometer results in a high proportion of holdings of little more than one-half hectare per family. At this settlement density, the power problem fades and land area becomes the limiting factor in the potential of the farming system. In the western Kenya high-rainfall areas, highest yields are obtained with the currently recommended 600 hybrid series bred at Kitale. These hybrids, planted in early March, stand in the field until mid-September. With unreliable rainfall in January and February and with the late-maturing 600 maize, only 100 days are left for the recultivation of the land for a second maize crop. This second maize crop is particularly important to small farmers, since in a significant proportion of years maize prices reach 300 to 400% of the post-harvest price in June and July, before the new long-rains maize is harvested. Unless there is a second crop, the small farmer is forced to buy maize for food at these very high prices, and then because of a lack of cash or because he has had to mortgage his current crop to buy food earlier, he is forced to sell his crop at the low, post-harvest price.

Because of this need for a second crop, and because of the high penalties paid by farmers forced to buy in the market before the main harvest, experimental work has been done in farmers' fields in western Kenya to reconsider varietal recommendations. Varieties of 120 to 180 days to maturity are being compared for performance in the long rains (March to August) and short rains (August to December), to identify the combination which gives the best production over the whole year. Also, and this is relevant to many other situations in the region, a high proportion of families are dependent on local markets for buying expensive maize for food in the pre-harvest months in some years. An early planted, early maturing variety can command three to four times the price of maize harvested at the usual time. A short-term variety could be grown for food security, for avoiding having to buy maize when it is at its most expensive or for being able to sell it for profit to exploit the market. Although such a variety might have only 50% of the yield potential of a standard variety, its earliness would allow the farmer to benefit from these high prices, making it 100% more profitable than a longer maturing standard type. The experiments allow an evaluation of earlier maturing varieties with these circumstances in mind.

Agronomic considerations of intercropping—Two agronomic aspects of these experiments are of interest. First, with these extremely resource-poor farmers, a negligible number are using fertilizer on their maize, which is heavily intercropped with beans, and to a lesser degree, cassava and sorghum or finger millet. It is unlikely that there can be a transition to the use of fertilizer until food security can be assured throughout the year, as the time when fertilizer must be bought is the time farmers need cash to supplement their home-grown food supplies; therefore, varietal comparisons are being made under the low levels of organic manure currently used by local farmers. Because of the possible interactions between maize and the heavy intercrop of beans, comparisons will also be made on an intercropped basis, measuring the effect of the change in maize varieties on bean production.

Second, local farmers utilize their maize stover intensively for feeding a dairy animal to provide highly prized milk for the family. The possibility exists for opening up the tall standing maize by stripping the lower leaves, not only to provide fodder but also to give access for light to a second maize crop, relay planted in the interrow after the beans are removed. This may be a more viable option than the use of two shorter-term varieties. It would allow a late-maturity variety for the early rains and an earlier maturing variety for the late rains, or perhaps even long-term varieties for both rains. Such options can only emerge from an understanding of farmer needs and current practices in a specific local situation.

Case 3. Circumstances in which farmers use specialized varietal types

Case 1 and Case 2 are situations where a knowledge of farmer-resource endowments and management strategies is important to an understanding of their varietal needs. Case 1 examines some of the varietal implications of low power resources, common to many small-farmer systems across the region. Case 2 is an extreme situation where land has become the limiting resource despite low power availability. Case 3 brings together three examples of how circumstances other than resource endowment play a large part in farmers' choice of varieties for their particular circumstances.

The growing of several varieties with different consumption characteristics—Multilines are often associated with wheat growing as a strategy to avoid heavy losses from disease. The growing of a number of varieties is also a frequent feature of small-farmer management strategy, especially when production for consumption and for sales are multiple objectives. Farmers in part of Zambia make early plantings of traditional short-term maize varieties (100 to 120 days) to obtain early food. These varieties also taste better as green maize than do the hybrids SR52 and H21 (170 days), which form the main crop. Farmer priority for early planting of these traditional varieties leads to a delay in the planting of hybrids; 25% of hybrid plantings are made with expectations of only 125 days of rain. In answer to the question of whether an improved 120-day variety would be useful, 96% of the farmers answered that it would be; 63% mentioned the advantage of early food. In areas investigated in Malawi, virtually all farmers plant local maize and give it priority in establishment over MH12, because of its storage and consumption characteristics.

Working in the Ol-Obeid area of the Sudan, Intsormil found a range of sorghum varieties being mixed in the same planting. Different varieties were identified with differently valued consumption characteristics. Farmers mentioned as desirable such characteristics as, "Gives a large food crop in a good season," "Comes through with sufficient food in a dry season," "Stores well to allow a carry-over until the current crop is in," "Is good for brewing," and "Stalks make good animal feed." In many small-farm systems in the region, there will be no single "best" variety. Selection and perhaps even breeding can be usefully oriented toward replacing specific varieties of major importance to farmers, and can be guided by an understanding of the strategies of farmers in growing a range of varieties.

The use of more than one planting for adaptability to weather conditions—Mid-season droughts are a feature of significant areas of the drier parts of the ESA region. About once every three years, farmers in part of southern Zimbabwe face a floating mid-season drought, which occurs anytime between Christmas and the end of February. They manipulate two plantings of R200 and R201 (135 to 140 days) so that one of the plantings can escape this possible drought. The strategy is for the early planting to start setting grain before the drought when it occurs late, or for the late planting to stand through the drought if it occurs soon after its establishment. Once it was understood that this was the farmers' drought-avoidance strategy, it became clear that a shorter-term variety would improve their flexibility to manage this hazard, allowing greater probability of escape for the early planting, and the option to plant the second crop later, perhaps as late as January, in those years when the drought occurs early.

The consideration of crop by-products in variety selection—Case 1 highlighted the decreasing pools of draft power as a result of the competition between arable land and grazing land. In many parts of the world that are more intensively cultivated than the ESA region, the stover of cereal crops, used for animal feed, sometimes has a higher value than the grain itself. Strong local markets exist for stover, with farmers who do not own draft animals trading their residues for services from draft owners, or finding their niche in the milk market by selling forage to dairy farmers. The possession of stover by non-animal owners can be seen as a bargaining position for access to draft power; the beginnings of such a situation can be identified in the ESA region. In some drier parts of Zimbabwe, although tradition allows access to all crop residues by livestock, 90% of the cattle owners collect their maize stover from their fields and store it from time of harvest in April and May until it is fed to their cattle from August to November. A few cattle owners in the area report planting maize after the harvest of groundnuts in February, some six weeks before the end of the rains; their aim is more nutritious fodder for their animals in the dry season.

In western Sudan, where transhumant farmers move through settled areas with their animals in the dry season, the beginnings of a fodder market can be seen. Settled farmers get the value of the manure in exchange for the residues grazed by the transhumant animals. In all of these cases, as pressure on dry-season feed increases, the market for fodder will become more important as a criterion in variety choice. In part of the Mount Kenya area of Kenya, farmers have indicated preference for the 600 series over the recommended 500 series of hybrids, as the larger 600 plant structure gives more biomass for stall feeding one or two dairy cows; milk is a major source of cash for these households.

Conclusions

These cases illustrate how OFR/FSP uses a systems perspective to understand local farming situations. The first two more-detailed cases show how OFR/FSP mobilizes TCR output by identifying new techniques appropriate to those situations. All of the cases illustrate how OFR/FSP can feed information back to breeders to help them assemble and evaluate selection blocks and yield trials, using the same technical and economic criteria that farmers will use in assessing varieties recommended for their use. Descriptions of small-farmer situations must specify the management context into which selected varieties are going to be introduced. This can bring realism to the management of selection trials, making the products of research more pertinent to the needs and capabilities of the small farmers who constitute the market for those products.

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IV. Plant Protection

Maize Diseases in Africa and Their Role in the Varietal Improvement Process

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Abstract

Diseases are greater in number and intensity in the tropics than in the nontropical regions of the world. In Africa, annual yield losses to diseases are commonly in the range of 15 to 50%, compared to the world average of 9%. Some years, epidemics of such Africa-specific diseases as maize streak virus can cause yield losses of 100%. The yield-depressing effect of maize diseases is among the principal causes of the instability of maize production in Africa. This paper discusses the groups of diseases which are most widespread and important in Africa, their symptoms, control measures and the availability of sources of resistance in maize. The groups discussed are seedling rots and other seedling diseases, local-spot foliar diseases (including leaf blights, rusts, leaf spot and brown spot), the systemic foliar diseases (including the economically important maize streak, maize mottle/chlorotic stunt, maize dwarf mosaic and downy mildew) and stalk and ear rots. Maize is also prone to attack by the parasitic seed plant Striga *(witchweed), which feeds on the plant, depriving it of essential nutrients, metabolites and water. IITA has developed techniques for disease-resistance screening by exploring host-plant resistance (among adapted varieties first in order to hasten farmer adoption). Three parameters are considered in disease assessment, incidence, intensity/severity and crop yield. The role of maize diseases in catalyzing the variety development process in Africa has been tremendous; the birth of many national programs of maize research was a direct result of the spread of disease on the continent. IITA and CIMMYT have collaborated to develop varieties resistant to the systemic foliar diseases, especially maize streak. Future efforts of IITA will continue to be concentrated on the development of maize varieties with combined resistance to the major economically important diseases, maize mottle/chlorotic stunt,* Striga *and stalk and ear rots.*

Maize (*Zea mays* L.) is a cereal crop of great dietary and socioeconomic significance in Africa. Its cultivation spans the entire continent, from the subtropical south through the central tropical region to the arid subtropical north, where production is irrigated. It is the dominant cereal food crop in many countries of tropical Africa, playing the same role as rice in Asia and wheat in Europe and the Mediterranean. The place of maize in the farming system of the African farmer is very important; it is sometimes planted as a sole crop, but more frequently it appears in mixed cropping with legumes, root crops, leafy vegetables and other cereals.

Even though the total annual volume of maize production in Africa has increased by about 150% in the past 25 years, from 12 to 30 million tons, yield has stagnated at about one ton per hectare; this unprogressive yield trend is particularly true of the tropical region. Disease attack is a major reason for the low yields obtained by African farmers. Diseases are greater in number and intensity in the tropics