To Feed Ourselves

A Proceedings of the First Eastern, Central and Southern Africa Regional Maize Workshop

Lusaka, Zambia, March 10-17, 1985

Sponsored by: The Government of Zambia and CIMMYT

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Bantayehu Gelaw
Workshop Organizer

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Preface

The last 20 years have seen little if any increase in maize production in many African countries, while population has increased considerably, leading to a decline in per capita production in these countries. The result has been a growing dependency on imports and food aid, and adverse impacts on foreign exchange holdings. This situation has been aggravated by drought. The worst famine in recent African history took place in 1984, and 1985 was predicted to be still worse.

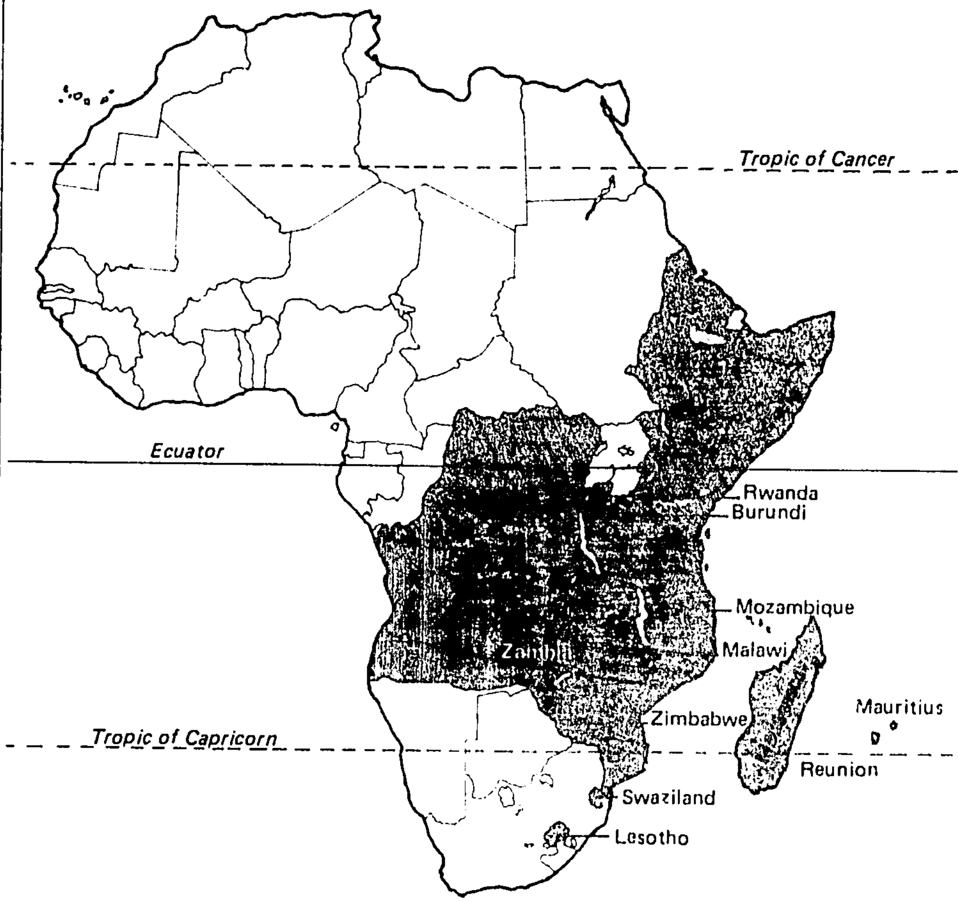
Many formidable problems lie in the path of African farmers, barring the way to more vigorous and efficient maize production. Overcoming these problems will require determined action by many groups and a firm resolve on their part to work together. The scope for cooperation and its potential benefits are particularly great for Africa's agricultural researchers, who stand to gain, among other things, better access to ideas and techniques from inside and outside the continent.

For several years, CIMMYT has been helping construct a framework for research cooperation through its two regional maize programs in Africa. One of the fruits of that work was the Eastern, Central and Southern Africa Regional Maize Workshop (held in Lusaka, Zambia, March 10-17, 1985), the first meeting of African maize researchers since the termination of the East African Community in 1977. The chief aim of the workshop was to create a better awareness among researchers of their mutual problems and of various approaches to solving them.

With this proceedings, our aim is to further strengthen that awareness, which is the foundation of regional cooperation in maize research. The proceedings consists of 17 country reports and 13 contributed papers by prominent maize scientists from both developed and developing countries. Some of the reports and papers are followed by questions and answers or comments that were made at the end of the presentations and give further information on the subject under discussion. The contributed papers address many critical issues (research planning, breeding strategies, on-farm research, seed production) that African nations are confronting as they seek more effective agricultural research strategies. Many of the papers treat some aspect of maize improvement, with particular emphasis on genetic resistance to insects, diseases and drought. These resistances are vital to the improvement of grain yield stability, which in the African context is at least as important as increased yields, if not more so.

Maize scientists should find much useful information in this fairly detailed and comprehensive account of the conditions, problems and activities of their counterparts throughout the region, as well as of maize research being carried out by the international agricultural centers. We hope that this proceedings will not only make those scientists better informed about maize research in Africa, but that it will also help them identify specific opportunities for research cooperation.

Bantayehu Gelaw
Workshop Organizer



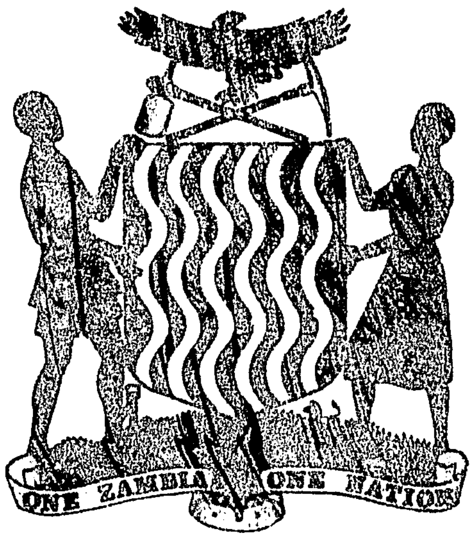
Participating Countries in the First Eastern, Central and Southern Africa Regional Maize Workshop

2

Opening Ceremonies

Welcome to the First Eastern, Central and Southern Africa Regional Maize Workshop

The Honourable G.K. Chinkuiu, MP, Minister of Agriculture and Water Development, Zambia



The need to expand the production of maize, as well as that of other cereals, is recognized as one of the most critical issues presently facing Zambia and other countries in the region. Therefore, I want to express my sincere pleasure and appreciation at being invited to open this maize workshop, which I understand is being attended by delegates from 17 neighboring countries in eastern, central and southern Africa.

It is extremely gratifying to note that many organizations, including the International Maize and Wheat Improvement Center, the International Institute of Tropical Agriculture, the International Development Research Centre and the United States Agency for International Development, have provided funds to sponsor the attendance here of many of the delegates from outside Zambia.

Scientists of international renown are also here, sponsored by their own institutions. We are indeed fortunate to have such experts join us. They will be presenting stimulating papers, leading discussions and providing the cohesion required for this regional workshop.

I welcome you all and hope that you will be well satisfied with the workshop and by your visit and experiences in Zambia.

This week's workshop is the first of its kind to be organized in Zambia since the Third East Africa Cereals Research Conference in 1968, some 17 years ago. That conference was jointly sponsored by Zambia and Malawi, and was part of a tri-annual gathering of agricultural specialists which was held in various countries. I understand that some of the delegates here today were also at that conference. This maize workshop is part of an attempt to revive such regular meetings.

As many of you know, the Consultative Group for International Agricultural Research (CGIAR) now has a number of centers under its financial wing. They conduct research in the major food crops and livestock and have mandates to work in close cooperation with national research and development programs. CIMMYT has a global responsibility for maize, and works in close cooperation with IITA, which concentrates particularly on the humid tropics of Africa.

The international centers were established to help regions such as ours. They are there to guide us in our long- and short-term research projects and to spread improved technologies around the world. They cooperate in providing guidance in the training of personnel, in establishing procedures for conducting sound research, in organizing production and marketing programs and in helping to transfer knowledge regarding crop improvement.

I am glad that the international institutions responsible for maize have recognized the importance of our region. Hopefully, production can be increased to such an extent that we will be able not only to feed ourselves and supply our agroindustries, but also to export to those who are less fortunate and thus earn needed foreign exchange.

The objectives of this workshop are to outline the "state of the art" for maize in the region, to clarify the major constraints to increased production and to identify priorities. An effort has been made to bring together as many scientists and other lay personnel as possible, so as to create a forum for a fruitful exchange of ideas and regional priorities and to discuss the possibility of sharing resources and materials. This workshop provides an excellent opportunity to communicate, to think, to evaluate and to improve upon these interactions. Each country, however, is ultimately responsible for its own destiny, and must develop sound, meaningful and long-term maize-improvement strategies, with assistance from the international institutions.

In Zambia, the party and its government has made a clear statement that this country should become self-sufficient in the major foodstuffs by 1990. "Operation Food Production Programme." The program, announced in 1980, is spearheaded by small-scale subsistance farmers, lima farmers (those cultivating one lima, about ¼ acre or 625 m^2), commercial farmers and state farms. For this program to succeed, careful thought and action need to be given to the positive and careful use of the country's resources; this means that crop production will have to be tailored to appropriate agroecological zones. In Zambia, we are now well-aware that we cannot continue to push production of maize to all areas, especially those where other crops can be grown with comparative advantage. The country's resources should be used to produce food crops and other agricultural products in areas where they are best adapted.

In terms of rainfall, its distribution and potential evapotranspiration, a large part of this region can be considered to be in the semiarid tropics. Rainfall tends to occur over only a few months of the year, while evapotranspiration exceeds rainfall for most of the year; it is important that sensible and careful use be made of the rain that falls. There are some very large rivers in the region, and it is extremely important that agricultural practices not result in our precious soil being transported away from the farms and down the rivers to be irretrievably lost in the sea.

The soil is our heritage, and it must not be lost. The conservation of soil and water and the use of irrigation is of utmost importance, as is the development of more drought-tolerant crop varieties. We are all aware that large areas of Africa have been severely affected by drought conditions over the last several years, and in many countries this continues to be the sad situation. I trust that this aspect of maize research will be given urgent consideration at this workshop.

Farmers live in a risky physical environment, and many are in a constant poverty cycle, especially those who operate on a small scale. Many factors contribute to this situation, such as inadequate education and training, limited resources, variable marketing and pricing policies, a lack of credit, land tenure problems and limited or poor extension services. The farmers can do very little to change their physical environment, which also has a part in keeping them in this cycle of misery.

What the farmers can do, however, is to make an all-out effort to protect their environment and grow crops and follow farming systems which are better adapted to their own particular conditions. They need guidance for solving many day-to-day problems, which crops to grow and where, which varieties to use, how to lay out storm drains and contour systems, where to put access roads, how to manage wetland areas, and how to manage the wet dambos such as we have in Zambia.

The overall objective that you have as agricultural scientists, like all those connected with the agricultural sector, is to increase the well-being of your fellow human beings. The problems of rapid population growth and the necessity of increasing national food production are of concern worldwide. There is a general belief that people in Africa are eating less food now than they were ten years ago, and that the food is nutritionally poorer. This trend must be reversed, and strategies for increasing production must be adapted to local conditions in each of our countries. We should not and cannot afford to continue to import foods which can be grown locally; our scarce resources must be used to import materials and equipment to help us produce the goods and finished products.

Every nation interested in maize improvement has no doubt received seed and other support from the international centers and has benefited from it. If your country has not already done so, take the appropriate action so that your national programs can become more productive. It is most important that our African scientists have continuous access to the centers' generous flow of germplasm and technologies, and that no unnecessary quarantine requirements or plant breeders' rights are in the way.

Plant breeders and other scientists must produce varieties which minimize farmers' constraints, particularly in marginal areas. You are the key to our future health and prosperity. Your shoulders must be strong, your skills and judgment sound. Good scientific procedure demands that you be energetic, humble, both constructive and critical, open-minded but not credulous, accustomed to think before you act and then to act upon your conclusions. You must safeguard the public interest in matters of health and safety, and discharge your professional responsibilities with integrity.

The staff working on maize in Zambia have gone a long way in this respect, and I am sure you will be pleased to learn that the research branch of the Department of Agriculture has made excellent progress; they have released eight new hybrids and two open-pollinated varieties in the past year. When multiplied and available, these will reduce our 20 years of dependence on the excellent and productive, but late-maturing, hybrid SR52. The new varieties will provide a choice for all types of farmers in the various ecological regions of the country. The maize staff are to be congratulated on this tremendous achievement.

The major thrust now must be to ensure that technical solutions be found to the production problems faced by small-scale farmers; as I mentioned before, the majority live in a harsh environment with limited resources. Many large-scale farmers also operate within a difficult financial environment, with the banks breathing down their necks. Care must be taken so that small-scale farmers are not locked into their traditional practices, and large-scale farmers are not burdened with financial millstones. This workshop should endeavor to ensure that technology is relevant for both of these groups. An effort is being made in Zambia and elsewhere to tackle this problem through on-farm research. The adaptive research planning team in Zambia functions on a regional/provincial basis, and supports the work of the multidisciplinary commodity research teams that operate nationally.

There are many examples in which a change in crop management and/or variety brings an array of new problems to be solved. Each country has to understand its own constraints and utilize its own research capabilities to provide appropriate solutions. The international centers are ready to provide assistance in germplasm, materials, technologies and advanced training. Sometimes scientists with the necessary skills can be loaned by the centers and placed at strategic locations in a region. Perhaps this workshop can recommend action and decide on a possible location or locations in this region. It is also important that each country encourage the creative ability of its scientists, so as to ensure maximum productivity in those areas where maize has considerable potential. It is sometimes difficult when only a few staff members are available to develop well thought-out strategies, but even a few, supported by funds and equipment, can make remarkable progress.

Training is imperative to success. All of our countries need to train and have available competent agriculturists. We greatly appreciate assistance from scientists from other countries, but how much longer can we rely on outside aid? The international centers have excellent courses for scientific and technical personnel in most disciplines. It is the task of all countries in the region to utilize these opportunities, arranging sponsorship for their workers, either from those centers or elsewhere. This workshop may reveal what can be done and possibly suggest the number of students that can be accommodated annually. There should also be opportunities for training within the region. I understand that CIMMYT recently held a successful training program for maize technicians in Malawi, and that plans are underway to hold one in Zambia in 1986. This workshop can further stimulate such plans.

All of us are faced with a very considerable challenge. Zambia offers excellent conditions for increased production through its soil, water resources, rainfall and other climatic factors. We look to the maize section of the cereals research team in the research branch of the Department of Agriculture for guidance, commitment and enthusiasm. Researchers must continue to select improved, disease-resistant, high-yielding varieties suitable for all types of farmers. The grain of these varieties must be of the quality demanded by the consumer. The research program must identify packages of technologies for achieving production targets in the shortest possible time. Similarly, the extension services and the various development and aid programs must vigorously disseminate the acquired knowledge and help farmers during all stages of production.

We hope that everyone here will contribute effectively to the objectives of this workshop and that all of our countries will benefit from it. Good research and production strategies must be worked out for each country. Let us collect and collate the facts of maize production. How much maize is or could be grown? Where is it grown, and what is the potential area within each ecological zone? In which areas would it be better to concentrate on more drought-tolerant crops? What are the major constraints of maize production, and how can they be eliminated? What are the market prices for maize, and are they sufficient to encourage farmers to stay on the land rather than seeking alternative employment in the towns? What are consumer demands as to amount and quality, and are the marketing organizations and millers able to fulfill those demands on a regular basis? What are the training needs of researchers, extension workers, farmers and others in agriculture? Let us produce first to feed ourselves, and then hopefully to export.

In conclusion, I would like to repeat my very sincere thanks to the sponsors of this workshop, especially to CIMMYT and our own Department of Agriculture and its cereals team. I understand that many Zambia-based organizations have provided assistance by way of funding and transport; I thank them all most sincerely. Let me also say how grateful we are to the management of our Lusaka Intercontinental Hotel for providing the conference facilties and accomodations for our international guests.

To all participants, may I wish you well in your deliberations at this workshop and success in your challenging tasks when you get back home. I will look forward to receiving a copy of the workshop proceedings and recommendations. And most of all, of course, I look forward to seeing a surplus of maize in all of our countries!

It is with great pleasure that I declare this workshop open.

The Delegates' Response to the Honourable Minister

A.J. Moshi, National Maize Research Programme, Tanzania

On behalf of my fellow participants, I would like to extend our thanks to the Government of Zambia for allowing us to attend this maize workshop. We also wish to thank the Honourable Minister of Agriculture and Water Development for the very sound advice he has just given us. We hope that by the end of the workshop we will know more about the problems and successes of maize production in the countries represented here and will have identified ways of solving those problems.

We extend our thanks to the organizers of this workshop, especially Dr. Bantayehu Gelaw of the CIMMYT East African Maize Program, who has worked so tirelessly in its organization. We also thank the Zambian research team for assisting him, as well as for welcoming us so warmly to Zambia. Our thanks also go to the several institutions and international organizations without whose sponsorship many of us would not be here.

We hope that this workshop will not be the last and look forward to another in two years. Perhaps, in the interim, we can put into practice the recommendations of this workshop and will have new achievements to report in 1987.

Honourable Minister, again we wish to say, "Thank you."

Initiation of the First Eastern, Central and Southern Africa Regional Maize Workshop

B. Gelaw, Workshop Organizer, CIMMYT East African Maize Program, Nairobi, Kenya

On behalf of the workshop steering committee and the East African Regional Maize Program of the International Maize and Wheat Improvement Center (CIMMYT), I would like to welcome all of you to the First Eastern, Central and Southern Africa Regional Maize Workshop here in Lusaka, Zambia. CIMMYT's East African Regional Maize Program was formally established in September 1982 and is headquartered in Nairobi, Kenya; one maize breeder is assigned to the program as coordinator. Since that time, I, as the program's representative, have been attempting to organize such a workshop as this, but due to a number of circumstances, I have been unable to do so sooner. I am pleased that the time has finally come for this long-awaited meeting of African maize research workers.

We feel that Zambia is a good place to hold such a workshop; the Zambian National Maize Research Program successfully released eight hybrids and two open-pollinated varieties in 1984, and other hybrids and varieties are in the pipeline for possible release. Their hybrid maize work is backed up by a strong population improvement program. It is my belief that Zambia's experience can provide an excellent opportunity for maize scientists in the region to see the results of an integrated breeding approach.

During the 1960s and 1970s, there was a forum known as the East African Cereals Research Conference, where scientists from various countries in the region got together every so often to exchange ideas and research results. This conference was terminated in 1977 with the discontinuation of the East African Community, and since then we have had only a few sporadic conferences and workshops organized by national programs and assisted by international centers and donor agencies.

Production of maize, the primary food crop in Africa, has remained stagnant over the past 20 years in most African countries, averaging about 1 ton per hectare. In certain countries, production per capita has actually declined. To cover deficits in consumption, several African countries have become dependent on imports and food aid, which has seriously affected their balance of payments. Africa is the only continent where Malthus' prediction of food production not being able to keep pace with population growth seems to be a reality.

The year 1985 was the target of the famous 1980 Lagos Plan of Action, which was adopted by African leaders for eliminating hunger from their continent. However, FAO's forecasts show that 21 African countries will face more severe food shortages in 1985 than they faced in 1984, one of the worst famine years in the continent's recent history. There is, nevertheless, some hope that existing improved maize hybrids and varieties, as well as production practices, can increase maize yields in Africa.

To make this hope a reality, research activities must be stepped up to generate new and more appropriate technological components that can increase yield dependability across a wide range of environments. More emphasis should be given to developing varieties with greater tolerance to drought, mineral stresses and temperature extremes and with improved resistance to economically important diseases and pests. For this reason, we have invited internationally renowned maize scientists to share their experiences with us by presenting papers and contributing to our discussion sessions.

In addition, each participating country has been officially requested to present a "country report" outlining current maize research activities, materials released, pressing problems and needs and future plans of action. An exchange of such information, as well as of techniques and breeding materials, should facilitate maize production in the region. It is my firm belief that this workshop will help encourage cooperation in maize research efforts by broadening our awareness of each country's conditions and activities and by strengthening our relationships with one another. It should also help familiarize the participants with the current and planned maize research activities of the international centers in the region. Scientists from this region have often met outside the region or continent, but not in one another's trial plots.

Twenty-two countries received formal invitations for two senior national maize scientists to attend this workshop. Sudan and Botswana sent their regrets. The Seychelles and Comoros Islands have not responded, and the expected Rwanda delegates have not arrived. The other 17 countries accepted our invitation and have sent their delegates. Special invitations were also sent to a few prominent maize scientists from developing as well as developed countries to join us here; all have accepted our invitation, for which we are indeed grateful. Some international and bilateral donor agencies have also sent representatives as observers. All in all, over 100 participants are here at the workshop, including observers representing a number of organizations in Zambia. Thank you all for your interest in this endeavor.

This workshop would not have been possible without the generous financial and moral support of a number of governmental, bilateral and international organizations. First and foremost, I would like to extend my sincere thanks and appreciation to the government of the Republic of Zambia, in general, and to the officials of the Ministry of Agriculture and Water Development, in particular, for graciously hosting this First Regional Maize Workshop, and for organizing it in cooperation with CIMMYT. Zambia has also contributed immensely in meeting all local expenses, including hotel bookings, transportation, secretarial assistance, receptions, banquets, refreshments and many other incidentals. Many senior officials and scientists have spent a great deal of time in organizing this workshop. A number of organizations in Lusaka have also provided assistance in funding and transport, including Zamseed, Power Equipment, the EEC, SIDA, Barclays Bank and Shell Chemicals.

The International Development Research Center (IDRC) fully funded two candidates each from Ethiopia, Uganda and Burundi; their regional office in Nairobi was also very helpful in encouraging the holding of this workshop. The East African Regional Economic Development Service of the United States Agency for International Development (USAID/REDSO/ESA) covered the cost of plane tickets and per diem expenses of many participants. USAID's Kenya office funded the two Kenyan delegates nominated by their government, and the University of Florida/USAID/Malawi

Government Agricultural Research Project funded one of the participants from Malawi. The International Institute for Tropical Agriculture (IITA) has pledged to fund one participant each from Tanzania, Malawi and Zimbabwe. CIMMYT's Eastern and Southern African Regional Economics Program is covering many of the expenses of the workshop.

Last but not least, CIMMYT's Maize Program was ultimately responsible for meeting the expenses of all other participants, as well as being responsible for inviting the participants, guest speakers and observers. The arrangement of travel plans within and between countries, telephone calls and the sending of letters, cables and telexes was undertaken by CIMMYT's East African Regional Maize Program office. To all others who have contributed in any way, and there are many, I am indeed grateful.

I hope that, before this workshop ends, a recommendation will be made that such a Regional Maize Workshop be held every other year, rotating the host countries so as to give each country an opportunity to hold such a meeting.

In closing, I wish once again to express our heartfelt thanks to the government of Zambia for the wonderful hospitality they have extended to us.

3

Country Reports

Maize Research Activities in Angola

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Maize is the staple food of nearly one-third of the 2.5 million people of Angola and is also the main food crop of the country. Annual maize production in the 1970s, the last period for which figures are available, was about 700,000 tons, of which about one-sixth was exported. The three main maize-growing areas of the country were the central highlands (70%), the Huila highlands (15%) and the Malange highlands (10%).

About 85% of the total production in the 1970s was by small-scale farmers, who had an average yield of about 500 kg/ha. The other 15% was produced by larger farmers, with yields ranging between 1 and 4 t/ha.

The principal grain types grown in Angola at that time were white flint (80%), white dent (10%) and yellow flint (10%). The main cultivars grown were Branco Redondo (a white flint, open-pollinated variety), SAM2 (a yellow flint synthetic) and SR52 (a white dent, single-cross hybrid).

Today, because of problems due to the war, no accurate statistical data is available, but it is supposed that present production does not exceed 200,000 tons per year.

Maize Research Activities

Maize research in Angola was begun in the 1940s and is conducted by the Agronomic Research Institute (IIA). Presently Angola and Yugoslavia have a bilateral contract for cooperation in two projects, one in maize breeding between IIA and the Maize Research Institute (MRI) of Zemun Polje, Yugoslavia, and the other in maize seed production, with MRI, IIA and DNOPA (the National Department for Agricultural Production).

Maize breeding

The principal activities of the maize breeding project are:

- Conservation of a small germplasm bank, including about 800 heterozygous populations;
- Development of inbred lines (1400 lines are being studied, of which 600 are in their sixth or later generation of self-pollination and 800 are between the third and fifth generations);
- Study of approximately 400 hybrids of various types;
- Collaboration with CIMMYT in international trials (with the best results obtained in 7 EVTs, 2 ELVTs and 1 QPMT);
- Selection for resistance to streak virus, the principal maize disease in Angola (phenotypic selection is being carried out with late material and MSR-EVT materials introduced from IITA);
- Selection for tolerance to *Helminthosporium turcicum*, which causes leaf blight in the central highlands;
- Selection for tolerance to soil acidity (most of the Angolan areas suitable for maize growing have acid, ferralitic soils); 2 apparently very tolerant varieties, 8 tolerant varieties and 18 varieties with medium tolerance to aluminium toxicity have been selected, and

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- Selection for reduced plant height for lodging resistance. The CIMMYT materials have better plant height, but are normally more susceptible to *Helminthosporium turcicum* than the Angolan materials.

Seed production
The controlled production of maize seed presently involves only one single-cross hybrid, ZPSC852b, a tall, late, white dent variety similar to the SR52 grown at Malange, and one synthetic, SAM3, a yellow flint with broad adaptation, moderate tolerance to *H. turcicum* and good yield potential (sometimes more than 7 t/ha in small trials at Huambo). In the 1983-84 season, 31 tons of ZPSC852b seed was produced, and 2 tons of SAM3 basic seed was ear selected.

Agronomic improvement
A small program of field trials has been conducted on the use of nitrogen, phosphorus, potassium, sulfur and magnesium fertilizers and rock phosphates. Also, tests on herbicides have been conducted, in which Primextra was found best for chemical control of weeds, especially nut grass.

Other research achievements
Other accomplishments of the national maize program have been:

- Inbred lines—12 inbred lines have been selected as most promising, including three of late and one of medium-late maturity;
- Hybrids—18 experimental hybrids have been selected, 7 white (4 single crosses, 1 double cross, 1 top cross and 1 triple cross), 6 yellow (4 single crosses and 2 top crosses), 5 white-yellow (mainly from one inbred line developed from the hybrid Pioneer 44), and
- CIMMYT populations—the populations showing best performance in Angola among the CIMMYT trials have been SIDS 7844, Poza Rica 8022, Across 7921, El Paraiso 7929 and Across 8043. The best one, Poza Rica 8022, has yielded more than 8 t/ha.

Research Staff

The staff of the national maize program includes two Angolan maize breeders, two Yugoslavian maize breeders and six Angolan technicians. At times additional part-time staff are employed; for example, more Yugoslavian maize breeders and Angolan technicians are needed at pollination time. There is also close collaboration with the staff of the Soils and Climate and the Phytopathology departments of IIA.

Constraints to Maize Research

The principal problem in the maize breeding project is that experimental trials are carried out only in the central highlands. However, it is hoped that, in the near future, they can be extended to two other locations, Malange and Huila (Matala).

The principal problems in the maize seed production project are the inadequacy of seed processing facilities in the country and the lack of farms that are well adapted for seed production. The first problem will be partially solved with the installation of two seed processing plants, at Chianga and Malange, by an FAO-UNDP project. The establishment of state farms for seed production at Huambo, Malange and Huila will further increase the amount of quality maize seed available in the country.

Farmer Rejection of Late-Maturing, High-Yielding Maize in Burundi

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Burundi is a landlocked country in central Africa. The country is mostly mountainous, except for the plain at the tip of Lake Tanganyika. The climate varies from tropical to temperate according to elevation, which ranges from low (800 to 1200 meters) to medium (1200 to 1800 meters) to high (1800 to 2600 meters).

Maize is the most important cereal crop in Burundi and is grown by all farmers in all localities. It is most important at high altitudes, where it is consumed as fresh green ears or made into flour for the making of *ugali*. In low altitudes, maize is consumed only in the form of immature ears. In medium-altitude areas, tuber crops such as cassava and sweet potato tend to be more important in the human diet than maize.

Maize is cultivated in association with legumes, particularly beans (*Phaseolus vulgaris* L.) in the first season and peas (*Pisum sativum* L.) in the second. It is grown by small-scale farmers, and land preparation, sowing, weeding and harvesting are all carried out by hand.

The principal constraints to maize production are:

- Diseases, especially maize streak virus, but also leaf blight and rust;
- Lack of early varieties with high yield potential, which would permit a second-season rotation crop;
- Storage insect pests, particularly *Sitotroga cerealela* and *Sitophilus* spp.;
- Infertile, acid soils, which are found in many regions, and
- Poor infrastructure within the country, which makes it difficult for farmers to get the necessary inputs and technical advice.

The maize program is one of the research programs organized by the Burundi Institute of Agricultural Sciences (ISABU). Financial assistance for this program is provided by the International Development Research Centre (IDRC) of Canada. Staffing includes one expatriate adviser, two graduate agriculturists, two technicians, one administrative assistant and one agricultural assistant.

The principal objectives of the maize program are:

- Selection and improvement of varieties that meet the needs of farmers (with active collaboration from the farmers in the testing of varieties);
- Assessment of new problems identified at the farm level, and
- Establishment of research projects for solving these problems.

Results of the program to date have included the release of Kitale Composite A (KCA) for the high-altitude zone, Igarama-4 for the medium-altitude zone and GPS5 for the low-altitude zone.

Presently, special emphasis is being placed on the development of a high-altitude population that is resistant to

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maize streak disease and early enough in maturity to permit double cropping. Resistance is being developed by selecting within local materials under artificial inoculation, as well as by introducing genes for resistance by backcrossing local materials with an IITA source. Two low-altitude materials derived from CIMMYT experimental varieties (Population 43) have entered verification trials on farms, following their promising performance in variety trials; these varieties are being multiplied and will probably be distributed to farmers in 1986. It is hoped that the program can identify a synthetic variety, using IITA inbreds, to serve the medium-altitude zone.

The Burundi maize program collaborates with international organizations, including CIMMYT and IITA; it is felt that the successes registered by the program are a result of that collaboration.

Maize Research

In 1980, the Burundi maize program recommended for release a high-yielding, long-season maize variety selected from Kitale Composite A (KCA), which is of Kenyan origin. Maturing in approximately 220 days, this tall ($>$ 2.5 m) variety is harvested in late May; it is rather susceptible to lodging. Although it yields 20 to 40% more than previously released varieties (8), KCA has met with considerable farmer resistance because of its lateness. The principal complaints are that farmers have to wait six weeks longer before they can begin their harvest, and that this does not permit a good second-season pea crop.

Informal surveys by the Burundi Maize Program have revealed that one of the most common cropping systems in the highlands is a maize/bean-pea intercrop/rotation. Maize is typically planted with beans in late September at the onset of the rains. The beans are harvested dry in late December and January. After a short dry season, farmers plant peas in mid-March among the ripening maize, which is harvested a few weeks later. The peas mature as the rains taper off in May and June, and are harvested dry in July. Thus, harvests are staggered over the year. Almost all production is consumed in the home, with any surplus entering the local market. Commodity prices are set in the local market place with no government intervention.

This paper presents a critical analysis of the variety KCA within the context of this local cropping system. In 1982 and 1983, field trials were conducted according to farmers' traditional practices to quantify the impact of the use of KCA on the system. The three principal questions addressed were whether the farmers gained by planting high-yielding, late-maturing maize, whether it was possible to modify the cropping system to make the variety more attractive, and whether by closely following traditional practices, researchers could modify selection strategies to insure that new varieties would be accepted by farmers.

Trials

Trial 1. Impact of maize maturity on following-season pea yield—In September 1982, 16 varieties and lines of various maturities were planted in a multilocational yield trial, generally following CIMMYT's methods for their EVTs, at three high-elevation sites, Kisozi at 2090 m, Munanira at 2140 m and Nyakararo at 2100 m. In early March, 10 t/ha of manure was lightly tilled into the soil of the plots, and on March 15, peas of the local variety Kyondo were planted at a density of 62,500 plants/ha. Because of the differences in the maturity of the various varieties and lines, the peas were planted in some cases as much as six to eight weeks before the maize was harvested. In some plots, the maize was harvested to determine if tilling for peas had had an adverse effect on maize grain yield. Total economic yield was based on the market prices of 25 Burundi francs/ha for maize (120 FBu = US$ 1) and 65 FBu/ha for peas. Although the crops under consideration were not cash crops, these freely set prices were thought to fairly represent their relative values.

Trial 2. The impact of maize maturity and density on yield in a three-crop system—A second trial was planted at Munanira in September 1983 to compare the performance of KCA with that of Igarama-4, an improved local maize which matured 35 days earlier than KCA in the typical maize/bean-pea system. Both varieties were planted with uniform spacing at six densities (55,000, 45,000, 35,000, 25,000, 15,000 and 5,000 plants/ha) to determine which density led to maximum yield for each crop in the system. Plots measured 5 x 5 meters and manure was applied at 30 t/ha; the trial was arranged in four randomized blocks. The local bean mixture was interplanted at a density of 125,000 plants/ha. As in Trial 1, peas were planted among the maize plants on March 15, but with a density of 125,000 plants/ha, which more closely approximated farmers' plant densities.

Maize was harvested at maturity, and yields were corrected to a 14% moisture level. Disease severity data were noted for all crops during the year. Total economic yield was calculated with actual market prices at harvest, beans at 65 FBu/kg, maize at 25 FBu/kg and peas at 90 FBu/kg. The pea harvest was poor in 1984 because of a lack of rain; this accounted for the higher price. Total protein yield was based on beans at 22%, maize at 9% and peas at 22.4%. Simple land equivalent ratio (LER) was calculated for each maize density and variety over the two seasons from the expected yields determined from regressions of yield data on planting density. The standardizing factor for beans (1430 kg/ha) was the intercept of the combined KCA and Igarama-4 bean yields as a function of maize density; that for peas (1003 kg/ha) was the mean of the two intercepts for the pea regressions. Maize standardizing factors were their expected maximum yields (8807 kg/ha for KCA and 6120 kg/ha for Igarama-4). Effective LER (ELER) was calculated according to Mead and Willey (5). All regressions or correlations referred to in the text or in the figures are significant at least at P = 0.05.

Trial results

Trial 1—There was no significant correlation between maize maturity and total economic yield, but there was a highly significant correlation between maize efficiency and total economic yield; this differed among varieties. High-yielding, late-maturing varieties such as KCA didn't have total economic yields significantly different from those of earlier varieties. Maize and pea yields as functions of maize maturity followed a similar distribution at the three sites (Figure 1). A significant maize x site interaction was

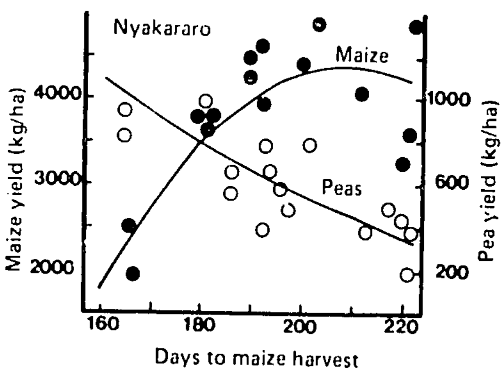

Figure 1. Maize and pea yields as functions of maize maturity at Nyakararo, Burundi
Note: Each point is the mean of four replicates

detected for maize yields and appeared to be due to the lower yields (compared to previous years) of the late-maturing lines at Munanira than at the other sites. This interaction precluded across-site comparisons. Pea yields as a function of maize maturity at all sites closely followed exponential decay, with high levels of significance. Peas grown with late maize varieties were observed first to etiolate and then die, leaving sparse stands of spindly plants after maize harvest. No difference in maize yield was measured between border rows with no interplanted peas and maize interplanted with peas.

Trial 2—First-season bean yields as a function of maize density for the two varieties were identical, as indicated in Figure 2. Grain yields (kg/ha) of the two maize varieties were best described as logarithmic functions of density (Figure 3). Pea grain yields as functions of maize density are presented in Figure 4. There was no significant correlation between maize density and pea grain yield for Igarama-4, with yield expressed as the overall mean. In contrast, pea yield as a function of KCA density followed exponential decay.

The distribution of total economic yield over the two seasons as a function of maize density followed a binomial distribution for both varieties, with no statistically significant differences between predicted yields at their maximum levels (Figure 4). Differences in disease levels were not related to maize density.

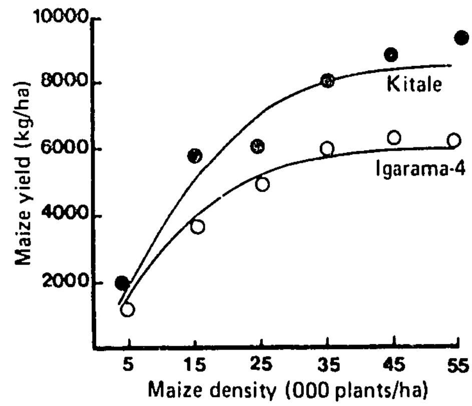

Figure 3. Maize yield as a function of maize density
Note: Each point is the mean of four replicates

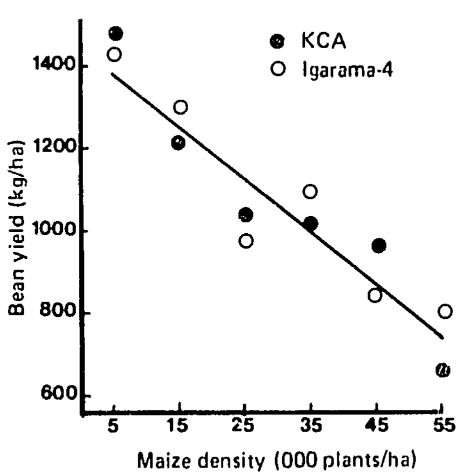

Figure 2. Bean yield as a function of maize density
Note: Each point is the mean of four replicates

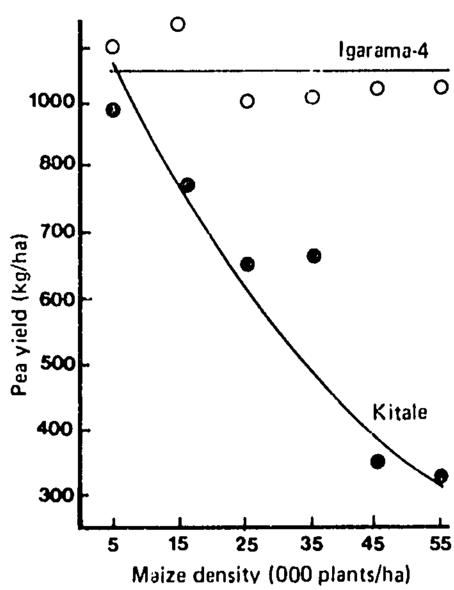

Figure 4. Pea yield as a function of maize density
Note: Each point is the mean of four replicates

In 1984, the rains in the second pea season were below normal and poorly distributed, resulting in very dry soils at pod filling and a heavy attack of aphids and powdery mildew. Based on the same pea variety in the same field at the same density in the previous year, predicted pea yield could be calculated from the regression equations. Using the "normal" price of peas (65 FBu/kg), predicted total economic yield could also be calculated. The conservative figure of 75% of the 1983 pea yield, or 1712 kg/ha, was taken as normal for the field in question. The predicted total economic yield as a function of maize density of both varieties followed identical binomial distributions (Figure 5). Total predicted protein yield, calculated in a similar manner and plotted as a function of maize density, also followed a binomial distribution for the two varieties (Figure 6).

Simple LERs, as a function of maize density over two seasons for the two maize varieties, followed a similar pattern of decreasing LER with increasing density after a peak at low density. This decline was less marked for Igarama-4, regardless of whether maximum yields for KCA or Igarama-4 were used as standardizing factors for maize yield (Figure 7). With the yield of KCA as the standardizing factor, Igarama-4 had a higher LER over the range of densities found in farmers' fields (35 to 55,000 plants/ha). This trend, though less striking, is also present when Igarama-4 yield is the standardizing factor.

The ELER might be a more appropriate comparison of the two varieties within this system, but it is difficult to calculate since there are no direct data available on the desired proportion of the crops. Based on data from this trial, however, one can estimate from the average on-farm maize density (approximately 45,000 plants/ha) that the desired crop proportions within local constraints (with a maize having a maturity such as that of Igarama-4) would be 0.49 for

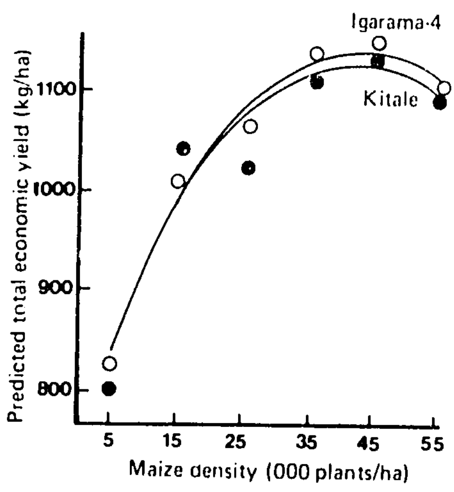

Figure 5. Predicted total yield of three crops over two seasons as a function of maize density

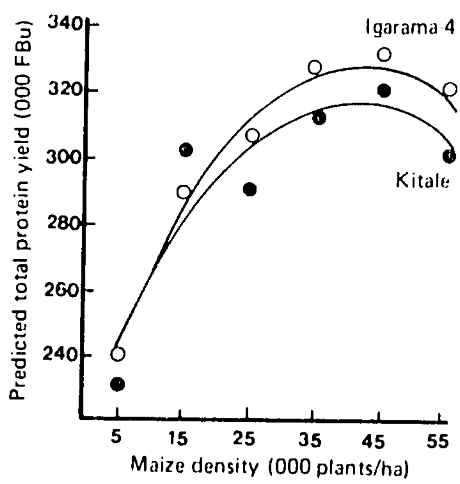

Figure 6. Predicted total protein yield of three crops over two seasons as a function of maize density

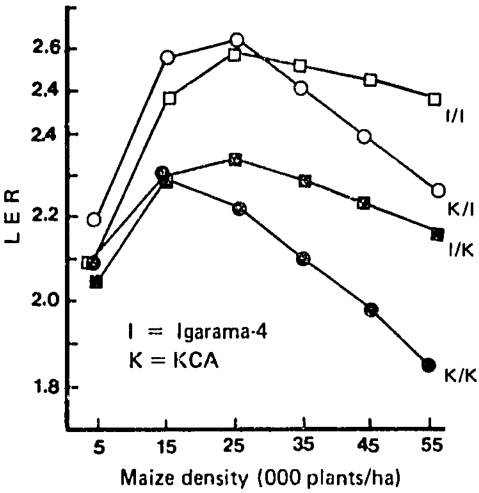

Figure 7. LER over two seasons as a function of maize density

Note: Numerator is variety in question, denominator indicates maximum yield used as maize standardizing factor

peas and 0.51 for maize. The ELER for KCA (calculated at 15,000 plants/ha, which gives approximately the same grain yield as Igarama-4 at 45,000 plants/ha) was 1.46 and that for Igarama-4, 1.90. Adding the bean component for each appropriate density gives a total ELER of 2.29 for KCA and 2.52 for Igarama-4.

Discussion

If maize were selected solely on the basis of yield in Burundi, late-maturing varieties could be recommended. However, increases in maize yield would be gained at the expense of the second-season legume crop, thus eliminating the yield advantage of long-season maize. No advantage in total economic yield and protein yield for the late maize was shown in either trial, and at local planting densities LERs were less favorable for the late variety. The ELERs indicate that there is no density at which KCA is clearly superior to Igarama-4.

Site x variety interaction is striking in long-season maize. At Munanira, the two maize varieties were damaged by heavy wind, and at Kisozi they suffered from a short but severe drought that coincided with flowering. Thus late maize, although it has a higher yield potential, leads to greater instability, perhaps simply by being exposed longer to the vagaries of nature. Since risk avoidance is a characteristic of subsistence agriculture, farmers may prefer to divide potential productivity among their principal food crops.

When comparing late- and medium-maturity maize, a most significant consideration becomes yield quality and distribution. With KCA, most of the protein in the system is incomplete, being entirely from cereals; with Igarama-4, a significantly greater proportion of the protein is nutritionally complete because it comes from both cereals and legumes. Igarama-4 is consumed with the beans remaining from the earlier harvest, and peas are consumed with other starch staples which are grown on land too poor for maize. If KCA were the principal variety grown, maize would only be available after most of the bean crop had already been consumed, and no legume would be available as a complement to maize during the dry season.

The different maxima among the curves of total economic yield and protein yield and LER as functions of maize density are noteworthy. LER reaches its maximum at 20,000 plants/ha; total yield maxima are reached at 40,000 plants/ha. This commonly encountered discrepency (5) agrees with Riley's observation that intercrops with similar LERs may have very different levels of attractiveness to farmers (7).

Thus, selecting maize on the basis of yield alone for the Burundi highland cropping system could result in the release of a variety that would disrupt the system unacceptably from the farmer's perspective. It is clear that, within the context of the whole system, farmer objections are quite rational. Biological and economic yield analyses show that a high-yielding, long-season maize offers no particular advantage, and an examination of LERs and food availability and distribution indicates that there may even be a serious disadvantage to pursuing a selection strategy of maximizing maize yield with no regard for the other components of the system.

This understanding of the place of maize in the local cropping system has permitted the Burundi maize program to develop selection and evaluation methods that ensure that maize varieties released in the future are compatible with farmer needs and limitations (9). These methods include the improvement of populations under intercropping and low-input conditions, as well as on-farm, farmer-managed evaluations of promising material. Particular attention is given to maturity and problems that may increase yield instability across years.

In discussions on crop improvement in the developing world, the criticism is often encountered that many of the recommended varieties and technologies are not relevant to the needs of the farmers or are actually incompatible with the constraints they face (6). Farming-systems research was developed, in part, to address this problem and to guide agronomists to more appropriate technologies (2). However, even in well-integrated projects, friction can develop among researchers having different perspectives (3). Farming-systems teams frequently exist as separate entities, and this may result in there being little communication between these teams and the commodity programs; there may, in fact, be competition for scarce resources (1). The results presented here show the inappropriateness of some recommendations developed from a strict commodity orientation, and they suggest how a farming-systems approach may be incorporated into a national commodity research program with relative ease.

National commodity research programs should select and evaluate their materials and technologies on the basis of farmers' limitations and requirements. Informal surveys conducted by the commodity researchers themselves can suggest how this may be done for a given situation. It is essential that the commodity program be given the responsibility for on-farm work, regardless of whether or not there is an independent farming-systems team. This allocation of responsibility does not necessarily require major institutional reorganization, but it does require sensitive commodity researchers who conduct a substantial portion of their work in farmers' fields.

Acknowledgements

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Discussion

Mr. Olver: We have no intercropping in Zimbabwe. Since you find that it is important, and since plant population is reduced in intercropping systems, how do you select for prolificacy?

Mr. Kayibigi: We select by routine extraction under standarized intercropping systems. One of our released varietes has tow ears.

Mr. Olver: Is prolificacy a genetic character?

Mr. Kayibigi: Prolificacy is influenced by the environment, and given the right conditions, that variety will give two ears.

Maize Research and Production in Ethiopia

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Discussion

Ethiopia is a large country (1,222,000 km^2) with a range of climatic conditions suitable for the growing of both temperate and tropical crops. A great variety are grown, ranging from *teff*, millet and cotton in the tropics to such temperate crops as wheat, barley and potatoes. The main native food crops are sorghum, maize, *teff*, millet, wheat, barley and *enset*. Coffee, cotton, castor beans, peanuts and pulses are the major cash crops.

The amount of cultivated land in the country is small in proportion to the total area; only about 10 million hectares are farmed (Table 1). Of this amount, about 50% are planted to the cereals *teff*, barley, wheat, maize, sorghum and millet (Table 2).

In Ethiopia, maize is grown throughout the country, with the bulk of production concentrated in the southern, southwestern and western

Table 1. Land use, Ethiopia

Type	Area 000 km^2	% of total
Cultivated land	104.3	8.5
Fallow land	20.9	1.7
Orchards and stimulants	7.2	0.6
Meadows	0.1	0.1
Pastures (rough and dry)	656.7	53.7
Swamps	51.8	4.2
Forestland, open woodland and bush	88.1	7.2
Barren land and built-up areas	172.0	14.1
Lakes and rivers	120.9	9.9
Total	1222.0	100.0

Source: National Atlas of Ethiopia, 1981

Table 2. National estimates of areas planted to the major cereai crops, Ethiopia, 1974 to 1982

Year	*Teff*	Barley	Sorghum	Maize (000/ha)	Wheat	Millet	Total
1974	1247.8	864.6	755.7	802.5	785.1	205.6	4661.3
1975	1470.7	648.1	782.2	786.1	556.9	378.4	4622.4
1976	1365.7	807.9	751.3	723.0	867.3	199.0	4414.2
1977	1333.5	897.8	767.5	901.4	512.3	232.3	4644.2
1978	1423.2	940.6	731.1	964.1	531.6	238.3	4828.9
1979	1513.3	909.8	1026.3	870.9	786.7	215.9	5022.8
1980	1362.0	830.9	979.1	735.5	536.3	232.9	4711.8
1981	1331.5	810.4	844.3	652.3	684.9	226.5	4629.3
1982	1399.8	908.0	905.7	819.7	715.0	225.2	5029.2
Rank	#1	#2	#3	#4	#5	#6	

Source: Central Statistics Office of Ethiopia, 1985 regions. Among the major cereals, maize ranks first in total production and in yield per hectare; it ranks fourth in total area (Tables 2 and 3).

Almost all of the maize produced in Ethiopia is used for human consumption in the form of *injera* (a large, thin pancake-type bread), *kitta* (bread), porridge, or boiled or roasted as a vegetable, particularly in the milk to early dough stage. The rest is used for making *tella* (local beer) and *araki* (a local alcoholic beverage); a very small amount is used for animal feed. The stalk is used for construction, fuel and animal feed.

History of Maize in Ethiopia

The precise date and route by which maize was introduced into Ethiopia is not known. However, it is generally believed that it was brought to East Africa, and hence into Ethiopia, during the late sixteenth or early seventeenth century (5). Since its introduction, the crop has gained much popularity and has become adapted to the various ecological conditions of the country. There are many different varieties, the most important ones being dent and flint types (1).

In reporting on their visit to Ethiopia in 1967, Harrison, Eberhart and Hazelden mention that the main source for Ethiopian maize varieties may be Tuxpeño with some Caribbean and US Corn Belt dents. However, further investigation will be needed after local collections are made from the major maize-growing areas and pockets in the country, and those varieties are identified.

Even though Ethiopian maize is well adapted to the environmental conditions in the country, the average national yield from 1974 to 1982 was only about 1.5 t/ha, far below the world average (Table 3). This low yield may be attributed to one or more of the following factors:

- The majority of the farmers still use varieties that have not been improved for yield potential, agronomic traits (such as ear placement, plant height and lodging)

Table 3. National yield estimates for the major cereal crops, Ethiopia, 1974 to 1982

Year	Maize	Sorghum	Barley	Wheat (q/ha)[a]	Millet	*Teff*	Average
1974	10.5	8.3	7.2	8.9	7.6	6.8	8.2
1975	17.4	11.2	8.3	9.6	10.0	6.8	10.2
1976	13.1	10.1	11.1	10.7	8.7	7.3	9.9
1977	10.3	9.2	7.7	8.4	8.9	7.7	8.6
1978	10.2	9.3	7.4	8.4	8.0	7.6	8.5
1979	17.5	16.0	11.6	11.0	9.9	9.4	12.7
1980	12.9	14.4	12.9	11.5	8.8	9.6	11.9
1981	18.4	14.3	11.5	10.3	8.7	8.1	11.7
1982	19.6	15.0	12.9	12.8	10.7	9.8	13.4
Rank	#1	#2	#3	#4	#5	#6	

[a] q = quintals (100,000 kg)

Source: Central Statistics Office of Ethiopia, 1985

and resistance to the major insect pest (*Buseola fusca*) and diseases (*Helminthosporium turcicum* and *Puccinia sorghi*);
- Farmers use unimproved cultural practices in land preparation, planting date, seed rate, weed and insect control and fertilizer application, and
- Farmers lack proper storage facilities.

Maize Research

Agricultural research was initiated in the Ethiopian institutions of higher education in the late 1950s and early 1960s to boost agricultural production and feed the country's large population. However, a well-organized research program with research stations located in the varying agroclimatic areas of the country was initiated only in the late 1960s. The national crop research program is organized and conducted by the Institute of Agricultural Research (IAR); research is also carried out by the College of Agriculture.

The IAR coordinates all crop research activities in the country through its crop teams, which were organized in 1980. A team comprises various disciplines, including breeding, agronomy, soil science, entomology, pathology and weed science. Due to the shortage of trained manpower, staff are involved in more than one crop team.

Long-term maize program objectives

The national maize research program has the following long-term objectives:

- Develop high-yielding maize varieties with desirable agronomic characters, to be made available to state farms and farmer associations;
- Create gene pools from which open-pollinated varieties, lines and hybrids can be developed at different stages of the breeding program, and
- Improve the nutritional quality of maize through the selection and release of highly nutritious maize varieties.

Short-term objectives

The short-term objectives of maize research are:

- Develop open-pollinated varieties adapted to the different agroclimatic areas of the country, making them available to small farmers;
- Develop hybrid varieties for state farms which have trained personnel and production know-how;
- Determine proper cultural practices for the different agroclimatic areas of the country;
- Strengthen the research and extension linkage so that improved varieties and management practices can be disseminated to farmers;
- Strengthen cooperation with international and national research centers of various countries, and
- Screen varieties for Ethiopia's moisture-stress areas.

The varieties which have already been developed or will be developed can be classified into three groups, according to their maturity. The early group (90 to 100 days to maturity) are adapted to those areas with a short rainy season or erratic rainfall, and the intermediate group (120 to 130 days to maturity), to areas with intermediate rainfall; the late group (160 to 170 days to maturity) are suitable for areas with a long rainy season.These varieties may be either open-pollinated materials or hybrids.

Current Research Activities

Breeding

The breeding program is working to meet the germplasm requirements of moisture-stress, intermediate- and high-rainfall areas. For intermediate- and high-rainfall areas, open-pollinated varieties, mainly composites, with experimental yield potentials of 80 to 100 quintals per hectare (1 quintal = 100,000 kg), have been developed and released. The weak point of these varieties is their lodging susceptibility, which makes them unsuitable for mechanization and reduces final grain yield. The good qualities of these varieties are their high yield potential and resistance to *H. turcicum* and *P. sorghi*. A full-sib family selection breeding approach is being followed to reduce plant height among lodging-resistant varieties with high yield potential.

In the late 1970s, a breeding program for moisture-stress areas was initiated to develop early maturing, open-pollinated varieties which could escape stress through earliness. The breeding program was begun with different populations, of which four were found to have good general combining ability. Then, an S_1 selection procedure was followed to improve agronomic traits, such as days to flowering, plant height and final yield potential. The result from two cycles of the S_1 selection program is shown in Table 4. From this breeding program, an open-pollinated variety was developed and has been presented to the National Variety Release Committee (NVRC) for final approval.

Agronomy

An improved variety *per se* is not sufficient for producing high yields, but must be accompanied by proper cultural practices. Agronomic research is a necessary component for developing packages of recommendations for improving production. The agronomic studies emphasized to date are in the areas of planting date, optimum population density for varieties from the different maturity groups, intercropping, crop sequence, tillage practices, the effect of row planting and crop water requirements. Since Ethiopia is a large country with many different agroclimatic areas, the studies have been carried out in different zones with varying local conditions.

Table 4. Improvements in three characters after two cycles of S_1 selection in four maize populations, Ethopia

Population	Yield		Days to flower		Plant height	
	Total gain	o/o gain/ cycle	Total reduction	o/o red./ cycle	Total reduction	o/o red./ cycle
47B/52	8.6**	4.30	12.5**	6.25	9.8*	4.90
Indian synthetics	7.7**	3.85	13.0**	6.50	9.3*	4.60
Katumani (MI)	14.2*	7.10	12.5**	6.50	16.8**	8.40
Neghelle (MI)	12.5**	6.25	10.8*	5.40	15.8**	7.90
$\bar{x}$	10.75**	5.38	12.2**	6.16	12.9**	6.45

*, ** Significant at P = 0.05 and 0.01, respectively

Soil fertility

In this research activity, various aspects of fertilizer use are being tested, such as timing and method and rate of application (particularly of nitrogen and phosphorus for different soil types). Studies are also being carried out on the use of green manure crops.

Insect control

Entomology—Surveys are being made to identify the different species of insect pests found in the country and their importance in maize production. This step is necessary to arrive at control measures (chemical, cultural or biological) for an integrated pest-management system. In the survey, *B. fusca* was found to be the major insect pest, causing heavy damage from the seedling stage to maturity. It occurs at altitudes of 1235 to 2600 meters.

Pathology—Very limited studies on maize diseases have been conducted over the last few years. They include a disease survey, a loss assessment study and a study of control measures, such as varietal screening and chemical control of some of the major diseases. According to the routine survey, there are fifteen diseases affecting maize in Ethiopia, among which rust (*P. sorghi* Schw.) and leaf blight (*H. turcicum* Pass.) are the major ones. Head smut (*Sphacelotheca reiliana* Kuktn. Cunt.) has also been found on certain state farms in the southern part of the country. Other diseases are minor, or their intensity is not yet known.

Weed control

Weed problems in maize were found to be varied and complex. In general, annual and perennial grasses are less of a problem than are the broad-leaf species, which cause the greatest loss and are less easily controlled. Apart from these, *Striga asiatica* and *S. hermonthica* were found to be the major parasitic weeds in specific areas of the country. Some cultural and chemical means of weed control have been identified for the nonparasitic weeds.

Seed Production, Marketing and Distribution

The national seed program was implemented in July 1978 with the establishment of the Ethiopian Seed Corporation (ESC). However, large-scale seed production and distribution has been carried out only since 1980. At present, maize seed production is concentrated in the wet western lowlands and in the southern part of the Rift Valley. These regions are important for both seed and grain production. The production of maize seed during the last four years (1980 to 1984) has been substantial (Table 5).

Table 5. Crop seed distributed by the Ethiopian Seed Corporation (ESC), 1980 to 1984

Year	Maize	Wheat	Barley	Sorghum	*Teff*	Haricot-bean	Rape seed	Soybean	Sunflower	Total
					(quintals)					
1980	19,996	194,792	1,656	250	4,147	612	-	660		214,113
1981	25,746	224,413	1,596	1,757	1,834	146	832	40	-	267,364
1982	16,967	256,815	23,430	3,046	1,490	2,797	500	217	-	305,262
1983	26,155	186,088	8,936	3,256	1,047	860	36	47		226,425
1984	13,190	122,473	16,476	1,081	2,581	1,832	257	12	.	157,901
1985	118,831[a]	229,630	12,878	11,752	56,000	2,490	432	1,050	160	433,218

[a] Of this, 74,8312 is commercial seed, not certified but field approved

Seed prices before and after processing are fixed by the government's central planning council. Based on these prices, the ESC delivers seed to the state farms and sells it at their processing stations; they do not have extended marketing and distribution facilities. Farmer associations obtain their seed through the Agricultural Marketing Corporation (AMC); the AMC, along with other organizations and individual farmers, gets that seed at the ESC processing stations.

Research Challenges

Since the introduction of maize into Ethiopia, various varieties have been grown by farmers under the different agroclimatic conditions of the country. Cultivation techniques used by 95% of the maize farmers include hand hoeing and plowing with oxen. Row planting is still not used, despite the efforts of the IAR. The need for improved cultural practices as well as improved varieties is obvious.

In the past, late-maturing varieties of maize were developed and distributed to a few farmers in the major maize-growing areas of the country. The importance of these varieties is now declining as a result of the changing weather pattern over the last three or four years; rains have begun late and have stopped before crops have reached physiological maturity. Hence, the development of medium-maturing varieties (120 to 130 days) is now indispensable.

On the state farms, which account for about 5% of total maize output, production is semi-mechanized. The need is great for uniform, high-yielding, lodging-resistant varieties for this sector, which has the necessary manpower and sufficient production know-how. The farmers in this sector grow hybrid maize as well as open-pollinated varieties.

Research Constraints

As mentioned earlier, since 1980 the maize research program has been organized into teams combining different disciplines. Due to a shortage of highly trained researchers, individuals are involved in more than one crop team, which leads to inefficiency. In addition, most team members still lack experience and/or high-level training. Hence, although there is a pressing need for upgrading the present staff in terms of training, this is not being done because of the economic situation in the country.

Research activities are also affected by a lack of facilities, such as laboratory equipment, cold storage facilities, irrigation at some research stations and transport vehicles. For the present, the removal of these constraints is probably beyond the economic capacity of the country.

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Discussion

Mr. Watts: Does Ethiopia receive any foreign aid that is specifically for maize research?

Mr. Debelo: No, we do not. However, the World Bank is aiding crop production in general in our country.

Maize Research in Kenya: An Overview

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Maize is the staple cereal diet of over 80% of Kenya's population of some 19 million. More than 90% of the maize is currently produced by small-scale farmers, often on farms as small as 0.25 ha or even less in some heavily populated parts of the country. The Kenyan Government aims at self-sufficiency in the production of food, including maize, through a 4% per annum increase in crop production (11).

Only about 33% of the land area in Kenya is arable, a limitation imposed mainly by rainfall regime. The arable regions are divided into the following agroecological zones:

- High-potential (HP) zone-unimodal rainfall pattern: 1000 to 2200 mm, 1600 to 2300 meters altitude
- Medium-potential (MP) zone-bimodal rainfall pattern: 700 to 1800 mm, 1000 to 1700 meters altitude
- Low-potential (LP) zone-scanty, short-duration rains
- Coastal strip (CS)-hot, humid belt, some saline soils

Maize varieties for Kenya have to be tailored to fit these climatic patterns, i.e., late-maturity varieties, designed to take full advantage of the whole season, for HP areas, medium-maturity varieties, grown in two seasons a year, for MP areas, early maturity varieties, for drought escape, for LP areas, and special varieties capable of withstanding the soil conditions prevailing in the CS.

Maize Research Achievements

Maize breeding in Kenya began in 1955, and since then has gone through many phases:

- Assembling local land races of maize of Tuxpeño origin from farmers' fields (1950s);
- Building synthetic populations to form basic breeding stocks (Kitale Synthetics II and III);
- Introduction of exotic germplasm, notably Ecuador 573 and Costa Rica 76 from Central America, and a search for maize with heterosis in crosses with local strains (1959);
- Inbreeding and hybridizing local germplasm and the release of the first series of hybrids (early 1960s);
- Mounting a maize breeding methodology study (MBMS) to identify selection methods appropriate for each objective, i.e., intrapopulation selection for improved open-pollinated (OP) varieties, interpopulation selection methods, e.g., reciprocal recurrent selection, for hybrids (HYB) (1965 to 1977);
- Incorporation of a comprehensive breeding program into the MBMS for developing the products of the breeding program, i.e., OP for small-scale farmers, HYB for large-scale farmers (1967);
- Initiation of a qualitative genes program, using maize endosperm mutants, e.g., opaque-2 and floury-2 to improve the amino acid profile in local maizes and brachytic-2 to reduce plant height (1969 to 1978, discontinued in 1980);
- Initiation of systematic maize variety testing through National Performance Trials (NPT) before their release to farmers (1979), and

- Initiation of a breeding component aimed at reducing field losses (pre and post-harvest), i.e., phytopathology and entomology (in collaboration with the International Centre of Insect Physiology and Ecology (ICIPE) and selection for maize stalk strength (planned to start 1985-86).

The achievements of the Kenya maize improvement program are summarized in Table 1. Hybrid maize has become so popular in Kenya that most farmers in the HP and MP ecozones will not accept anything else. To date, however, Katumani Composite B and Coast Composite are the only commercial maize varieties available for the LP and CS zones, respectively; replacements for these are in the pipeline.

In the late-maturity maize breeding program based at Kitale, experimental maize varieties yielding far better than Hybrid 625 (the latest commercial variety) have been identified. The new varieties, in the final stages of the National Performance Trials, yield 4 to 24% higher than H625, and some of them have greater stability (lower regression coefficients) over environments.

Progress from population improvement in Kitale Synthetic II (KSII), Ecuador 573 (Ec573) and the variety cross KSII x Ec573, over eight cycles of reciprocal recurrent selection (RRS), is summarized in Figure 1. No significant genetic improvement was detected in either KSII (-14.3%, b = -0.46) or in Ec573 (1.9%, b = 0.53). However, significant genetic advance was attained in the variety cross KSII x Ec573 over six cycles of selection (28.5%, b = 3.10), although a plateau effect was discernible after the eighth cycle. A 28.5% yield gain over eight cycles is equivalent to a gain of 3.6% per cycle or 1.8% per annum, still far

Table 1. Maize varieties released by the Kenya national breeding programs

Variety	Type[a]	Year of release/ introd.	Yield (bags/ha) Farm[b]	Potential[c]	Yield[d] (°/o of KSM)	Altitude (m)	Days to maturity	Potential ecozones	Special problems	Observations
KSM	OP	--	--	--	100	--	--	--	--	Never grown
Ec573	OP	1959	--	--	--	Over 2200	--	--	--	Never grown
KS II	OP	1961	--	--	107	1700-2200	--	--	--	Not grown
H611	VC	1964	--	--	142	1800-2400	105	High	Too tall	Not grown
H621	DC	1964	--	--	132	1000-1700	100	High	?	Not grown
H631	TWC	1964	--	--	140	1000-1700	100	High	?	Not grown
H622	DC	1965	54	62	135	1000-1700	100	High	Streak	
H632	TWC	1965	54	55	140	1000-1700	100	High	Streak	
H612	TC	1966	63	75	155	1500-2100	90	High	--	
KCB		1967	25	--	--	500-1600	65	Marginal	Streak	
H511	VC	1967	40	52	--	1000-1700	60-70	Medium	Headsmut, streak	
H512	VC	1970	45	62	--	1000-1700	65-80	Medium	Headsmut, streak	
H611C	VC	1971	63	75	155	1800-2400	105	High	Too tall	
H613	TC	1972	68	75	166	1500-2100	100	High	--	
CMC	OP	1974	35	--	--	0-1000	80	Coastal	*P. sorghi* rust	
H614	TC	1976	68	77	166	1500-2100	100	High	--	
H625	DC	1981	76	87	176	1550-2100	95	High	--	

[a] KCB = Katumani Composite B, CMC = Coast Maize Composite, OP = open-pollinated, VC = variety-cross hybrid, DC = double-cross hybrid, TWC = three-way cross hybrid, TC = top cross hybrid

[b] Source: Report on Research Programmes; Achievements, Constraints and Training, Director NARS, Kitale, Kenya, 1982 (adjusted down 10°/o)

[c] Source: National performance trials (late-maturity maize), transformed means from combined analysis over nine environments

[d] Source: Crop Improvement in East Africa, C.L.A. Leakey, ed., 1970

below the target of 4% per annum. A previous preliminary evaluation from estimates of genetic variance components had indicated a genetic advance of 7.3% per cycle by the RRS method in KSII x Ec573.

A program of selection for prolificacy in Kitale Composite B (KCB) and Kitale Composite E (KCE) by the full-sib method was initiated at Kitale in the late 1960s. Four cycles of selection revealed inconsistent changes in yield over cycles, but percent prolificacy was increased by 20 to 30%. The composites, now under RRS for increased prolificacy, have a fairly high percent of prolificacy, approximately 15 to 25%. Table 2 summarizes the average heterosis for yield in the varietal cross KCB x KCE over two cycles of full-sib selection for prolificacy.

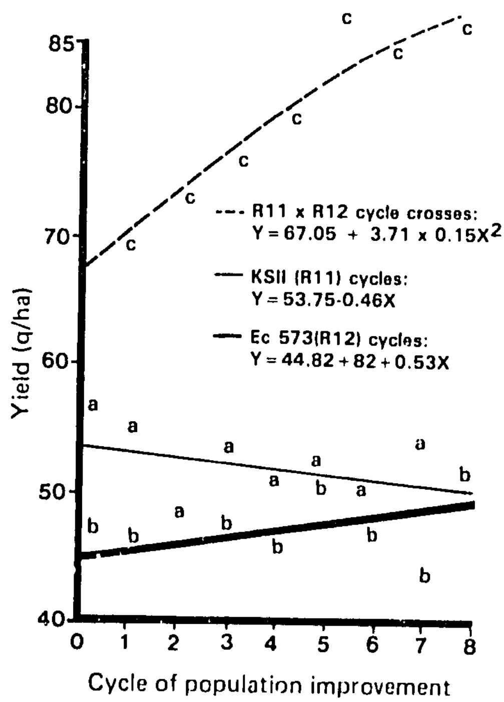

Figure 1. Regression of population and hybrid yields on cycles of improvement, Cycle Evaluation Trials, Kenya, 1983

Maize Research Constraints

The main constraints in the Kenya maize improvement and production programs fall within three principal areas:

- Technical
  Plateau effect in the basic breeding stocks KSII and Ec573 due to erosion of genetic variability
  Inconsistent progress from selection in KCB and KCE due to poor heterosis between the two populations
  Poor harvest index (< 30%) in most late-maturity hybrids
  Pre-harvest losses to maize diseases (maize streak, headsmut, common smut), pests (stalk borers) and lodging, especially stalk lodging before grainfill
  Post-harvest losses to insects, such as weevils, grain moths and the greater grain borer

- Social
  Resistance to hybrid maize adoption by some farmers on the claimed basis of low palatability
  Low test weight of the kernels
  Poor tolerance to witchweed (*Striga* spp.) in western Kenya

- Natural
  Limited arable land for expanding maize production Erratic rainfall patterns in some traditional maize-growing areas, presumably caused by the encroaching desert

The Use of Quality Seed

These has been a distinct upward trend in the use of improved seed in Kenya between 1963 and 1981. This is reflected in Figure 2, which shows the number of hectares planted to hybrids. Large-scale farmers predominated in hybrid use until 1968, when the number of small-scale farmers growing improved varieties began to increase greatly.

Table 2. Heterotic patterns for yield from cycles of full-sib selection in Kitale Composite B (KCB), Kitale Composite E (KCE) and the variety cross

Cycle of selection and year of evaluation	No. of obser-vations	Yield (q/ha) KCB	Yield (q/ha) KCE	Yield (q/ha) KCB x KCE	% average heterosis
Cycle 0					
1968	11	48.9	52.4	56.1	110.9
1969	7	55.2	59.9	69.9	121.5
	7	68.2	75.9	88.2	122.4
	7	37.9	38.4	45.5	119.3
1972	4	42.6	46.9	46.1	103.0
1973	4	31.8	26.6	33.5	114.7
1974	2	67.0	78.4	93.4	128.5
1975	5	69.9	46.8	57.1	100.0
1976	6	59.0	55.2	52.9	92.6
Mean[a]		52.87	53.05	59.44	112.24
Cycle I					
1972	4	46.3	47.6	47.5	101.2
1973	4	32.3	34.1	33.8	101.8
Mean[a]		39.30	40.85	40.65	101.43
Cycle 2					
1973A	4	33.6	36.4	35.7	102.0
1973B	4	78.4	86.9	90.2	109.1
Mean[a]		56.00	61.65	62.95	107.01

[a] Means weighted according to number of observations

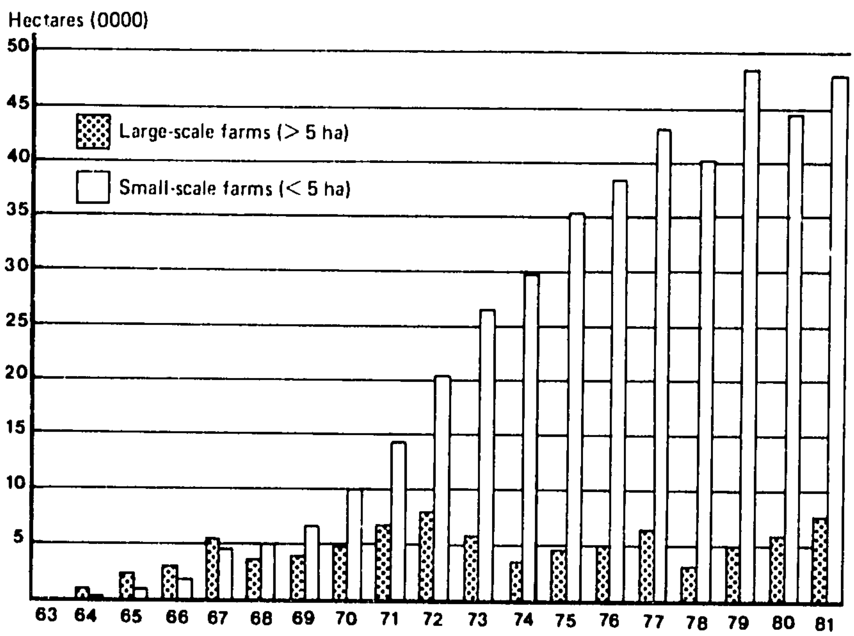

Figure 2. Hectares of hybrid maize, Kenya, 1963 to 1981
Source: Sales Department, Kenya Seed Company

Production of certified seed in Kenya is the responsibility of the Kenya Seed Company (KSC), which obtains parental materials (inbred lines) from national research programs. The KSC then puts the lines through a screening program to check on synchronization of flowering dates for the male-designated and female-designated lines. The company is responsible for maintenance of the lines as well as of the composites (Katumani Composite B and CCM), once they are released from breeders' stock. Cross-checking for trueness to type is performed annually by the National Seed Quality Control Service (NSQCS) by growing out the lines under maintenance by the KSC against breeders' stock in post-control plots. The NSQCS also routinely grows all commercial maize varieties (both old and new) in large plots to check for distinctness, uniformity and stability (DUS) every year; they also inspect seed-production fields through all of the required stages for the purpose of certification.

Currently, the major constraint to seed production seems to be a lack of adequate isolation, since farms are becoming smaller and smaller in the face of increasing population pressure. The former large-scale farms are being subdivided into small parcels under settlement schemes.

On-Farm Research

The difficulty in the dissemination to farmers of new information based on research findings has tended to be a constraint in Kenya. This has been due, in large part, to the researchers' inappropriate approach to technology transfer and to deeply entrenched beliefs and practices, especially among small-scale farmers.

Lately, new approaches have been sought to address this problem and to bridge the gap between the practices of farmers and those of researchers. The Training and Visits (T and V) Extension Project, funded by the World Bank since 1982, is one such approach. The method involves creating and maintaining close links between agricultural research scientists (ARS), especially crop agronomists, and the agricultural extension subject matter specialists (SMS) through monthly workshops. There such matters are discussed as land preparation (technique and timing), fertilizer types and rates, intercropping maize with various crops, planting density and weed management.

The information coming out of the workshops is written in language the farmers can understand by the SMS and is relayed to the farmers by technical assistants. Projects such as adaptive trials are then jointly conducted by SMS and ARS in the fields of contact farmers. These adaptive trials serve as demonstrations for those follow-up farmers who live near the contact farmers.

A similar project, involving not only crop agronomists but also agricultural socioeconomists, has been launched in some parts of Kenya under the auspices of CIMMYT. The new project does not differ fundamentally from T and V, except that it is divided into several stages:

- On-station research, which involves precision experimentation requiring a high degree of error control, high-risk research with new chemicals, experiments requiring back-up laboratories, etc.;
- Exploratory research, which includes agroeconomic farmer surveys and agronomic experimentation simulating farmer practices. The surveys enable researchers to identify recommendation domains, become more familiar with farmer practices, and define areas in which further research is needed;

- Levels experimentation, in which economic levels of agricultural inputs versus sufficient levels required to elicit crop response are investigated for the formulation of technological alternatives for maize production;
- Verification experiments, in which comparisons between farmer practices and research recommendations are made to guide future research, and
- Experimental production plots, which are used for demonstrating factors of production on a large scale (at least one hectare) in maize plots managed jointly by the extension staff and a farmer.

If, after these various steps have been followed, the farmer still does not adopt the technological packages recommended by the researchers, it can be concluded that nonadoption is due to socioeconomic constraints and not to an information gap. This project is still in its infancy (began late 1984), and time will tell whether it will be effective in Kenya for bridging the gap between research findings and farmer practices.

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The Maize Program in Kenya

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Kenya lies astride the equator on the high East Africa plateau. It averages about 1500 meters in elevation, although altitude over the country as a whole ranges from sea level to about 3500 meters. Because of the country's geographic position, daily variations in temperature are very small, usually less than 5°C; however, temperatures can vary significantly as a result of seasonal changes and altitude.

Kenya has a land area of about 60 million hectares. Maize is the most important crop and is high on the list of marketed agricultural products. It is grown on about 1.5 million hectares, a large portion of the country's limited arable land.

Maize Breeding

Kenya's maize breeding program, which was begun in 1955 at Kitale Agricultural Research Station, has released more than ten improved hybrids and varieties for commercial production. The early ones yielded 30 to 80% more than local varieties, depending on the ecological area. For the high-potential areas, the newer hybrids are at least 20% better than those early ones, with a potential of 12 t/ha. This exceeds current maize yields by nearly 700%.

Figure 1 shows the location and rainfall of the five agricultural research stations in Kenya. Currently, there are five major maize breeding programs, the National Agricultural Research Station at Kitale for late-maturity maize, the Agricultural Research Station at Embu for intermediate-maturity maize, Nyandarua for high-altitude maize and Msabaha for coastal maize; the Dryland Farming Research Station for early maturity maize is at Katumani.

Late-maturity maize

The late-maturity maize breeding program was begun in 1957 at the National Agricultural Research Station at Kitale, a substation of the Njoro Plant Breeding Station. Kenyan inbred lines were developed from Kitale Station maize, which was basically Kenya flat white. The first generation of these inbred lines was tested by a form of progeny testing, and a minimum of ten of the best performers were merged to form the new synthetic, Kitale II. In 1961, Kitale Synthetic II was released to farmers west of the Rift Valley, where it outyielded the ordinary Kitale maize by 10 to 20%.

Single-cross hybrids were also tried and proved promising, to the extent that a group of inbred lines, as an average of all their crosses, yielded 30% better than Kitale Synthetic II. Consequently, the double-cross hybrid 622 and the three-way cross H632 were released for commercial

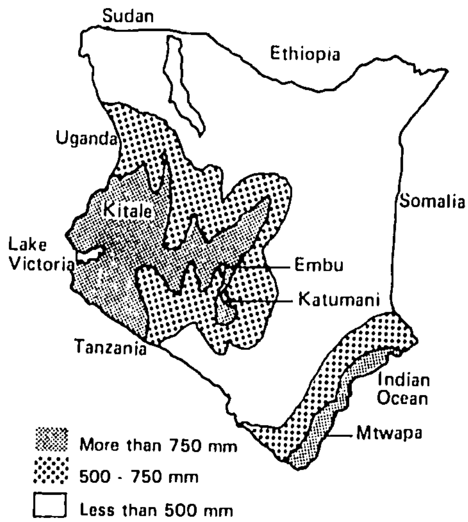

Figure 1. Mean annual rainfall in Kenya

production in 1965. It was also found that certain crosses of Kenya maize with Central American open-pollinated varieties on both sides had very good crossing value. Crosses of Kitale Synthetic II to Costa Rica 76 and Ecuador 573 yielded 40% above the best parent, Kitale Synthetic II. This led to the release of H611, the variety-cross hybrid of Kitale Synthetic II x Ecuador 573, in 1964. Others that have been released to date are the hybrids 612, 613, 614 and 625.

The station at Kitale serves the areas west of the Rift Valley, where there is precipitation of 750 to 1778 mm during the seven-month rainy season. The type of maize bred for these areas takes six to eight months to mature. Additional hybrids are being tested in the National Late-Maturity Maize Performance Trials.

Intermediate-maturity maize
Breeding of intermediate-maturity maize for the central part of the country is carried out at the Embu Agricultural Research Station. Maize in this area, where 350 to 750 mm of rain falls in two distinct seasons (April to September and October to February or March), takes five to six months to mature. Table 1 is a summary of the climatic data for Embu for a 6-year period.

The Embu program was started in 1965. Two hybrids, 511 and 512, are commercially available, and many others are under study. Rapid progress has been made because of the two seasons per year which allow for breeding two generations; with irrigation, a third generation is possible. Also, the work has gone faster because of the experience already gained at Kitale.

Two composite populations, Embu 1 (E1) and Embu 2 (E2), form the basic breeding stock at Embu. They are currently being improved through reciprocal recurrent selection. Embu Composite 3 was formed in 1980 and has been improved by mass selection; five local varieties were merged in its formation. More hybrids are being tested in the National Medium-Early and Coast Maize Performance Trials.

Table 1. Climatic data for Embu Agricultural Research Station, Kenya, 1977 to 1983

Year	Days of rain	Total rainfull (mm)	Mean temp. (°C)	Mean rel. hum. (o/o)		Mean daily sunshine (hrs)	Annual open pan evaporation (mm)
				9:00 a.m.	3:00 p.m.		
1977	119	1508	18.9	58.5	--	6.7	--
1978	139	1581	17.9	80.3	62.9	6.2	1402
1979	112	1320	18.3	83.7	60.1	6.2	1538
1980	95	1071	19.3	79.2	52.1	6.5	1803
1981	100	1226	17.4	76.1	52.3	5.7	1539
1982	114	1464	19.4	81.6	57.4	7.0	1744
1983	76	1081	19.6	80.7	55.3	6.7	1628
Mean	108	1322	18.7	77.1	56.7	6.4	1609

Note: The station has a bimodal rainfall pattern, the long rains occurring March to June and accounting for about 60o/o of annual rainfall. The short rains occur October to December and account for about 30o/o. The period January to mid-March is hot and dry. The annual P/E is about 68o/o.

Early maturity maize
This program is based at Katumani (Machakos). The two breeding streams which have formed the basis of the program are Katumani Synthetic VII and Katumani Synthetic VIII. The Katumani maize currently on the market is Katumani Composite B, which was derived from the original cross of Katumani Synthetic V and Katumani Synthetic VI and was released for commercial production in 1967. A second population, which is much earlier than Katumani, has been developed from the lines derived out of Taboran and top crossed by the progeny (ex French via Malagasy); it is at present being evaluated under the name of Makueni.

Coastal maize
This program is located at Msabaha Agricultural Research Station at Kilifi. Coastal Composite Maize has been developed there and is already commercially grown in large areas of the coast. This open-pollinated variety compares favorably with the intermediate-maturity hybrids 511 and 512. It has been decided that a second breeding population will be formed of Jamaican lines and materials from CIMMYT.

High-altitude maize
The Nyandarua Agricultural Research Station at Ol-Joro-Orok is breeding maize for altitudes above 2000 meters; at those elevations, the local maize planted by farmers takes 12 months or more to mature. Ten percent of the total area of Kenya is located at this elevation, and farmers have continuously tried to grow maize without success.

The program of maize improvement for high altitudes was started later than that for other areas. The first maize population formed is now referred to as High Altitude Composite (HAC.) After its formation, the population was slowly improved until the 1970s, when intensive ear-to-row selection was begun. Later, half-sib selection was used to extract lines, since a tester with good combining ability was already available in Ecuador 573. The lines so far extracted are intended to produce hybrids for these areas. The main problems of maize grown at this altitude are maturity and the danger of frost.

Maize breeding system
The comprehensive maize breeding program developed at Kitale has been the basis of all of the breeding programs in Kenya. The essential features are:

- Evaluation of local and exotic materials to assess their merits for a long-term breeding program;
- Formation of two or more composites of the selected material, so that each population has wide genetic variablility and the potential for crossing well with the other populations;
- Use of recurrent selection in the populations so that their crosses are improved with each cycle, and
- Release of a commercial variety as a cross of two populations, as single, double or three-way crosses from the elite lines or as a synthetic variety derived from the advanced generations of the population crosses.

Seed Production and Distribution

The importance of a program capable of supplying good quality seed to farmers cannot be over-emphasized; the success of maize production in Kenya has been largely due to well-organized seed production and marketing. The relationship between the various agencies involved is described in the following seed-production sequence:

Stage 1. Breeders' seed
Inbred development and maintenance
Open-pollinated variety development
National Performance Trials
Variety release and naming

Stage 2. National Seed Quality Control Services
Quality control and testing for yield
Inspection of seed growers' fields
Regulation
Certification

Stage 3. Kenya Seed Company
Seed multiplication
Seed drying and conditioning
Seed processing, sizing, treating and packaging
Seed storage, labeling and distribution

Stage 4. Seed marketing and distribution
Kenya Farmer Associations
Farmer cooperatives
Small stockists

The seed for hybrids and open-pollinated varieties that are presently available in Kenya is shown in Table 2.

Table 2. Hybrid maize seed available in Kenya, 1985

Hybrid	Yield (% of H 613)	Altitude range (m)	Length of rainy season (months)	Observations
611	95	1800-2200	6-8	To obtain good results from hybrid maize, a high level of inputs is essential
612	106	1500-2100	5-7	Land preparation: Early plowing for a good seedbed ready for planting when the rains start
613	100	1500-2100	5-7	Population: Between 40,000 and 53,000 plants/ha, depending on rainfall reliability and soil fertility; two plants per hill spaced 75 x 50 cm or one plant per hill spaced 75 x 25 cm
614	116	1500-2100	5-7	Fertilizer: Phosphate essential; farmers should seek the advice of their agricultural officers regarding top-dressing
622	91	1000-1700	4-7	
511	96	1000-1700	3-4	
512	100	1000-1700	3-4	
X105A	66	0-1000	3-4	Heat-tolerant tropical hybrid produced under licence with the Pioneer Hybred Seed Company
625	134	1500-2100	5-7	Similar to H614 but higher yielding
Open-pollinated variety				
Katumani Composite	54	1000-1900	2-3	Short-season crop
Coast Composite	64	0-1000	3-4	Good heat tolerance; tolerant to leaf rust

Maize Agronomy

The maize agronomy research program has identified the factors which limit maize yields in Kenya. In order of importance, these are:

- Land preparation and planting date (estimated as the main contributors to yield);
- Weed control and planting density;
- Use of suitable hybrids or varieties;
- Use of fertilizers in appropriate quantities, and
- Pest control and harvesting date.

In the Kenya Ministry of Agriculture food policy document (8), projections were made that, if the country were to become self-sufficient in maize, production growth rates of 12.7% between 1980 and 1983 and of 6.8% between 1980 and 1989 would be necessary. These estimates included maize for livestock feed and industrial uses. The Economic Planning Division of the MOA forecast the need for a maize production growth rate of 85% between the years 1983 and 2000 if self-sufficiency were to be maintained.

Dissemination of Research Information

To extension

There are many ways in which extension can help in the dissemination of research findings. It is important that staff members be included at seminars and field days at the research stations, and that the agricultural information centers keep them informed so that they can pass information on to farmers. In order for extension to perform this task effectively, there must be direct contact between extension subject matter specialists and the research stations; this can be accomplished through training and visits to projects. The annual maize tours are also a valuable part of the program.

To the farmer

The group approach has been found to be a good method for reaching farmers, through field days at research stations and through field demonstrations. Training sessions can also be held at the farmers' training centers. Each research station should organize at least one field day per year for farmers, although the farmers should also be encouraged to visit their research stations whenever they have problems that they wish to discuss.

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Maize Research in Lesotho

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The nation of Lesotho is entirely surrounded by the Republic of South Africa. The country may be divided into three main agroecological regions, the lowlands, the foothills and the Maloti mountain range, where land is being farmed at elevations as high as 3048 meters. Each region has its own distinct climatic characteristics and agroeconomic potentials and problems.

For the low elevations in Lesotho, most of the maize varieties (usually hybrids) are imported from South Africa; the hybrids are found to outyield open-pollinated varieties. In the mountainous regions, hybrids usually do not yield well because of the shorter growing season and cooler conditions. There, open-pollinated composite varieties better meet the farmers' needs.

Maize Research

The maize research program of Agricultural Research Lesotho is carrying out a number of experiments to increase maize production in the country. Maize variety trials are usually planted in September with varieties from CIMMYT (highland Mexico) and South Africa, as well as local varieties. No fertilizer is used; Thiodan drench is usually applied at planting to control cutworms and other insects. The maize is harvested in May or June, with counts made of the number of plants per plot and the number of plants harvested. Earworm and ear rot incidence is recorded. The ears are shelled manually, and grain weight and moisture content are determined. The weights are adjusted to 15% moisture content and the yield calculated.

In the trials, the standard pattern of 75 cm between rows and 50 cm between hills is used; three seeds are planted per hill. Plot size is 3 x 3 meters, planted in a randomized block arrangement with four replications of each variety. The plants are thinned to two per hill after emergence. After harvest, the results are analyzed statistically.

Considering the yield of maize varieties in both station and on-farm experimental plots, Mexican highland maize has proved more successful than other varieties over the past six years. The best two varieties, highland early white flint and highland early white dent, have yielded 62% better than the two best South African hybrids, SA4 and SA11, and they have yielded 108% better than local varieties (Figure 1).

Insect control

Cutworm control—In insect control experiments, highland early white dent is sown in plots measuring 3 x 3 meters with four replications. Chemicals are applied either at seeding time or on emergence of the young plants. Thiodan is applied at the rate of 16.5 liters per hectare, using one tablespoon of the 35% emulsifiable concentrate in 12 liters of water, applied to the soil with a watering can. In addition to controlling cutworms, Thiodan controls insects around the germinating seeds.

Endosulfan 0.175% bait, which is specifically for cutworms, is applied at 10 kg/ha on the soil surface, above the seed or around the emerged plants. Curaterr (10% carbofuran) is applied at the same rate as Endosulfan, but is placed in the ground with the seed; it is a systemic insecticide and is mainly effective against stalk borer. The plots are harvested and average grain yields determined from the two central rows (yields are adjusted to 15% moisture content). Yield results have shown that it is more effective to apply the chemicals at seeding than at emergence. Thiodan gives the best control, followed by Endosulfan and Curaterr (Figure 2).

Stalk borer control—To test for stalk borer control, highland early white dent is planted at various locations in plots measuring 3 x 3 meters. Curaterr is placed in the ground with the seed in one set of treatments as recommended for stalk borer control. In others, Curaterr, Thiodan and Endosulfan are poured into the funnels of the plants just before flowering. The plots are harvested, the grain weight and moisture content measured and the weights converted to 15% moisture content. The results of the trials are shown in Figure 3.

Two applications of Curaterr, at planting and preflowering, have been found to be the most effective treatment. One application of Curaterr, either at planting or at preflowering, gave only a slight increase in yield over the control, as did treatment at preflowering with Thiodan. When Endosulfan was applied at

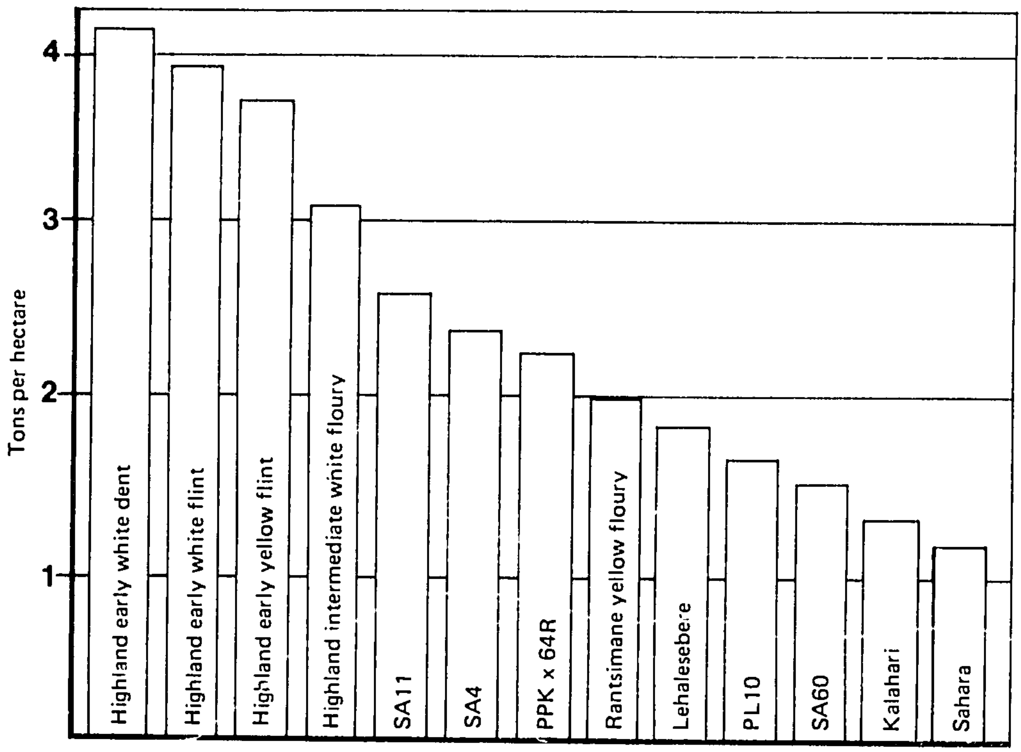

Figure 1. Average yields of Mexican, South African and Basotho maize varieties, Thaba-Tseka, Lesotho, 1979 to 1984

preflowering, yield was slightly lower than the control. The systemic effect of Curaterr persists only until the first wave of stalk borers appears, when the plants are still young. It seems that a second application may be necessary to control later attacks by the insect. It had been supposed that both Thiodan and Endosulfan would be effective when applied in the funnels of the plants, but only Thiodan was found to be beneficial.

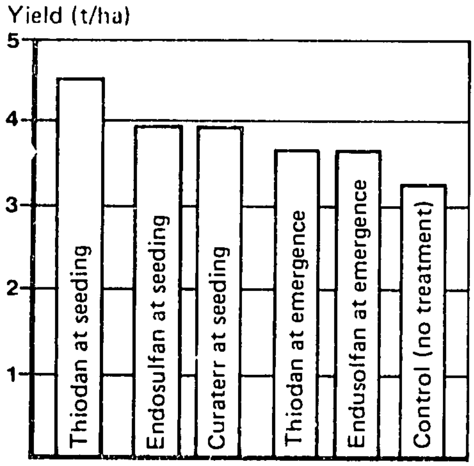

Figure 2. Yield of highland early white dent, accroding to chemical treatment for cutworm control, Lesotho

Maize agronomy

Maize yield tests have been conducted under varying cultural regimes. Highland early white dent was planted in October in the standard plots of 3 x 3 meters with four replications. For planting, the ground was either plowed or left untilled. Seeds were planted in rows or broadcast, and plots were unweeded, weeded once or weeded twice. The middle two rows of each plot were harvested in June, and grain weights converted to 15% moisture content. Figure 4 shows the results of the trial.

No-till planting, even with two weedings, was not shown to be significantly better than regular cultivation with only one weeding. No-till with a single weeding yielded

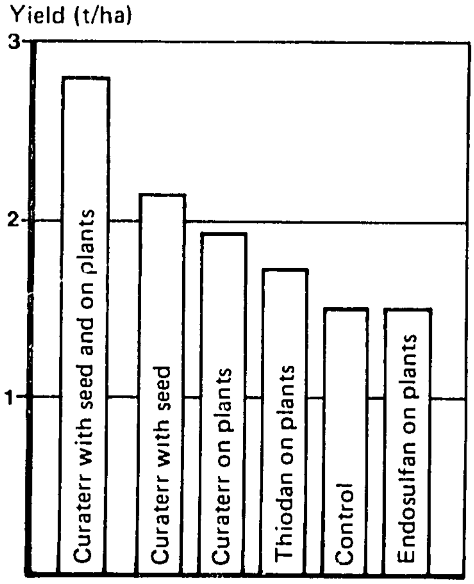

Figure 3. Yield of highland maize, according to chemical treatment for stalk borer control, Lesotho

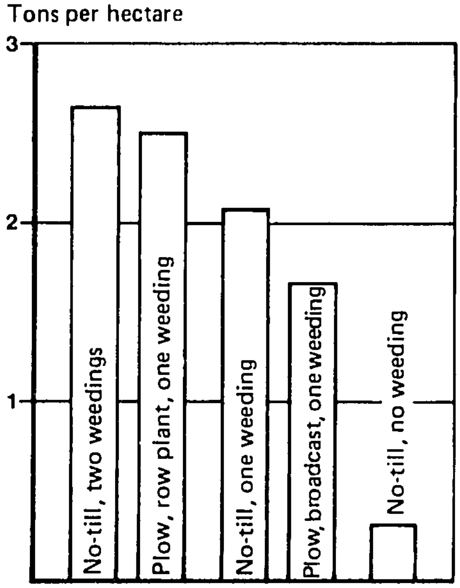

Figure 4. Yield of maize grown with varying cultural practices, Lesotho

significantly less than regular cultivation with one weeding. This was in contrast to the previous season, when no-till with one weeding had yielded significantly more than regular cultivation with one weeding, probably due to the better rainfall distribution in the current season, which resulted in heavier weed growth. In the previous season, a drought occurred in the spring (October and November), and better spring growth was evident in the no-till plots. As in other seasons, maize yield was negligible with no weeding.

Planting date experiments—To test maize yield against planting date, highland early white dent, SA11 and CIMMYT-German early maize were sown at two-week intervals between September 16 and December 8. Plots measured 3 x 4 meters, with two rows of each variety per plot and outside barrier rows of HEWD; the plots were replicated four times. Emergence was very irregular, especially in the first replications at the edge of the field. The graph of yield and planting date (Figure 5) shows that, as in past years, yields diminished with each succeeding planting in the beginning. There was also the usual dip in the middle of the season due to cutworm attack.

For very late maize plantings, yields increased with later plantings, starting on November 24 and continuing until December 8. This increase was less marked for SA11, but the yield of HEWD went from 0.6 t/ha, when planted on November 10, to 2.39 t/ha when planted on November 24 and to 2 92 t/ha when planted December 8. The CIMMYT-German maize showed a similar pattern, yielding 3.37 t/ha for the December 8 planting. The early planted maize had showed lower

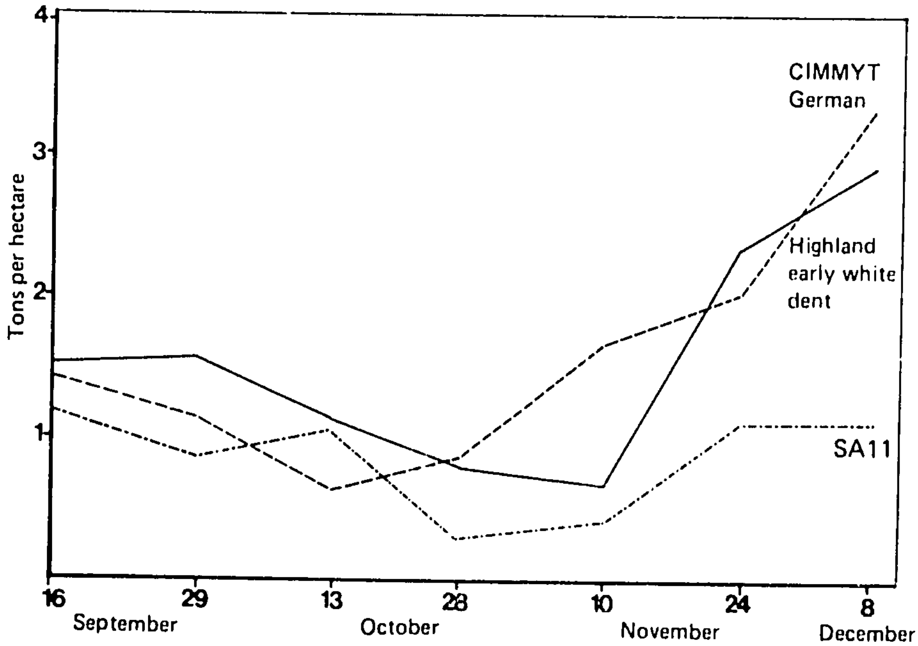

Figure 5. Maize yield as a result of planting date, Lesotho

yields, partly because of poor emergence; this was probably caused by drought at flowering in December and January. The interesting conclusion that can be drawn from this experiment is that, in some seasons, it is possible to get higher yields by planting late, if a fast-maturing maize is used and there is not an early killing frost.

Genetic improvement

Half-sib recombination blocks—The half-sib recombination block method of genetic improvement is used at CIMMYT to increase yields of maize lines and to change them as desired. This method consists of growing seed from selected ears and plants in double rows, with a single row in between which is seeded with a mixture of all of the selected ears. The tassels are removed from the double rows, and these serve as females. They are pollinated by the plants in the single rows, the males. The best plants in the female rows are then used the next year along with additional selections.

Highland maize has a few disadvantages which are presently being addressed. The plants are prone to lodging in the strong winds of the mountainous areas. Selection is being carried out for shorter plants with lower ears to correct this problem, and at the same time, for large ear size, good plant type and frost tolerance. Plants in the seed multiplication fields were selected the previous season and either self- or cross-pollinated with other selected plants, the ears being saved for row planting in the half-sib blocks. This procedure has been used for all four highland varieties.

Hybridization—A second approach for adapting the highland maize to local conditions is to cross it with well-adapted Basotho varieties. The latter have low yields, but some are able to withstand high winds and cutworm attack better than the highland maize. Basotho varieties tend to send out several tillers which mature almost as fast as the main shoot, i.e., there is less apical dominance and the main shoot is shorter. This gives lower plants with several ears each. The goal is to produce a plant with this form, but with ears like those of highland maize and the resistance to cutworms that is found in the Lehalesebere (flint) maize. Table 1 shows the crosses that have been made to date.

The CIMMYT-German line is a fast-maturing maize which was developed by selecting for earliness in Mexico in the winter and in Germany in the summer. It can mature at Thaba Tseka even when planted as late as the beginning of December. The Basotho yellow floury maize (Rantsimane

Table 1. Maize crosses made by Agricultural Research Lesotho

Female	Male
Highland early white flint	Basotho white flint
Basotho white flint (Lehalesebere)	Highland early white flint
Highland early yellow flint	Basotho yellow floury
Basotho yellow floury (Rantsimane khutseanyane)	Highland early yellow flint
CIMMYT white German	Basotho yellow floury
Basotho yellow floury	CIMMYT white German
CIMMYT white German	Basotho white flint
CIMMYT yellow German	Basotho yellow floury
CIMMYT yellow German	Highland early white flint

khutseanyane), with which it is being crossed, produces small ears, a characteristic that has discouraged farmers from growing it. However, last season it yielded well in trials because of the maturation of the ears on the tillers. The cross-pollinated ears in the trials were individually harvested and labeled for planting the following season.

Seed Multiplication and Distribution

From the multiplication of highland maize varieties, 100 5-kg lots were distributed to 50 leading farmers with the understanding that they would return the same amount of seed after harvest. Each lot had information on recommendations for planting.

Farmers had been told of the advantages of planting highland maize at courses at the farmers' training centers, and their response has been enthusiastic. Highland maize seed is also sold by the Crops Research Seed Multiplication Section.

Extension Activities

The extension service holds maize demonstrations in the fields of leading farmers. Field days are also held in various locations to provide opportunities for both farmers and officials to see how seed multiplication is carried out. The farmers and officials can also visit on-farm experiments to see the difference between local varieties and varieties being developed through the maize research program.

Maize Production and Research in Madagascar

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Maize is the staple food in the southern part of the island of Madagascar. In other parts of the country, it is used as a food complement and as feed for livestock.

Maize production is scattered over nearly all parts of the island (Figure 1), although most is produced on the high plateaus (Table 1). Table 2 shows the characteristics of the principal maize-growing areas of Madagascar.

The maize crop is grown currently on some 136,000 hectares, an increase from 92,000 ha in 1962 (Table 3). Both area and production have increased over nearly all of the island districts since 1980 (Table 4).

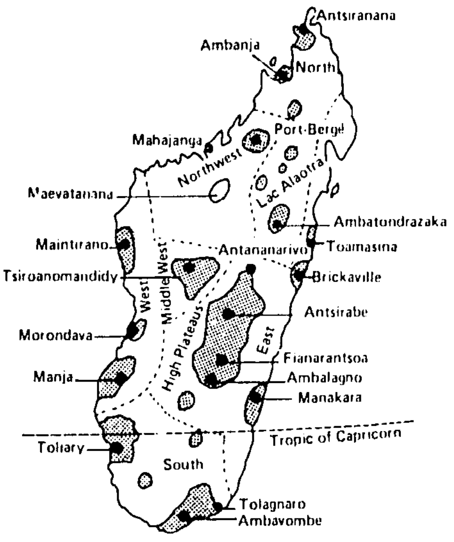

Figure 1. Maize production areas, Madagascar

There are two government farms, FEO and FESA, in the midwestern part of the island, as well as one agroindustrial firm (SAGPIM), which produce maize for feed and for export. They use improved varieties yielding up to 4.5 t/ha. Local market needs cannot be met by small-scale growers using local varieties and achieving average yields of only 1 t/ha. Since 1981, maize production has been increasing because of an increase in price of almost 100%, from 53 to 100 FMG/kg (600 FMG = US$ 1).

Maize Research on Madagascar

Maize research was started by the IRAM (Institut de Recherches Agronomiques à Madagascar) in 1961-62. In 1974, FOFIFA or CENRADERU (Centre National de Recherche Appliquée au Développement Rural) took over the research on varietal improvement and fertilizers.

Table 1. The location of maize production in Madagascar, 1980

Location	Production (o/o)
High Plateaus (Antananarivo and Fianarantsoa)	62.1
South (Toliary and Morondava)	15.7
Alaotra	4.0
North (Antsiranana)	3.5
West (Mahajanga and northern Morondava)	3.2

* Department of Scientific and Technological Development Research

Table 2. Characteristics of the principal maize-growing areas of Madagascar

Region	Principal towns	Altitude (m)	Climate	Temperature (°C) Max.	Min.	Rainfall (mm)	Soil types	Target farmers[a/] (principal groups underlined)	Observations
High Plateaus	Tananarive Antsirabe Fianarantsoa	1000 - 1600	High tropical	22.3 23.3 23.7	12.3 10.3 13.2	1250 1450 1200	Very desaturated ferralitic soils	1-2-3	Dense population
Middle west	Tsiroanomandidy Mandoto	700 900	High warm tropical			1550	Fairly desaturated ferralitic soils	2-3	Most favorable maize-growing area
Lake Alaotro	Ambatondrazaka	700 - 900	High warm tropical	26.6	14.7	1200	Fairly desaturated ferralitic soils and fluviatile alluvium	2-3	Rice growing predominant
North	Montage d'Ambre Ambanja	250-500 30-500	Semi- to very humid tropical	29.0 31.0	18.0 20.4	1300 2150	Fairly desaturated ferralitic soils on basalt	2-3	Favorable maize-growing area
Northwest and West	Port-Bergé Maevatanana Morondava	20- 40 50-100 5 - 20					Fluviatile alluvium and ferruginous tropical soils	2-3	Irrigation Developing region
West	Morondava Maintirano Manja	5 - 30 5-200 200-350	Semihumid warm tropical	30.0 29.7 32.4	19.8 21.7 18.1	750 1000 900	Ferruginous red tropical sand and ferralitic soils	2-3	
East	Tamatave Brickaville Manakara	5-200 5-200 5-100	Very humid warm tropical	31.0 29.4	20.4 20.1	3550 2800 2500	Ferralitic soils and alluvium	1-2	High presence of viral diseases
South	Tuléar Ambavombe	10-500 100-400	Semiarid warm tropical	29.7 28.7	17.9 17.1	350-700 600	Ferralitic and ferruginous soils and tropical soils and red sand	1	High risk area for agriculture

a/ Target farmers: 1 = traditional farmers, 2 = farmers in the process of modernization, 3 = commercial farmers

Maize breeding

Improvement of local populations—Two stable and improved populations were obtained by recurrent selection for general combining ability in the southern part of the island. They are synthetics from Fianarantsoa and from Tuléar. These two populations were intercrossed, forming the variety Plata 264, which is now proposed for release. The variety Tsakomalady has shown resistance to virus diseases on the east coast.

Formation of lines—More than 150 lines have been created from introduced varieties.

Table 3. Area and production of maize, Madagascar, 1962 to 1984

Year	Area (ha)	Production (tons)
1962	92,000	85,000
1972	95,000	106,000
1980	128,000	127,200
1981	128,000	127,600
1982	116,500	112,800
1983	131,100	150,500
1984	136,300	160,500

Source: Agricultural Statistics Service, Ministry of Agriculture

Hybrid formation—Several hybrids have been obtained, three of which are being recommended by the Extension Service. They have had yields of 10 to 12 t/ha in station trials.

Polyhybrids—Polyhybrids have been created in Madagascar by crossing hybrids; they are used as synthetics or composites. The best ones are the white-grain polyhybrids 266 and 377, which were obtained from H632, SR11, SR13 and three lines from Natal. Three polyhybrids with yellow grain are 374, 384 and 387.

Intervarietal hybrids—Three hybrids recommended by the Extension Service are 321, 375 and 383. The latter is one of the best maize varieties obtained to date, with a mean yield of 8 t/ha in station trials. This variety is best known as a polyhybrid for use in advanced generations, at which stage it has given a mean yield of 6 t/ha in trials.

Composites—Three composites have been created, but only one is still in use, Composite High Plateau, with 60 entries.

Table 4. Maize production in each *faritany* (district), Madagascar, 1980, 1983 and 1984 forecast

Faritany	Area (ha)			Production (tons)		
	1980	1983	1984	1980	1983	1984
Antsiranana	3,800	3,700	3,900	3,000	3,500	4,700
Mahajanga	13,000	13,900	15,200	10,400	15,700	15,200
Toamasina	10,400	13,500	12,100	10,700	13,500	12,500
Antananarivo	65,100	60,200	63,400	70,300	76,000	83,700
Fianarantsoa	15,000	15,400	16,300	14,700	16,200	18,000
Toliary	20,600	24,400	25,400	18,100	25,600	26,400
Total	127,900	131,100	136,300	127,200	150,500	160,500

Source: Ministry of Agriculture

Fertilizer studies
In fertilizer trials it was shown that yield is lower on land being cultivated for the first time; this was especially true on the high plateaus. There, production was almost nil, even when large amounts of inorganic fertilizer was applied. It was found that this phenomenon could be overcome through the use of a mixture of chemical and organic fertilizers containing manure.

Nutrient deficiency studies—The first step in the fertilizer studies was the qualitative determination of deficiencies in maize plants grown in pots. The results of these studies are shown in Table 5.

Chemical fertilizer studies—The results of the study of elements showed that:

- Nitrogen, phosphorus and potassium are essential on the high plateaus (K and sometimes P are less needed in other regions);
- It is beneficial to apply N and K in split applications;
- Dolomite is needed on acid soils and on soils deficient in calcium and magnesium;
- On virgin lands, potassium can be lost through leaching, and
- Phosphorus should be applied annually at the rate of 45 kg of P_2O_5/ha, rather than in a large, one-time dose to bring the phosphorus level up to par.

Studies of mixtures of organic and chemical fertilizers—These studies showed that:

- When the crop residue is plowed under, less fertilizer is needed (especially potassium);
- The use of compost has a negative effect, and
- Manure, composed of animal matter and harvest residues, is often poorly decomposed. The amount of manure available is often limited to 5 t/ha per year.

It is recommended that organic matter be combined with chemical fertilizers.

The Present Status of Maize Research in Madagascar

Varietal improvement
The varietal improvement program has resulted in a national collection which is utilized for:

- Maintenance of 112 pure lines and 176 varieties;
- Increase of certain varieties for subsequent use in trials or in forming promising varieties;
- Formation of promising varieties, and
- Introduction of nine parent lines (which were lost because of maintenance problems), and the introduction of two new varieties, IRAT83 and IRAT200.

The recommended varieties and others released to extension are evaluated in two ways:

- Tests of varieties in order to identify promising ones for a given location, and
- Comparative variety trials for studying their performance in other regions.

From the 1983-84 variety trials, two varieties were found to be best, 383 for yield in high elevations and 374 for adaptability.

Agronomy
The main areas studied since 1983-84 have been fertilizer use and seed production.

Fertilizer use—The main objective has been the identification of economical fertilization schemes adapted to selected sites and to different levels of production. Areas under study include the maximum use of resources, such as manure, straw, harvest residues and dolomite, and rotating cereals with legumes.

Table 5. Fertilizer recommendations resulting from nutrient deficiency studies, Madagascar, 1960 to 1980

Region	Station (altitude)	Principal soil type	Observed deficiencies	Recommended fertilization: Correcting fertilizer (kg/ha) P_2O_5	K_2O	Dolomite	Annual fertilizer (t/ha) N	P_2O_5	K_2O	Dolomite	Manure (2)	Observations
High Plateaus	Ampangabe (1300 m)	Ferralitic soils on acid rock (gneiss, migmatite) (very poor)	P,Ca,K, S,Mg	400	300	2000	90-135 60- 90	45-60 45	30-60 0-30	500 250-500	 10-20	P and K main limiting factors, also dolomite
High Plateaus	Ambohi-mandroso (1600 m)	Ferralitic soils on basalt (very poor)	K,Mg,Ca, P (in fields)	600	350	2000	90-135	30-45	30	250-500	a/	
High Plateaus		Ferralitic soils on basalt (fairly poor)	P (medium)	250						After 4 years	a/	N main limiting factor
Middle west	Kianjasoa (1000 m)	Ferralitic soils on glacial debris	P (medium) K (low)	300								
North	Anketrakabe (300 m)	Ferralitic soils on basalt (medium poor)	P (medium)	250								N main limiting factor
North-west	a/	Alluvial soils a/	None	0	0	0	90-135	0-45			a/	
West	a/	Vertisols a/	a/	a/	a/	a/	90-120	45-90			a/	Liming not necessary, slow evolution of organic matter
South	Ihosy (700 m)	Tropical ferruginous soils (hydro-morphic soils on red sand)	P (medium)	100								
South-west	Ankazoabo (Tuléar)		P (low)	80			45- 90	50-60			5-15	N main limiting factor

a/ No information available

The areas in which fertilizers have been tested are the high plateau, with an elevation between 1000 and 1600 meters, and the midwest, with an elevation of 700 to 1000 meters, a relatively cool and humid tropical climate (1200 to 1500 mm of rainfall per year) and ferralitic soil.

Some of the recommendations from the fertilizer studies are:

- The use of nitrogen fertilizers, even on maize planted after legumes;
- The use of a nitrogen supplement with NPK fertilizers;
- The use of a balanced mixture of organic and chemical fertilizers, and
- Further study of the use of NPK with dolomite and manure and of NK with manure.

Studies have also been made on soils, and their responses to the essential elements (N, P and K), to dolomite (Ca, Mg) and to manure. These have been carried out on the northern part of the island, which has a low-elevation climate (250 to 300 m) and moderately poor volcanic soil.

Rotations—Studies have been made to determine promising rotation systems which include the two main food cereals, maize and rice, and the legumes, groundnuts, beans and soybeans. The studies have been conducted on the volcanic soils in the north and on the ferralitic soils of the Lake Alaotra area.

Cultural practices—Studies have also been conducted in various parts of the island on cultural practices, such as time of planting x depth of seeding, time of planting x variety and methods of land preparation x Ca and Mg application.

Seed production

The seed production studies are a continuation of the work on varietal improvement and formation. FOFIFA produces prebasic and basic seed for the agronomy complex of Lake Alaotra (CALA). Since 1976, the seed of three polyhybrids (383, 377 and 266) has been released to growers. It is multiplied and distributed by CALA. Table 6 shows the amount of seed distributed in 1983-84.

Maize Research Staff

The genetic and varietal improvement program has two Malagasy staff members, a maize breeder and an agronomist; there is one expatriate breeder in the program. There are also personnel in the areas of entomology, plant pathology and soil science.

Table 6. Seed production and distribution, Madagascar, 1983-84

Receiving agency	Variety (kg) 383	377	266	374	Total	Observations
MPARA - MPAEF	690	8	8		706	
Private societies	400				400	SAGRIM (Morondava)
Farmers	120	20	10		150	
Testing program (FOFIFA)	106	30	60	15	211	For testing
DRZV (FOFIFA)	1000		200		1200	For food
Total	2316	58	278	15	2667	

The Relationship between Research and Extension

Until 1982, varietal release was not efficient in Madagscar because of a lack of coordination between FOFIFA and the Ministry of Agriculture (MPARA). In 1982, a liaison service (SALIAR) was created at MPARA to act as a bridge between research and extension. The service of plant material (SMV) at MPARA has established a national seed policy for maize and rice. FOFIFA's seed production program will be determined by this service to satisfy the national demand.

Conclusions

Important results have been obtained since maize research was begun in 1961, in the areas of both varietal improvement and agronomic practices. After a four-year interruption, research was begun again in 1983. Since then, it has been oriented, in the short and medium term, to the maintenance of the main seed collection at Lake Alaotra, the reconstitution of degenerated polyhybrid lines intended for extension, the reintroduction of parental lines that had been lost, as well as of new lines and varieties, and to research into economical fertilizer practices.

Maize Research and Production in Malawi

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Maize is the staple food and major source of carbohydrates for over 80% of the people of Malawi. The rising demand for food in recent years has turned maize into not only an essential staple food crop, but also into a cash crop; it can be sold to the Agricultural Development and Marketing Corporation (ADMARC), which later sells it to meet urban food requirements and other needs. Maize is now being grown for food even in those areas where cassava, sorghum or millet used to be the principal foods.

Maize Production

Although most of Malawi's maize is produced on the central plateau, it is widely grown throughout the country, primarily by smallholders. Approximately 970,000 hectares were grown in 1980-81, of which about 80% was grown in pure stands. This reflects a dramatic shift from mixed cropping, as more than 90% of the 1,070,000 hectares planted to maize in 1968-69 was in stands mixed with pulses. This decline in hectarage was accompanied by a modest production increase (13%) between the two surveys. About 90% of the production is of local flint varieties which are preferred for home consumption; most of the composite and hybrid production is sold. The production of maize in rotation with tobacco on estate farms has increased in recent years.

Maize yields in Malawi vary widely, from less than 1000 to over 4000 kg per hectare, depending on such factors as location, variety and fertilizer use. Conditions are suitable for maize production in the drier areas of the Shire Valley and the lake shore; there the production potential is high.

Maize is grown at altitudes ranging from a few meters above sea level to 1700 meters or more. The main maize-growing areas are between 600 and 1300 meters above sea level, although some maize is also grown in the marginal areas above or below this range. The marginal areas offer the biggest challenge to research for the breeding of varieties suited to their conditions.

There are three marginal areas for growing maize. Parts of the Shire Valley in the southern tip of the country has a semi-desert climate with a very short rainy season (two to three months); rainfall is erratic and unreliable. The very hot lake shore area also has a short rainy season of only three to four months. In the hills in the northern and central parts of the country, cool temperatures and overcast conditions are unfavorable for maize production.

Maize is grown in Malawi by two types of farmers. Estate farmers have large land holdings and can afford to invest large amounts of capital in their crops. They grow maize purely as a cash crop and, therefore, prefer growing high-yielding dent hybrids. The maize from the estates is sold either to ADMARC at a premium price or directly to the Grain and Milling Company in Limbe, Lilongwe or Mzuzu at a price higher than that of ADMARC (to cover transportation costs). The Grain and Milling Company processes most of this maize into flour for human consumption, with a small amount being processed into animal and poultry feed. The company also buys maize from ADMARC to meet the ever-increasing demand for maize flour from the urban population. The estate sector plays an important role in feeding the ever-growing urban population, as well as in the National Food Reserve Program.

Smallholders farm small parcels of land (8 ha or less). These farmers grow maize for food, with only surpluses being sold. They normally have limited capital and cannot afford to grow hybrids, which have high demands for fertilizer without assistance loans for fertilizer and seed. Most of them grow local unimproved flint maize.

The average yield of unfertilized local maize in Malawi is less than one-third that of fertilized hybrid maize. However, the local, unimproved flint maize has some grain characteristics that farmers like. The grain is resistant to weevil attack in storage; therefore, it stores well, even without pesticide treatment. There is also less grain breakage when the seed coat is removed by pounding in the traditional mortar and pestle. As a result, less grain is lost along with the seed coat. There is a need for the development of improved semi-flint, open-pollinated varieties so that farmers have available higher-yielding varieties which demand less fertilizer, as compared to the hybrids, and are closer to the unimproved local maize in grain characteristics. Table 1 is an estimate of the types of maize grown in Malawi in the 1982-83 season.

National Policy

Malawi national policy is to increase maize production in order to maintain self-sufficiency in the rural areas and to provide enough food for the growing urban population. The government is also trying to accumulate sufficient grain reserves to meet the country's needs in times of adverse weather. The goal is to increase yields per hectare, through improved seed and cultural practices, the use of both manure and chemical fertilizers, and effective disease and pest control measures.

Maize Research

Maize research in Malawi is the sole responsibility of the Department of Agricultural Research (DAR) of the Ministry of Agriculture. Maize seed production and distribution is carried out by the National Seed Company of Malawi (NSCM), the Seed Technology Unit of the DAR, and ADMARC. The Seed Technology Unit was set up to be responsible for seed certification and quality, and the National Seed Company of Malawi, seed production and processing; ADMARC has the responsibility for seed distribution. The maize program is designed to develop high-yielding varieties and cultural practices for both the high-potential and marginal areas of the country and for both estate farmers and smallholders.

Table 1. Estimated maize production, Malawi, 1982-83

Type of maize	Area (ha)	o/o of total	Total production (tons)	o/o of total production	Yield (kg/ha)
Local unimproved	1,067,525	90.2	1,017,114	77.7	952
Composite	26,954	2.3	46,097	3.5	1709
Hybrid	89,004	7.5	245,573	18.8	2759
Total	1,183,493	100.0	1,308,784	100.0	1106

Maize research is coordinated from the DAR Chitedze Research Station, situated 16 kilometers west of Lilongwe. The research is multidisciplinary, with the program divided into the areas of breeding, agronomy, pathology and entomology. A unit has been formed recently to carry out, among other things, on-farm research.

The maize breeding program

A systematic maize-breeding program was set up in the early 1950s, and the production of inbred lines from a wide range of base materials was begun at that time. Until 1971, emphasis was on the production of synthetic varieties (SV) and double-cross hybrids (coded LH for local hybrid). The lines were recombined in the early 1960s to form synthetic varieties or crossed into double-cross hybrids. This approach was successful, and a number of synthetic varieties (SV17, SV28 and SV37) and a hybrid variety (LH11) were released to farmers after testing in the mid-1960s. These varieties were grown for a long period.

In 1967, a breeding program for the formation of composite varieties was initiated. Random pollination of some 20 varieties, which included local synthetics and hybrids and a few introduced materials, was carried out for three generations. In 1971, recurrent selection was started with the new population thus formed; it was named Chitedze Composite A (CCA). At that time, emphasis was shifted from synthetics to composites, and the hybrid program was suspended. Chitedze Composite B (CCB) was formed almost exclusively from exotic materials and was very broad based. The selection criteria used in the program was grain yield, grain characteristics and ear and plant height. The S_2 testing method of selection was chosen, since it appeared to make the best use of the resources available. Table 2 shows the schedule that was followed.

However, problems were experienced with this method. It was difficult to get enough S_2 ears because the S_1 lines did not grow well because of reduced vigor and consequent poor seed set. In

Table 2. Maize S_2 selection method used in Malawi, 1971 to 1973

Cycle	Site	Operation
First wet season (1971-72)	Chitedze	From 1 ha, 1500 plants were selfed for S_1s, 300 ears selected
First dry season (1972)	Makhanga[a]	300 S_1s planted ear-to-row and selfed to S_2
Second wet season (1972-73)	Chitedze Bvumbwe Mbawa	Yield trials for best 200 S_2 entries, two replications at each site, best 10 to 20 entries selected based on yield and desirable agronomic characteristics
Second dry season (1973)	Makhanga[a]	Selected entries recombined by the Kitale "Irish method" of planting best ears from selected families ear-to-row, the resulting best ears mixed in equal proportions to represent one improved cycle of the population

[a] Grown under irrigation

1974, it was decided to change the selection method to modified S_1 testing. Therefore, the top-crossing of the S_1 lines to the original population (C_0) in the first dry season was substituted for the S_2 production. The remnant seed of the best 10 to 20 families of the S_1 lines were then recombined in the same manner as in the S_2 method. Two other populations, Ukiriguru Composites A and B (UCA and UCB), were introduced from Tanzania and also underwent this method of selection.

In the mid-1970s, the two composite varieties, UCA and CCA, were released for high-potential and low-potential areas, respectively. Farmers expressed dissatisfaction with them because they were too tall. A recurrent selection program was therefore started to reduce the ear height of these composites. Some progress has been achieved in ear height reduction in both varieties (Table 3).

The hybrid program was revived in 1977 in order to satisfy the country's demand for hybrid seed, which had risen due to an increase in the number of commerical maize growers. Until that time, all hybrid seed had been

Table 3. Mean grain yields of two maize varieties over three seasons of testing, Malawi

Cycle	Grain yield (kg/ha)	Plant height (cm)	Ear height (cm)
CCA			
C_0	5785	301	184
C_1	6253	282	165
C_2	6646	293	172
UCA			
C_0	6678	285	185
C_1	6851	293	165
C_2	6525	277	158
SE I	666	8	64
CV (o/o)	5.6		

imported from neighboring countries. By producing its own hybrid seed, Malawi could free much-needed foreign exchange for other development projects. The hybrid program was to be followed along with the composite program (for open-pollinated varieties) which catered to smallholders who grew maize with fewer inputs, either for home consumption or for the market.

The hybrid program—In 1977, the development of inbred lines from local and exotic populations was initiated. Inbred lines were also acquired from cooperating institutions outside the country. The ear-to-row inbreeding method was used. Selections were made both within and between families, with the populations involved being CCA, UCA, Ecuador 573, Cortazar and TL73B. At S_2 the lines were evaluated for general combining ability (GCA), and selfing was continued only in the lines which showed good GCA. At S_6 the lines were evaluated for specific combining ability (SCA). Three new high-yielding hybrids have been released from this program, for both the high-potential and the marginal areas. Three lines of these hybrids are now with NSCM for bulking and seed production and distribution to farmers; they are CXH66, CXH74 and CXH43.

The composite program—In the composite program, there is continuous population improvement for both high-potential and marginal areas. For high-potential areas, the emphasis is on high yield, late-to-medium maturity, low ear placement, short plant height and disease and pest resistance/tolerance. The populations undergoing improvement in this program are UCA and CCC. Work is also underway to synthesize new populations using local and exotic materials. Like the hybrid program, the collection and evaluation of new introductions is an ongoing process.

Cooperation with international institutions, such as CIMMYT, is an important part of the program.

In the marginal areas, the emphasis is on breeding for stable yields, early maturity and tolerance to diseases and insect pests. CCA is recommended for the lakeshore areas and is undergoing improvement for stable yield and better agronomic characters. Tuxpeño, a CIMMYT population, has just been released for the Karanga Agricultural Development Division (KADD).

Cultivar evaluation and release—Any new cultivar showing some potential, whether from the national program, international institutions or seed companies, is required to undergo vigorous testing before it can be recommended for release to farmers. The Variety Release Committee, which is a decision-making body, requires three seasons of trial data; it only approves the release of varieties that show consistent superiority over the current recommended varieties.

The released cultivar then goes to the National Seed Company for seed increase and distribution. In the case of hybrids, parental lines are provided to the company, which contracts commercial growers for bulking and hybridization. The Seed Technology Unit at Chitedze, in liason with breeders, keeps a close watch on the seed-multiplication scheme to maintain varietal purity and quality. The seed company sells the seed directly to large maize growers; ADMARC, the sole distributor of farm inputs to small-holder farmers, sells the seed to those farmers.

The maize agronomy program

A small maize agronomy program was initiated at Chitedze in the late 1950s to develop improved cultural practices for the new synthetic and hybrid varieties coming out of the breeding program. At that time, emphasis was mostly on time of planting, spacing and planting density. The little work done on fertilizer rates was mostly for the few estate farmers growing maize at the time.

Almost all maize agronomy work was conducted at the major agricultural research stations and substations. Technologies developed on the research stations were directly transferred to farmers for adoption, although management and soil conditions on farmers' fields were very different from those of the stations.

In 1970, due to increased maize production (especially hybrid maize) by small-holder farmers, the government felt that work in agronomy should be intensified. In 1971, for the first time, a full-time maize agronomist was recruited under an ODM project. The objective of the new project was to increase both maize yields and grain quality by determining fertilizer requirements for the improved maize varieties in the main maize-production areas, and by investigating factors reported to be constraints in maize trials in those areas. The new project was heavily oriented toward trials conducted in farmers' fields; these were supported by more critical trials, which were carried out on the research stations.

Fertilizer-response trials were conducted both on farmers' fields and at the stations to test the response of maize varieties to nitrogen and phosphorus, the most important nutrients limiting maize yields in Malawi; earlier research and soil surveys had shown that potassium was not a limiting factor. Trials involving micronutrients were also carried out where they were a limiting factor. This project was highly successful and provided reliable fertilizer recommendations for the country by the mid-1970s.

The present maize agronomy program is an outgrowth of the ODM project. However, the size and scope of the program has changed, because maize cultivation in Malawi has extended to areas that in the past were under cassava, sorghum or millet as food crops. New problems have also come about because of increased maize production. In some areas, maize monoculture has become a practice, since maize is now being used as both a food and a cash crop, and in a few cases, because of population pressure on the land. Nutrients which were in abundant supply in the soil are now becoming deficient, because of the use of high-yielding varieties which are more demanding of soil nutrients. This is particularly true of the micro-nutrients, especially boron and sulfur, and in some areas, potassium. Weeds, especially witchweed (*Striga asiatica*), are also becoming a problem because of monoculture or insufficient rotation. The land is not allowed to rest long enough between crops to reduce the incidence of witchweed.

The maize agronomy program is charged with developing improved cultural practices for the new high-yielding varieties coming from the national program or those introduced from outside the country. Research work in maize agronomy presently includes plant density and spacing, soil fertility and crop nutrition, the intercropping of maize with legumes, and weed control. Maize physiology studies are also investigating the efficiency of the various maize varieties in partitioning dry matter into grain.

The maize pathology program
With the intensification of the production of maize, its disease status has changed, with the occurrence of more diseases in epidemic proportions every year. Therefore, it has became necessary to engage a pathologist to initially screen existing materials for resistance or tolerance to the most common diseases. These materials can later be incorporated into the disease-resistance breeding program in case any of the diseases reach economic levels.

The most serious diseases at present are maize streak virus, maize leaf blight (*Helminthosporium turcicum* and *Trichometa-sphaeria turcicum*), rust (*Puccinia sorghi*) and leaf anthracnose. Since the economic importance of these diseases has not been studied previously in Malawi, the preliminary program consists of investigations into the economic importance of maize leaf blight and rust and into varietal reactions to the diseases and disease development over time.

The maize entomology program
The entomology section of the maize research program is responsible for monitoring the incidence of economically important pests in Malawi and investigating control measures. The maize entomologist, like other maize scientists, is also involved in advisory work with farmers.

The most serious pests are stalk borer, termites and armyworm. While termites are difficult to control, stalk borers can be controlled by 2% Dipterex granules; armyworm can be controlled by Sevin 85% wettable powder or Dipterex 95% soluble powder.

Maize Research Staffing

The maize breeding program is staffed by three maize breeders. They are supported by staff at the technical officer and technical assistant grades and a labor force which fluctuates, depending on the season. Two of the maize breeders are assigned to the breeding project for the high-potential areas; the third breeder is responsible for breeding for the marginal areas.

The maize agronomy program is manned by a senior maize agronomist and a professional officer, two technical officers, a senior technical assistant and a technical assistant. The labor force again fluctuates, according to season. The maize pathology program is composed of one professional officer, a technical officer and a technical assistant. Maize entomology is manned by a senior entomologist, a technical officer and a technical assistant. All maize research scientists work as a team under the coordination of the Maize Community Team Leader.

Conclusions

Maize production in Malawi has dramatically increased in recent years in all parts of the country. Malawi is now not only self-sufficient in maize, but has become an exporter as a result of increased production in recent years. Table 4, which shows ADMARC purchases of maize from smallholder farmers, is an indication of this increase in production. The increase in farmer sales may be attributed to increased yields per hectare, to farmers' adoption of improved cultural practices and to the use of improved seed and fertilizer. These factors are partly the result of the Malawi maize improvement program and partly of good government policy and intensified extension efforts.

Table 4. Amount of maize sold to ADMARC by smallholder farmers, Malawi, 1981 to 1983

	Amount of grain sold (000 tons)			
Year	Northern region	Central region	Southern region	Total
1980-81	20,723	65,559	4,923	91,205
1981-82	36,387	96,186	4,018	136,591
1982-83	46,306	152,993	45,617	244,916

Maize Production, Constraints, Research and Development in Mauritius

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Mauritius and its island district, Rodrigues, form part of the Mascarene Archipelago in the southwest Indian Ocean. Mauritius is situated at 20°S latitude and 57°E longitude, about 880 km east of the Madagascar. It is of volcanic origin, and the land rises from a coastal plain to a central plateau, with elevations ranging between 73 and 275 meters. It has a maritime climate, tropical in summer and subtropical in winter (8); temperature is mild the year around. The mean maximum temperature in the warmest areas varies from 25.9°C in August to 31.2°C in February, and the mean minimum in the coolest areas, 14.9° to 20.5°C. Annual rainfall is less than 1000 mm on the coast and more than 5000 mm on the central plateau, but the amount varies from year to year. Most of the rain falls between December and April, the cyclone season. Tropical cyclones cause considerable damage to crops.

Mauritius occupies an area of about 1840 km^2, of which 57% is cultivated. Sugarcane occupies about 90% of the cultivated area, and tea, about 6%. The agricultural economy is, therefore, dominated by the production of sugar.

In the past decade, Mauritius' food imports have increased alarmingly. In 1982, the value of imported food represented about 25% of total imports, with the balance of trade suffering a heavy deficit. About two-thirds of the foreign currency earnings from the main export, sugar, was absorbed by this cost of imported food (4). Hence, the government declared a policy "to achieve the greatest autonomy in the control and production of our food supplies" (2).

In 1984, 54% of the country's food imports could not have been produced locally, 39% could have been produced and would not have required arable land, and 7% could have been produced but would have required arable land. In this last category, maize and vegetables were the most important items (10). Therefore, much emphasis is being placed on increasing maize production.

Maize is not a new crop in Mauritius; its cultivation has a long history dating back to the first decades of colonization. On several occasions in the past, particularly when sugar prices were low or in times of crisis, such as wars, interest was also shown in agricultural diversification through the production of maize and other food crops.

Presently, efforts are again being made to increase maize production, with a view to attaining self-sufficiency by 1990. The annual per capita consumption of maize in Mauritius is 16 kg, most of which is used as livestock feed. In 1984, only a quarter of this maize was produced on the island; the rest was imported.

About half of the maize produced in Mauritius is grown in sugarcane interrows; the other half is grown in rotation with cane. Most is produced by the sugar estates, but recently other producer groups have started to show an interest in the crop.

The main constraints to maize production are land scarcity, the occurrence of tropical cyclones and of drought, insufficient shelling and drying facilities and relatively low economic profitability. These constraints are discussed in this paper in relation to research objectives and achievements, as well as the role of extension and the planning and organization of production. Emphasis is on the attempts being made to remove the constraints through research and development. The uniqueness of some of the Mauritian approaches are underlined.

Maize Production and Utilization

In the eighteenth century, the early French colonists grew maize in Mauritius in order to avert the threat of famine. When a guaranteed market for sugar was established in 1825, sugarcane became the dominant crop, and by the end of the nineteenth century, maize was no longer grown; it continued to be of some importance in Rodrigues, where cane was not grown. During the first and second world wars, when rice supplies were disrupted, schemes were launched for the production of maize, but these were not very successful. In 1944, the production of maize was only 5500 tons, whereas demand for rice was about 55,000 tons. After the Second World War, maize production declined, reaching its lowest level in 1962 to 1964. There was some increase in production in the 1970s, but no further progress was achieved until 1984, when production again increased to 4000 tons (Figure 1). On the basis of orders for seed, it is estimated that production in 1985 will reach more than 7000 tons.

There has been a large increase in the country's demand for maize. The average amounts utilized annually for the periods 1969 to 1973, 1974 to 1978, and 1979 to 1983 were 4280, 5630 and 14,180 tons, respectively. This rapid increase was associated with an increase in the demand for livestock products as a result of rising incomes. At present, about 99% of the maize in Mauritius is used as feed for livestock, especially poultry. Mauritians do not eat much maize, and surveys have revealed that if imported rice and flour, the main staples, were not available, they would prefer manioc, sweet potatoes and potatoes to maize (3). By contrast, maize figures largely in the Rodriguan diet, although rice is the preferred staple (9).

Agricultural Production Systems

There are presently three main maize production systems in Mauritius, extensive pure-stand cultivation, intensive pure-stand cultivation and intensive intercropping with sugarcane.

Extensive pure-stand cultivation (System 1)

System 1A—Extensive pure-stand cultivation is practiced in Mauritius by small-scale farmers, many of whom are squatters on Crown Lands. Maize

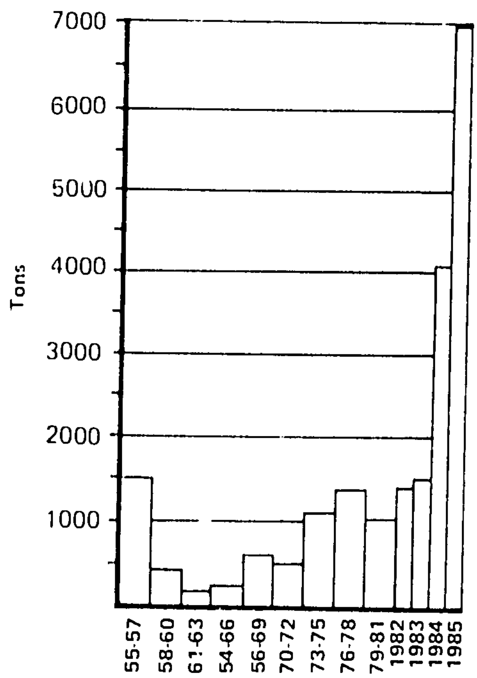

Figure 1. Maize production, Mauritius, 1955 to 1985

cultivation is not their main occupation. Small plots on mountain slopes are cleared with a machete and hoe at the beginning of the rains, and three or four seeds are sown in holes dug at a spacing of approximately 1 x 1 m; this usually results in a stand of two plants per hill. Grain yields are about 2 t/ha, and the total production of these farmers in 1984 was estimated at about 100 tons. In the extensive pure-stand cultivation of maize, there are no cash inputs in the form of fertilizers, herbicides or irrigation. Invariably, the local maize variety is utilized; due to its rusticity it is well adapted to this traditional method of production.

System 1B—Extensive cultivation is also practiced in much the same way on Rodrigues, although in contrast to Mauritius, small-scale maize farmers there do not always plant in pure stands; their maize is often intercropped with manioc and sweet potato. Local Rodrigues varieties are used, and yields reach about 2 t/ha. Total production was estimated at 2000 tons in 1983, with most of the maize being grown for home use. Maize is the most important crop in Rodrigues.

Intensive pure-stand cultivation (System 2)

Intensive pure-stand cultivation of maize has been carried out on Mauritius mainly by the sugar estates; only in 1984 did it begin to be used by other farmers. In this system, which is very important since it presently accounts for about half of the maize produced, maize is grown in rotation with sugarcane. The maize is grown on the land lying fallow between the sugarcane harvest and the next cane planting. Inputs such as fertilizers, herbicides, insecticides and, often, supplementary irrigation are provided.

Maize planted in sugarcane interrows, Mauritius

Highly responsive varieties, presently hybrids, are planted at 62,500 plants per hectare, and average yields are about 4.3 t/ha.

Intensive intercropping with sugarcane (System 3)

Intensive intercropping with sugarcane (growing maize between the rows of cane), has also been done on the sugar estates; only in 1984 did other groups adopt the practice. This system accounts for about half of the present production. Although the system exists in a few other sugar-producing countries, such as India, Taiwan and the Philippines, nowhere is it as important as it is in Mauritius. The most common pattern of intercropping sugarcane with maize is to grow one row of maize in alternate interrows of the sugarcane crop and of the first and second ratoon crops. In this system, the maize population density is one-third that of pure-stand maize. The maize is fertilized, and it benefits from the irrigation given to the young cane; sometimes it also receives supplementary irrigation. Grain yields are about 1.4 t/ha, the equivalent of a yield of about 4.2 t/ha of pure-stand maize.

Production Structure

Maize production increased remarkably in 1984, and is expected to increase still further in coming years. Recently, there has been a gradual change in the structure of maize production in Mauritius (Table 1). The amount produced by small planters by traditional methods (System 1A) has increased slightly in response to an increase in price. However, it is anticipated that in the future this production will decrease as pressure is exerted on squatters on Crown Lands to stop cropping erosion-susceptible mountain slopes.

A campaign was begun in 1984 to get producer groups other than sugar estates to grow maize on sugarcane lands, and this has started to bear fruit. In that year for the first time, small planters ventured into maize production in sugarcane interrows and in rotation with sugarcane. Sugar estates, which own about 55% of the cane lands, produced 93% of the total maize crop in 1983. The proportion decreased to 85% in 1984 and is expected to be about 86% in 1985. The proportion may decrease further in the

Table 1. Maize farming systems, Mauritius, 1983 to 1985

		Estimated Production					
		1983		1984		1985	
Farming system	Type of farmer	Tons	Percent	Tons	Percent	Tons	Percent
Extensive pure stand	Small-scale	50	3	100	3	200	3
Intensive pure stand	Sugar estates	600	40	1600	40	2500	35
	Large-scale	—	—	—	—	50	1
	Small-scale	—	—	100	3	150	2
Intensive intercropping	Sugar estates	800	53	1800	45	3600	51
	Large-scale	—	—	50	1	100	1
	Small-scale	50	3	350	9	500	7
Total		1500	99	4000	101	7100	100

future if other producer groups increase their production. The proportion of maize produced in sugarcane interrows is expected to increase from about 55% in 1983 and 1984 to about 58% in 1985. This can be attributed to an increase in first-season (March) plantings when the only free land is found in sugarcane interrows.

Constraints to Maize Production

Numerous constraints limit the production of maize in Mauritius and account for the failure of past attempts at increasing production. The main ones are described here in relation to the research objectives and achievements of the maize program of the Mauritius Sugar Industry Research Institute (MSIRI), the organization responsible for maize research.

Land scarcity

Since most of the arable land in Mauritius is presently cropped, there is very little scope for increasing the cultivated area. The only lands that could eventually be developed are located in the dry zones, and not only is it too expensive to provide them with irrigation, but water is not always available. Also, the present official policy is to maintain sugar production at current levels because about 80% of the sugar is exported at a guaranteed, negotiated price; this policy implies that diversification should not come about at the expense of sugarcane. The solution, therefore, is to intensify maize production on sugarcane lands. The challenge of Mauritian agriculture is to find a way to produce more food crops without an increase in arable land and while maintaining the level of sugar production. This can only be done by rotating crops in the sugarcane lands (System 2) and by making maximum use of sugarcane interrows (System 3).

Research on intercropping sugarcane with food crops started at the end of the nineteenth century, but intensive studies have been recent. Intercropping patterns have been considered, and in the case of potato, widely adopted; 85% of potato production in Mauritius is in sugarcane interrows. This does not reduce sugar production. With maize, the recommended pattern of growing one row of maize in alternate interrows of plant and first and second ratoon sugarcane accounts for about 50% of maize production. Research is being pursued to further intensify the system by growing such crops as potato, groundnut and beans in the plant cane interrow which presently is not planted. This should make the practice of intercropping maize with plant cane still more attractive. Another approach being studied is that of increasing maize density in sugarcane interrows. Presently, the density utilized is 20,800 plants per hectare, one-third of the density recommended for pure-stand cultivation. The average maize grain yield of about 1.4 t/ha is also one-third of the yield of that of pure stands, somewhat low compared to other crops which compete with maize for the sugarcane interrows. The density of potato intercropped with plant cane is 50% that of sole-cropped potato, and yield, about 60%.

A way to increase intercropped maize density, and hence yields, has now been proposed. This consists of planting two rows of maize in large sugarcane interrows created by pairing cane rows. This would increase maize yield by more than 60% over that of the presently recommended pattern. Moreover, it would allow the intercropping of older (third and fourth) sugarcane ratoons. The system of pairing cane rows has not yet found favor with sugarcane producers because of a number of problems which are presently being studied.

The success of intercropping maize with sugarcane depends on the use of early maturing, short-statured, high-yielding maize cultivars. Such cultivars were not available in the past, and this may explain why past attempts to encourage the intercropping of maize with sugarcane met with little success. Hybrids imported from Europe were not suitable to Mauritian conditions because of their susceptibility to diseases, and quarantine regulations made it impossible to import seed except from a few European countries, Zimbabwe and the Republic of South Africa. Therefore, Mauritius started its own breeding program in 1970. Since then, much research at MSIRI has been devoted to the selection of cultivars for intercropping, with the first objective of the breeding program being the development of cultivars for use in sugarcane interrows. The first two hybrids were developed in 1980, and they are now the only cultivars recommended.

The second approach to intensified cropping is to make maximum use of sugarcane rotation lands. This land lies fallow for four or five months between the harvest of the last sugarcane ratoon and the replanting of the field. As sugarcane is replanted only after an average of ten cycles (one plant crop and nine ratoon crops), one-tenth of the area under sugarcane is replanted every year.

For various reasons, the area available for growing pure-stand maize is less than one-tenth of the sugarcane area. First, not all sugarcane lands are suitable for maize. Second, in many instances and particularly in nonirrigated zones, the fallow period is too short for a maize crop. Finally, other crops, such as tobacco and vegetables, compete with maize for sugarcane rotation lands. In order to boost maize production on rotation lands, a project has been launched to identify the reasons why lands suitable for maize are not used for cropping and to remove the constraints. In most cases, this can be done by shifting the harvest date of the last cane ratoon and the date of replanting.

Other alternative cropping systems have been proposed but have not yet been studied. For instance, reducing the cane cycle from ten to eight years has been suggested for increasing the amount of available rotation lands. It might also be possible to increase the fallow period from four to eight months to permit the growing of two successive short-cycle maize crops. The feasibility and the economics of these suggestions will be studied.

Cyclones

The second most important constraint limiting maize production in Mauritius is the occurrence of tropical cyclones. Sugarcane has become the dominant crop in Mauritius because, of the many crops that have been planted over the years, it is least vulnerable to cyclones. The history of maize in Mauritius lists innumerable occasions when cyclones have seriously reduced production, causing hardship for the people of the island. Maize can become an important crop only if ways are found to avoid the destructive effects of cyclones. These occur in the wet summer months, December to March, the period which otherwise is the most suitable for maize cultivation. It is recommended, therefore, that maize be planted in August or September, before, or in March or April, after the cyclone-prone period. The use of short-cycle cultivars is also important.

In Mauritius, cyclones bring gusts of wind of 120 kph; no maize cultivar can resist such winds. Also, however, in the cyclone season, and even in mid-winter, winds of 35 to 60 kph are common, and there are cultivars that can withstand these winds. It is imperative that lodging resistance be incorporated into all cultivars grown on Mauritius, and this is one of the principal objectives of the maize breeding program.

Drought

While the effects of cyclones can be avoided by growing maize before and after the wettest months, this increases the risk of crop failure due to drought. In Rodrigues, most of the annual precipitation is associated with cyclones, and farmers there have to risk growing maize in the cyclone season. In some parts of Mauritius, where supplementary irrigation is available, maize can be grown in the dry season. In rainfed areas, drought is a serious factor limiting yield.

There are two main approaches for overcoming drought in Mauritius, the use of short-cycle cultivars for drought avoidance, and irrigation. Irrigation is provided when and where it is available, although the rise in the cost of energy has been responsible for the abandonment of a number of irrigation schemes. Except in the drier regions, it usually does not pay to irrigate sugarcane unless gravity-fed systems are employed; for maize, on the other hand, supplemental irrigation is usually worthwhile. The intercropping of sugarcane with maize will make irrigation schemes more economically viable, since irrigation applied to maize benefits the cane and vice versa.

Insect pests

At present, insect pests are not limiting factors in maize production in Mauritius. In the past, insect pests of stored grains were important because maize was stored for long periods, but currently the production is regularly absorbed by the feed mills. A few insects, such as the webworm (*Angustalius malacellus*), the greasy cutworm (*Agrotis ipsilon*) and the defoliating caterpillar (*Spodoptera littoralis*), attack maize seedlings, but they are controlled reasonably well by the use of insecticides (5). Earworms (*Heliothis* armigera and Cryptophlebia leucotretra) do not appear to cause economic damage.

Diseases

Leaf diseases are important yield-limiting factors. In Mauritius, the leaf blights *Helminthosporium maydis* and *H. turcicum* prevail in the maize-growing areas (5). The latter is more serious and may cause reductions in yield by as much as 50% for susceptible cultivars. Rust, *Puccinia polysora*, is prevalent during the warm season, and can also seriously reduce yields. In addition to leaf blights and rust, maize streak virus (MSV) is also important in Rodrigues. The approach to the control of leaf diseases is the breeding of resistance into the cultivars grown on Mauritius (6). The cultivars presently grown in pure stands are tolerant, but those grown in the sugarcane interrows are moderately susceptible to leaf blights. A number of resistant inbred lines have recently been introduced from the USA and the Republic of South Africa, and they will be crossed with the best local inbred lines. MSV-resistant populations have been introduced from IITA and will be used in the development of a composite for Rodrigues. So far, no material with good resistance to rust has been found; the CIMMYT populations and gene pools that have been grown so far appear to be susceptible to rust.

Weeds

Weeds create a serious problem in maize fields in Mauritius. At the beginning of the nineteenth century, the root parasitic weed *Striga hirsuta* was a major pest, but it has now almost disappeared. The nutgrasses, *Cyperus rotundus* and *C. esculentus*, are particularly noxious weeds in maize and sugarcane fields. A number of herbicides are recommended against nutgrass (5), but they are costly.

Infrastructure

A major difficulty with maize production on Mauritius is the shelling and drying of the crop at the producer level. Because of the need to keep the crop cycle as short as possible, it is necessary to harvest maize when the grain moisture content is still at 25 to 30%. The ears then have to be shelled and the grain dried to 12% moisture content. The first maize-drying plant was erected in 1917, and three modern regional maize-processing plants for the shelling, drying and temporary storage of maize are now operational. One is privately owned and has been in existence since 1980; two other government-owned plants were built in 1984. Some sugar estates also use tractor-driven shellers and bagasse-fired dryers. These facilities are adequate to process the present production, although more will be required as production increases.

The need to dry maize artificially increases the cost of production by about 10%. For this reason, alternative, low-cost drying methods are being examined. At the small-farm level, crib drying appears to be a possibility. Solar dryers also offer some potential, and they are being developed at the University of Mauritius. In Rodrigues, maize is hand-shelled and then dried in the sun.

Economic Considerations

In 1983, it was calculated that the cost of the production of maize grain at 12% moisture content was about 2885 Rs approximately US$ 185) per ton for non-mechanized and rainfed crops (Table 2). The guaranteed price for local maize was 3750 Rs per ton or 130% of the cost of production; this was not considered attractive by the farmer. In 1984, the price for local maize was increased to 4050 Rs per ton, and the effect on production was remarkable. This situation is reminiscent of what happened in the 1946 to 1950 period, when maize subsidies resulted in a three-fold increase in production. When the subsidies were removed, production dropped back to low levels (7). The present price is not considered a subsidy since the price for imported maize is also about 4000 Rs per ton. It is, instead, an incentive price.

An analysis of the breakdown of the cost of production reveals that material inputs, especially fertilizers, labor, and shelling and drying, are the main components of the cost of production. Material inputs cannot be reduced without reducing yields. The work being done on natural drying has already been mentioned, and there are also other areas where a reduction in production costs is possible.

In spite of the amount of unemployment on Mauritius, it is felt that some labor-intensive operations should be mechanized. It has been shown that the cost of labor could be cut in half through the use of appropriate implements for planting and harvesting. The mechanical planters presently utilized by some planters are not very efficient, and new

Table 2. The cost of production of rainfed maize, Mauritius, 1983

Cost component	Rs/ha[a]	Rs/ton[b]	Percent of total
Material inputs			
Seed	1000	285	9.9
Fertilizer	3150	900	31.2
Biocides	1150	330	11.4
Labor	2550	730	25.2
Transport	350	100	3.5
Shelling and drying	1750	500	17.3
Interest	150	40	1.5
Total	10100	2885	100.0

a/ US $ 1 = 15.60 Rs
b/ Based on an average yield of 3.5 t/ha

models, including pneumatic planters, are being tested. Corn pickers have been in use in pure stands since 1977. In 1978, a prototype one-row corn picker for use in sugarcane interrows was designed and built and found to work reasonably well (1). On sugar estates it is not used, because presently the permanent labor force can be shifted from cane to maize.

Finally, the cost of production per ton can be reduced by increasing yield. For instance, irrigation could improve the efficiency of the other resources, such as fertilizers, and increase yields.

Extension

The Mauritius Sugar Industry Research Institute, which conducts research on maize, is also responsible for extension for the sugar estates and large planters, the owners of 40 hectares or more, through its Extension and Liaison Division. Lectures on maize are regularly given at the MSIRI; research recommendations are also made in its annual reports and advisory bulletins, and updates appear in mimeographed recommendation sheets. Moreover, maize specialists visit the maize plantations regularly, and trials are conducted on land belonging to sugar estates and large planters.

Extension for the 33,000 small cane planters is the responsibility of the Extension Services of the Ministry of Agriculture. There are two or three extension officers in each of the ten districts of Mauritius, and they collect information from MSIRI and pass it on to the farmers whom they visit regularly. They also broadcast recommendations on radio and television and publish a news bulletin.

The Organization and Planning of Production

The removal of technical constraints alone, through research and efficient extension, are not necessarily translated into increased production. The Mauritian experience with the potato has demonstrated the need to devote more attention to development. Even when information is quickly made available to producers, new technologies are not adopted for several years, and some not at all.

On Mauritius, maize is a controlled product. The Agricultural Marketing Board is responsible for calculating costs of production, fixing prices and quotas and allocating subsidies, as well as for conditioning, storing and marketing maize. This is done through a Maize Production Committee, which is made up of representatives of producers, research and extension services, feed mills, the Chamber of Agriculture and the Consumer Association.

The Chamber of Agriculture monitors the use of sugarcane lands for the production of food crops; lands not used by sugar estates are leased to small planters. The seed requirements of the different producer groups are also channeled through the Chamber. The activities of seed importers and local seed producers are coordinated so that there will be no shortfall in production because of a lack of seed.

At a higher level, the High-Powered Committee for Agricultural Diversification has a maize subcommittee which makes recommendations to the government on all matters pertaining to the development of maize production; it also monitors the activities of all of the other organizations. The subcommittee reviews past performances in the light of government policy and production targets. The target set by the government in 1983 was to satisfy the country's annual needs by 1987 (4). This has now been revised, with the present goal that of attaining self-sufficiency by 1990.

Conclusions

After several decades, Mauritius now has the possibility of increasing its maize production substantially. This is the result of concerted effort on the part of all those concerned with maize. Producers are motivated by the attractive price. Research workers are determined to face the challenge of developing methods to increase production without reducing sugarcane yields. The government has demonstrated that it has the political will to support local production. Therefore, the goal of achieving self-sufficiency by 1990 should be attainable.

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Research on the Constraints to Maize Production in Mozambique

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Maize is the preferred staple food of most Mozambicans, and it is grown throughout the country, both single cropped and intercropped. The total area under maize is about 500,000 hectares annually. Yields are generally low.

South of the Save River, the principal factors limiting maize yields are lack of rainfall (or for irrigated maize, poor irrigation techniques) and diseases, mainly downy mildew and maize streak virus; pests, such as stalk borers, are also constraints. In the higher rainfall areas of central and northern Mozambique, the principal agronomic factors limiting maize production are low soil fertility, periodic droughts in the lowland areas, and diseases, such as fusarium and diplodia ear rots and *Helminthosporium* spp. Weed control is a major problem under both peasant and commercial maize-growing conditions throughout the country, with the worst problems being the weeds *Striga lutea* for the peasant sector and *Rottboellia exaltata* and perennial sedges for the mechanized sector.

The most serious limitations to maize production, however, are economic. For the peasant sector, the most important is that, in the countryside, there is a lack of consumer goods that would serve as incentives to production. For the mechanized sector, problems include a serious shortage of trained manpower, insufficient management expertise, organizational difficulties and frequent shortages of vital inputs, such as fuel.

The national maize research program was started in 1977. Initially, the main research emphasis was on the selection of introduced maize germplasm for Mozambican conditions. As a result, three varieties (based on CIMMYT materials) are ready for release.

Selection for resistance to drought, downy mildew and maize streak virus continues in the southern part of the country; in the north there is a small program of hybrid seed production. It has become clear, however, that the use of improved varieties is only a minor factor influencing maize production. Since 1982, the maize program has adopted a more balanced farming systems approach. This paper summarizes results from planting date, plant density, fertilizer use, insecticide and herbicide trials. Land preparation studies have also been initiated.

Mainly post-independence work is described in this paper. Because of the transfer of power from the colonial to the independent government of Mozambique, there was an interruption both in agricultural production and in research. There was complete discontinuity in terms of research staff, and much unpublished data was lost. It has taken time to rebuild research capability, and work at times is still rudimentary. While not attempting to present experimental details, an

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overview is provided here of maize production and its constraints, as well as of progress made in maize research during the ten years since independence.

Maize-Growing Areas of Mozambique

According to the agricultural census of the 1960s (3), the country could be divided into three categories in terms of maize production, the area where maize was the major staple food crop, the area where it was of equal importance with sorghum and the area where it was of secondary importance. At that time, maize was the major staple crop in the highland areas of Niassa, Tete and Manica provinces, the lower Zambezi Valley and most of the southern part of the country, Maputo, Gaza and Inhambane provinces. In the central area, most of lowland Manica and inland Sofala, maize had about equal importance with sorghum, and in the rest of the country either sorghum, cassava or rice was dominant (Figure 1). There is no evidence to suggest that this pattern has changed in the last 20 years.

The highland areas are those with altitudes of 500 to 1300 meters, mean annual rainfall between 1000 and 1300 mm and PET (potential evapo-transpiration) (Penman) of less than 1500 mm per annum. There is a single rainy season, from November to April, giving a growing period of about 180 days. A recent analysis of the agroclimatic suitability of Mozambique for maize classifies these areas as suitable or very suitable for rainfed maize (5) (Figure 2). It is interesting to note that the predominance of maize as a staple does not always follow the indicated agroclimatic suitability for growing rainfed maize.

The whole of the northeastern part of the country is classified as very suitable for maize production, but in fact, sorghum and cassava predominate. This must be due then to other factors, and the most probable ones are soil fertility limitations and the competition for land and labor from cotton, the main cash crop.

Southern Mozambique is classified as marginally suitable or unsuitable for rainfed maize production. This region is characterized by irregular rainfall in terms of both total annual amount and distribution. Prolonged drought during the growing period is the norm, and crop failure is common as a result of either drought or flooding.

The coastal strip has more reliable rainfall, with a mean annual total of 800 to 1000 mm and PET below 1350 mm. Moving from the coast, the rainfall drops to less than 400 mm per annum in the interior of Gaza Province, while PET rises to over 2000 mm. In Gaza, maize is not a rainfed crop; it is irrigated or grown in depressions with residual moisture and hence is susceptible to flooding.

In the peasant secor of the highland areas, maize is grown on hand-formed contour ridges in which plant residues are incorporated. It is intercropped, mainly with beans, cowpeas and other legumes and sometimes potatoes. In each of these areas, the system is well developed and adapted to the heavy soils, the abrupt beginning of the rains, the high risk of erosion and the shortage of chemical and mechanical inputs. Planting dates in the highlands are fairly well defined, from mid-November to mid-December, as soon as sufficient rain has fallen. Yields of the intercropped maize are between 0.8 and 1.5 t/ha.

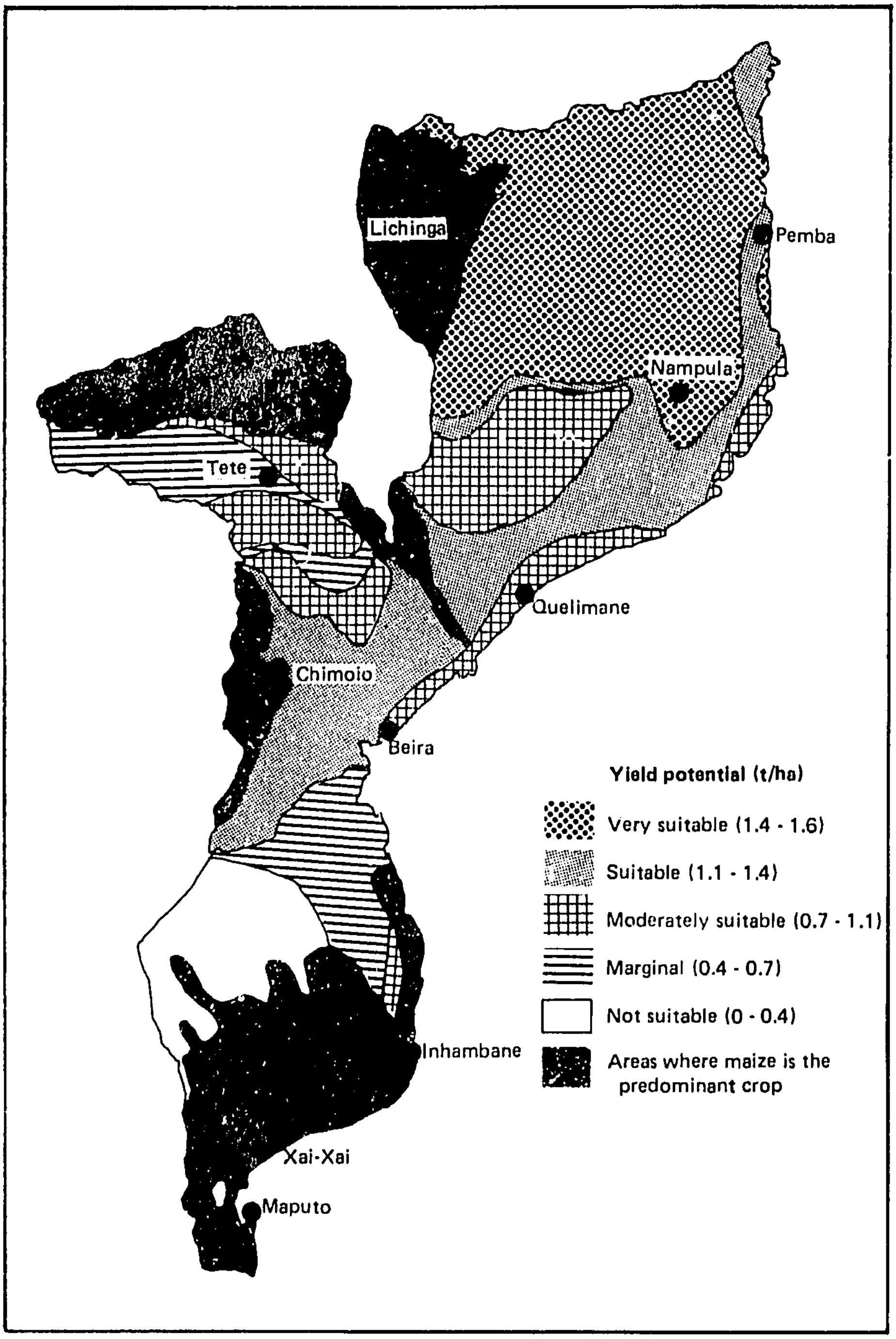

Figure 1. Climatic suitability for rainfed maize production at a low level of inputs, Mozambique

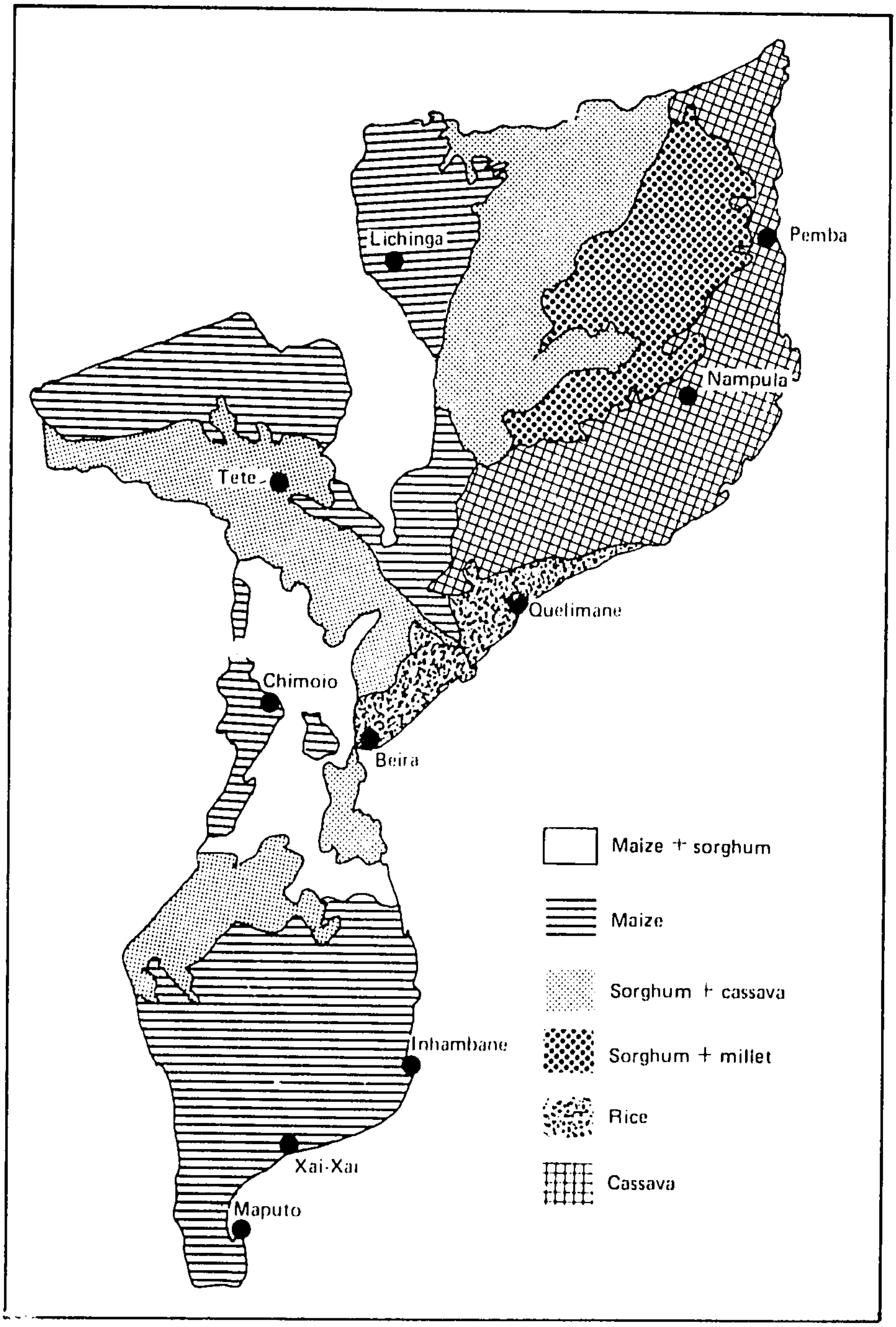

Figure 2. Dominant crops produced under peasant conditions, Mozambique
Source: Mario de Carvalho

In the south, oxen are used to cultivate the heavier irrigable soils, although hand cultivation is also common. In these soils, maize is grown as a row intercrop, usually with cowpeas, and pumpkins are undersown at an irregular density. In the sandy soils of the coastal strip, cultivation is mainly by hand. Maize is planted at a low density (less than 10,000 plants per hectare) and with irregular spacing in fields of cassava, groundnuts and cowpeas. Although the maize-planting season in the south is considered to be from the beginning of September to mid-October, maize is planted throughout the year following any sizable rainfall.

Mechanized farming with high agrochemical input is largely confined to the state farms. These were set up soon after independence in 1975 to secure continuing agricultural production despite the exodus of the Portuguese farmers; they were formed by putting several smaller units under one management in order to make full use of the limited expertise available. They are very large, usually over 1000 ha. On each farm the crop mix is dominated by one crop, either maize, cotton, sugarcane or rice, and on the cotton farms a considerable amount of maize is also planted. The combination of crop farming and the raising of livestock on one farm is rare. The location of these state farms is shown in Figure 3.

Cooperatives and private farms also exist on a more limited scale, with a lower level of inputs than the state farms and with mechanization usually limited to land preparation. The distribution of these farms loosely follows that of the state farms.

Maize Research

Maize research in Mozambique is carried out by the National Agricultural Research Institute (INIA) and the Rural Development Department (DDR) of the Ministry of Agriculture. In 1977 a program, mainly of variety selection, was started at INIA with FAO help; the FAO expert was joined by a Mozambican agronomist in 1981. In 1982, the FAO expert left the country, and since 1983 research has been carried out with the help of a five-person Yugoslavian team subcontracted by FAO.

Expatriate scientists have also worked on pest and disease problems and fertilizer requirements since 1977 and on weed control since 1981. These were initially separate, uncoordinated programs, but in 1982 all research on maize was coordinated under the National Maize Program. In 1983,

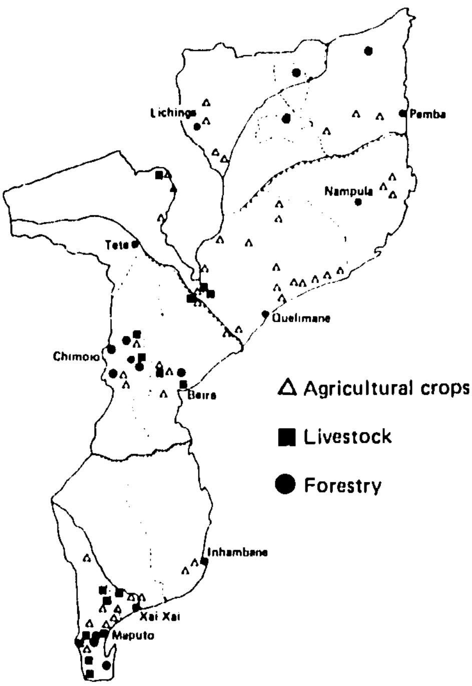

Figure 3. Location of state farms and their production, Mozambique

attempts were made to make research more meaningful in the solving of immediate problems limiting maize production.

In the early years, conditions of staffing and equipment on the experiment stations were such that experiments tended to be sown and harvested by visiting scientists (based in Maputo) and looked after by poorly qualified station staff. This led to a high percentage of failures, high CVs and low yields. In 1983, priority was given to three main experimental sites, Lichinga for the highlands, Namapa for the northern lowlands and Chokwe for the south; experienced research scientists were assigned to each, resulting in a dramatic increase in the quality of experimental results. However, the present war is making this quality difficult to maintain.

The Rural Development Department has its own centers, in six of which research on maize has been carried out for the last couple of years. These centers work with the peasant sector and cooperative farms, while INIA research has been aimed at fully mechanized agriculture.

Factors Limiting Maize Production

In the peasant sector

Although it is estimated that 50% of the marketed maize in Mozambique is produced by peasant farmers, this sector receives very little help from the state. There is practically no extension service and little distribution of seed and agrochemicals; even tools are unavailable some years. Manufactured goods in general are in short supply in the countryside, including basics such as salt, oil, sugar, cloth and kerosene, as well as such items as bicycles and spare parts, radios, lamps and sewing machines. It is probable that the lack of consumer goods is a major factor limiting the amount of maize produced.

Apart from this lack of assistance, the major constraints to peasant maize production are drought, flooding, pests and diseases in the south and declining soil fertility in the north. The soil fertility problem has been aggravated in recent years by the movement of population from the countryside into villages. This increases the pressure on the land and reduces the utilization of traditional bush fallows.

Trials carried out by the DDR centers have shown that the varieties used by the peasants are as productive, within the constraints of their farming system, as are the improved varieties presently available (1); the grain also has the added advantages of palatability and resistance to storage pests. The improved varieties tend to have a greater potential under high-fertility conditions, although this is not always the case. Some local maize populations have given experimental yields of up to 5.6 t/ha with the application of fertilizer.

In about 100 nonreplicated trials on peasant farmers' fields in two areas of the lowlands in the north, row planting of maize in maize-legume intercropping led to an average increase in yield of about 24%. Neither the yield of the companion crop nor the densities of the non-row planted maize intercrop was measured, but it is possible that row planting leads to an increase in plant density.

In the mechanized sector

Soon after independence, most farmers with experience in mechanized agriculture left the country, and because of the very low level of education and work experience that had been allowed the black population in colonial times, this sector still suffers from a shortage of skilled agricultural workers. This fact is especially serious because of the need to deal with the problems which arise from external factors, such as badly organized transportation and distribution services, the shortage of crucial inputs and spare parts, flooding, drought and, at present, the war. However, in the last few years, there has been an improvement in yield on some of these farms as farmers have gained more experience.

The lack of experienced managers and skilled workers at all levels has been the cause of many of the problems which have led to average yields of less than 2 t/ha on many mechanized farms. One of the most serious of these problems is that work is consistently late, from the preparation of the land to the harvesting of the crops. This stems partly from a lack of understanding of the crucial importance of timeliness, but even more from organizational difficulties, which are further aggravated by deficient machine maintenance. As a result, a high percentage of the farm tractors are not operational at any one time, and tractor life is short. The size of the farms also implies that considerable skill is necessary to productively manage the large work force.

Limitations of a more agronomic character are also influenced by the lack of skilled personnel. Often machines are badly adjusted, irrigation water is not properly controlled, and agrochemicals are inappropriately applied. These problems, although identified, cannot be solved by agricultural research unless the production system can be simplified.

Research Challenges

Land preparation and sowing

One of the major areas in which research needs to provide viable and economic recommendations is in that of land preparation for the mechanized section. Even when high-quality hybrid seed is used, plant density is often low, serious erosion is evident in maize fields, and there is little weed control by mechanical means. In the highland areas, the start of the rainy season is often abrupt, allowing only about a month for land preparation and sowing after the rains have begun. Alternatives have been proposed to the present system of plowing and harrowing the hard dry soil; some have been tried, but have not yet been properly tested. These alternatives include various forms of minimum or reduced tillage and a rescheduling of present operations; for instance, plowing could be done immediately after harvest, when there is still some moisture in the soil.

Irrigation and drainage

In the south, the alluvial plains of almost all of the rivers are used for growing maize on both mechanized and peasant farms. In some areas, the maize is not irrigated and adequate ground water control is the major problem. Drainage problems, at both superficial and deep levels, occur in these generally heavy soils, including that of increased soil salinity. Pumped drainage is sometimes practiced. Irrigation is by means of furrows, although sometimes small basins or sprinkler irrigation are used.

Major drainage problems and salinity occur in the country's most extensive irrigation scheme at Chokwe. This area is presently being used more and more for growing maize instead of the traditional rice. On both peasant and cooperative farms, small amounts of maize are grown in the limited, well-drained seepage zones called *machongos*. Peat may have developed in some places, but generally minor open drains are adequate for maize.

The medium to large irrigation schemes date from before independence. More recently, small self-help schemes are being constructed for the peasant sector. On the state farms and the cooperatives, limited expertise in water management hampers the optimization of production from irrigated agriculture. There is major need for training at all levels.

Soil fertility

In both the mechanized and the nonmechanized farming sectors, the principal nutrient limiting maize yield is nitrogen: it is deficient in all soils on which maize is grown. The response of maize to nitrogen is greatest in the high-rainfall areas. There, experimental results indicate that doses of nitrogen up to 150 kg/ha are economic in mechanized farming (6). The corresponding figure for the northern lowlands is 110 kg/ha. In the south, the economic optimum has not yet been determined, and in this area response may be suppressed by a lack of water and by pests and diseases.

Phosphorus deficiency is common in the soils of Mozambique, but experimental results show that economic response to phosphorus fertilizer can only be expected when other factors permit a maize yield of at least 2.5 t/ha. Test results have shown that yield is limited when there are fewer than 16 ppm of available phosphorus in the soil (North Carolina or Mehlich extract) (6).

Sulfur deficiency has been detected in widely dispersed areas of the country, but responses to sulfur have not been quantified. Nitrogen, phosphorus and potassium are considered major nutrients by the fertilizer importing and distributing bodies, and attempts are being made to ensure that fertilizers destined for areas with sulfur deficiencies contain sulfur in the future. The results of sulfur deficiency in the peasant sector, where almost no fertilizer is used, has not been studied.

In general, soil potassium levels are satisfactory for maize growth, although one important area of low-potassium soils exists in southern Cabo Delgado and northern Nampula provinces. No results from systematic studies of micronutrient deficiencies are available. Zinc deficiency has been detected from leaf analyses of maize grown on sandy soils in the northeast part of the country, and it is expected to become more evident as yields increase. Molybdenum deficiency is also to be expected but has not yet been detected, due possibly to the widespread use of molybdenum-treated seed on the mechanized farms.

Weed control

The principal weed species found in maize in Mozambique are similar to those of neighboring countries, with the addition of *Mucuna pruriens* in the north, *Parthenium hysterophonus* in the south and *Brachiaria deflexa* and *Urochloa mossambicensis* throughout the country as a whole (2).

In peasant farming, the principal problem weeds in maize seem to be *Striga lutea* and some perennial weeds, such as *Panicum maximum*. Little is known about traditional methods of control, although the use of maize companion crops, cowpeas, groundnuts, squash and sweet potatoes, obviously helps to smother weeds; virtually all cultivation is carried out with heavy hoes. The presence of *Striga lutea* and some other species, such as *Eragrastis arenicola* and *Rhychyletrum repens*, is taken by the peasants as an indication of low soil fertility and as a signal to abandon a site for two to ten years.

In mechanized farming, herbicides are used on most of the maize area. The principal one utilized is Atrazine mixed with Alachlor or Metolachlor. In large areas of the north, the annual grass weed *Rottboellia exaltata*, which is resistant to these herbicides, has become dominant, particularly on farms where maize is grown continuously without rotation. Pendimethalin (mixed with Atrazin) is the standard herbicide on these farms, but it is very expensive and requires good soil moisture. Organizational difficulties prevent the implementation of alternative measures, such as rotation with broad-leaf crops combined with the use of Trifluralin.

Other problem weeds include the perennial sedges *Cyperus esculentus*, *C. rotundus* and *Scirpus maritimus* in the Limpopo Valley. Incorporated herbicides such as EPTC are rarely used against these weeds, due to a lack of suitable equipment and to organizational problems. *Mucuna pruriens* (buffalo bean) poses a problem in some of the central and northern areas. As well as competing with the maize plant, it produces pods with stinging hairs which can make harvesting impossible. A control measure found to be successful on one large farm was the application of 2,4-D at the knee-high stage of the maize.

The weed control sector of INIA has carried out weed surveys and some herbicide trials. These have mainly been devoted to demonstrating well-tried and economical chemicals as a countermeasure to the hard sell of new expensive herbicides by the agrochemical companies.

Pest control

Stalk borers (*Chilo partellus*, *Sesamia calamistis* and *Busseola fusca*) are the most important maize pests in Mozambique. As a result of continuous planting in the southern part of the country, stalk borer incidence is severe. In the north infections of only about 10% of the plants are common, causing losses as low as 1%; in the south, infestation may reach 100% of the plants with considerable yield loss. Two generations of the borers can develop on the same plant, the first in the stem and the second in either the stem or ear, also causing ear rot in the latter case. Experiments show that two insecticide applications in the first five weeks of the growing season can reduce stalk borer incidence to an acceptable level. A study on the biological control of stalk borers has shown promising results, but is still in the early experimental stage.

Termites (*Microtermes* spp.) cause lodging at harvest time, which may result in severe losses if harvest is delayed. Soil treatment with Aldrin or Dieldrin is a common practice on state farms in the northern part of the country. In some years, birds are also important pests. Occasionally field rats and black maize beetles (*Heteronychus* spp.) are problems.

Disease control

Four viruses have been identified in maize in Mozambique, of which maize streak virus is the most important. The others are maize mosaic virus, maize stripe virus and sugarcane mosaic virus. Three vectors have been identified for maize streak virus, all Jassids of the genus *Cicadulina*; they are *C. mbila*, *C. parazeane* and *C. triangular*. This disease seriously affects the maize crop in the south. It is very common throughout the year, and no crop there completely escapes damage; with late planting, losses are heavy.

Recommended control measures are early planting and good weed control in the vicinity of the crop. Promising results have been obtained in experiments on the control of the vector by using either Carbofuran at sowing or Pyrethroids in two applications during the first four weeks after sowing. The only real solution, however, is varietal resistance, and experiments have been begun this season.

The other group of diseases of importance in the southern lowlands is that of the downy mildews. The major pathogen involved is *Peronosclerospora sorghi*. Recently there has also been a considerable increase in the incidence of crazy top, which has been attributed to *Sclerophthora macrospora*. Experimental downy mildew-resistant varieties and populations have revealed a marked susceptibility to maize streak virus, which severely limits their direct usefulness. Recommended control measures include the manual elimination of diseased plants and seed treatment with Metalaxyl.

In the north, the principal problems are the helminthosporium (*Drechslera*) blight complex and diverse ear rots, with associated serious seed infections. Ear rots caused by *Fusarium* spp. and *Diplodia maydis* are the most important and generally give rise to primary ear rot infections in the highlands. All three helminthosporium leaf blights and spots are in evidence, *H. turcicum*, *H. maydis* and *H. carbonum*. They can occur simultaneously, although the first is the most frequent and damaging. In the lowlands, natural climatic conditions do not seem to favor the spread of these diseases, although inoculation experiments have shown great potential susceptibility.

Rusts of maize, either singly or collectively, are not very important in the general disease pattern, although they can be observed regularly in the field.

Planting date and density

Even though the importance of correct planting date is recognized on the mechanized farms, external factors, such as the late arrival of seed and agrochemicals, or internal organizational problems still lead to late planting. In the north, the optimum planting time for the mechanized sector ends the last week of December; loss of yield in later-planted crops is assumed to stem from a decreased availability of water and nitrogen. Experimental results from Lichinga and Lioma show yield losses of 1 to 2% for each day that planting is delayed between about December 7 and January 7 (4). In the south, the optimum planting time for irrigated maize ends on November 15, because of the occurrence of disease attack after that date. No consistent experimental results are available, but after the end of October, disease attack increases rapidly.

Plant densities that farmers anticipate are about 50,000 plants per hectare in the highlands and 42,000 in the lowlands, both in the north and the south. However, these densities are rarely achieved. Problems of erosion, land preparation and machine availability have already been mentioned. Where nationally produced seed is used, seed quality also plays a part, as do certain pests (field rats, termites, etc.). Experimental trials on planting date were held at eight sites, but only for one year each, so that conclusions cannot yet be drawn. However, in both highland and lowland areas, yields seem to increase when planting densities are increased to 40,000 to 50,000 plants per hectare.

Maize Seed Production

The three national institutions involved in maize seed production and quality control in Mozambique are the National Agricultural Research Institute, the National Seed Company (ENS) and the National Seed Service (SNS). In addition, two state companies and the Provincial Agriculture Directorates (DPA) are involved in the distribution of seed.

Responsibility for seed production and control has been defined as set out in the following diagram:

Quality control by SNC	Breeder seed Prebasic seed Basic seed	INIA
	Certified seed - first generation	ENS seed farms
	Certified Seed - second generation	ENS seed farms and contract growers

Breeder and pre-basic seed production

At the time of independence, the major varieties in mechanized production were Silver Mine, Silver King, Kalahari, White Cango, Hickory King and Yellow Sahara, as well as the hybrid SR52. All of this seed was imported. Seed renewal took place on the farms at intervals of three or four years in the case of open-pollinated varieties. Silver Mine and Kalahari continue to be in production today. Silver Mine is highly productive but very susceptible to lodging, and Kalahari is very susceptible to pests and diseases.

Since 1977, materials of various origins, both varietal and hybrid, have been tested, and certain varieties from CIMMYT's collection have shown themselves consistently superior to the pre-independence varieties. For five of these, Obregon 7643, Cotaxtla 7921 and Ferke 7822 for high altitudes, and San Andres 7823 and Mexico 8049 for the northern lowlands, prebasic seed has been produced. For the south, no adequate varieties have yet been identified; all of the above are highly susceptible to maize streak virus. Materials with horizontal resistance to maize streak have been obtained from IITA in Nigeria, and they are being tested this season. The trials are not yet harvested, but good resistance to attack is evident in some of the varieties (Figure 4).

Eight drought-resistant varieties from CIMMYT are also being evaluated this season. However, six have been eliminated by virus attack and/or drought, and even the remaining two (Ilonga 8043 and Ikenne 8243) are moderately susceptible to virus attack. Other breeding programs have been started on a modest scale to improve the varieties selected for the north, as well as Silver Mine and Kalahari. Germplasm is being collected from the peasant sector for evaluation and use in these programs. Conditions for long-term seed storage are presently poor; the program's cold storage facility was damaged in the floods of 1984. However, the most important materials, including the drought and virus-resistant materials, are being maintained.

In experiments, well-adapted hybrids have consistently given higher yields than open-pollinated varieties in the highland areas. However, the production of any of these hybrids implies the annual importation of large quantities of seed, bought with scarce foreign exchange. At present, this is not justified by the yields obtained on the vast majority of farms.

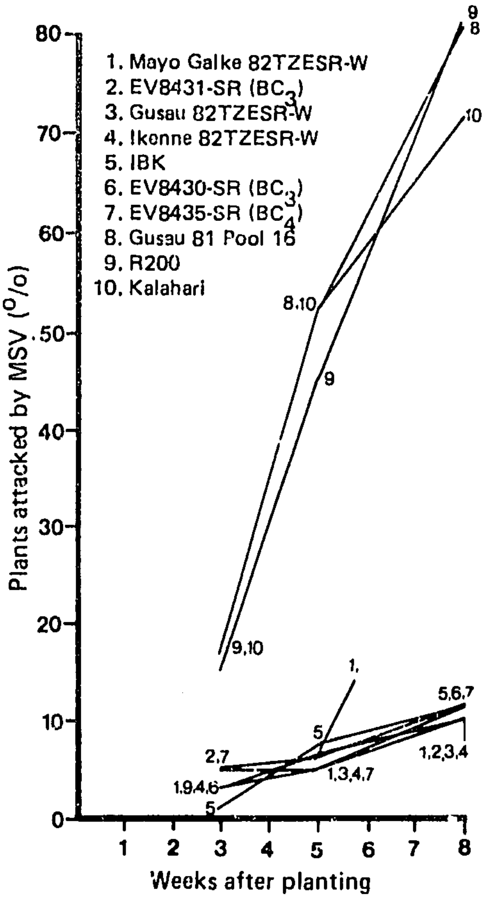

Figure 4. Results of trials of IITA maize varieties for resistance to maize streak virus, Mozambique

Since the arrival of the Yugoslavian team, local hybrid seed production has begun. Various tropical hybrids from the Yugoslavian Maize Institute are being tested in Lichinga, with SR52 as the control. Last season, 180 hybrids were tested and ZP752b significantly out-yielded SR52; the yield of 27 others did not differ significantly from the control. Breeder and prebasic seed of the parent lines of ZPSC852b was produced last year in pilot production, together with breeder seed of other inbred lines.

Basic seed production
Mozambique suffers from a lack of adequate basic seed of the varieties in production, because no organized maintenance of these varieties took place for a number of years. INIA is now responsible for basic seed, and last year some was produced for both Obregon 7643, which is almost ready for release, and Kalahari, which remains in production. Also, small quantities of seed of the parental lines of the experimental hybrid ZPSC852b have been produced.

Certified seed production
ENS has three large farms for certified seed production, Namialo (for the northern lowlands), Chimoio (for the highlands) and Lionde (for the southern lowlands) in Nampula, Manica and Gaza provinces, respectively. This seed is for open-pollinated varieties. All of the problems of mechanized agriculture are also found in seed production, with the added problem of the lack of drying facilities, which jeopardizes seed quality.

Quality control and seed pathology
The SNS operates a central laboratory in Maputo and two small laboratories in Namialo and Lionde. An additional laboratory is being constructed in Chimoio. The national staff at SNS is able to conduct purity and germination tests, but as yet has little experience in field inspection.

No seed population of any significant magnitude has proved to be free from seed-borne infectation, and it is common to encounter from two to seven different pathogens in a single seed sample. As a result, an average of three seeds are required to generate one plant. Damping-off losses are estimated to account for approximately 30% failure in plant establishment.

Seed is generally treated with insecticide (Damfin) and fungicide (Captan). However, experiments on the treatment of seed with a wide range of fungicides and bactericides have indicated that the contribution of bacteria to poor establishment is as important as that of fungal pathogens. The nitrofuran antibacterial formulation Furasol at 100 ppm (by seed weight) was found to be the most effective single seed treatment. Bacterial infection is caused by members of the genera *Erwinia* and *Pseudomonas* and often occurs in the presence of *Fusarium* spp. *E. carotovora* is widespread.

Seed distribution
A state company (BOROR) distributes seed to state, cooperative and private farms, whereas a second state company (Agricom) and the provincial agricultural directorates are involved in the distribution of seed to the peasant sector. The present unsettled conditions in the country pose major difficulties in distribution, as do the lack of transportation and storage facilities and the shortage of trained personnel.

Maize Research Staff and Training

The shortage of trained personnel in Mozambique is grave. There are fewer than 50 Mozambican agronomists; of those, four work in INIA with two assigned to the maize program. Two more are located at the university and one of the largest state farms; they also collaborate with the maize program.

The maize program staff also includes five agricultural technicians, one at the diploma and four at the certificate level. None of the personnel have much experience in maize research, and all need further training.

At present, the certificate and diploma-level staff attend two- to three-week annual courses at INIA on various aspects of research and agronomy. For the graduate staff, courses of four to six months are planned at international institutes, currently in Yugoslavia and at CIMMYT. It is intended that this staff specialize in breeding, agronomy or basic seed production.

The national staff of the DDR centers have only certificate-level training, and the work is headed by expatriate scientists.

Conclusions

The war is at present disrupting both maize production and research. However, the placement of qualified and experienced staff in the experiment stations is already showing results, not only in improved experimental work and basic seed production, but also in the identification of factors limiting maize production. Efforts to improve maize production must concentrate on the following aspects:

- Further staff training, especially at the international institutes;
- Production of good-quality seed of the best open-pollinated varieties presently available;
- Selection and breeding for resistance to maize streak virus and downy mildew, and
- Organization of available data for a clearer understanding of the major agronomic limitations, and the selection of appropriate solutions.

As soon as the security situation returns to normal, more emphasis must be placed on field diagnosis and economic evaluation to provide a firmer basis for the design of the research program.

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The Reunion Island Maize Breeding Program

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Maize has a long history in the islands of the Indian Ocean. It was introduced very early and is an important source of food. Today, its importance varies from island to island. It is important in Reunion, and even more so in Comores and Rodrigues. It is of secondary importance in Madagascar, Mauritius and the Seychelles.

Reunion is a small island, located between Madagascar (700 km) and Mauritius (200 km). Sixty thousand tons of maize are utilized on the island annually, of which 40,000 to 45,000 tons are imported. Most of the maize is used as feed for livestock; however, that consumed by the islanders themselves, although the amount is not known exactly, is far from negligible. Probably in certain regions, such as the western highlands and Cirques, maize is the principal staple food.

There is widespread cultivation of maize on the island; at least one-third of the farmers grow maize although the total area under cultivation is small. This is estimated at less than 6% of total arable land (Table 1). However, for several years, there has been an upward trend in maize cultivation, presumably in response to the scarcity of maize on the local market. As cultivation patterns are extremely varied (there is both single cropping and intercropping of various degrees of complexity), and the harvest does not pass through the type of market system that would make counts readily available, figures presented here are estimates.

The remarkable adaptability of maize is evident from the various microclimates of Reunion where it is grown: these environments range from those of the coast (sea level) to 800 to 1000 meters elevation. Maize is also grown under all types of cultivation patterns, pure-stand intensive cultivation (sometimes under irrigation), intensive cultivation

Table 1. Maize area and production, Reunion Island, 1983

Cultivation Scheme	Undeveloped area (ha)	Developed area [a/] (ha)	% of total cultivated area	Production (tons)
Pure-stand maize	2780	4450	4.33	10,690
Intercropped maize	580	580	0.90	920
Total	3360	5030	5.23	11,610

[a/] Developed area represents total area planted to maize; if there are two harvests per year, these figures will double

Source: Hainzelin (4); Ministry of Agriculture (13)

* Institute for Research in Tropical Agriculture and Food Crops

intercropped with sugarcane (with manure fertilization and good cultural practices, in some cases completely mechanized), semi-intensive cultivation intercropped with legumes, flowers, etc., and very intensive garden-style cultivation. For all of these cultivation schemes, farmers use local varieties which have evolved from old introductions which have undergone decades of natural selection and have become remarkably well adapted to local conditions. A large number of different maize ecotypes are in use, due to the varied environments found on such a small island.

Research or Maize Viruses

In tropical Africa, certain viruses, such as maize streak virus (MSV) and maize stripe virus (MStpV), often cause severe damage, sometimes destroying entire crops, i.e., MSV epidemics in East Africa and MStpV epidemics in Sao Tome. In Reunion Island, climate peculiarities have caused several viruses to merge into a particularly agressive "cocktail;" MSV, MStpV, maize mosaic virus (MMV) and sugarcane mosaic virus (SCMV) are all found on the island. The insect vectors of MSV (*Cicadulina mbila*) and MMV and MStpV (*Peregrinus maydis*) thrive under island conditions.

All of the island's cultivated maize materials have undergone extreme natural selection in order to survive not just one virus, but this combination of viruses which varies from place to place. Therefore, the collection of local varieties (at least those grown on the coast where the viruses thrive) presents remarkable levels of tolerance to the different viruses. This becomes evident in the comparison of local and introduced varieties. Several hundred introductions from all parts of the world have been tested, but none have been found to have tolerance comparable to that of the Reunion varieties. Research programs in other tropical countries are stiving to create varieties tolerant to the virus diseases, but in the Reunion environment their tolerance is not found to be sufficient. This may be because the Reunion Island virus strains are particularly aggressive, or because a tolerance to one virus does not necessarily imply a tolerance to another one. For this reason, Reunion ecotypes are choice genetic materials for programs selecting for virus tolerance, and many leading programs have used them. Exhaustive trials in the USA have recently confirmed the exceptional characteristics of the island varieties (1).

In 1979, the Institute for Research in Tropical Agriculture and the Department of Subsistence Crops (IRAT) in Reunion began research on virus tolerance to take advantage of the island varieties and the exceptionally favorable environment for virus work. The program has now grown considerably with additional financing from the European Economic Community.

Maize Breeding

IRAT's program for the improvement of maize varieties has two objectives, the meeting of the specific needs of Reunion farmers and the search for varieties or hybrids suitable for the tropics in general; in both cases there is emphasis on tolerance to streak and stripe viruses. Happily, these two objectives are compatible, at least as regards yellow maize, which is the type grown in Reunion. The island's conditions have been found to be particularly favorable for the selection of maize in its two environments. On the coast, with its low-altitude, hot, tropical climate, streak viruses and the two classic low-altitude diseases, *Puccinia polysora* and *Helminthosporium maydis* are found, as well as "warmonger" birds (*Ploceus cucullatus*), which attack the maize ear. In the mountains (above 800 meters altitude), with cooler, high-altitude tropical climates, viruses are rarely a problem, but helminthosporium (*H. turcicum*) is severe. *Puccinia sorghi* is also present, and insect attacks and soil diseases can do serious damage. Stalk borers (*Sesamia* spp.) often cause considerable damage. At even higher altitudes (above 1000 meters), soils become highly acidic, with pH levels as low as 4. In all of these regions, winds are often strong and rainfall can be either excessive or lacking altogether.

Socially, the farmers in Reunion include the three principal groups, traditional farmers, those in the process of modernization, and commercial farmers using intensive cultivation systems. This justifies research into improved local varieties as well as into hybrids and other improved varieties. There is a need for maize of early, medium and late maturity. The classic situation is, therefore, found in the breeding program, that of working with the three maturity groups of maize for the three levels of farmers, both for the coastal areas and for the highlands.

The program has two objectives, the development of two groups of varieties and hybrids, those suitable for hot, tropical climates and those for high-altitude environments, and the selection of streak-resistant varieties. Thus, the work of the program consists of the collection, study and preservation of plant materials, the development of varieties for low-altitude sugarcane-growing regions, the development of varieties for high-altitude regions and the study and utilization of virus-resistant varieties.

The collection and preservation of material

The collection and, above all, the preservation of plant materials are subject to various problems. The sensitive coastal varieties are difficult to renew, because of virus presence. Also, labor costs limit the volume of renewals. Storage has been a problem, but it should be solved with the construction of a cold storage building in St. Denis. Because of these problems, the current collection numbers only 300, of which 85 are local varieties and some 60 are introduced varieties (mostly from the Indian Ocean area and East Africa); the rest are either local or introduced lines.

The development of varieties for low-altitude areas

Figure 1, a varietal grid, summarizes the origins of the plant materials that are presently being used by the maize breeding program for the three groups of farmers in the lowlands.

Traditional farmers (Target 1)—For traditional farmers, local varieties are used. Ecotypes collected on the island have been tested for several years and, from them, twelve varieties will be chosen. Early maturing maize ecotypes were collected on Rodrigues and testing began in 1984; their resistance to viruses makes them promising. A simultaneous selection of early maturing varieties is in progress in Revolution.

Farmers in the process of modernization (Target 2)—For these farmers, improved varieties are best adapted to their needs. CIMMYT varieties perform well for them in the absence of viruses. Both the yellow and white CIMMYT maize are excellent for carrying out resistance transfers (over the long term), as well as for planting in winter, when viruses are less of a problem. IITA's streak-resistant selections, which were tested in 1984, are also good in a number of respects, but are sensitive to MMV and MStpV.

Commercial farmers (Target 3)—For these farmers whose production system is intensive and mechanized, hybrids are best. Introductions from France, South Africa and Madagascar have proved disappointing due to virus sensitivity. However, tests are being continued with materials originating in the tropics. Work on local x temperate zone hybrids has led to the recommendation of IRAT 143 = (Revolution x INRA 508). However, it will have to be replaced as it is very sensitive to viruses.

Although the I137 line from South Africa seems to show a certain tolerance to viruses, it cannot replace INRA 508 because it is much later maturing. It can, however, provide promising hybrids in crosses with Revolution; the hybrid IRAT 279 = (Revolution I137TN) is proposed for development. It can also be used in crosses with other lines originating in Revolution. Other sources of genes being tested are Rodrigues lines crossed with Revolution, and Rodrigues and Reunion varieties crossed with Revolution.

All of this work is being done with yellow maize. White-grain maize is not being used at this time due to its susceptibility to virus attack.

The development of varieties for high-altitude areas

Work on high-altitude maize is less advanced than that for coastal areas for a number of reasons. Historically, before 1975 most trials were conducted on the coast; later, those planted at higher altitudes often failed as they were planted in farmers' fields and were not adequately controlled. Also, the maize teams are located on the coast, and limited land is available for their use in the highlands. Although the demand for highland maize varieties calls for increased research, this will only be possible when sufficient facilities become available.

Traditional farmers (Target 1)—Of the 85 local varieties in the collection, 20 are being used for selection; all are of yellow maize. Traditional white varieties will probably be introduced from various African countries in the future.

Figure 1. Origins of maize materials used for low-altitude tropical environments, Reunion Island

Target Group	Early maturity Yellow	Early maturity White	Medium maturity Yellow	Medium maturity White	Late maturity Yellow	Late maturity White
Traditional farmers (1)	Reunion local varieties Rodriguez local varieties Revolution varieties	?	Reunion local varieties Revolution improved varieties Reunion composites Revolution streak- and lodging-resistant varieties	?	Reunion local varieties	?
Farmers in the process of moderni-zation (2)	CIMMYT lines and varieties	CIMMYT lines and varieties	CIMMYT and IITA lines and varieties	CIMMYT and IITA lines and varieties	CIMMYT and IITA lines and varieties	CIMMYT and IITA lines and varieties
Commercial farmers with intensive, mechanized production systems (3)	Locally developed varieties	?	Locally developed varieties	?	Locally developed varieties	?

Farmers in the process of modernization (Target 2)—The answer to the need for greatly improved varieties by these farmers may be provided by CIMMYT, in both yellow and white maize, in spite of some sensitivity to *H. turcicum*. Selection made in 1984 points to the recommendation of Tocumen (1) 7931 for this group.

A breakthrough in the understanding of resistance to *H. turcicum* has come about as a result of the work of phytopathologist J.C. Girard in St. Pierre, and from introductions from South Africa being multiplied in Mon Caprice. Lines carrying different resistance genes are presently being tested, using artificial inoculations.

Commercial farmers (Target 3)—Hybrids developed specifically for the coast, as well as French and South African hybrids, are being tested simultaneously. Although in the beginning stages, tests have already shown that the early-maturing French hybrids are poorly adapted to the region. Nevertheless, it is felt at present that it may be better to continue to utilize introductions, rather than to develop original hybrids. This will lead to quicker results in the program.

The study and utilization of virus-resistant sources

Preservation of local genetic material—With the increase in the exchange of materials and the opening up of the islets, the diversity of the island's ecotypes was beginning to be threatened. In 1979, the entire island was searched and 85 l[illegible] varieties collected (5). Their behavior under severe virus pressure allowed for the selection of the most promising material for crossing for composite virus research. It has been noted that the island of Rodrigues has promising local maize. Therefore, a search of Rodrigues Island was made in 1980 in close collaboration with MSIRI (Mauritius Sugar Industry Research Institute) (3). Selected ecotypes demonstrated tolerance to viruses, and several varieties were included in composite virus research.

Exploitation of tolerance to virus diseases—Existing tolerance to virus of island maize offers the challenge of complex biological phenomena that researchers have long sought to understand. They have also searched for an answer to how this tolerance is genetically determined; no doubt it involves numerous genes in multiple allelic combinations. The varieties must be resistant to a combination of viruses, which varies from one area to another and even from one field to another. This study thus involves a complexity of the highest order. The Reunion breeders have chosen the simplest and most effective route of classic repetition to concentrate tolerance. Simultaneously, there will be an attempt to transfer this tolerance to various materials, such as breeding stock, composites used in other selection projects and varieties popular in West Africa, where virus disease is beginning to take on importance.

Selection principles are simple, although their execution and effectiveness require a great deal of practice and the existence of certain tools, such as techniques for rapid and simple virus detection, a knowledge of biology and the insect vectors, and the mass rearing of a great number of vectors for artificial infestation.

Detection of viruses—Several analyses have been carried out in France, with the help of the phytopathologists of MSIRI, to catalog the maize viruses present on Reunion. The four viruses cited earlier (MSV, MMV, MStpV and SCMV) were detected either by microscopic observation, by serum testing or by transmission testing. During the next two years, within the framework of the CCE project, various techniques will be used to continue virus detection. It will be necessary to perfect rapid serological techniques (the ELISA test in particular) to allow for the identification of a great number of on-site samples. These techniques, which are indispensable for repeated selection tests, should be operational by early 1986.

Mass rearing of vectors—For efficient selection for virus resistance, vector stress must be the result of artificial infestation that is severe, homogeneous and reproducible. This assumes the availability of a great number of vectors capable of transmitting the disease; it also assumes the capability for mass rearing the *Cicadulina mbila* and *Peregrinus maydis* vectors and the ability to optimize their performance in acquiring and transmitting the virus during the selection tests. A beginning study of insect populations and their vector mechanisms has now been completed. In the next two years, work will continue on improving mass rearing techniques.

Maximum collaboration among breeders will determine the success of the last phase, multilocational testing of selections for tolerance, especially those varieties into which tolerance has been transferred. Their working together can lead to the refinement of methods and the success of the program.

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Maize Research in the Economic Community of the Great Lakes Countries (Burundi, Rwanda and Zaire)

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This paper is based on a document entitled Status Report: Research in Agriculture and Livestock in the CEPGL (1983) and on visits to the national institutes and interviews with researchers from the three members (Burundi, Rwanda and Zaire) of the Economic Community of the Great Lakes Countries. The paper is incomplete since not all pertinent data have yet been gathered, and not all researchers involved in the work under discussion have been contacted.

At a meeting held in Kinshasa in March 1984, the Institute for Research in Agriculture and Livestock (IRAZ) was charged with the preparation of a report pinpointing the shortcomings of existing research programs and making concrete proposals for their improvement. The meeting was attended by leaders of the national agricultural research institutions of the three countries and by the IRAZ Management Committee. IRAZ believes that program shortcomings and areas for improvement can best be indentified through discussions among the researchers of the member nations. It is hoped that, as a result of this workshop, IRAZ will be able to further assist in developing maize research in the region and will be able to elaborate a complete document on research for the three countries.

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The Importance of Maize in the Great Lake Countries

Maize is an important cereal crop in the CEPGL countries. In Burundi in 1982, an estimated 180,760 hectares were planted to maize, making it the principal cereal crop and the third most important subsistence crop after beans and bananas. In production, estimated at 144,000 tons, maize was in fifth place, after bananas, sweet potatoes, cassava and beans. The objective for maize in the fourth Five-Year Economic and Social Development Plan (1983 to 1987) is to increase the 1982 production to 166,700 tons by 1987; this would necessitate an annual growth rate of 3%.

In Rwanda, maize is second among cereal crops, after sorghum; it is cultivated in all rural regions of the country. In 1980, 71,820 hectares (or 7.2% of the area under subsistence cultivation) yielded 85,059 tons (1.9% of total subsistence crops). In area of cultivation, maize was fifth, after beans, bananas, sorghum and sweet potatoes. In volume of production, it was seventh, after bananas, sweet potatoes, cassava, potatoes, beans and sorghum. The third Five-Year Economic and Social Development Plan (1982 to 1986) predicts an annual growth rate of 2.9% in area (to 88,500 hectares by 1986) and of 3.8% in production (from 85,059 tons in 1980 to 106,200 tons in 1986).

In Zaire, maize is first among the cereals and is one of the basic subsistence crops, along with rice, cassava and bananas. Maize is cultivated in all regions, although the major production zones are Kasai, Shaba and Bandundu. In 1975, 675,100 hectares were planted to maize (16% of the subsistence crop area and 67% of the area planted to cereals), producing 495,400 tons (2.6% of subsistence production and 65% of cereal production). Thus, in terms of area, maize is second only to cassava; in volume it is third, after cassava and bananas. The Agricultural Renewal Plan estimated 1980 maize production at 562,340 tons; in 1977, 509,600 tons had been produced.

Maize is not used only as food in Zaire, but also by the national breweries for beer. Its recent introduction into urban and semi-urban centers has increased demand considerably, resulting in a shortage of approximately 200,000 tons annually. One of the objectives of the Agricultural Renewal Plan 1982 to 1984 (an extension of the Mobutu Plan) was to eliminate maize shortages by 1984 by raising production from the 1982 figure of 687,785 tons to 810,630 tons.

Maize Research in the Great Lake Countries

In Burundi and Rwanda, research is essentially aimed towards the development of varieties adapted to the various ecological zones of the two countries. In Rwanda, particular research emphasis is on developing varieties adapted to high altitudes and for meeting the needs of the glucose and starch mill at Ruhengeri (Mukamira). In Zaire, maize research is conducted for the development of an integrated program to improve plant breeding techniques (cultivation trials) and increase maize production, both quantitatively and qualitatively.

Maize Production Constraints

Burundi
The factors limiting maize production in Burundi are:

- Lack of high-yielding, early-maturing varieties adapted to high-altitude regions (the variety currently distributed in these regions is late maturing, thus preventing the timely planting of the following crop);
- Poor soil fertility, and
- The diseases maize streak virus and downy mildew, which cause great economic losses.

The research program is seeking solutions to these problems.

Rwanda
The factors limiting maize production in Rwanda are:

- Diseases, the most important of which are maize streak virus and downy mildew;
- Poor soil, and
- Climatic conditions, which are unfavorable for the cultivation of maize. These include drought in the eastern regions and the high altitude of the northern regions, which prolong the maize growth cycle, making it susceptible to cryptogamic diseases.

The maize program is searching for solutions to all of these problems for maize cultivation.

Zaire
The factors limiting maize production in Zaire exist at five levels:

- Non-utilization of appropriate seed and technologies;
- Severe diseases, such as maize streak virus and downy mildew;
- Lack of adequate roads;

- Lack of a high-quality training program for maize program staff, and
- Lack of sufficient vehicles and/or gasoline for program staff use.

The solution to these problems must come from high government levels and through the research of the National Maize Program.

Maize Research in Burundi

Varietal selection
The station at Kisozi, created in 1929, conducts research on maize and other high altitude crops. Breeders work with both the local maize variety Igarama and introduced varieties. Selection criteria are productivity, grain quality, adaptability to various ecological conditions and early maturity. The selected varieties made available to farmers have been Kisozi 41 (in 1941) and Bambu and GPS5 (after 1964). In 1977-78, with Belgian cooperation, multilocational, semi-annual trials were set up at altitudes of 830 and 2250 meters. The objective of the program was the identification of varieties adapted to each of the country's ecological areas. These trials were concluded in 1980, and the results analyzed in 1980-81. Table 1 shows the recommendations made as a result of the trials.

Table 1. Maize varieties recommended for four ecological zones as a result of varietal selection trials, Burundi, 1981

Altitude (m)	Variety
800 to 1250	GPS5
1250 to 1500	GPS4 x SR52
1500 to 2000	Igarama-4
Above 2000	Kitale and Isega

The Selected Seed Service has observed that the GPS4 x SR52 varieties are very sensitive to stalk borers. Moreover, all of the varieties are sensitive to maize streak virus, especially under conditions of low fertility.

A new varietal improvement program was begun in Burundi in 1979, following a cooperative agreement signed with the International Development Research Center. Objectives of that program included:

- Identification of varieties superior in yield and disease resistance to those currently recommended;
- Crossing of local adapted maize with promising introduced varieties at Imbo and Kisozi (this will be a long-term program);
- Selection of varieties resistant to maize streak virus, utilizing IITA varieties (this disease is found throughout the country, especially on the Imbo plains in the second season and in the marshes of the intermediate and high-altitude areas), and
- Improvement of currently recommended varieties for yield and resistance to lodging and the major diseases (leaf blight, rust and maize streak virus). This will be a permanent, ongoing program.

The program also conducts CIMMYT international trials (EVTs and ELVTs), and in 1982 it also began participating in the regional trials of the Burundi National Maize Program. The following changes in recommendations were made as a result of the 1983 multiregional trials:

- For low and midaltitudes, the high-yielding varieties with acceptable characters were Across 7643 (a variety with relatively wide adaptation) and Cotaxtla 7929; these varieties would continue to be field tested. The GPS4 x SR52 variety was very susceptible to weevil.

GPS5 was proven to be the best for the plains areas, due to its satisfactory resistance to maize streak virus.

- For high altitudes, the introduced varieties performed poorly, with low yields, disease susceptibility and/or late maturity. Kitale continued to be the best choice among late varieties. Igarama-4 had equal or only slightly higher yield than local varieties; however, it would be recommended until a better variety became available. Isega, a local variety which matured a month earlier than Kitale, had good potential and was very resistant to cold; it was chosen for selective breeding in 1984. For the improvement of the recommended varieties, 250 families were selected for each variety, and these were used for basic seed in 1982.

Varietal improvement
In 1981, the Maize Program began crossing varieties as part of its improvement objectives. GPS5 was crossed with 25 varieties of the 1981 collection, and hybrid testing was conducted in 1981B (results are not available). The IITA hybrids TZSR-W and TZSR-Y, which possess genetic resistance to maize streak virus, were crossed with GPS5, and the resulting hybrids were tested in 1982B (results not available).

Agronomic testing
Planting density and spacing trials—At Kisozi in 1981A, the variety Kitale was tested in trials comparing five planting densities, from 30,000 to 70,000 plants per hectare (with two seeds per hole); each density had three different spacings between the rows, 50, 70 and 100 cm. The highest yield was obtained with a planting density of approximately 50,000 plants per hectare, but the difference was not significantly different from that of 30,000 plants per hectare.

Intercropping trials—In the research program on beans, the Burundi Institute for Agricultural Sciences (ISABU) conducts trials on intercropping maize and green vine beans. Since this program is new (1981A), the trials have not yet resulted in recommendations to farmers.

Fertilizer-use trials—A fertilizer-use trial, also utilizing the Kitale variety, was conducted at Kisozi in 1982 in order to define adequate dosages of nitrogen and phosphorus and their interaction. The results of this trial are not yet available.

Maize Research in Rwanda

Varietal selection
Maize research here began in 1930 at the Rubona station of the National Institute for the Study of Agronomy in the Congo (INEAC). Research goals for the program were:

- Introduce varieties that would be more productive and earlier maturing than the local varieties (from 1930 until 1982, over 650 varieties were introduced from more than 40 countries; in 1982, the collection totaled 483 varieties), and
- Utilize genetic improvement to raise maize yield and shorten the growing cycle.

In 1978, the Rwanda Institute for Agricultural Sciences (ISAR) replaced INEAC and continued to pursue these goals. The best varieties developed in the program were:

- Golden Corn (1951), which was rejected by consumers and millers because of its hard grain, and its distribution suspended. Nevertheless, it is still recommended, due to its high productivity and medium maturity.

- Bambu (until 1966), which is predisposed to lodging due to its height. However, its yield and resistance to diseases make it suitable for the central regions and areas with sufficient rainfall. In high altitudes, its growing cycle is long (eight to nine months), and under prolonged dry conditions the stalk is weak and very susceptible to corn borers. This variety is in high demand at the Selected Seed Service.

- Katumani, which is early maturing and well adapted to the eastern parts of the country. The first adaptability tests conducted around Lake Kivu revealed its positive potential in that region.

- Nyirakagoli, which emerged from massive selection of local materials in 1975. It is adapted to high altitudes, but can also be grown in other environments in the country. Its early maturity, large grains and sweet flavor make it more desirable than either Bambu or Golden Corn. The Selected Seed Service notes that its growing cycle is quite long in high altitudes.

Table 2 is a summary of some of the features that characterize each of the recommended varieties.

Varietal improvement
Pedigree selection for grain color and early maturity was begun at Rubona in 1955, and a white maize having the same yield as the yellow Plata was perfected. This program was later dropped, but was reinitiated in 1980.

The Nyirakagoli, Bambu and Golden Corn varieties were crossed with materials with brachytic-2 genes for short plant height and opaque-2 genes for high lysine content. These same varieties were also freely crossed with different CIMMYT varieties in attempts to raise their yield levels. Before the br-2 genes were incorporated into Bambu, this variety was treated with Cycoccel Extra and with X-rays to inhibit the elongation of the internodes and thus reduce its height; this treatment was very expensive and did not prove to be effective. In 1981, the br-2 and opaque-2 genes were combined and introduced into Bambu. Work on all of the resulting materials continues, and apart from reduced height and increased lysine content, early maturity and resistance to disease and insects are also being addressed.

Table 2. Characteristics of recommended maize varieties, ISAR, Rwanda

Variety and country of origin	Year of intro-duction	Area of adaptation	Growth cycle (days)	Plant height (m)	Yield of dry grain (kg/ha)
Golden Corn (Zaire)	1930	Midaltitude, eastern area	155-225	2.75	4000
Bambu (Zaire)	1959	Midaltitude, eastern area	155-225	3.15	5000
Katumani (Kenya)	1972	Low elevation, eastern area	99-110	2.25	2500
Nyirakagoli (Rwanda)	1975	Mid- and high altitude	130-160	2.75	3800

Note: ISAR has participated in comparative trials in collaboration with East Africa (RMSX, Kms, WMsX) and with CIMMYT international trials (EVTs, ELVTs)
Source: F. Iyamuremeye, 1983, Synthèse des Acquis Scientifiques et Techniques de la Recherche Agricole au Rwanda.

FAO is developing a program for the creation of photo-insensitive maize adapted to both tropical and temperate regions. Within the framework of this program, the seeds of the base varieties were planted at Rubona and were crossed with Bambu in 1980. The best crosses have been sent to Rome for further study.

Agronomic testing

Planting density and spacing—Planting density and spacing trials at the station have shown that, for Bambu, optimal yield is obtained with a density of 40,000 to 60,000 plants per hectare, with respective spacings of 80 x 60 cm with two seeds per hole and 80 x 20 cm with one seed per hole. Highest yields of Katumani were achieved at 125,000 plants per hectare under station conditions at Rubona.

Intercropping trials--Experiments in intercropping maize with other crops have shown that maize and beans, maize and soybeans, and maize and peanuts are the most satisfactory. The combination of maize and vine beans is good as the maize plants serve as stakes for the beans, although the maize decreases the bean yield.

Fertilizer-use trials—In several trials conducted at Rubona station, yields of up to 6 t/ha have been achieved with the application of 120-60-60 units of nitrogen, phosphorus and potassium per hectare. The Golden Corn variety responded better to a complete fertilizer (100-100-100).

Irrigation trials—In Karama in 1971A, irrigation trials were conducted to determine the optimum water regimes for maize. The average daily evapotranspiration (ETP) was determined to be 4.5 mm or a total of 651 mm of water for the growth cycle of 138 days for Bambu. The ETP coefficient versus the evaporation of a free sheet of water determined irrigation frequency and quantity; natural precipitation and evaporation were also taken into account. The water provided by sprinkler irrigation averaged 170 mm. No trials were conducted in 1979-80 as the sprinkler system was out of order, but irrigation research was re-initiated in 1981.

Maize research in Zaire

Selection and varietal improvement

Maize research began in Zaire at the Gandajika station in the 1940s and was later extended to the stations at Kiyaka, Mulungu, Nioka, Bambesa and Yangambi. Each station focused on a different set of activities, and there was very little contact between stations. Therefore, the selected varieties were highly specific to their regions of origin, leading to difficulties in adaptation in other environments. Approximately 12 years passed between the initiation of the selection process and the launching of a new variety. Until 1972, the varieties of maize recommended in southern Zaire were GPS4, GPS5, double hybrid and Hickory King.

The National Maize Program has conducted research since 1971 at Kisanga in the Shaba region and other stations throughout the country. The PNM focuses on maize research, production, and the training of national staff. Since the beginning, the goal of the program has been the development of high-yielding varieties that fulfill farmer preferences (exclusively white maize), are adapted to the various agroecological regions of the country and are resistant to the principal diseases (maize streak virus and downy mildew). Over the years, the National Maize Program has developed and distributed six improved varieties, Shaba Safi, Salongo, Salongo 2, PNM 1, Kasai 1 and Shaba 1. However, since September of 1978, only Salongo 2, Kasai 1 and Shaba 1 have been recommended by the program. Table 3 lists some characteristics of the National Maize Program varieties, as well as their cultivation zones.

Table 3. Characters and cultivation zones of the National Maize Program (PNM) varieties, Zaire

Variety and year	Cultivation zone	Characters
Shaba Safi (1969)	South Shaba Kivu (high altitudes)	Cross between H632 (three-way Kenyan hybrid) and SR52 (simple Zimbabwe hybrid) Tall plants susceptible to lodging Resistant to leaf blight On-station yields of 8-9 t/ha Used in crosses for lateness (No longer distributed)
Salongo (1974-75)	North Shaba Bandundu Lower Zaire Equateur Kasai Upper Zaire (mid- and low altitudes)	Mixture of ten best Tuxpeño cycle 2 families selected at Gandajika in 1974 White dent-type grain Plant height 193-216 cm 1000-grain weight 200-385 g Susceptible to maize streak virus and downy mildew if sown late Yield 7 to 8 t/ha Growth cycle 3-4 months Being replaced by Salongo II, which is more homogeneous and productive
Salongo 2 (1975)	North Shaba Kasai Lower Zaire Bandundu Upper Zaire Equateur (mid- and low altitudes)	Mixture of the ten best Tuxpeño cycle 2 families recombined in Mexico White dent-type grain Plant height 200-225 cm 1000-grain weight 250-400 g Yield 7 to 8 t/ha Growth cycle 3-4 months
PNM 1 (1973-74)	South Shaba Kivu (high altitudes)	Cross of Tuxpeño (Mix 1 x Colima group 1) x Eto x Shaba Safi White, flat dent-type grain Plant height 210-240 cm 1000-grain weight 396.5 g Susceptible to maize streak virus and downy mildew if sown late Yield 8-9 t/ha Growth cycle 5-6 months
Kasai 1 (1974-75)	North Shaba Kasai Lower Zaire Bandundu Equateur Upper Zaire (mid- and low altitudes)	Cross of Tuxpeño and Eto varieties in Mexico White flint-dent type grain Plant height 190-205 cm 1000-grain weight 280-400 g Yield 7-8 t/ha Growth cycle 3-4 months
Shaba 1 (1975)	South Shaba Kivu (high altitudes)	Cross of (Tuxpeño x Eto) x Shaba Safi White flat dent-type grain Plant height 230-240 cm 1000-grain weight 440 g Yield 8-9 t/ha Growth cycle 5-6 months

Each year, the National Maize Program conducts the National Maize Program Variety Trial (NMPVT), which includes all varieties recommended by the program, to study the performance of these varieties and any new introductions in the regions where the PNM conducts research. The PNM also conducts CIMMYT international variety trials, IPTTs (International Progeny Testing Trials), OMPTs (Opaque-2 Maize Population Trials) and EVTs (Elite Variety Trials). In addition to testing improved varieties, the PNM has a permanent program for improvement of its recommended varieties.

In 1980, the yields of the National Maize Program varieties were judged satisfactory, and so this is no longer an improvement objective. In the area of disease resistance, emphasis is on the two main diseases that affect late-sown maize, maize streak virus (*Cicadulina Mbila*) and downy mildew (*Sclerospora maydis*). Leaf blight, rust and damage caused by the gray worm and the root worm are of low incidence.

In collaboration with CIMMYT and other African and Asian countries, a selection program against maize streak virus and downy mildew was put into effect in 1977. However, after three years of work, it was seen that no satisfactory results had been obtained. The technique that had been used (natural infection) was ineffective, and many plants found to be resistant became susceptible in following generations.

In 1980, the PNM started a selection program with IITA varieties, including TZSR-W and TZSR-Y, which were resistant to maize streak virus and downy mildew. The IITA varieties were crossed with PNM varieties (results are not available). In 1981, the Zaire streak-resistant and mildew-resistant populations were perfected; evaluations of these varieties were continued in 1982 (results not available). GPS5 was shown to have certain tolerance to the two diseases, and it was crossed with PNM varieties in 1980. Evaluation of this work was done in 1982 (results not available).

Agronomic testing

Rotation trials—A six-year rotation trial was carried out from 1974 to 1979. A second cycle of the same trial was begun in 1980. Due to this trial, it is no longer recommended that land be left fallow, but rather that there be a maize-vegetable rotation with *Crotalaria caricca* and soybeans (*Glycine max*). Crotalaria has proved extremely helpful, due mostly to its high density planting, but soybeans are preferred since it is a food crop. It has been observed that yields are higher if a fertilized crop of maize is preceded by a crotalaria-soybean rotation.

Hill planting and intercropping with legumes—Most farmers in Zaire plant maize in hills, some 40 to 45 cm in height and one meter apart. After harvest, the maize residue and weeds are placed in the furrows between the hills. New hills are then formed by covering the residue with soil from the old hills. Trials held on farmers' fields have shown the advantage of flat cultivation, in both density and yield. A long-term trial comparing hill planting and flat cultivation, with vegetable intercropping and with and without manure fertilization, was begun in 1973-74. The results of this trial, completed in 1979-80, showed the beneficial effects of plowing under both the maize and the soybean residue two weeks before planting the new maize crop.

Planting date trials—Trials conducted from 1972 to 1976 showed that maize should be planted within a month and a half after the first rains.

Plant density trials—As a result of these trials, the National Maize Program recommends spacing maize plants 75 x 25 cm apart, with one seed per hole; this results in 53,333 plants per hectare. However, very good yields can still be obtained by closer planting.

Fertilizer-use trials—Trials conducted in the various regions have shown that the low nitrogen level is a constraint to maize production in Shaba, and low phosphorus is a limiting factor in Kasai; a lack of potassium is not considered a problem. The PNM thus recommends the application of 66 kg of nitrogen and 46 kg of P_2O_5 per hectare for small-scale farmers and 120 to 150 kg of nitrogen and 90 to 120 kg of P_2O_5 for large-scale farmers with more capital. Phosphate fertilizers are applied before sowing, as is a third of the nitrogen; the remaining two-thirds are applied 45 days after planting.

Seed Production and Distribution

Burundi

The Ministry of Agriculture in Burundi provides a service called the Selected Seed Service (SSS). The SSS is continuing a project created in 1977 in cooperation with the Belgian government. Besides the SSS centers, there are other centers for seed multiplication and distribution that are part of the SRD (Regional Development Agency) and of specific projects. There are a total of 41 seed centers in the country; 22 are controlled by the SSS and 19 by the SRD and the projects.

The seed farms vary in size from 8 to 20.25 hectares (including fallow and grazing land). Seed is multiplied and distributed through a process that integrates research (ISABU), the SSS and other organizations (SRD and the projects). Basic seed produced by ISABU is delivered to the SSS, which carries out a first multiplication on its farms. The seed is then distributed to other organizations, which depending on their needs, multiply it once or several times before distribution to farmers (either for credit or cash).

In the 1979A season, the SSS produced 17,698 kg of maize (1,210 kg of Kisozi, 7,600 kg of GPS5 and 8,888 kg of Bambu) on 21.8 hectares. In 1982, the production rose to 46,891 kg (13,363 kgs Kitale, 5,336 kg GPS5, 650 kg Igarama, 1,010 kg GPS4 x SR52 and 26,532 kg Bambu) on 29.07 hectares (6.56 ha of Kitale, 3.2 ha of GPS5, 0.8 ha of Igarama, 0.7 ha of GPS4 and 17.81 ha of Bambu).

Rwanda

Rwanda's Selected Seed Service was established in 1968. It reports to the directing staff of Agricultural Production at the Ministry of Agriculture, Livestock and Forestry. The service has five seed-multiplication centers for food crops dispersed throughout the country, at Mutura-Gisenyi (two centers), Ruhunde-Byumba, Muyumbu-Kigali and Bumbogo-Gitarama, as well as one laboratory and one packaging plant at Kigali. The SSS receives requests from community agronomists, project personnel and individual farmers who wish to obtain seed, and the service multiplies prebasic seed supplied by ISAR at its experiment stations. The resulting production makes up the basic seed, which the SSS then distributes, prorating the costs among its clientele. The SSS distributed 17,996 kg of maize seed in 1979 and 27,456 kg in 1980.

Zaire

Seed selected by the National Institute of Agricultural Research (INERA) reaches the farmers directly from INERA, from the Agricultural Production Office of the Department of Agriculture or from the projects, as shown in Figure 1.

The National Maize Program oversees the production of pre-basic seed at the Kisanga station, and it is then multiplied either at the Kaniama-Kasese State Farm or by private farmers. This seed is then offered to the projects and to agrobusinesses, which supply it to farmers. In 1980, the PNM sold 20,625 kg of maize seed, of which it had produced 775 kg. In 1979, it had distributed 45,885 kg of seed.

The overall seed situation in Zaire rapidly deteriorated after the Colonial Office's Adaptation and Improved Seed Production Center (CAPSA) ceased to function. To remedy the situation, the Executive Council requested that a national seed plan be developed. The resulting plan consists of five levels:

- The national sector programs (PNM for maize), to be charged with seed production;
- The seed farms, to produce controlled seed by multiplying national program seed in specialized centers; at least one farm will be established in each region for a total of ten farms;
- Development agencies (including projects, agrobusinesses, cooperatives and groups of producers), to multiply the controlled seed on farms to produce commercial seed;

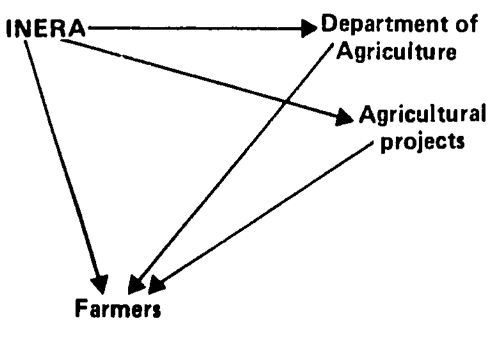

Figure 1. The relationship between INERA, the Department of Agriculture and the agricultural projects in the distribution of maize seed to farmers, Zaire

- Development agencies, to distribute selected seed, and
- The National Seed Bureau (BNS), headquartered in Kinshasa, to control the process. The BNS will set up regional analysis and service laboratories to better organize local systems and ensure the necessary controls.

The financing for this plan is now under negotiation.

Conclusions

As can be seen from this paper, maize is important among the cereal crops of the CEPGL. In Burundi and Zaire, maize is in first place among the cereals; in Rwanda only sorghum is more important.

During the INEAC era, some maize varieties were common to the three countries. Today there is a diversity of varieties in many crops, including maize, because although the three research institutes conduct research that is parallel, they have not worked together. In Zaire, the National Maize Program has made great strides, and the PNM has collaborated with ISABU (Burundi) in National Maize Program Variety Trials since 1982. No data are yet available on the results of this collaboration.

It would be advisable that the agronomic research institutes of the three countries adopt a common maize research strategy in collaboration with IRAZ. This would allow for better use of time, effort and human and material resources, and would help to eliminate constraints at the research and production levels. The collaboration of the three countries could result in a division of tasks, an agreement on trial management, the exchange of information and material, and the formation of a training program for research personnel. This would lead to a regional program for maize research, and regional level activities could be strengthened in the following areas:

- The creation of productive, early varieties adapted to the high-altitude regions of Burundi and Rwanda;
- The acceleration of the recently initiated maize breeding programs in Burundi and Rwanda;
- The collection of local maize varieties in farmers' fields;
- The identification and development of productive varieties resistant to the economically devasting diseases (maize streak virus in all three countries, leaf blight in Burundi and Rwanda and downy mildew in Zaire); the three institutes are now working separately on varieties provided by IITA for resistance to maize streak virus;
- The conducting of fertilizer trials, especially in Burundi and in Rwanda where little work has yet been done;
- The conducting of trials on the intercropping of maize with other crops (in Burundi and Zaire); these trials can help improve the farmers' systems of agricultural production without necessarily leading to the replacement of those systems;
- The improvement of grain storage techniques, and
- The improvement of communication (technology transfer) and the reduction of the yield gap between experiment stations and farmers' fields.

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Discussion

Mr. Mauree: You say you don't use fertilizers on your maize. Don't you think it is important to try to get fertilizers to farmers since maize is a crop that responds well to fertilization?

Mr. Mpabanzi: It is very expensive to get fertilizers into the region because of its landlocked position. Therefore, it is not economical to use fertilizers there. Farmers have very small holdings, and they cannot afford the cost of fertilizers.

Maize Improvement in Somalia

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In Somalia, maize is the second most important food crop after sorghum. It occupies about 30% of the cultivated area or approximately 150,000 hectares, which are cropped twice a year under the favorable conditions of the country. The majority of the maize crop is grown under irrigation along the Juba and Shabelle rivers, and to a lesser extent under rainfed conditions, particularly in the *Gu'* season (April to July).

The most common method of maize cultivation in Somalia is to plant on flat, not ridged, land, with a distance of one meter between the rows and two plants per hole, which results in 20,000 plants per hectare. Two to three hand weedings are usually done, and flat irrigation is used where possible. In most areas, maize is planted alone, but a considerable amount is intercropped with sesame; a small amount is also intercropped with cowpeas, mungbeans or tomatoes.

Somali consumers prefer white, flint-type maize for pancakes and a thick porridge (the principle staple food); they also use it as green ears for roasting. It is used as fodder for livestock, after the ears are harvested, and in the case of total crop failure (which happens about once in four years in the *Der* season (October to December), the entire crop is fed to livestock, especially cattle and camels.

After harvest the maize is stored in one of two ways, in pits dug in the ground (*bakaar*) or in various kinds of containers and sacks. With the first method, maize can be stored for a long time, either shelled or on the ear. The maize is stored in sacks when the grain is threshed and will be used immediately, either for food or for seed.

Maize production on farmers' fields in Somalia is 8 to 10 quintals (1 q = 100 kg) per hectare. This very low yield can be attributed to various factors. The local varieties used by the farmers are low yielding. Also, a considerable amount of the crop is grown under rainfed conditions or under very limited irrigation. Little fertilizer is used, or none at all. Disease and insect control are also insufficient for Somali conditions.

To overcome these constraints, steps need to be taken to breed maize with high yield potential and with resistance to stem borers, earworms, downy mildew and moisture stress. Farmers also need to adopt suitable agronomic practices.

Maize Research Program

The maize improvement program at the Central Agricultural Research Station (CARS) at Agfoi was begun in 1976. In 1979, the variety Afgoi Composite was developed from germplasm of Somali land races, Guatemala flint and US hybrids. It performed well under the standard cultural practices in different locations in the country. A yield of 5.7 t/ha was reached under experimental conditions at CARS.

Another variety was developed in 1980 from half-sib crosses between Afgoi Composite and Tuxpeño obtained from Tanzania. This variety was named Somtux (Somalian Tuxpeño), and was characterized by white, semi-dent grain and full-season maturity. The average grain yield under experimental conditions was 5.7 t/ha and 3 t/ha under farmers' conditions. Due to a lack of continuity in the breeding program, both varieties have lost their genetic purity and have become contaminated.

Since 1981, extensive research in maize improvement and appropriate production practices has been carried out at CARS. The main objectives are to develop high-yielding varieties that are tolerant to drought and to the stem borer (*Chilo partellus*).

Major breeding activities

International variety trials (CIMMYT)—Nearly 200 maize introductions have been evaluated in field trials at CARS since 1981. The introductions have mainly been open-pollinated varieties of variable maturity and grain type. Some of these introductions have proved promising, among them Across 8121, Across 8149, Los Diamantes 7823 RE (RE = reference entry), Across 7822, Pirsabak 7930 and Poza Rica 7926.

Regional variety trials (SAFGRAD)—Since 1981, two sets of trials have been obtained from the Semi-Arid Food Grain Research Development Project (SAFGRAD). These trials have included the varieties RUVT-1 and RUVT-2. The best-performing varieties in those trials were Pool 16 and TZPB.

Composite and synthetic variety development—Population improvement through the development of composite and synthetic varieties has been the main goal of CARS since 1981. A preliminary yield trial of 11 newly advanced breeding stocks and the best introductions were evaluated in the *Gu'* season of 1984. The best performing entries were the multivarietal hybrids, followed by ISOMA (improved Somtux), Population B.RBS. and a new Afgoi Composite.

Development of early-maturing varieties—Early maturity is advantageous where maize is grown as a rainfed crop or where moisture is deficient for the normal development of full-season varieties. Recently, greater attention has been focused on production areas. Thirty F_2 seedlots resulting from crosses between Pirsabak 7930, Pool 16 and ISOMA were planted in the *Gu'* season in 1984 in order to introduce earliness to ISOMA. Ears from a bulk pollination of the selected plants were planted, and ears from plants which matured within 90 days of planting were harvested.

Future Research Plans

Future plans of the Somali Agricultural Research Service include the release of some of the newly developed breeding stock which has already proved to have better performance than that presently in use. These promising new materials include multivarietal hybrids, ISOMA, the new Afgoi Composite and Population B.RBS. These materials will be tested in multilocational trials, increased and then released to farmers.

It is hoped that Somalia can have closer contact with its neighbor countries, such as Kenya, Zambia and Tanzania, in order to be able to exchange information and materials which will be useful for further breeding activities.

Maize Research Activities in Swaziland

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Maize is the principal staple food in Swaziland. It is the single most important crop that is grown on Swazi Nation Land (SNL), which occupies about 60% of the total land area of the Kingdom (Swazi Nation Land is land held in trust for the nation by the King who delegates the power to the chiefs to allocate these lands). About 83,000 hectares of arable land was cropped in 1982 (4); at least 70% of that amount (59,000 ha) was in maize. Yields on SNL, however, were low, varying between 1.4 and 1.6 t/ha.

The climate of Swaziland is subtropical, with the rainy season from October to March and precipitation between 500 and 2000 mm; droughts are frequent. According to Murdoch (7), serious moisture deficiencies are likely to occur in any month one year out of ten, even in the wettest areas. Some areas, such as the lowveld, have an 80% risk of receiving less than 625 mm of rainfall during the summer season; these are drought conditions. Besides the climate variations, altitude also varies between 200 and 1300 meters. The highveld, with an elevation of 1300 meters, is in the western part of the country; it receives sufficient rainfall (1000 to 2000 mm) which is normally well distributed. The middleveld and Lubombo Plateau, with average elevations of 700 meters, also receive ample rainfall of some 900 to 1250 mm, which is also well distributed. These three areas are noted for their deep soils with good moisture-holding ability. The soils are, however, fairly acidic. The lowveld is hot. It receives about 700 mm of rainfall, but this tends to be erratic and unreliable. Hence, farmers face greater risks because of frequent dry spells.

Maize Research in Swaziland

With such variable environments as are found in Swaziland, there is need to test maize cultivars over as wide an area as possible and under various management situations to identify cultivar x environment interactions. This can facilitate the identification of maize cultivars and farming practices that will be conducive to high yields. There are six experiment stations in the country where this testing takes place.

During the last two decades, attempts have been made to introduce improved maize cultivars into the country, mainly from the Republic of South Africa and Zimbabwe, in a search for cultivars that will outperform materials already in commercial production, i.e., SR52 and NPP x K64R. More recently, CIMMYT maize varieties have been introduced into the Swaziland research program for the same reason. Further maize research is planned to evaluate:

- Fertilizer use, for identifying rates and time of application, as well as specific cultivar nutrient requirements;
- Weed control methods, especially the control of witchweed (*Striga* spp.);
- Maize diseases and their control, with emphasis on maize streak virus, and
- General crop management practices.

Recently, two new projects have been undertaken by the Ministry of Agriculture and Cooperatives to increase agricultural output. These are the Cropping Systems Research and Extension Training Project and the Seed Multiplication Project.

Cultivar evaluation

Several maize trials are conducted each year. These trials are grouped into three categories:

Regional trials—These trials were organized in southern Africa, using newly released hybrids which had been tested against standard maize cultivars. The trials are conducted at more than 100 locations, both within and without the region. The trials are important to Swaziland in that they introduce newly released materials into the country. From these, selections can be made for testing in the national maize trials. Results from one such trial for the 1983-84 season are shown in Table 1.

International trials—These trials, sent from the CIMMYT maize program, are conducted to identify suitable varieties in terms of yield and disease resistance. Promising varieties then receive further testing in multilocational and on-farm trials. The best varieties from these tests are released by the seed project for commercial production. One such variety that is already commercially available is Across 7443. Several more varieties, from populations 22, 23, 24 and 47, have been selected, and these are now undergoing further testing on station and on farmers' fields. (Data for Swaziland in the CIMMYT 1983-84 trials are published in the Maize International Testing Program 1983,

Table 1. Results of Regional Maize Variety Trial,[a/] Malkerns Research Station,[b/] Swaziland, 1983-84

Variety	Yield T/ha	Yield °/o of standard	Shelling (°/o)	Root lodging (°/o)	Variety	Yield T/ha	Yield °/o of standard	Shelling (°/o)	Root lodging (°/o)
SNK2147	12.2	143.2	66.7	12.0	R201	8.7	102.0	65.7	7.0
CG4504	11.0	130.9	70.7	5.0	RO430	8.6	101.4	67.7	19.0
CG4512	10.5	123.4	66.7	10.0	PNR473	8.6	100.9	74.7	6.7
CG4405	10.0	118.1	68.0	4.0	PNR95	8.5	100.4	64.0	14.3
PNR394	9.9	116.5	72.3	4.0	CG4602	8.5	100.4	66.7	7.0
Tx 14	9.9	116.1	70.3	9.3	SSM2039	8.5	99.9	68.7	7.3
PNR6429	9.8	115.3	70.7	4.7	A210	8.5	99.8	69.0	19.3
SNK2236	9.7	113.6	67.0	15.0	SSM2041	8.4	98.9	63.7	12.0
PNR482	9.7	113.5	66.3	42.7	HL1	8.4	98.8	70.7	9.0
PNR6405	9.6	113.0	62.3	9.0	SNK2232	8.4	98.4	75.3	8.7
CG4141	9.6	112.6	68.7	8.7	HL2	8.3	97.8	65.7	19.7
PNR542	9.5	112.4	66.7	5.7	IP87304	8.0	94.5	67.0	10.7
CG4403	9.4	111.4	71.3	9.3	RO422	7.9	93.3	72.3	13.7
SSM2045	9.3	109.2	68.7	8.0	R70	7.9	92.3	66.3	18.7
SABI7200	9.2	108.8	68.0	10.0	IPB7302	7.8	92.3	66.0	4.3
PNR496	9.2	108.8	70.0	7.7	A471 W	7.8	91.9	62.3	17.0
A1600	9.2	108.2	63.0	5.3	A475	7.6	89.0	68.7	14.7
SABI707	9.1	106.6	67.0	20.0	A1650	7.4	86.8	69.7	9.7
SNK2244	9.1	106.5	69.7	5.0	CG4502	7.4	86.5	63.3	27.7
RS5205	9.0	106.1	64.7	4.0	AX305 W	7.3	86.1	69.7	12.7
PNR432	9.0	106.0	70.0	3.0	SSM72	7.2	85.0	67.7	18.7
SABI7004	9.0	105.5	67.0	8.3	SA4	6.6	77.1	63.3	26.7
SSM48	9.0	105.5	69.7	3.7					
Sx 24	8.9	104.2	71.0	14.0	Overall mean	108.8	104.1		
Tx 24	8.8	103.9	65.7	9.0					
SABI308	8.8	103.9	65.0	12.0	SDEV(+/–)	01.1	12.6		
PNR6514	8.7	102.3	69.7	5.7	CV(°/o)	12.1		NS	NS

a/ Planting date November 1, 1983; harvest, 1984
b/ Rainfall 1203 mm

CIMMYT, Mexico.) Maize streak trials are now being conducted for the first time, but no data have yet been accumulated.

National trials—These trials are multilocational. Two test sites are located in the highveld, three in the middleveld, one of which is in the drier part, and one in the lowveld. The trials incorporate those materials identified or selected from the single-site trials. The performance of these new selections are compared with standard maize varieties and hybrids for a period of not less than three years. In the past, cultivars that yielded well, ranked high and possessed certain desired characteristics were identified and directly transferred to the farmers for commercial production. Such data as are summarized in Tables 2 and 3 were considered sufficient for the recommendation of cultivars.

Now, however, attempts are being made to evaluate these cultivars more critically. This is because average yields of specific cultivars in specific areas were found to vary considerably; thus, yield data were considered unreliable as it was impossible to run tests under all possible climatic conditions. The new procedures being introduced are based on the regression analyses that have been successfully used by Robbertse (8). Unlike Eberhart and Russell (3), Robbertse developed his procedures for regression analysis by evaluating the test cultivar yields (the dependent variable) against the mean yield of a set of standard cultivars (the independent variable). In practice, the difference between the yield of a given cultivar and the mean yield of the standards is plotted as the dependent variable. Results of these analyses for the seasons 1980-81 to 1983-84 are presented in graphical

Table 2. Results of multilocational National Maize Trials, Swaziland, 1982-83

Variety	Yield (t/ha)					Across - site means
	Hebron	Mangcongo	Nhlangano	Malkerns	Luve	
SR52	3.5	3.6	2.7	2.4	3.7	3.2
R5205	5.7	5.7	3.6	3.9	4.9	4.8
R201	5.5	4.7	3.5	2.7	5.3	4.4
R215	5.3	4.1	2.8	2.2	4.2	3.7
Tx 9/ZS229	4.0	2.2	3.3	3.0	4.0	3.3
Tx 379	4.8	4.1	3.0	4.2	4.1	4.0
RO415	4.8	3.2	3.2	3.4	3.4	3.6
A323 W	5.1	4.4	4.0	4.1	4.2	4.4
A471 W	5.3	3.5	4.7	4.9	4.2	4.5
SSM2039	5.1	4.0	2.2	3.2	3.8	3.7
SSM2043	5.5	2.2	3.1	3.3	3.8	3.6
PNR6501	5.3	5.5	3.6	4.0	3.8	4.4
PNR651	4.9	4.1	3.0	3.7	4.3	4.1
PNR493	3.8	4.4	3.3	4.7	4.2	4.1
PNR473	4.5	5.0	3.6	4.5	3.6	4.3
PNR95	5.0	4.3	3.7	3.5	4.4	4.2
Across	3.0	3.3	1.7	3.7	1.5	2.6
CG4141	4.3	3.8	2.8	3.1	3.1	3.6
CG4801	5.0	2.8	3.8	2.3	4.4	3.7
NPP	5.1	3.5	2.0	2.4	3.5	3.3

form for selected maize cultivars that show different types of cultivar behavior.

Figure 1 presents yield data for Across 7443. It shows a Y-intercept of zero and a negative regression coefficient. This cultivar performed worse than the standards under all conditions, i.e., in both high- and low-yield environments. It is best suited to areas where the potential is low and technology fairly poor. Its biggest disadvantage is that it requires a long growing period.

Figure 2 represents the hybrid Pioneer 95. The regression line has a positive intercept and a negative regression coefficient. This cultivar would perform better than the standards in low-yield areas, but not so well under better environmental conditions. It can thus be recommended for low-yield environments.

Figure 3 presents yield data for the hybrid SR52. The regression line has a negative intercept but a positive regression coefficient. This type of

Table 3. Results of multilocational National Maize Trials, Swaziland, 1983-84

Variety	Yield (t/ha) Hebron	Mangcongo	Malkerns	Nhalangano	Luve	Across - site means
SR52	9.5	6.2	6.0	9.8	6.6	7.6
R5205	7.6	8.4	10.4	11.2	6.8	8.9
R201	7.2	6.1	7.8	11.2	6.4	7.7
R215	6.4	5.5	7.1	10.2	5.9	7.0
ZS229(Tx9)	7.5	8.2	10.4	11.6	5.4	8.6
Tx 379	8.3	7.1	10.1	9.1	5.6	8.1
RO415	7.7	6.9	10.5	10.9	6.1	8.4
A323 W	7.5	5.9	10.3	9.9	6.3	8.0
AX305 W	6.0	5.3	10.1	10.1	5.8	7.5
A471 W	6.2	5.1	9.2	7.8	6.1	6.9
SSM2039	7.3	7.3	9.6	9.0	5.4	7.7
SSM2041	6.9	5.4	9.8	8.5	4.1	6.9
SSM2043	5.6	3.7	9.1	6.2	6.2	6.2
PNR6501	8.8	8.4	10.5	12.0	5.6	9.0
PNR6405	8.6	7.4	8.8	12.0	5.3	8.4
PNR651	6.4	8.5	10.2	11.0	5.7	8.4
PNR493	6.8	5.5	10.7	8.4	5.4	7.4
PNR482	6.3	7.4	9.6	10.4	6.6	8.1
PNR473	6.8	6.0	11.0	11.5	5.5	8.1
PNR95	7.1	5.5	10.3	9.8	5.4	7.6
IPB7308	5.7	6.4	9.8	9.5	5.4	7.1
Across	5.3	4.1	6.9	6.8	6.7	6.0
CG4141	7.5	6.8	9.6	9.8	5.0	7.7
CG4801	7.3	6.2	7.8	10.7	5.4	7.5
NPP	6.2	5.8	7.2	8.6	5.5	6.4
Site means	7.1	6.4	9.3	9.9	5.7	
SE(Diff) +/–	0.4	0.2	0.3	0.3	0.2	
CV (%)	19.6	13.6	13.2	12.4	13.7	
LSD (5%)	0.8	0.5	0.7	0.7	0.4	

graph indicates a cultivar which performs poorly when compared to the standards in low-yield environments, but performs better than the standards in high-yield areas. It could, therefore, be recommended for the high-yield areas, such as the highveld and the middleveld. The level of technology should also be high if this type of cultivar is to fully express its potential.

The hybrid R5205 in Figure 4 represents the ideal type of cultivar, which is stable across many environments; the graph shows a positive intercept and a regression coefficient of nearly zero. This type of cultivar is regarded as better than the standards in all areas. It can be noted that the intercept for the hybrid is very small; this implies that there is only a small improvement when it is compared to the performance of the standards. However, such hybrids can be recommended for all areas of Swaziland.

The use of regression line graphs as a technique for processing yield data, especially for the formulation of cultivar recommendations, has proved very promising in Swaziland. It is a big improvement over previous techniques which were based on mean yields and ranks without reference to any standard.

Weed control

Trials conducted in the past indicated that weed control was the single most important factor determining maize yield in Swaziland (1). Several trials are presently in progress to evaluate herbicides and herbicide applicators, the effect of weeding frequencies on maize yields and control methods for witchweed (*Striga asiatica*). Tentative results from some of these trials indicate the folllowing:

- Early weeding is more beneficial than late weeding, giving rise to more rapid plant growth and yields up to 40% higher;
- Witchweed in maize can be controlled by early planting (when temperatures are not conducive to witchweed seed germination), by the application of kraal manure long before planting, and possibly by the use of chemicals, and
- The ground-driven control droplet applicator (GCDA) is the best machine for use in weed control. In the applicator trials several issues were considered, such as labor, the quantity of water required, the cost of equipment and herbicides, and ultimately economic returns. After all possible comparisons were made, the GCDA was found to be the best.

Disease control

The plant pathology section routinely evaluates all of the maize trials for foliar and ear diseases. The main emphasis is on the evaluation of cultivars for their resistance to maize streak virus, using materials from IITA and CIMMYT and several seed companies in the region (6), and the development of control measures that can be applied at the farm level. To date, Ripcord and Curatter have been found effective for the control of the vector of maize streak (*Cicadulina mbila*); how economical their use is remains to be assessed.

Maize intercropping

Several trials were conducted from 1978 to 1983 to evaluate the intercropping of maize, with maize grown as the main crop with pumpkins, beans and groundnuts; these are all popular with SNL farmers. This work was conducted by the Faculty of Agriculture of the University of Swaziland (2). In these studies several promising intercropping situations were established, including dry maize-green beans-dry beans, green maize-green beans and dry maize-pumpkins.

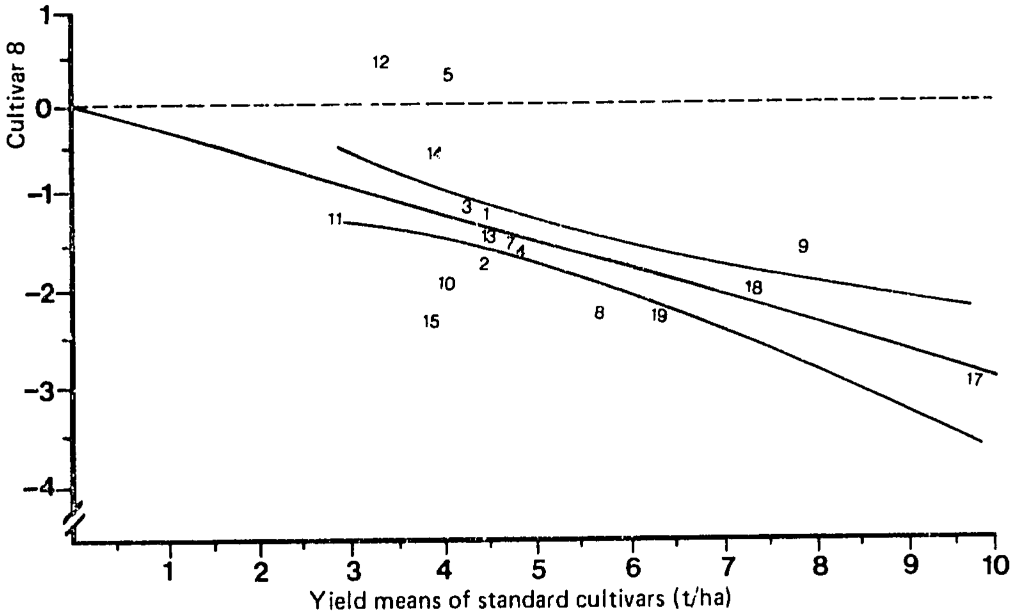

Figure 1. Yield data for cultivar Across 7443, Swaziland maize trials, 1980 to 1983
Note: Cultivar mean = 3.57, B-1 = −0.29, D parameter = 4.98, standard mean = 5.03

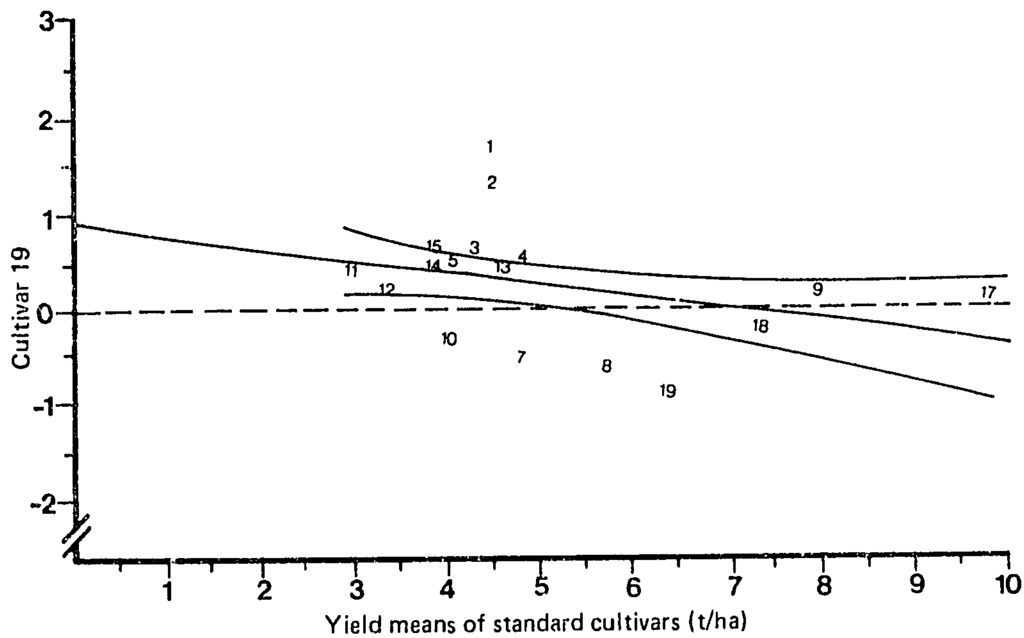

Figure 2. Yield data for hybrid Pioneer 95, Swaziland maize trials, 1981 to 1984
Note: Cultivar mean = 5.30, B-1= −0.125, D parameter = 3.99, standard mean = 5.03

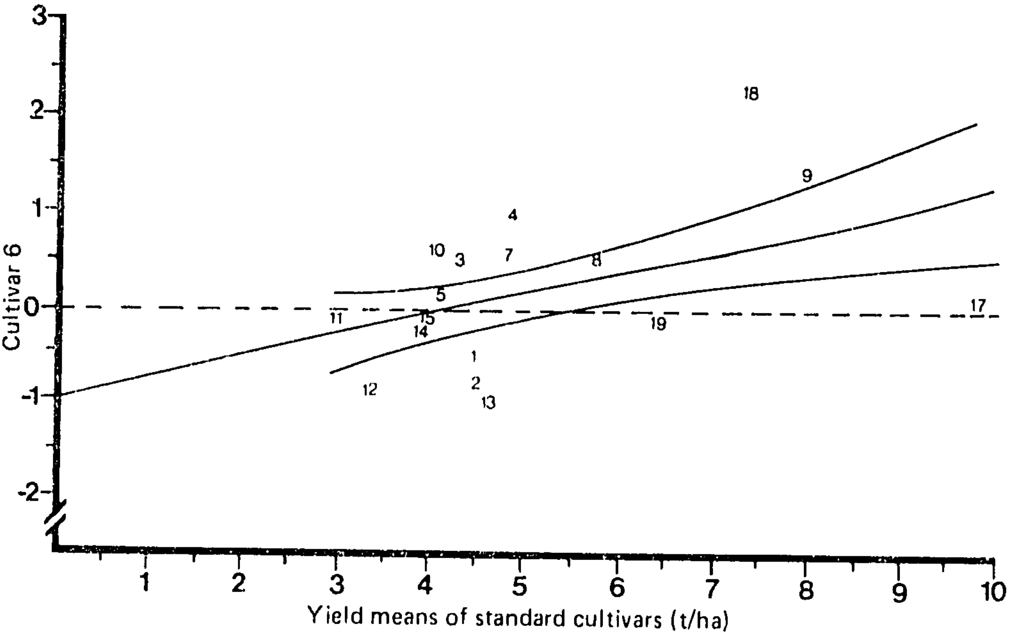

Figure 3. Yield data for hybrid SR52, Swaziland maize trials, 1980 to 1984
Note: Cultivar mean = 5.22, B-1 = 0.22, D parameter = 5.74, standard mean = 5.03

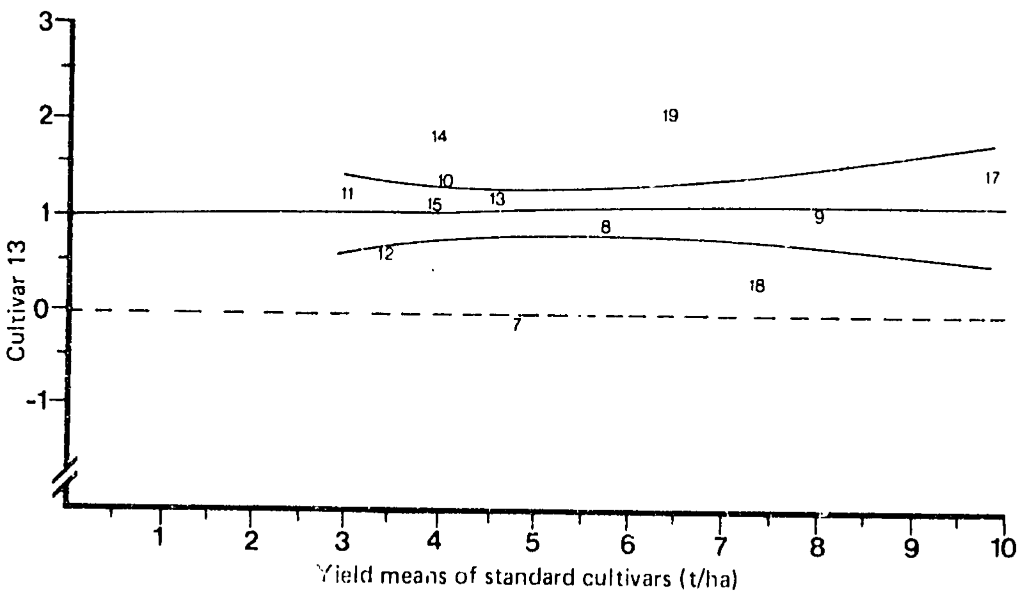

Figure 4. Yield data for hybrid R5205, Swaziland maize trials, 1980 to 1984
Note: Cultivar mean = 6.40, B-1 = 0.02, D parameter = 3.82, standard mean = 5.32

When maize was intercropped with dry beans, with the bean plantings staggered, highest returns were achieved when the beans were planted within three weeks after maize planting. The reason for lower bean yields was probably the lack of light available to them. Maize within the maize-pumpkin combination showed yield advantages of up to 20% over maize planted alone, possibly because the pumpkins smothered weeds and protected the soil surface. This system was the most popular with SNL farmers since they utilize pumpkins extensively.

Fertilizer use
Fertilization studies have been carried out to formulate recommendations for the use of lime, chemical fertilizers and manure. These recommendations are based on agronomy field trials at various research centers in the country. They are regional in nature and do not allow for differences in soil, climate, land use and fertility conditions. A new section has now been established to provide specific recommendations for individual farm situations.

Several studies are now in progress. These include reevaluations of existing lime recommendations, using methods based on extractable acidity; cultivars are also evaluated for their tolerance to various toxicities. Other studies are conducted on nutrient requirements, timing and rate of fertilizer application and how these rates are affected by such factors as plant density and time of planting.

It is hoped that these programs will provide sufficient information to enable the research division of the Ministry of Agriculture to develop more realistic production packages for Swaziland's maize farmers, especially those with limited resources.

The Cropping Systems Research and Extension Training Project

Agricultural research in Swaziland was initiated in 1959, and the Malkerns Research Station was established in 1962. Since then, Swaziland has had good physical resources for research in agriculture. Although it is one of the smallest countries in Africa, it has established itself as one of the leading countries in agricultural research (5).

The research division was first operated by the Ministry of Agriculture, and then by the Faculty of Agriculture of the University of Botswana, Lesotho and Swaziland; later it returned to the Ministry of Agriculture and Cooperatives (MOAC). At that time, contracts for expatriate research personnel expired and there were no replacements; due to the lack of researchers, work came to a standstill, and no new recommendations were forthcoming for five years. As a result, MOAC sought technical assistance from FAO and the UNDP.

The research that had been conducted in the country previously had not been specific to any group of farmers, and yet the feeling was that it was more applicable to the large-scale farmer than to the small farmer operating on Swazi Nation Lands. When the FAO team arrived in 1980, research was planned to be directed toward the problems and needs of the small farmers. The project was scheduled to run for three years, but was terminated by UNDP before the end of the contract (in early 1982). Immediately after that, the MOAC and USAID Cropping Systems Research and Extension Training Project was established and was begun in February of 1982. This new project is also focusing its research on the needs of the small farmers in the areas of agronomy, irrigation, horticulture and economics.

Objective
The objective of the project is to increase the economic viability of farming on Swazi Nation Land; this will allow a more focused approach to research and extension. The accomplishments of the project can be measured by the amount of this increase. At the moment, less than 10% of the SNL farmers market anything above their subsistence needs. The goal of the project is to increase this number to 20% by 1992 and to 30% by 1997.

Hopefully the MOAC research and extension programs can develop cropping systems recommendations relevant to the needs of SNL farmers in the following areas:

- Identification of constraints to progress on SNL farms, as well as of the expressed needs of the farmers;
- Response to the above through a program of on-farm research to identify relevant crops and cropping practices;
- Development of appropriate methods of information diffusion that will be understandable and usable by extension agents and farmers, and
- Provision of in-service training courses to improve the skills of the extension staff.

Project staff
Technical personnel for the project come from two US universities, Pennsylvania State and Tennessee State. The MOAC also provides personnel to assist with the project. There are specialists in agricultural information and extension training in the program.

On-Farm Research

On-farm maize research is being conducted in a number of areas, including weed control, pest control and planting devices.

Weed control
Informal and formal surveys showed that farmers seemed to be interested in the use of herbicides for saving labor in weed control; traditional weed control is by hand hoeing. On-farm herbicide trials were conducted to test the effectiveness of postplanting, as well as pre-emergence band applications of mixtures of Atrazine with Metholachlor in both liquid and granular form. The trials showed no significant differences in grain yields between the three treatments (at the 10% level of significance). Hand hoeing is cheaper for those with sufficient labor. Herbicides would be helpful to those with limited labor, but they are expensive.

After the trials, the cooperating farmers were interviewed by the economics section to determine the impact of the results. This survey indicated finally that farmers were not greatly concerned about the use of herbicides. The survey served to emphasize the need for studies on labor, timing and costs of weed control in the future.

Pest control
Cutworms greatly reduce maize plant populations by lowering the leaf area index, leading to lower yields. In cutworm control trials, bait was applied with a granular herbicide applicator. The treatment used was Kombat cutworm bait applied at 5 kg/ha over the row immediately after planting; in the control, no bait was applied. There were some differences in plant population and yield, but they were not significant.

Planting devices
Observations made by the Rural Development Area (RDA) Management Unit indicate that, for various reasons, plant populations commonly found in maize fields in Swaziland are very low (20,000 to 25,000 plants per hectare). Poor germination takes place due to

poor land preparation, and cutworms often destroy the emerging maize seedlings. Also, farmers do not plant at sufficiently high densities, and the SAFIM ox-planter has been found to be inefficient.

With the traditional ox-planter, fertilizer is placed on top of the seed rather than at the side; this causes burning of the seed. The hilldrop planter plate mechanism also damages the seeds. The planter wheel which drops the seeds tends to slip, leaving bare spots in the fields.

The World Bank Project in Lesotho has worked to improve the SAFIM planters. Two were bought from Lesotho and another was modified at the Malkerns Research Station. The shoe was widened so that the fertilizer would be dropped slightly to the side of the seed, thus hopefully eliminating the burning problem. The seed plate was also made about twice as thick as the standard SAFIM seed plate, and a chain drive was used instead of the standard SAFIM Pitman drive. This should eliminate the unplanted spots in the fields.

Only one modification has been tested in the field, the improvement of fertilizer placement. In the trials, half of a farmer's field was planted with the standard SAFIM planter and the other half with the modified SAFIM planter. Results indicated that, when the modified planter was used, yields improved significantly.

The Soil Testing Unit

Liming has been one of the most important areas of soil fertility research since the establishment of the Malkerns Research Station; the result is the existence of the Ministry of Agriculture Soil Testing Unit. The unit was established in 1975 with the following objectives:

- Make pH analyses from which accurate liming recommendations can be made;
- Make soil analyses from which fertilizer recommendations can be made, and
- Convince farmers of the importance of soil testing, and teach them to take representative samples and to use lime and fertilizers.

Lime demonstrations were set up as an extension tool and some farmers adopted the practice.

Soil testing problems and accomplishments

The soil testing unit has been in operation for six years, but has had little impact. There have been too few specialized technicians, such as soil chemists, and they have not been sufficiently competent to run accurate P and K analyses. No training was provided for them in the operation of new equipment, which had been donated to the program by various organizations. Lime recommendations which were made were based only on soil pH and texture, which is the least accurate method; also, lime was not easily available in Swaziland. Samples for testing were usually submitted late by the farmers, and therefore recommendations were often returned to them after they had already planted. The delivery of soil samples for testing and the return of the results were not efficient, due to a lack of funds in the program.

The Cropping Systems Research Project has now made some improvement in upgrading the efficiency of the soil testing laboratory and in the accuracy of the soil tests with the technical assistance of a Pennsylvania State consultant. New laboratory equipment with higher capacity and accuracy has been purchased. It has been installed by the consultant and the technicians have been trained in its use.

Lime recommendations are now based on soil pH and exchangeable acidity rather than pH and soil texture. Tests for phosphorus and potassium deficiencies are done using ISFEI methods. Also, the laboratory has doubled its efficiency; it can process 120 samples for pH exchangeable acidity, phosphorus and potassium and make recommendations within a week of receiving a sample. The Cropping Systems Research Project is working closely with the soil testing unit in correlating soil testing results with field response results.

The Seed Multiplication Project

The Seed Multiplicaton Project was established in 1978, sponsored by the Ministry of Agriculture and Cooperatives and FAO. The project was begun as a result of a great increase in the number of farmers using hybrid maize; it was felt that domestic production of seed would be a service to farmers, would make effective use of the country's resources and would exploit both local and export markets. The project was divided into three phases, with the following objectives:

- Build and operate a seed processing plant;
- Establish a seed testing laboratory;
- Organize production and certification of basic seed for maize and beans;
- Set up field inspection of seed crops;
- Formulate regulations for seed certification, and
- Train personnel for the project.

The target of the project was the production of 600 tons of maize seed and 50 tons of bean seed by the end of its second phase.

The above objectives were realized except for the target amounts of seed. Maize seed produced at the end of Phase 2 was 460 tons; bean seed production was 33 tons. The problems causing this shortfall were the shortage of land available for seed production, the lack of access to basic seed materials, and the scarcity of contract growers with the necessary managerial skills.

The number of contract growers has now increased from three to nine, and they have formed a Seed Growers' Association. The Association now recruits new members, and the members assist one another with the management of their seed crops.

In the first and second phases of the program, seed of the following maize varieties was produced: NPP x K6r, CG4141, PNR95, PNR6427, Tx 379, A471W, A323W and Across 7443. Also, seed of the potato variety BPI was produced, as well as that of the bean variety Bonus. The target for the 1984-85 season is to produce 600 tons of maize seed and 60 tons of bean seed.

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Maize Research in Tanzania

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Maize is the most important food crop grown and consumed in Tanzania. The major growing regions are Rukwa, Mbeya, Iringa, Ruvuma, Arusha, Kilimanjaro, Tanga and Morogoro. Maize is produced by over 50% of Tanzanian farmers on approximately 1,700,000 hectares. Only a small percentage is produced on large commercial farms.

Although grain yields are highest in the southern highlands where there is sufficient and reliable rainfall, production per unit area is low on small farms (less than 1.5 t/ha). This low production is a result of a variety of constraints. In the marginal rainfall areas, early rainfall is erratic and often insufficient. In the bimodal rainfall areas, mid-season moisture stress may result in considerable loss of yield, and in some cases complete crop loss. Supplemental irrigation is used to a very limited extent, although it would make maize production less risky in the lowlands and the coast and in the drier intermediate-elevation areas. In the southern highlands, acidic, low-fertility soils limit production when no fertilizer is used. In the western part of the country, soil fertility is generally low, but poor rainfall distribution limits response to fertilizer. In some seasons, maize streak virus disease reduces yields considerably. Although most farmers know the importance of weeding, it is often done too late to limit the adverse effect of weed competition.

In the past, government-fixed maize prices were low and tended to keep production low. Prices have now been increased, and farmers are responding by increasing production. However, inputs such as fertilizer and herbicides are often not available on time or in sufficient quantities.

Most farmers in Tanzania prefer white maize. There is also preference for flint types, which seem to store better and are more suitable for the preparation of *ugali*, the popular maize dish in the country. For preparing *ugali*, the pericarp of the maize kernel is removed by pounding in a mortar. Flint grains are less susceptible to breakage in the process than are dent grains.

The National Maize Research Programme

Prior to 1973, maize research in Tanzania was not centrally coordinated. In that year, the National Maize Research Programme (NMRP) was initiated with the help of CIMMYT and IITA. It is headquartered at the Ilonga Research Institute at Kilosa, and is centrally coordinated and national in scope. Presently, breeding work is conducted at Ilonga and at the Uyole Agricultural Centre, as well as at the Tanganyika Wattle Company in Njombe, under the supervision of Ilonga and Uyole. Other research institutions (Lyamungu, Ukiriguru, Selian, Maruku, Tumbi, Mlingano, KATRIN and Naliendele) cooperate in testing materials generated by the breeding program and in conducting agronomy trials to solve specific problems in the regions where they are located. Some of them have several experiment stations, thus increasing the number of sites for the multilocational testing of varieties and progeny materials. Varieties are also tested on farmers' fields before they are released. Each year the maize researchers meet to give progress reports and plan the work for the following season.

The NMRP has divided the country into three main agroecological zones, based on elevation and rainfall (Figure 1). The lowland zone includes the coast and areas below 900 meters elevation. The growing period of the varieties grown in this zone is three to four months. Major problems encountered are erratic rainfall and maize streak virus disease.

The midaltitude zone comprises those areas between 900 and 1500 meters. It is subdivided into two regions according to rainfall regime: intermediate wet, which receives more than 1100 mm rainfall and has a growing season of four to five months, and intermediate dry, with less than 1100 m of rainfall and a growing season of three to four months. Major problems in this zone are maize streak virus disease, especially around Lake Victoria and Arusha, and insufficient rainfall in the intermediate dry areas.

The high-altitude zone includes areas above 1500 meters elevation. Within this zone are the southern highlands,

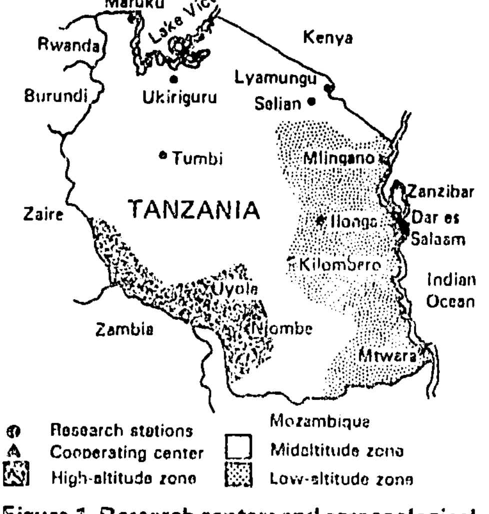

Figure 1. Research centers and agroecological zones, Tanzania

the major maize-growing region, which usually receives sufficient and reliable rainfall, and has a growing season of six to seven months. Maturity is delayed due to the low temperatures which prevail during the growing season. A few cases of frost damage occur in extremely high-altitude areas (over 2000 meters). Ear rot and stalk borers are occasionally serious problems, and *Helminthosporium turcicum* is a problem if resistant varieties are not used.

The breeding program

The breeding program has been involved in improving populations, in the formation and testing of varieties and in the supplying of national foundation seed farms with breeders' seed of both open-pollinated varieties and inbred lines. During the initial stages of the NMRP, efforts were concentrated on the development of populations as well as on improving varieties. Using local and exotic germplasm, several populations were developed for the various agroecological zones of Tanzania; Table 1 indicates major selection criteria. Thus far, the main breeding methods employed have been full-sib and half-sib family testing and selection. Progenies are formed at Ilonga, Uyole and Njombe, and are evaluated in replicated progeny trials during the wet season. Off-season nurseries are planted under irrigation during the dry season.

In the 1982-83 season, the NMRP began forming top crosses for possible hybrid production and for obtaining information for restructuring the populations on the basis of heterotic patterns. Beginning in 1984-85, the number of breeding populations in active use is being reduced to allow breeders to concentrate on the top-priority materials.

The NMRP cooperates with other breeding programs, including IITA, CIMMYT and SAFGRAD (Semi-Arid Food Grain Research Development Project). With the help of CIMMYT, the leadership staff of the program based at Ilonga has been maintained for nine years without serious disruption. However, local staff has changed continually, with some leaving for further studies and others being transferred. The resulting shortage of manpower, as well as insufficient funding and transport facilities, has limited testing for adaptability on farmers' fields.

Recommended varieties—Presently, four hybrids are recommended for the various zones of Tanzania. H6302 and H614 are recommended for the high-elevation, long-season areas of the southern highlands, Iringa, Mbeya, Rukwa and Ruvuma. These two hybrids were developed by the East African Agriculture and Forestry Research Organization (EAAFRO) and tested in Tanzania where the seed stocks were increased and then released. H6302 is the highest yielding hybrid in the country (Table 2); however, to realize its full potential, it requires top management under favorable environments. The hybrids

Table 1. Breeding populations of the National Maize Research Programme, Tanzania

No.	Major selection criteria	Grain type [a]	Days to 50°/o silk	Target zone
10	Streak resistance, plant type	WD	64	Low and midaltitude
11	Streak resistance, plant type	WF	57	Low and midaltitude
12	Streak resistance	YF/D	65	Low and midaltitude
62	Ear height, ear rot and blight resistance, grain type, yield	W/Y F/D	106	High altitude, long season
72	Yield, streak resistance	W/Y F/D	47	Low and midaltitude
76	Streak and stalk rot resistance, yield	WF/D	63	Low altitude
80	Streak and stalk rot resistance, yield	WD	61	Low altitude
84	Earliness, ear rot and blight resistance, yield	W/Y F/D	84	Mid- and high altitude
88	Yield, grain size	WF	45	Low and midaltitude
90	Ear height, ear rot and blight resistance, grain type, yield	W/Y F/D	108	High altitude, long season
92	Yield, grain type, ear rot resistance	WF/D	75	Midaltitude
96	Yield, grain type, blight resistance	WD	75	Midaltitude, dry

[a] W = white, Y = yellow, F = flint, D = dent, / = mixture

H632 and H622 and the open-pollinated variety UCA are recommended for the intermediate-elevation areas. For several years, Ilonga Composite has been recommended for areas below 900 meters. Tuxpeño, a full-season variety, is grown on a limited scale in the northeastern and southern lowlands of the country. Until recently, Katumani was the only early maturity variety available.

New releases—In 1983, the NMRP released three new open-pollinated varieties. Kilima and Staha, both full-season varieties, were recommended for the intermediate and low-altitude zones, respectively. Kito, an early maturing (90 days at Ilonga), white flint variety was recommended for areas below 1300 meters.

The agronomy program
Production agronomy trials are conducted to develop economical technology packages that can be recommended to farmers. The practices investigated include planting date, plant density, fertilizer use, weed control, chemical control of insect pests and diseases, and maize intercropping. Results so far obtained in the program have resulted in the

Table 2. Yield performance of commercial varieties in variety trials, Tanzania, 1981 to 1984

Variety	Yield (t/ha)				
	1980-81	1981-82	1982-83	1983-84	Mean
High-altitude zone					
H6302	8.9	11.2	8.4	8.1	9.2
H614	8.6	10.6	8.2	7.9	8.8
H613	8.7	9.7	8.0	—	8.8
H632	6.8	8.3	7.8	6.2	7.3
H622	6.8	8.2	6.5	6.7	7.1
UCA	6.2	7.9	7.6	6.3	7.0
No. of locations	5	2	4	4	
Midaltitude zone					
H632	5.0	6.4	3.9	4.4	4.9
H622	—	6.3	3.4	5.0	4.9
UCA	5.7	5.8	4.2	4.5	5.1
Kilima	6.3	6.0	4.4	4.9	5.4
No. of locations	4	2	5	6	
Low-altitude zone					
ICW	4.0	3.3	3.5	3.9	4.0
Staha	4.5	3.2	4.8	4.2	4.2
Tuxpeño	—	3.2	3.3	3.1	3.2
Kito	—	—	2.4	3.2	2.8
Katumani	—	—	2.2	3.1	2.7
No. of locations	3	3	4	4	

refinement of earlier packages of technology. For example, in the lowlands, grain yields are the same or slightly better when maize is planted at two plants per hill at 75 x 60 cm distance than when planted at one plant per hill at 75 x 30 cm. In the highlands, the rates of two plants per hill with spacings of 90 x 50 cm or 75 x 60 cm or three plants per hill at 90 x 75 cm do not change yield expectations from single plant stands at 90 x 25 cm or 75 x 30 cm. Changes in spacing are readily accepted by farmers.

Under farmer practices, particularly in areas of less reliable rainfall, 33,000 to 40,000 plants per hectare appear to be the best population for full-season varieties. To obtain high yields, the early maturing, small-statured varieties need to be planted at densities higher than those of full-season varieties. In the intermediate and high-elevation areas, farmers should change to earlier maturing varieties when forced to plant late.

Stalk borer control has not been found to be economical, except in the highland areas of Mbeya, Iringa, Rukwa and Ruvuma.

On-farm agronomy testing—For a number of years, the NMRP has conducted trials on farmers' fields in areas surrounding research institutions, experiment stations and villages. The trials have tested varieties for response to plant density, planting on ridges versus flat land, fertilizer application and rates, insecticide use and weeding regimes. In 1980, as a result of this work, packages of technology could be recommended for farmers in 11 areas where substantial testing had been done.

Presently, variety demonstrations are being conducted in the villages to compare the performance of promising experimental varieties under farmer managment with local varieties and released varieties. Owing to transport and manpower limitations, it has not been possible to conduct variety trials nor carry out demonstrations in some important maize-growing areas of the country.

The NMRP also cooperates with the new Farming Systems Research Project in conducting on-farm trials in a limited number of districts.

Post-harvest research
The NMRP does not do post-harvest research on maize *per se*. Other institutions, such as the Sokoine University of Agriculture, the Pest Control Project, the Tropical Development and Research Institute and the Tropical Pesticides Institute have collaborated with other local institutions in conducting research on maize storage pests, including the larger grain borer (*Prostephanus truncutus*).

Utilization of Improved Seed

Prior to 1973, when the national foundation seed farms and the Tanzanian Seed Company were founded, very little improved seed was used; most farmers used their own seed. Since that time, the use of improved seed has increased (Table 3), although even now many farmers do not use it for a number of reasons, such as cost, delivery problems and a lack of knowledge as to the importance of quality seed.

The Future of the National Maize Research Programme

Although contracts with outside organizations have been concluded, it is expected that there will be no disruptions in research; most local staff who were away for training have finished their studies and returned to the program. Due to its being such an important food crop, maize is now getting the research funding it deserves. Periodically, producer prices have been reviewed and increased by the government as an incentive to higher production. Concerted efforts also need to be made to see that research results reach the farmers.

Table 3. Utilization of improved seed, Tanzania, 1972 to 1984[a]

Season	Seed (tons) Hybrids	Open-pollinated varieties	Total
1972-73	420	1	421
1973-74	666	109	775
1974-75	1366	1050	2416
1975-76	1484	1638	3122
1976-77	916	2128	3044
1977-78	409	1061	1470
1978-79	2485	1615	4100
1979-80	3022	107	3129
1980-81	2129	1516	3645
1981-82	1525	851	2376
1982-83	1909	1465	3374
1983-84	2537	1114	3651

[a] Based on information from Tanzania Seed Company, Ltd.

Discussion

Mr. Haizelin: What are the origins of populations 10 and 12 in Table 1 for streak resistance?

Dr. Moshi: They come from the CIMMYT and IITA streak programs in which Tanzania has participated.

Ethiopian delegate: How can local maize types be conserved when national seed companies are activily distributing improved seed?

Dr. Moshi: Local germplasm has been included in our new composites, so they are not really lost. In addition, international research centers are making an effort to collect and maintain local types.

Dr. Gelaw: The International Board of Germplasm Resources has also made extensive collections of local types.

Dr. Darrah: Wouldn't it be well to include a list of composites and their progenitors in the proceedings of this workshop?

Note:
This suggestion was agreed to by the workshop delegates.

Mrs. Chungu: When a composite or hybrid is released by national programs, perhaps there is a need to indicate its potential yield at low- as well as high-management environments.

Dr. Gibson: There is a similarity in the genetic sources and responses of Tanzanian and Zambian materials. This indicates the potential advantage of cooperation between national programs.

Maize Research and Seed Production in Uganda

E.R. Xaahwa and F. Kabeere, Uganda Seed Project,
and E. Rubaihayo, Kawanda Research Station, Uganda

Maize was introduced into Uganda in the last quarter of the 1800s and had become an established crop by 1900. Its production is still at the subsistence level, although there are a few commercial maize farmers in the country.

Since 1965, Uganda government policy has been the encouragement of maize production in the country, with the objectives of ensuring self-sufficiency for domestic requirements and having a surplus for export. Maize is one of the main components in the country's diet and increasingly has become a source of income for farmers. The government's support for maize production has included sales of farm machinery to farmers, rentals of machinery at low rates for the preparation of seedbeds on a large scale, provision of improved seeds at low cost (in some areas) and a market for any surplus maize at a guaranteed price.

Maize is the only cereal exported in any quantity in Uganda. Up until the early 1970s, maize was grown mainly as a food crop, but since then it has become a cash crop, along with coffee, cotton, tobacco and tea. A large quantity of maize grain is exported to neighboring countries each year.

Marketing is organized in such a way that part of the crop is retained by the farmer for his own consumption, and another part is sold in local markets to consumers or traders, either in the green stage or as grain, depending on customer preferences. Any surplus is bought by the government through organized cooperatives and eventually is channeled into the milling industry. Part of that maize is redistributed throughout the country for internal consumption, and part is exported.

Maize research began in Uganda in a very limited way in 1927, with the evaluation of introduced varieties. The program was intensified in 1951 as a result of an outbreak of rust (*Puccinia polysora* and *P. sorghi*) in West Africa. Whenever conditions in the country have been sufficiently stable, new varieties have been released by the program. Two varieties, White Star and Western Queen, were developed in the 1950s and released to farmers in 1960; Kawanda Composite A was developed between 1968 and 1970 and released to farmers in 1971. The scarce research funds allocated to maize are now used for experimentation for solving problems in the short term; research which is not problem-oriented and whose results will only be realized in the long term is conducted by the University.

The maize breeders in the program have tried to carry out a continuous and coherent maize research program, avoiding the termination of experimentation before conclusive results have been realized, but due to problems in the country, this has often been inevitable; it is a frustrating situation for researchers and has not been conducive to productivity. The lack of facilities of the Uganda Seed Project for handling a number of improved varieties is also a problem. The variety Kawanda Composite B was developed, improved and ready for release to farmers in 1977; however, it has not yet been released due to the lack of seed multiplication facilities.

Early Efforts in Maize Improvement

In the early 1920s, no work was done for improving maize production, but many varieties were introduced, mainly from South Africa, Kenya and

Tanzania. The introduced varieties were evaluated for yield potential and released to farmers almost immediately. In 1927, the government decided to intensify research into the potential of maize by setting up experiment stations for the development of high-yielding varieties. Many hybridization experiments were carried out, utilizing local varieties and introductions, with the objective of producing varietal crosses that had white grain, relatively low ear placement and were early maturing and high yielding. The work was, however, not consistent; some experiments were abandoned before completion, and all of the varietal crosses made before 1950 were lost.

As a result of food shortages during World War II, maize was produced on a large scale, using seed imported from Kenya, with no initial testing for suitability for Ugandan conditions. Breeding work came to a stop, and only a few cultural experiments were continued. The Kenya varieties did not fit the Ugandan cropping system of two crops per year as they were late maturing, and in 1946, varietal evaluation was resumed at the Kawanda Research Station, the principal maize testing and breeding station. Many local varieties were collected from all of the regions of Uganda. The following procedures were adopted by the breeding program:

- Evaluation of the entire maize collection for yield and maturity over two seasons;
- Initiation of mass selection in varieties surviving the evaluation, and
- Production of varietal crosses by crossing elite varieties from the mass selection experiments.

Experimental plot cultivation, Kawanda Research Station, Uganda

The early mass-selection procedure included the selection of as many plants as possible with good phenotypic expression of grain character, maturity and plant height in open-pollinated varieties grown in isolation; the seed of selected ears was then bulked. This procedure was repeated over two years, with the bulked seed used as the base population, giving a total of four cycles. The improved variety was then increased and distributed to farmers. It is not known what techniques were used for producing varietal crosses from the mass-selected populations. This program was replaced in 1951 by a program for rust resistance.

Breeding for resistance to rust
Epidemics of rust (*Puccinia polysora* and *P. sorghi*) in West Africa in 1950 and 1951 caused crop losses of up to 70% in some places. The East African countries were warned of the disease and the East African Agriculture and Forestry Research Organization (EAAFRO) began research late in 1951. A survey of East African countries indicated the existence of the disease in the coastal areas of Kenya and in some parts of Uganda.

As it was believed that rust was indigenous to Central America, it was assumed that rust-resistant maize strains should be availabe there. The plant quarantine section of EAAFRO, stationed at Muguga in Kenya, introduced 152 varieties and lines from Mexico, Colombia and Purdue University in the USA. In addition, the 25 most promising varieties were collected within East Africa. The entire assemblage of material was subjected to intensive greenhouse testing at Muguga, and standard techniques for testing for resistance were established to be followed by the three participating countries, Kenya, Tanzania and Uganda. Comprehensive studies of the pathology of their maize crops were made by each of the countries. By late 1953, some F_1 seed was available at Muguga from selections of early maturing varieties. These were sent to Kawanda Research Station (Uganda), Kibarani (Kenya), Kizugu (the EAAFRO station in Kenya) and Nachingwa (Tanzania) for field testing.

The techniques used to assess field resistance were designed to detect resistance of single plants and to detect segregation for resistance to clarify the differences between resistant and susceptible plants both within and between entries. The method was also meant to indicate whether there was a genotype x environment x location interaction at the four locations where field resistance tests were being conducted.

The response of plants to the rust inoculum were classified according to the following scale:

- 4 Disease symptoms expressed from early stages of plant development (most susceptible class)
- X Necrotic and chlorotic spots and underdeveloped sori on most leaves (less susceptible than 4)
- 1 Sori developing in chlorotic and necrotic spots
- 01 Necrotic spotting (assumed to be due to *P. polysora*)
- 0 Few chlorotic spots and small specks on leaves (most resistant class)

Lines developed from AFRO 29, which had a Colombian background, were found to be resistant. Genetic studies conducted at Nachingwa in Tanzania established the existence of two simply inherited dominant resistance genes, $R_{pp}I$ (completely dominant) and $R_{pp}II$ (incompletely dominant). These genes could be differentiated on the basis of their response to the two different races of *P. polysora* which were identified at Muguga, East Africa I and East Africa II; they were believed to be indigenous to East Africa.

Intensive studies were carried out to establish the response of resistant materials to these two races, as it was assumed that the American material was potentially susceptible to East African rust strains. It was found that gene $R_{pp}I$ conferred resistance (class 0) to the rust race EAI, but was susceptible to EAII. Gene $R_{pp}II$ gave a range of responses from 0 through X, and sometimes even 4, against both races of rust. Since the response of $R_{pp}I$ was more reliable, and since EAI was predominant and more severe, it was decided that the East African countries should use materials crossed to the Colombian lines carrying the resistant gene $R_{pp}I$ during the preliminary field resistance tests conducted in 1953 and 1954 (9).

The objectives of the field tests were to assess resistance to rust and to breed resistant lines. The F_1 progenies which were distributed from Muguga in 1953 were handled at Kawanda as follows:

- 1953, season A—F_1 lines selfed and evaluated for response to natural inoculum in the field (infected leaves had been placed in the field to ensure disease spread)
- 1953, season B—confirmation of first season results
- 1954A—hybridization carried out with local materials being crossed with sources of resistance
- 1954B—F_1 generation selfed
- 1955A—F_2 seed grown and resistant plants selected
- 1955B—F_2 resistant plants selfed to isolate homozygous resistant plants
- 1956A—homozygous resistant lines backcrossed to local varieties

After the second season of 1956, backcrossing was continued without having to self and isolate homozygous lines, but in each backcross generation resistant plants were selected.

As a result of this program, four synthetics were developed:

5314 RRM58—dent, with gene $R_{pp}I$
5314 RRM58—flint, with gene $R_{pp}I$
5354 RRM58—dent, with gene $R_{pp}II$
MH59—dent, with gene $R_{pp}II$

The first two synthetics had the same parents, but the progenies were selected to establish two subpopulations with different kernel characteristics. MH59 was a varietal cross between two local varieties, Muratha and Kawanda 8.

In 1959, these four synthetic varieties, as well as the local variety Muratha and their nonrecurrent exotic parents, were evaluated for yield in replicated trials. 5314 RRM58 (White Star) and MH59 (Western Queen), the byproducts of this program, were increased and released to farmers as commercial varieties in 1960. Since Western Queen matured about two weeks earlier than White Star, it was recommended for the western region of Uganda where the growing season was shorter. White Star was recommended for the southern, eastern and central regions (9).

Between 1960 and 1968, there were no qualified breeders in the maize program, but an agricultural assistant continued to maintain the breeding stocks; he also made several introductions which were evaluated in preliminary trials until the time that a maize breeder would be available. An adequate supply of seed of Western Queen and White Star for farmers was maintained.

Maize Research Since 1965

In 1965, the government decided to expand the maize breeding program in order to produce improved varieties and increase maize production in Uganda. Though comprehensive breeding systems which had been developed at Kitale, Kenya, were available to Uganda, there were no qualified breeders to utilize them until 1968; then the development of Kawanda Composite A began, using the comprehensive breeding system which is currently widely used in Africa. In Uganda, the system is used for the improvement of millet and sorghum as well as maize, and it appears to be quite effective. The breeding system involves four phases:

- Evaluation of breeding materials
- Compositing the breeding populations
- Improvement of composite populations
- Release as commercial varieties

The Lonquist modified ear-to-row breeding method (1964) was used in the formation of Uganda's first composite, Kawanda Composite A (KWCA). Sixteen varieties and hybrids were selected to constitute the composite. The most promising hybrids and synthetics included more than one entry, thus increasing the number of entries from 16 to 36. These pedigrees are shown in Table 1.

Procedure

The entries were planted in replicated yield trials and detasseled. The male rows, which were composed of a physical bulk of all entries in equal proportions, were planted between female rows and around the entire trial to provide pollen. This procedure allowed maximum recombination among genotypes while making possible the elimination or replacement of less desirable entries at an early stage (2). Five percent selection intensity was used in the first cycle when the entries were relatively pure; this was changed to 25% in the second and third cycles and to 50% in the fourth cycle.

The objectives were to use the composites as commercial varieties as well as base populations for the development of others, such as synthetic varieties derived from advanced generations of population crosses for areas where hybrid production was not feasible. The crosses of two populations from inbred lines as varietal-cross hybrids, single, double or three-way cross hybrids were developed from elite material after each cycle of selection. A practical consideration was the ease of developing composites, especially since trained personnel was limited at the time the program was initiated.

Kawanda Composite A was recommended for commercial production in the long-rain, maize-growing areas in 1971. It is rather late maturing (133 days) and requires early planting. White Star is still recommended for the short-rain areas and for late-planted maize crops because of its early maturity (115 days). Western Queen is no longer commercially produced as it is highly susceptible to maize streak virus (9).

From 1972 to 1974, a second composite, Kawanda Composite B (KWCB), was successfully developed, and since then research has centered on the improvement of these two composites using mass selection, S_1 testing and full-sib and reciprocal recurrent selection. Progress was made between 1972 and 1976, but after that it became increasingly difficult for breeders to carry out research. The climax came in 1977 when the East African Community was discontinued. Then it was no longer possible for Ugandan breeders to collaborate with fellow maize breeders in Kenya, and they could not use the computer service in Nairobi for the more extensive experiments. Also, the cold storage facilities in Kitale were no longer available, with the result that many breeding materials were lost or damaged under ordinary storage.

Table 1. The components which constituted Uganda's first composite, Kawanda Composite A (KWCA)

Entry no.	Pedigree
1	Western Queen (or MH59), from a cross of improved Muratha KM54 x K.8
2	White Star (or 5314 RRM58), from a cross of Muratha x *P. polysora*-resistant material
3	KM54, improved Muratha
4	5354 RRM58, from a cross of Muratha x *P. polysora*-resistant lines
5	BR11, Muratha selection for bird resistance
6	BR29, Muratha selection for bird resistance
7	24 RRM58 x 56007, original Muratha x Machakos variety
8	SR8, streak-resistant Muratha
9-12	Four entries of SR52, Zambian hybrid ex Malawi
13-14	Two entries of Zambian Local Composite
15-16	Two entries of Malawi variety Askari
17-2-(Y)[a]	Four entries of Embu Composite 1
21-24	Four entries of hybrid 632
24-28	Four entries of Kitale Composite B
29-32	Four entries of Kitale Composite E
33-36-(Y)[a]	Four entries of Kitale Composite E x ACX Katumani A x (CBK1)Y

[a] Y = entries with some yellow color

East African Maize Variety Trials
Apart from developing and improving maize composites, Uganda participated in the annual East African Cooperative Maize Variety Trials from 1955 to 1977. The purpose of these trials was to test the maize varieties developed in East Africa under the varying ecological conditions of Kenya, Tanzania and Uganda. As a result of the trials, some hybrids developed in Kenya, such as H632, have been widely grown in some parts of Uganda where they perform better than local varieties.

International Maize Varity Trials
Uganda has also participated in the International Maize Variety Trials organized by CIMMYT after 1971; this has been the main source of diverse genetic material for the Uganda breeding program. Kawanda Composite B is composed of materials tested and selected under this program. KWCC and Opaque-2 Composite were also developed with materials from CIMMYT, but they have been lost. Uganda also participated in the OAU/STRC West African Uniform Maize Trial and the FAO Regional Cooperative Maize Yield Nursery, but could not continue as so many constraints prevented the achievement of the goals of the trials.

Maize Research Constraints

The constraints to maize research are many. Staff morale dropped during the time of severe national problems, and many facilities were not available. These included cold storage, greenhouses and computer services, as well as inputs such as timely land preparation, fertilizers, insecticides, waterproof bags, harvesting bags, proper field labels and stationery. In the 1970s, facilities were destroyed, and the problems reached a climax with the liberation war in 1979. Funds are now limited for the rehabilitation of facilities. Also, there is no maize pathologist or virologist in the program to assist in disease resistance work. The only resistance presently available is field resistance, and this is not reliable; hence, maize streak virus disease is rampant in spite of the intensive and extensive selection for resistance conducted since 1968.

Maize Seed Production

The need for improved, high-quality maize seed was recognized by the Uganda government over 20 years ago. The beginning of organized maize seed production began in 1968 with the establishment of the Uganda Seed Project; before 1982 it was called the Uganda Seed Multiplication Scheme. Seed of various food crops, including maize, was handled by the project. In 1970, the British government, through its Overseas Development Agency (ODA), provided a grant to finance a pilot seed project. With that grant, a seed testing laboratory, offices and staff houses were constructed, equipped and furnished, and machinery was purchased and installed. Vehicles, inputs and supplies were provided for all of the production activities. With the technical assistance section of the grant, a basic seed production structure was established, and staff were trained on the job.

With this assistance, it was planned that the production of improved seed would increase annually. However, British aid was withdrawn in 1973 and the seed production program was continued by the Uganda Seed Project. In 1976, the Karamoja Seed Scheme, sponsored by the Church of Uganda, was also started for providing the

Karamojong with seed for various food crops, including maize. This scheme mainly caters to one district of Uganda, but surplus seed is sold to neighboring districts which have similar ecological conditions.

The production of breeder seed and variety release

Plant breeders at the Kawanda Agricultural Research Station produce improved varieties of maize and other food crops. Maize breeder seed production has now been moved to Kigumba Experimental Station near Masindi, and all maize breeding is expected to be carried out there in the future. Breeder seed is released after the variety has been tested in various district variety trials and has been approved by the National Variety Release Committee. Since 1960, three varieties, Western Queen, White Star and Kawanda Composite A have been released and multiplied. White Star and Western Queen were released for the northern and western areas of Uganda, respectively. Since 1972, KWCA has been the principal variety in the improved seed multiplication program. Katumani, a Kenya variety, is used by the Karamoja Seed Scheme for that semi-arid region.

Seed multiplication

For certification purposes, after a variety is released, the breeder seed is multiplied in three stages, foundation, registered and certified seed. Currently, the foundation and registered seed stages are multiplied separately at Kisindi Seed Farm, a project partly funded by the European Economic Community (EEC). Multiplication of certified seed is carried out on government and contract growers' farms in Masindi, Gulu and Apach districts, the seed production areas in the midwestern and northern regions of Uganda. Arrangements are now underway to extend seed production to other parts of the country.

Seed production targets for each year are worked out in advance and form part of the annual plan of work. There is always room for flexibility to allow for weather factors, shortages of inputs and other problems during the season. Further measures needed to ensure continuity in seed production and availability include adequate and timely funding of the various operations.

The only seed-processing facility is in Masindi, but it is hoped that other centers will be set up in other parts of the country in the future. The Karamoja Seed Scheme has its own seed production and processing center in Kotido District.

When growing a maize seed crop, care is taken that no other maize of a different variety or earlier generation has been planted in that field for at least one previous season; this is to avoid contamination by volunteer plants. Only one variety of maize is grown on any one farm during a season. Recommended isolation distances for different stages of seed multiplication and proper agronomic practices are followed (Table 2). The crop is harvested when the ears are dry, but they are further dried in maize cribs to maintain seed quality.

The harvesting and shelling of maize seed is still manual, and sun drying is practiced by contract growers and on the project farms; artificial seed-drying machinery has just been installed at the seed processing facility. Each farmer harvests, dries and shells his own maize seed with guidance from project staff members. In order to improve the quality of seed, the project plans to assist contract growers with shelling and with storage facilities.

Seed quality control

At each stage of seed production, the quality of the seed is controlled by the staff of the Seed Quality Control Division of the Uganda Seed Project. Seed quality is guided by the established minimum seed certification standards of the Uganda Seed Certification Scheme (Table 2). Seed certification laws are being studied with a view to formulating relevant ones for Uganda. Currently, the only agreement between the project and the contract growers is a mutual understanding. It is planned that seed quality control services will be autonomous, so as to control the quality of seed effectively and without bias.

The seed crop is inspected by project seed inspectors who check on seed sources and history, agronomic practices, isolation distances, off-types, presence of other varieties, and diseases. Although not seed-transmitted, maize streak is currently seen as an objectionable disease due to its bad effect on yield; it is currently the major maize disease in Uganda. Studies to establish standards for the presence of maize seed-borne pathogens are being conducted. Roguing of off-types and other varieties is done before tasseling. The failure of a crop to reach certification standards leads to its being rejected as a seed crop.

Table 2. Seed certification standards, Uganda

Characteristics controlled	Minimum seed certification standards		
	Foundation	Registered	Certified
In the field			
Isolation distances	400 m	300 m	200 m
Off types	None	1 in 300 plants	1 in 200 plants
Other varieties	None	1 in 200 plants	1 in 200 plants
Disease symptoms (maize streak)	1 in 300 plants	1 in 300 plants	1 in 200 plants
In storage			
Off-color ears	None	1 in 2000 ears	1 in 2000 ears
Moisture content	11 o/o	12 o/o	10 o/o
In the laboratory			
Moisture content	11 o/o	12 o/o	12 o/o
Presence of seeds of other varieties	None	0.50 o/o	0.50 o/o
Presence of other crop seeds	None	0.50 o/o	0.50 o/o
Purity	98 o/o	98 o/o	98 o/o
Germination	85 o/o	85 o/o	80 o/o

After harvest the seed crop is inspected for quality, and the quantity to be harvested is established; only inspected seed is purchased. Moisture content is checked on the farm, and if it is too high the farmer is advised to further dry his seed. Then seed samples are submitted to the seed testing laboratory where moisture content, purity and germination tests are carried out. On passing the laboratory tests, the seed is taken by the project from the farm to the processing center. The price paid to the farmer is revised from time to time and is approved by the Central Tender Board. It usually includes a premium which takes into consideration the special care needed to grow and prepare seed for collection by the project.

Seed processing
Most of the handling of the seed during processing is manual. In the seed facility, it is cleaned, graded and treated with an insecticide and a fungicide; a Dieldrin-Vitaflo combination is currently used. After processing, seed lots are bulked into 20-ton lots. The seed is then bagged in labeled polypropylene bags of 10 and 25 kg capacity, enough to plant one acre and one hectare, respectively.

Seed marketing and distribution
Seed is usually marketed and distributed by the farmers' cooperatives. Since 1972, the Uganda Cooperative Central Union has been the main agent for marketing improved seed. However, project seeds are also sold at the Uganda Seed Project offices at Kawanda, Masindi and Gulu. It is hoped that, in the future, each district will have a depot for improved seeds, so that it will be more available to small-scale farmers. The Seed Marketing Division of the project also carries out research on seed marketing and distribution in close collaboration with the Extension Service of the Department of Agriculture.

Maize seed demand and production constraints
Approximately 10,000 tons of maize seed is required to meet the annual needs of Ugandan farmers; of this, only about 3,600 tons is improved seed. This requirement has been arrived at by considering the fact that, for a composite, e.g., KWCA, a farmer may need to buy improved seed only once every two to three years or every four to six seasons. Twenty percent of the total maize requirement is retained as buffer seed.

Table 3 shows figures for maize seed production and imports from 1970 to 1984. Generally, the production of maize seed progressed well during the years 1970 to 1974 and in 1983-84; it registered a general decline during the years 1975 to 1982. The situation worsened during and after the liberation war when the little that remained in the country, including farmer-saved and improved seeds, was looted.

During the period of low production of maize seed, the research activities for breeder seed production also declined. No new breeder seed was provided to the seed project, and finally only certified seed was produced. Inspection and other seed quality control activities declined, and consequently the quality of the seed declined as well.

As a result of these constraints, the importation of large quantities of maize seed became necessary. This caused problems, as the amount imported was not large enough to meet the country's demand. Almost all of the imported seed was also of hybrid maize, which many farmers had not previously used. During some years, when a prolonged drought prevailed, some of the imported Katumani seed, which is only suitable for semi-arid areas, had to be used in other areas as well. These situations resulted in the occurrence of very high maize streak incidence and general crop failures.

The success of maize seed production during the years 1970 to 1974 was attributed to the availability of inputs through the British government grant. Production has now increased again, mainly due to the financial assistance the project is receiving from the EEC. The target is to produce at least 1000 tons of improved maize seed annually for the next two years and, after that, 2000 tons. A steady increase in seed production is anticipated as the project continues to improve its operations.

Conclusions

The g(ernment of Uganda considers maize research and seed production as one of the priority crop production activities. Uganda has all of the required structure and personnel for both research and maize seed production. With the assistance of the EEC and other donor agencies for rehabilitating the seed industry, the future of maize seed, and consequently maize production, in Uganda is bright. It is research that now needs more aid, as the program cannot be effectively financed with scarce government funds.

Table 3. Maize seed production and imports, Uganda, 1970 to 1984

Year	Area planted with improved seed a/ (ha)	Improved seed production b/ (tons)	Imported seed (tons)
1970	160.0	16.8	--
1971	217.0	95.8	--
1972	49.4	14.3	--
1973	186.6	54.3	--
1974	783.7	1012.0	84.1
1975	473.1	139.7	23.4
1976	118.5	70.8	40.3
1977	217.2	81.8	288.7
1978	460.0	104.2	810.8
1979	240.0	68.2	400.0
1980	7.0	14.0	1300.0
1981	20.0	40.0	1700.0
1982	10.0	20.0	--
1983	127.3	354.5	--
1984	142.4	600.5	200.0

a/ Figures do not include areas and amount of seed produced by Karamoja Seed scheme; area planted indicates project farms only

b/ Figures include certified seed produced by contract growers

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Maize Research and Production in Zaire

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Maize, one of the major food crops in Zaire, is grown especially in the Shaba, Kasai, Bandundu and Bas Zaire regions. In the past, Zaire was a maize-exporting country. However, the growing urban population and increasing per capita demand for maize, as well as the use of degenerated varieties and traditional husbandry, forced the country to become a maize-importing nation (imports reached about 180,000 tons in 1980). For these reasons, the government of Zaire recognized maize production as a serious problem, and in 1971 the International Maize and Wheat Improvement Center (CIMMYT) was invited to collaborate in a program to significantly increase domestic maize production over ten years. The resulting agreement stipulated that CIMMYT would leave the program after ten years and that Zaire would continue. Indeed, CIMMYT did leave Zaire in 1981, and the program has moved ahead with local scientists.

Maize Program Objectives

Three main objectives constituted the mandate given to the National Maize Program by the government of Zaire:

- Development and field testing of new maize varieties and new cultural practices;
- Diffusion of the resulting technology packages (improved varieties and cultural practices) to farmers, and
- Indentification and training of potential candidates for maize research in its various fields.

Research Achievements

The Zaire National Maize Program (PNM) conducts research in the disciplines of maize breeding, agronomy and plant protection. The research objectives have always been to increase the production of maize per hectare, so that the country can achieve self-sufficiency in maize production and thereby eliminate the need to use scarce foreign currency for importing maize.

Maize breeding

Prior to 1972 and the creation of the PNM, the farmers from southern Shaba grew an old American maize variety, Hickory King, which has an eight-row flat ear. Those from northern Shaba and Kasai relied on three varieties of maize, GPS4, GPS5 and the hybrid HD11.9.7.2, all of which were developed by the National Institute of Agricultural Research (INERA). All of the materials had low yield potential.

Since 1972, the PNM has developed six high-yielding, widely adapted, open-pollinated varieties. These have successfully replaced the above varieties, which had become degenerated over time. Currently, three varieties, Shaba 1, Salongo 2 and Kasai 1, are being released, the first for high altitudes and the other two for low and midaltitudes.

The PNM varieties have yielded an average of 9 t/ha at the station and from 3 to 5 t/ha on farmers' fields under good technology. They are white dents, although Kasai 1 has some flintiness in its grain. Yield and agronomic characteristics of these varieties are shown in Table 1.

Table 1. Characteristics of three maize varieties released by the national maize program, Zaire

Character	Variety Shaba 1	Kasai 1	Salongo 2
Growing area	Southern Shaba, Kivu (high altitudes)	Northern Shaba, Kasai, Bandundu, Equateur, Haut-Zaire (mid- and low altitudes)	Northern Shaba, Kasai, Bundundu, Bas-Zaire, Equateur, Haut Zaire (mid- and low altitudes)
Genealogy	Tuxpeño x Eto x Shaba	Tuxpeño x Eto	Bulk of remmant seed held at CIMMYT, Mexico, from original 10 families of Tuxpeño-1, cycle 11
Kernel color	White	White	White
Grain type	Flat dent	Flat dent	Flat dent
Plant height (m)	2.35	1.98	2.28
Mean lower ear placement (m)	1.28	1.10	1.23
Days to flower	73	68	65
Vegetative cycle (months)	6	4	4
Ears per plant	1	1	1
Rows of kernels per ear	14-16	14-16	14-16
Mean ear length (cm)	18.9	16.5	16.5
Average shelled grain (%)	85.56	84.43	84.83
Grains per ear	569	515	530

Table 1. (cont'd)

Character	Variety		
	Shaba 1	Kasai 1	Salongo 2
1000-grain weight	440	340	325
Average yield on-station (t/ha)	9	8	8
Average yield on farmers' fields (t/ha)	5	4	4

Through the years, these improved varieties have suffered a decline in yield, so that it has been decided to repeat parental crosses during the 1985 growing season. In addition, diallel crosses are being made between good materials (with promising attributes) that exist in the Zaire collection. During the next season, their progenies will be evaluated and the best ones introduced in variety trials.

In the past, large-scale farmers purchased hybrid seeds abroad (from Zimbabwe, South Africa and the USA). In order to save scarce foreign exchange, the PNM began an inbred-line program in the 1980-81 growing season. Desirable plants that were selected in the Shaba 1 population (with Tuxpeño x ETO, SR52 and H632 as parents) are undergoing selfing. As inbred lines with good general combining ability have reached the fifth generation (S_5) this season, it is hoped that Zaire will have its own hybrids in the near future.

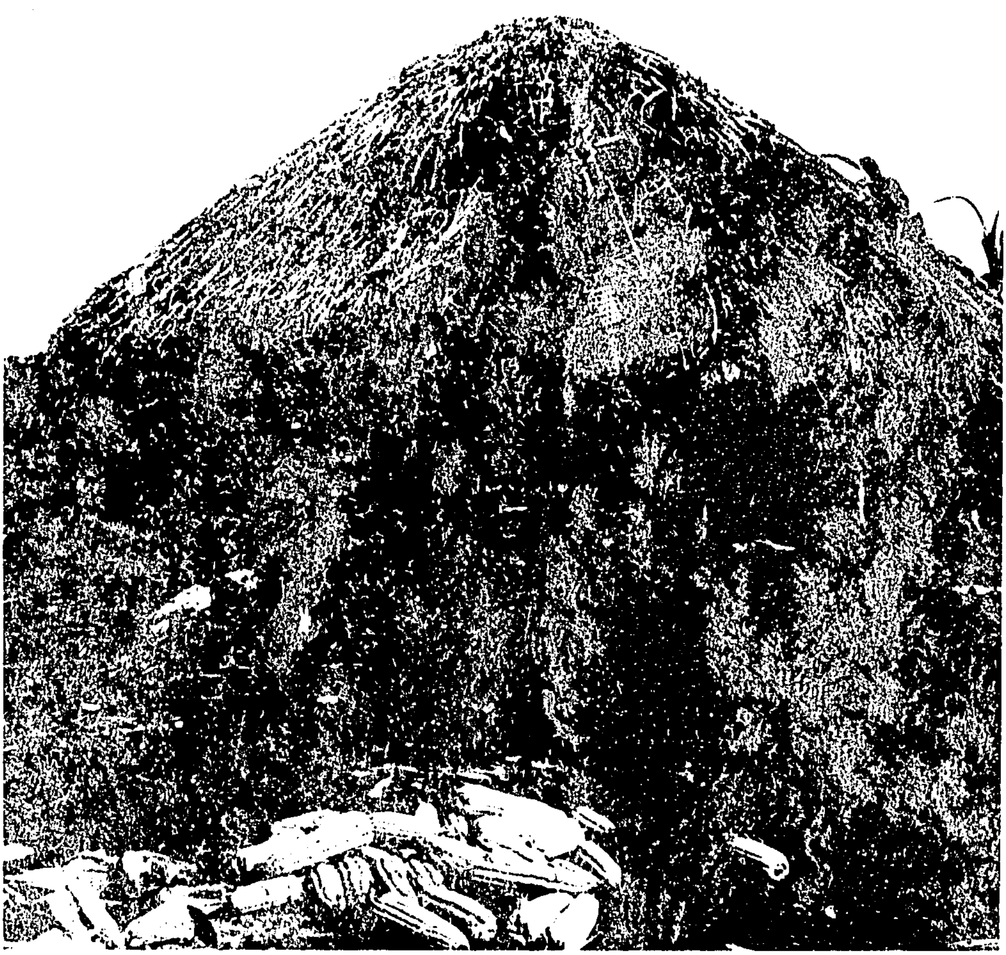
Breeding for resistance to streak virus—Although high yielding, all PNM varieties are susceptible to maize streak virus and downy mildew. Streak virus, which is prevalent throughout the growing area, is transmitted by the leafhopper *Cicadulina mbila* (Nande).

Several steps have been taken for controlling this viral disease, and PNM and CIMMYT scientists have taught farmers techniques for handling it. Also, in 1976, the PNM and CIMMYT, with other African countries, carried out a collaborative program of selection for resistance against maize streak virus. Several families screened for the disease were planted late in the season at Kaniama to hopefully obtain high natural field infestation. The apparently resistant plants were selfed and rescreened in Zaire and Tanzania and then planted again at Kaniama. Noninfected plants within selected families were selfed for one cycle and full sibbed the following cycle, with the best ears recombined to form a new population. Unfortunately this program was discontinued in 1979, because no progress had been made after three years of work; much of the apparent resistance was found to be the result of field escape.

The PNM has also cooperated with the International Institute of Tropical Agriculture (IITA) on streak virus work. In 1978, PNM received several full-sib families and S_1 lines from IITA, and they were evaluated for streak virus resistance at Kaniama and Gandajika. Families that were selected under natural infestation were planted late in the growing season at Kisanga.

The best families identified as Zaire streak resistant (ZaSR) were crossed with PNM varieties. The ZaSR6 family was chosen as the source of streak virus resistance, since the cross between PNM varieties and ZaSR6 (F_1 progenies) was found to be the best; it was also outstanding agronomically. The best plants selected from these F_1 progenies, and grown under a high level of natural infestation, were selfed to provide F_2 progenies. They were then evaluated and the best ones recombined to form S_1s. Since 1982, the S_1 population has been undergoing recurrent selection at Kaniama, Gandajika and Kisanga.

Breeding for resistance to downy mildew—Parallel to the program of selection for resistance to maize streak virus, the PNM, also in collaboration with CIMMYT, has been evaluating several materials for resistance to downy mildew, which is a serious problem in maize at low elevations. Some of the materials which showed some levels of resistance to downy mildew were selected and then bulked to form a variety (DMRF) to be used as



Grinding maize for family consumption, Zaire

a source of resistance. This variety was crossed with PNM varieties (F_1 progenies), and the best plants were planted late in the growing season. They were selfed to provide F_2 progenies, which are presently undergoing recurrent selection at Kaniama and Gandajika.

Today, materials are being screened for resistance to both maize streak and downy mildew in order to get a unique source of resistance, which can be incorporated into PNM varieties for the lowland areas where the two diseases are serious problems.

Agronomy research

The PNM has studied several factors that determine the success of the maize crop, including planting date and density, weed control, fertilizer use, and soil improvement by means of intercropping and rotation.

Planting date and density—The planting date trials conducted by the PNM in the maize-growing areas have demonstrated that, for high yield, maize should be planted during the month following the first good rain (of at least 25 mm of accumulated rainfall). Maize planted later than that undergoes many stresses (diseases, insect attack and lack of moisture) and yields are poor.

Small-scale farmers throughout Zaire used to grow maize on raised beds, 40 to 50 cm high, with an average spacing between beds of almost 1 meter. The PNM has carried out several trials with this traditional practice, and as a result of these experiments, recommends planting maize in rows of 25-cm intervals with one plant per hill or at 50-cm intervals with two plants per hill, both with a spacing of 75 cm between the rows. This results in about 53,333 plants per hectare.

Weed control—As is generally known, weeds compete with maize for light, nutrients and water, and as a result can substantially reduce yields. The PNM has found that, for maximum yield, fields should be weeded twice, first about three weeks after planting and then approximately six weeks after planting. The second weeding often coincides with sidedressing the crop with nitrogen.

Fertilizer use—The results of fertilizer trials carried out over a wide range of environmental conditions in Zaire's maize belt, and the limited availability and high cost of fertilizer, have led the PNM to recommend for small farmers a low dosage of fertilizer per hectare, 64 kg of nitrogen and 46 kg of phosphorus, an amount which gives an economic return. For large farmers with enough capital, the recommendation is for 150 to 180 kg of nitrogen, 120 to 180 kg of phosphorus and 90 to 120 kg of potassium per hectare. The use of potassium is justified by the high utilization of this nutrient with intensive maize production.

Studies on the timing of fertilizer application have led to recommendations of one application of phosphorus at planting and of split nitrogen applications. The PNM has found that one-third of the nitrogen should be applied at planting and the remaining two-thirds as sidedressing when the maize plants have attained a height of 50 to 75 cm.

After studying various fertilizer formulations suitable for maize, the PNM concluded that urea (46%) and diammonium phosphate (18-46) gave the proper balance of nitrogen and phosphorus, and if applied at the right time, were best for small farmers. These fertilizer formulations have the advantage of being highly concentrated, thus lowering transportation and storage costs, as well as being more manageable by the farmers. At present, PNM is also studying the residual and additional effects of fertilizer when applied on a maize crop being grown on virgin, unimproved soil. In each case, the cost and limited availability of fertilizer in Zaire have been considered.

Soil improvement—Research has been conducted by the PNM on different types of soils in the country, and they have found that the introduction of legumes, such as *Crotolaria caricea*, soybeans (*Glycine max*) and cowpeas (*Vigna unguiculata*), in a continuous maize-cropping system has maintained or improved the chemical and physical properties of the soil; this eliminates the need to abandon fields to long fallow periods. However, even though sufficient nitrogen is fixed by crotolaria, this legume is not recommended since it is not a food crop. Therefore, the PNM recommends either soybeans or cowpeas for rotation with maize.

Intercropping—In intercropping trials, PNM has found that maize intercropped with legumes yields less than maize grown alone. This is due to the fact that legumes compete with maize for light, water and nutrients. As a result of this problem, trials for determining planting date and density of legumes when intercropped with maize are underway.

Plant protection

As stated earlier, all PNM varieties are susceptible to streak virus and downy mildew. Until resistant varieties to these two diseases become available through the breeding program, PNM has recommended as control measures early planting, rotation, weed control, and for large farmers, the use of fungicides such as Ridomyl 50-W.

Insects have not been found to be a serious threat to maize in Zaire. However, since there has been a shift from traditional practices to new packages of technologies and since the area under maize production has increased, insects, such as *Busseola fusca*, *Heliothis armigera*, *Agrotis* spp. (cutworm) and *Spodoptera* spp. (army worm) could become a serious problem. To keep ahead of this possible problem, PNM has begun to screen Shaba materials under natural infestation in an attempt to get a source of resistance to *Busseola fusca* and to *Heliothis armigera*. This problem has also been addressed by testing the efficiency of other control measures, such as planting date, rotations and intercropping, sanitation, weed control and the proper use of appropriate insecticides.

Extension Activities

The PNM started extension activities in southern Shaba during the 1972-73 growing season, and in the following seasons, extended its activities to northern Shaba and the Kasai regions. It used as its strategy farmer demonstrations (or diamond demonstrations for more advanced farmers) to teach the farmers to increase their maize yields by using new packages of technologies (improved varieties and sound agronomic practices).

The farmer demonstrations, planted on a quarter to half a hectare, were next to farmers' fields where maize was grown in the traditional way. During these demonstrations, the PNM staff met several times with the farmers, emphasizing the use of new technologies. This technique had remarkable success among small-scale farmers, and as a result, the PNM also assisted the farmers technically in many villages in southern Shaba and provided them with credit for fertilizer and improved seed. To increase the efficiency of this system, the PNM appointed a well-trained extension worker (at the A3 level) to work with the farmers.

Because of economic problems, extension activities had to be curtailed in the 1975-76 growing season and suspended in the 1980-81 growing season. Since 1981, the PNM has released its new technology either directly to farmers around its stations or indirectly through private and official organizations, such as the North Shaba Project (PNS), Kasai Oriental Maize Project (PMKO), Lubudi Project, the Rural Development Center of Mueka (CIDERIM), CEPSE (Gécamines), church groups and the Department of Agriculture.

Training

To date, 22 agronomists and four assistant agronomists have been trained at CIMMYT, Mexico. Nine have gone to graduate school in US universities. Six received masters of science degrees and three others, PhDs in various fields. Because of economic difficulties (salary and facilities), most of that staff have left the program. Today, the program has only one PhD, two with master's degrees and seven agronomists with bachelor's degrees.

Fortunately, a new program has been designed, which will also involve the PNM, the national manioc program (PRONAM) and the national legume program (PNL). One of the areas of emphasis for this program will be the training of potential candidates for research on each of these crops.

Seed Production

In the beginning, PNM produced both foundation and commercial seed, although the production of commercial seed was not a principal goal. The responsibility for producing commercial seed was taken over by private or government organizations once the seed became available.

Since the 1979-80 growing season, PNM has produced the foundation seed of Shaba for high-elevation areas and Kasai and Salongo 2 for intermediate and low-elevation areas. The foundation seed is sold to official and private organizations, such as Kaniama Kasese, PNS, PMKO, Lubudi Project, CEPSE and church groups which produce commercial seed to be sold to farmers. PNM still produces a small amount of commercial seed to fill the needs of those farmers who live around its stations.

Maize Production Constraints

The following factors impede Zaire in its goal to obtain self-sufficiency in maize production:

- The shortage of funds, which does not allow the PNM to purchase the necessary supplies, such as breeding materials, fertilizers, pesticides, vehicles and laboratory equipment;
- The shortage of well-trained personnel in both research and extension, since many have left the program because of poor job incentives;
- The lack of well-trained, production-oriented extension agents (one per 1000 farmers);
- The lack of a well-organized marketing system (roads, especially in agricultural areas, are in most cases poor, and there is a shortage of transportation to ensure the movement of agricultural products; a better pricing policy is also needed);
- The shortage of fertilizers, fuel, seed and agricultural equipment for farmers;
- The lack of an adequate seed increase, storage and distribution system, and
- The lack of credit, which limits both farmers and businessmen in getting the facilities they need for maize production.

Discussion

Dr. Myers: In looking for ways to improve intercropping yields, you suggested altering the density of the legume. Other experience has shown that it is more important to alter the maize density.

Zairean delegate: In our case, both densities were high. We were also studying the interaction of intercropping yields with date of planting.

Dr. Darrah: For maximum benefit in intercropping, I would suggest reducing the maize density, making the spacing wider, planting two seeds per hill and breeding for prolificacy.

Tanzanian delegate: Our experience has shown that, at given maize populations, the yield of the legume can be increased with changed spacing.

The Zimbabwe Maize Breeding Program

R.C. Olver, Crop Breeding Institute, Harare, Zimbabwe

The Zimbabwe maize breeding program began in 1932, and since then 14 double hybrids, 4 three-way hybrids, 6 single hybrids and 4 modified single hybrids have been released. The program is totally hybrid orientated, and seed production is undertaken by a cooperative of large-scale farmers, known as the Seed Association of Zimbabwe. Originally the program was based on the open-pollinated varieties Southern Cross, Salisbury White, and to a lesser extent, Hickory King. These were varieties that had been grown and mass selected by individual farmers for about 25 years. The populations were high yielding and well adapted, and the initial inbreds selected from them were outstanding. Some of these early selections are still in use today.

More recently, exotic germplasm from CIMMYT, Europe and the USA, as well as other countries in Africa, has been introduced, and this material has been used in combination with elite local germplasm. In all, 28 composites have been constituted, and these form the long-term genetic source of new inbred lines. All populations have been constituted reciprocally and are being improved by various recurrent selection methods. Some of the composites can be termed relatively short-term, being made up of elite lines derived from locally adapted material; others are medium and long-term, being composed of different proportions of exotic and local material. Some populations have yellow grain, but the majority are white, and they range from early to late maturity. More short-term sources of new inbred lines come from the recycling of existing elite inbreds and introduced lines, as well as from backcrossing.

In recent years, comprehensive use has been made of US germplasm. The elite public lines B73, M017, B79, B84, B14, B37, N28H.t, VA26, A632 and others have been introduced and crossed onto selected local inbreds and selfed. They have also been backcrossed to local and introduced lines, before selfing to create new lines.

The US germplasm initially seemed to be ideal for complementing local material. Locally developed varieties are generally high yielding, but they are relatively poor in standability and stability under stress conditions. The US material is generally good in both of these respects, and by recycling local lines with selected US lines, it was hoped to create high-yielding, stable varieties with improved standability. However, this present wet season has exposed weaknesses in the US germplasm. Generally, this material is rather susceptible to leaf blight (*Helminthosporium turcicum*) and stalk rot pathogens, to which local germplasm has excellent resistance. Thus, whereas US material has shown good stability in fairly dry seasons, it has proved relatively unstable in high rainfall seasons.

One interesting observation made from initial lines developed by recycling and backcrossing local with US material is that lines derived directly from the F_1 do not appear as good as do those lines derived by backcrossing either with the local line or with the US line. It appears that good genes for one environment cannot be regarded as purely additive, but are rather components of a whole system which cannot be disrupted too much without negating the merits of the composite genes.

On average, around 2000 new inbred lines are test-crossed annually in the Zimbabwe maize breeding program, although this number fluctuates from season to season. Generally, a total of 3600 to 4000 varieties are tested in preliminary variety trials every year at two or three sites. The most promising of these new hybrids are subsequently tested more widely in intermediate and advanced variety trials. Four series of intermediate trials are conducted at ten sites each, and one series of advanced trials is conducted at 12 sites. These trials are located on research stations and commercial farms covering a wide range of climatic conditions. In each series of trials, 40 varieties (including commercial standard hybrids) are tested with three replications. Thus, annually, around 170 varieties are widely tested throughout the country.

Maize Trials in the Marginal Areas

In addition to these trials, 20 variety trials testing 15 varieties with two replications are being conducted in various communal areas, mainly in the marginal areas of the country. The objective of these trials is two-fold:

- Observe which varieties perform best under prevailing conditions, and
- Demonstrate good production technology to the farmers in those areas.

The Crop Breeding Institute has been conducting variety trials of several crops in the communal areas for two years, and the initial findings may be of interest to this workshop.

Since one of the objectives of these trials is to demonstrate good production techniques, all trials conducted by the institute are adequately fertilized. Trials are planted at the optimum time, which in the case of maize is generally at the time of the first rains; the land is always winter plowed. Holing out and fertilizing takes place prior to the expected rains, and teams from the institute go out to plant as soon as the planting rains occur. (A lot of guesswork and intuition is required to assess when these rains are going to fall in some of the remote areas, but in two seasons it has been miscalculated only a few times). Too often research workers, through poor planning and poor communication, have not planted their trials at the optimum time, and consequently the farmers' crops have looked better than the research trials. Farmers will never adopt new technology, no matter how proven, unless it can be demonstrated to them that it will benefit them under their conditions. Thus, on-farm trials must be managed efficiently, and yields must be higher than those of the farmers' crops. Only then will farmers readily adopt a new technology. Communication with farmers is also very important, and often if the reasons for new production methods are explained logically, they will try the recommended practices. Generally, the communal area farmers in Zimbabwe are very receptive to new technology that will assist them in achieving greater production.

One of the major differences observed between conducting trials in the marginal areas, as opposed to those on commercial farms and research stations, is that the physical structure of the marginal soils is generally poorer, largely as a result of traditional cultural practices. The communal-area farmer generally removes virtually all the stover from his land to feed livestock. Although manure is occasionally applied to the fields, the soils have become deficient in organic matter and tend to compact severely. This makes good seed emergence difficult, and plant populations are generally well below optimum. Concentrating on this aspect alone could virtually double the yields in the communal areas. Simple techniques like presoaking maize seed can also significantly increase plant stands and final yields. Being aware of the problem will make farmers more particular about their planting methods and timing. A general observation made by the maize research team while traveling in various communal areas of Zimbabwe was that, on average, the peasant farmer was achieving plant stands about half the optimum for the area.

Because of the lack of organic matter in these soils, their moisture-holding capacity is relatively poor and rainfall run-off is appreciable. Moisture retention techniques like tie-ridging and pot-holing are therefore important in the dry season. It has also been observed that manure gives a definite response over and above those of normal chemical fertilizers. However, although manure obviously improves the physical structure of the soil, it appears that minor nutrients like magnesium, zinc and sulfur are also deficient in the soil in many of the marginal areas.

Despite the fact that there are unique problems associated with maize production in the communal areas, the Crop Breeding Institute, through normal production practices this season, is successfully demonstrating that good yields can be achieved there. All but one of the maize trials should yield in excess of 5 t/ha, and many of the sites will yield in the region of 10 t/ha. This has demonstrated to the peasant farmers that, given reasonable rainfall, they can achieve good yields under their conditions.

Objectives of the Zimbabwe Maize Breeding Program

The major objective of the maize breeding program is to breed varieties with greater productivity for all environmental conditions in the country. As opposed to yield potential *per se*, a lot of attention is being given to yield stability, i.e., the ability to yield consistently well under a range of climatic conditions. Maize is particularly sensitive to drought at flowering, when poor pollination can result, but apart from this critical period, it can withstand serious dry spells. The most important single selection criteria for drought tolerance is the ability of the variety to silk early relative to pollen shedding. Having a long pollen-shedding period is also an advantage, and for stress conditions, variable hybrids like three-way and double hybrids have an advantage over single hybrids.

In the Zimbabwe breeding program, various methods are being investigated to facilitate selection for stress tolerance. One relatively simple technique is to grow segregating materials at above-normal plant populations. The competition for moisture increases between plants, and the gap between silk emergence and pollen shedding increases. Stress-tolerant varieties generally pollinate under high population pressure, while drought-sensitive varieties do not. Testing in the marginal areas has also been expanded considerably in recent years, and inbred lines that show good stress tolerance are continually recycled. Selection under stress conditions is also frequently practiced.

Generally, Zimbabwe is following a similar trend in maize breeding to most programs in the USA, aiming to create shorter-statured plants that perform better at higher plant populations. However, the opposite approach, the breeding of prolific varieties that give good yields at low populations, is also receiving some attention, particularly for the communal areas where achieved stands are generally low. As a further exercise in researching for drought tolerance in maize, N.M. Manyowa is investigating the theory that dwarf varieties may peform better than conventional varieties under moisture-stress conditions. Dwarf varieties might conveivably have a lower moisture requirement than taller varieties, and it is possible that they may divert more assimilates into a more extensive root system.

Disease Research

The major maize disease problems in Zimbabwe are diplodia and fusarium ear rots and leaf blight (*Helminthosporium turcicum*). Generally, local material has good resistance to leaf blight but only average tolerance to ear rot pathogens. Surprisingly, some US material has shown reasonable resistance to ear rots, but the heritability of this trait appears low and seems largely dependent on the physical characteristics of the husk.

Various inoculation techniques for diplodia and fusarium ear diseases were investigated in past seasons, but most methods were too severe, resulting in all varieties succumbing to the pathogens. It has been found that spraying spore suspensions of the pathogens in the general direction of the ear has tended to show up the more susceptible varieties, although invariably there are some escapes. However, this latter form of inoculation has proved most satisfactory, particularly in population improvement cycles.

Some breeding for maize streak resistance is also underway, using high levels of natural infections, although at this stage, streak is not regarded as a major disease problem in Zimbabwe.

The Seed Association of Zimbabwe

All varieties released by the Crop Breeding Institute are produced and marketed by the Seed Association of Zimbabwe. The association has a rather unique agreement with the Zimbabwe government that gives it sole right to produce government-bred hybrid varieties. In return, it is obliged to carry over an estimated 25% reserve of seed annually, and seed prices are negotiated between the government, the Commercial Farmers' Union and the association. This tripartite agreement has served the country well, and besides fully providing for its own seed requirements, Zimbabwe has developed a sizeable seed export market.

The Seed Association works very closely with the Crop Breeding Institute, and they make available their research farm, Rattray-Arnold, for preliminary variety testing. In addition to providing the government with the extensive facilities of this farm, the Association itself conducts a large maize breeding program to supplement government research.

The Seed Association breeding program has three full-time maize breeders and one part-time breeder, who developed SR52. Their program has expanded considerably in recent years, and anually they test about the same number of new hybrids as the government maize breeding program. They work with similar types of material as does the government, although they have given greater attention to selection from the original open-pollinated varieties. Breeding for resistance to maize streak and ear rot is also receiving considerable attention in their program.

Before any variety is released from the Rattray-Arnold program, it is first tested and approved by the government. This highlights the excellent working relationship that exists between government research and the Seed Association. The combined breeding efforts of the two organizations should ensure a bright future for maize production in Zimbabwe.

Summary

Much of the credit for the success of the Zimbabwe maize breeding program must go to the early farmers, who as amateur plant breeders mass selected the early open-pollinated varieties until they were elite, high-yielding, well-adapted populations. The fact that these early open-pollinated varieties gave excellent inbred lines that are still in use today is a strong argument in favor of population improvement as a long-term source of germplasm in any breeding program. Since population improvement is such a long-term process, any breeding program should also have short-term sources of improved germplasm. Recycling existing elite inbreds and selfing good, introduced hybrids can yield promising new inbreds in a relatively short time.

Research is well directed and meaningful only if the research worker has a direct link with the farmer. Rescsearchers should involve themselves in on-farm trials as a way to experience the real constraints of crop production. The best way to reach the small-scale farmer is through the use of demonstrations. If new technologies can be demonstrated to work under their conditions, the farmers will readily adopt improved production techniques, provided they have the means to do so.

Communal-area (small-scale) production could be increased significantly if more attention were given to establishing optimum plant stands. Communal area farmers should be encouraged to return organic matter to the soil, as this will facilitate the establishment of better stands. It will also increase effective rainfall by minimizing run-off and so improve the moisture-holding capacity of the soils.

For the high-altitude areas of southern Africa, US Corn Belt germplasm can be useful when it is recycled with adapted local germplasm.

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Contributed Papers

I. Maize Research

Integration of Research Activities and Planning

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Abstract

Integration is the bringing together of researchers of various disciplines and other specialists as a team to attack the constraints that limit the production of a given commodity. To increase the production of any crop, the activities of researchers, extension, economists, national planners and farmers must be integrated, as well as those of workers in seed production, input supply, credit and marketing. A lack of integration is the major reason that increases in agricultural production have been modest in most countries. Also, agricultural scientists must prepare themselves to conduct the type of research that will provide the technology necessary to increase production. They must think on a broad plane and become involved in more areas than the ones in which they specialized. By working as a team, researchers within the various disciplines can deal with the whole agricultural system, working as equals in the crop improvement process and making sure that it flows all the way to and from the fields of farmers. Only the genuine integration of agricultural planning and execution can lead to an adequate world food supply.

It is an honor and a privilege for me to participate in this regional workshop, and I am pleased to have the opportunity to discuss with you the integration and planning of research activities. What do we mean by integration in this context? We mean bringing together all of the elements of research into a team to attack the constraints that limit the production of a given commodity. In this case, it is maize.

To increase the production of any crop, we cannot only consider research. We have to integrate the activities of researchers, extension, economists, national planners and farmers. We also need to coordinate seed production, input supply, credit and marketing. A general lack of integration is a major reason that increases in agricultural production have been modest in most countries.

Let us look at food-surplus countries as an example. What are the factors that have helped them to have those surpluses? They are the countries that have had strong support from the agribusiness community for the input of those factors necessary for increasing food production. Those businesses provide good quality seed and other inputs to farmers, as well as much of the technology to increase food production. They stimulate the availability of sufficient and timely credit to farmers, so that the farmer can capitalize on all inputs. They provide services that are not provided by government agencies.

Today there are too few net food-exporting countries, and the situation of food production is extremely serious. In the majority of the net food-importing countries, the agribusiness community is unable to provide many of the services needed for agriculture. Therefore, there have to be other ways of providing these services, as well as organizing, financing and managing research, extension and other agricultural agencies to meet the challenge of increasing food production. Complete integration is needed for this, and for such integration to be possible, each component of the whole production package must be well organized.

Research

In organizing research programs, the integration of the various professional disciplines involved in agricultural research and production is important. It may seem that this integration should be easy to accomplish; it should just be necessary to call together the people representing the different disciplines to talk about an integrated plan or program. This often happens, but unfortunately it often stops with talk; actual integration does not take place.

How can effective integration be achieved? Do research personnel know enough about one another's fields or specialities to be able to work together to get the maximum benefit from all concerned? It is doubtful that they do, since many are so specialized as a result of their educational experiences that they are not conditioned to think of the broad issues. The years of specifically disciplined thought processes also weigh against integration. However, it is not effective to operate as individuals when the broader issues must be attacked; cooperation and integration become essential. This is a problem that is difficult to resolve, although it is possible. Thinking must be changed to overcome these training shortcomings.

What can be done to overcome such stereotyped thinking? Perhaps the first thing that should be examined is how present ideas and training evolved. Science is a process of evolution, of acquiring knowledge, of fitting together the pieces. In the early days of scientific endeavor, biologists were taught to observe and try to understand what they saw; later, more precise experimentation was employed. Over the years, the various disciplines, such as breeding, entomology, pathology and agronomy, became fields of full-time study, each in its own right. Now these broad fields have evolved and become specialized for delving more deeply into scientific investigation. This process provides the tools that the applied agricultural scientist needs.

Present educational programs provide great depth within a narrow subject, and prepare the student for in-depth type research. We, as agricultural scientists, however, need to prepare ourselves to conduct the type of research that will provide the technology necessary to increase production; we must train ourselves to think on a broader plane. As individuals, we must become interested and involved in more disciplines than the ones for which our basic education and training have prepared us.

Some administrative and budgeting patterns are based on the disciplinary concept. This pattern provides a natural situation for the buildup of jealousy and disagreement; this can lead to a lack of cooperation rather than the necessary integration. Other types of administration encompass all disciplines, although there can still be competition for funds, especially in projects where there is a certain amount of overlapping. As a result, some research might be considered redundant and not worthy of separate funding.

These problems have caused the work of the applied agricultural scientist to be separated by departments or other artificial divisions. Scientists report to different administrative heads and compete, according to their department or other division, for scarce resources. We give lip service to the concept of cooperation and integration, because we all know that it is the only way for long-term gain; however, we do not participate because of the possibility of the loss of personal short-term rewards.

Within this present system, researchers tend to go their independent way unless there is a common recognized reward, such as a joint paper to be published. Scientific papers may play an important role in the dissemination of knowledge, but they are not likely to increase food production *per se*. We must formulate, direct and execute programs that reward true integration with adequate funding and recognition. This requires a new way of thinking about organization and management.

Too often potential reward necessitates that agricultural scientists consider how they should divide their time between basic and applied research. Let us forget these labels and, rather, think in terms of farmers, the basic production unit, and their problems. If we dedicate ourselves to the urgent task of solving their production problems, and apply our mental and physical resources at this level, we can achieve cooperation across disciplines and institutes. We will then be conducting essential research, instead of setting artificial barriers to integration by pursuing disciplinary interests or thinking in terms of basic or applied research.

Research and Crop Improvement

When crop improvement is considered, it is obvious that genes are the hub of the issue. Genes for such traits as yield potential, disease resistance, insect resistance, adaptation and stability must be manipulated in order to produce varieties with higher yield and reduced risk for the farmer. Where do the entomologist and the pathologist fit into the system? In my view, they fit directly into the variety development process. They can provide the artificial infestations and inoculations to put the appropriate pressures on the segregating populations. Their special skills are needed to understand and select the tolerance and/or resistance required in plant materials; they are part and parcel of the gene manipulation and selection process.

The dynamic programs needed today should not follow the traditional concepts of such scientists as breeders, pathologists and entomologists. The biosystem does not, nor has it ever, recognized these disciplines as isolated areas. Instead, crop species have evolved, with the help of man, surviving all of the interactions of the forces of the biosystem that have sorted out the genes and gene combinations available to us today.

Why then should we not break away from the comfort and convenience of studying one isolated sector of the biosystem, and accept the fact that we, as a team, must deal with the whole agricultural system? If this is done, integration of disciplines will be accomplished. We will then have the breeders, pathologists and entomologists working together as equals in the crop improvement process, resulting in a more effective manipulation of genes within a crop species. Superior cultivars will be developed more rapidly, and with effective research management, broader adaptation and greater stability will be achieved.

A step that is often overlooked in research is the simple but important one of variety definition. What must a variety be like to be acceptable to the producer? It is a waste of time to develop a variety, through the combined efforts of the research team, if it does not fit the needs of the producer and the consumer.

We must integrate and organize the research system so that it flows all the way to and from the production fields of the farmer. Only then will the researchers be certain that they have, in fact, put together combinations of genes that are useful and will provide the farmer with a tool for increasing production.

Research and Extension

If is not enough to have integration of disciplines within research; of equal importance is the integration of research and extension, as well as the integration of the two areas with the farm community.

One of the key links which is often missing in the research system is on-farm research. Through this testing in farmers' fields, superior varieties can be identified, and such factors as fertilizer responses, economic rates of insecticides, and plant densities can be validated. These production functions should be examined in cooperation with extension workers and farmers, who must understand that they are an essential part of the research system. The success of this operation is the responsibility of the research staff.

Where in this dynamic system does research stop and extension begin? If a time flow system were developed, we could see that one does not stop and then the other begin; rather, one should flow into the other without a break. In this way, research would not be isolated from the real needs of agriculture, and the researcher's product would have a positive influence on production. Extension would not be isolated from research or the farm community, and therefore appropriate technology and its correct application would reach the farmer.

Farmers, extension and the research staff must get together, work cooperatively, and integrate their respective capabilities. This process will bring the farmers physically and emotionally into the center of the system, so that they can decide which products of research are useful to them; they can help determine, along with the research and extension staff, what research needs to be done. This type of integration recognizes the role of the farmers; their recommendations direct the researchers. Extension and research become full partners as a result of this process.

Some countries have administrative and budgeting structures that actually discourage communication, cooperation or integration among these three groups. There is often a lack of respect, with power struggles among the heads of the different agencies. The farmer, the consumer and the societies that finance these agencies are the losers. In this type of situation, the organizational pattern defeats the very objective it was set up to accomplish. This is the reason that agribusiness has been so important in the food-surplus countries. They have, to a large extent, supplied much of the essential technology that, through their effort, has flowed directly to the farmer.

Why has this lack of cooperation between research and extension been allowed to continue? Again, the system, often run by the civil service, provides the perfect medium for the fostering of a lack of cooperation, rather than integration. There is no incentive for cooperation. Each person receives his salary and his satisfactions from setting his own targets. There is seldom any stigma attached to the individuals or agencies that do not accomplish their objectives.

In the agribusiness community, however, there are great incentives for commercial products (technology) to move to the farmer. The loss of the job for the individual, and the loss of sales for the business, may mean personal or commercial ruin. I am not suggesting that national research and extension systems should operate as a business, but I do believe that we must evolve systems with incentives and penalties that are applied on a fair and equitable basis.

Research and Support Services

Let us assume that organizational systems have evolved that allow the products of crop improvement research to flow to the farmer. There are other concerns that we should have in a totally integrated agricultural system, such as seed production and distribution, the availability of credit and inputs, and marketing.

Seed production and distribution
Seed has been a limiting factor in many situations. There are few, if any, examples in which government seed agencies and seed farms have been very successful in meeting seed requirements. There are also few examples of private seed-producing firms meeting the seed needs in the net food-importing countries. It is of little value to have a successful variety with a successful production technology if there is no mechanism by which the farmer can get seed. Since the development of a seed industry is slow and must evolve over time, interim ways must be found to meet this need.

Traditionally, farmers have saved their own seed, and seed has moved from farmer to farmer. In trying to replace this traditional system with a more sophisticated one, complicated seed policies have often been established that could not be implemented. Perhaps we should change this philosophy and encourage farmers to save seed of their own superior varieties and to sell seed to their neighbors. If we did this, and if the extension worker and the agronomist encouraged it in their on-farm testing efforts, adequate seed quality could be maintained. They could encourage and help farmers throughout the country to grow, promote and sell good quality seed of superior varieties, so that they would not have to depend completely on the more sophisticated approaches that are often not able to fulfill national seed requirements.

Credit, inputs and national planning
Where does credit fit into the total integrated system? Credit agencies often are not agriculturally oriented, and they operate under various bureaucratic systems. This leads to credit not being available at the time appropriate for the farmer. In other situations, it is so difficult to handle the paperwork that farmers find it simpler to go to traditional, expensive credit sources. As a result, credit programs often fulfill the concept of credit to agriculture on paper, but do not actually help the rural community.

Inputs, such as fertilizer, are often unavailable when they are needed. In other cases, agencies not attuned to agricultural needs manage the purchase and distribution of fertilizer, and as a result the correct kinds of fertilizer are not available to the farmer. These agencies need to be closely allied with the research and extension services to avoid this type of costly mistake that wastes precious foreign exchange and does not serve food production.

Marketing and financing policies also must be allied with research and extension, so that they can be geared to the needs of the rural community. Economists and planners often work in isolation from agricultural research and extension, and as a result are not aware of potential rapid changes that can take place in agricultural production. Thus, there are often miscalculations of input requirements or the quantity of a crop that will be harvested. These are costly mistakes, and they could be avoided through greater integration and communication within the total system.

The World Food Picture

Let us also consider factors in the total agricultural system that do not involve food crops *per se*. With the world's repidly expanding population, how much time do we have left to meet our food production needs? At the present rate of population increase, food production per capita is going down; in Africa, per capita food production has been dropping since 1967. How many years will it take to absorb the surplus from food-surplus countries without any increase in per capita consumption?

If there were areas with guaranteed surpluses that could keep pace with population growth, how could that food be distributed? The world transport system is already so overloaded that there are continuous delays in deliveries. Building more ships is not the answer; almost every major port has a continuous line of ships waiting to dock. After food and other commodities reach a country, the internal transport facility is also usually so overloaded that there is a continuous deterioration of imported food before it reaches the consumer. In countries where there are both surplus and deficit regions, the transport system can hardly cope with internal distribution. All of these problems must be of concern when we consider integration, organization and management.

Little additional land remains that can be brought into agricultural production. In fact, in many places, the clearing of large expanses of mountainous land has been of negative value because of erosion. Forestry is part of total agricultural land use, and timber and fuel are in short supply; there must be a balance between the land and resources dedicated to agriculture, animal husbandry and forestry. A lack of balance in planning and carrying out a total agricultural system can have dire consequences in just one generation. What will the situation be for the world's major watersheds? How many years will be subtracted from the predicted life of our major irrigation reservoirs? Let us begin to do whatever is necessary while we still have time.

I have no magic answers, but I plead with the world's planners and policy makers to consider the total agricultural system. We can no longer afford to think and plan only for today and tomorrow. We must think of the next generation, and stop using our natural resources without concern for the future. Furthermore, we must make every possible effort to bring population growth under control. Increased food production in conjunction with lower population growth is necessary to avoid catastrophe.

Summary

Let us return to the general topic, "Integration of Research Activities and Planning." The expertise for achieving our goals is available among the personnel of local, national and international agencies. The interests and activities of these people must be integrated and coordinated to achieve maximum efficiency.

Planning is an integral part of the success of any program. This is not a desk task; rather it requires that the people concerned get into the field to determine what the limiting factors to increased production are, and how these constraints can be remedied. Only then can the production of acceptable varieties through appropriate technology lead to increased food production.

A well-planned, dynamic production program will result in the identification of problems and constraints. As each one is overcome, the next limiting factor can be seen and corrected. Such a program would become progressively more productive each year.

Genuine integration in planning and execution is certain to result in success, if governments can respond with the necessary policy changes and can keep a balance across the total agricultural system. You, as representatives of the various parts of the total agricultural production system, hold the key to increased food production. Only through the integration of your combined capabilities can the key be turned to open the door to an adequate world food supply.

Discussion

Mrs. Chungu: There is a definite need for this integration between research and extension, so that farmers' questions may be answered.

Mr. Mauree: Integration across disciplines is an expensive affair. How can we also integrate across crops?

Dr. Sprague: It may be expensive, but at least personnel should work on a crop as a team. If it is difficult to integrate across crops, at least there should be integration among disciplines within a crop.

Question: Some crops have lower economic returns than others. Should work on these crops be integrated with that on high-return crops?

Dr. Sprague: A balance is needed on efforts devoted to each crop, with consideration being given to their relative importance.

Mrs. Chungu: Our resources often are scarce. Since we can't do everything, guidance is needed for allocating available manpower on a priority basis.

Dr. Trifunovic: The Yugoslavian maize program began with government support, but now the seed industry is self-supporting. It can be catastrophic for a seed industry to have to rely completely on a government budget, as funds for research are often the first to be cut. Seed production is an important matter, and the money generated by the industry should be used to foster integration.

Mr. Ngwira: How much integration is there among crop programs at CIMMYT? Now the emphasis is on adaptive research, involving many crops in the same area, and often there is not sufficient personnel available. Previously, research was carried out on a single-crop basis.

Dr. Sprague: This question will best be answered on Friday, during the discussions on farming systems.

Mr. Ochieng: You suggested that seed regulation laws may be relaxed to allow farmers to produce their own seed, instead of depending solely on the seed companies. This may work for areas using open-pollinated varieties, but it may lead to problems. Don't you think there will be problems of seed shortages during years of poor rainfall?

Dr. Sprague: This problem may be overcome by overproducing during the better years, and carrying buffer stocks over for the years of poor rainfall. I envisage that this will need to be done until the market is saturated and seed companies can meet the seed needs of farmers.

Dr. Gibson: Researchers have job definitions. How can they foster intergration?

Dr. Sprague: The optimum situation would be for each individual to have a spirit of cooperation. Organizations can also foster cooperation by encouraging researchers to work together, sharing rewards and opportunities.

Mrs. Chungu: Training for many of us was not oriented toward an integrated approach. How can we structure training for today's students, so that they get the idea of integrated systems?

Dr. Sprague: I do not expect that a sudden change can take place in our institutions. Our educational systems have become narrower and have drifted more toward basic research.

Universities can help by preparing students with wider perspectives instead of the narrow view of only one discipline.

Mr. Munyinda: You spoke of incentives. What kind of incentives did you have in mind?

Dr. Sprague: When a variety is released, the team should get the credit rather than the breeder alone. It is important that the whole team be recognized for what it has accomplished by being rewarded, for example, by promotions. Penalties for mistakes should also be for the whole team.

Mr. Ngwira: It is difficult to measure the value of research. Quite often credit goes to the extension worker, and this demoralizes breeders.

Dr. Sprague: Many varieties may be developed, but they are not useful unless they are used by farmers. Hence, research and extension ought to be integrated to ensure that the farmer uses the developed varieties along with recommended practices.

Mrs. Sibale: Although breeders are interested in their varieties being utilized, it is unfortunate that they are left to work without sufficient funding and with limited facilities.

Mr. Watts: Is it possible to provide incentives through the civil service? Could research be funded from levies on semiprivate firms?

Dr. Sprague: That is a viable alternative. Historically, commodity marketing and export boards had levies on cash crops. In Mexico, wheat farmers in one region tax themselves, supporting about 50% of the wheat research in the country.

Dr. Trifunovic: Support for research need not come only from seed companies, but also from the various production systems in a country.

Mr. Mauree: Although there is some concern that the status of extension workers is lower than that of researchers, I feel that this is not universally true.

CIMMYT's Maize Improvement Program

R.P. Cantrell, Director, Maize Program, CIMMYT, Mexico

Abstract

The objective of the Maize Improvement Program of the International Maize and Wheat Improvement Center (CIMMYT) is to supply national research programs with essential goods and services for improving maize productivity in developing countries. Among the goods provided are improved varieties, which are developed through the program's population improvement scheme and tested and distributed by means of its international testing network. These varieties are intermediate research products that must be further refined and adapted by national programs before being released to farmers. Other goods and services provided by the maize program are various research methodologies (including approaches to on-farm research) and training, which is offered both at headquarters in Mexico and in the countries whose national programs work with CIMMYT's regional maize specialists. An important task of these staff members is to assist national researchers in identifying and meeting research needs and to pass back to CIMMYT information that may be useful in directing the research conducted there.

The International Maize and Wheat Improvement Center is one of 13 international agricultural research and training centers supported by the Consultative Group for International Agricultural Research (CGIAR). Within the CGIAR system, CIMMYT has a mandate to complement, support and strengthen maize and wheat research and production in developing countries where these are economically important crops. The ultimate aim of this work is to assist developing countries around the world in raising the quantity and dependability of their supplies of food and feed.

The Maize Improvement Program is headquartered and has one of its high-altitude experiment stations at El Batan, Mexico, which is 2200 meters above sea level. The program's other research sites in Mexico (shown in Figure 1) are a second high-altitude station at Toluca (2600 meters), a low altitude, tropical station at Poza Rica (60 meters) and a midaltitude station at Tlaltizapan (900 meters). At Tlaltizapan, both tropical lowland and some highland materials can be grown.

A point I would like to emphasize about CIMMYT's assistance in supplying developing country research programs with goods that are essential for improving the productivity of maize is that those goods and services are *intermediate* research products. We leave the development of final products for farmers entirely to our clients, the national programs; we merely supply the materials from which they can develop those products.

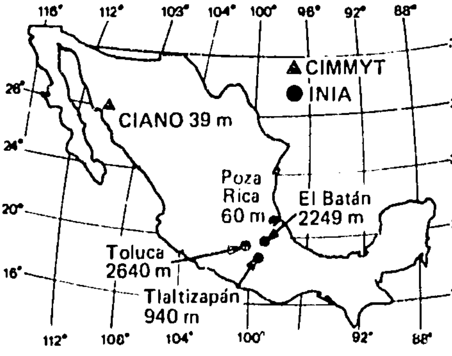

Figure 1. Experiment stations in Mexico where maize is tested, CIMMYT and INIA

The maize program's goods and services, which include not only germplasm but also research procedures, training and information services, are developed and delivered by some 15 scientists working at our headquarters in Mexico and by an equal number of maize researchers involved in bilateral or regional programs outside of Mexico. These scientists represent a number of agricultural disciplines, including genetics, agronomy, entomology and plant pathology.

Germplasm Development

CIMMYT staff members based in Mexico carry forward an extremely diverse but fully integrated germplasm development program that is divided into several units, as shown in Figure 2. In the "back-up unit," gene pools are developed and then subjected to population improvement in the "advanced unit." Quality protein maize (QPM) is the main concern of a third unit, which over the last fifteen years has been working to eliminate various drawbacks (such as soft endosperm and low yields) from the original opaque-2 populations, so as to make them more acceptable to farmers and therefore more useful to national programs.

In all of these plant breeding units, we take a practical approach and aim for results that can have immediate applications in national programs. However, there is also an additional unit that conducts more basic research on wide crosses (between maize and *Tripsacum* or sorghum, for example). Unlike the other units, which produce germplasm for immediate use, the wide cross unit is attempting to develop a greater variability in maize, which may or may not be of immediate use in maize breeding.

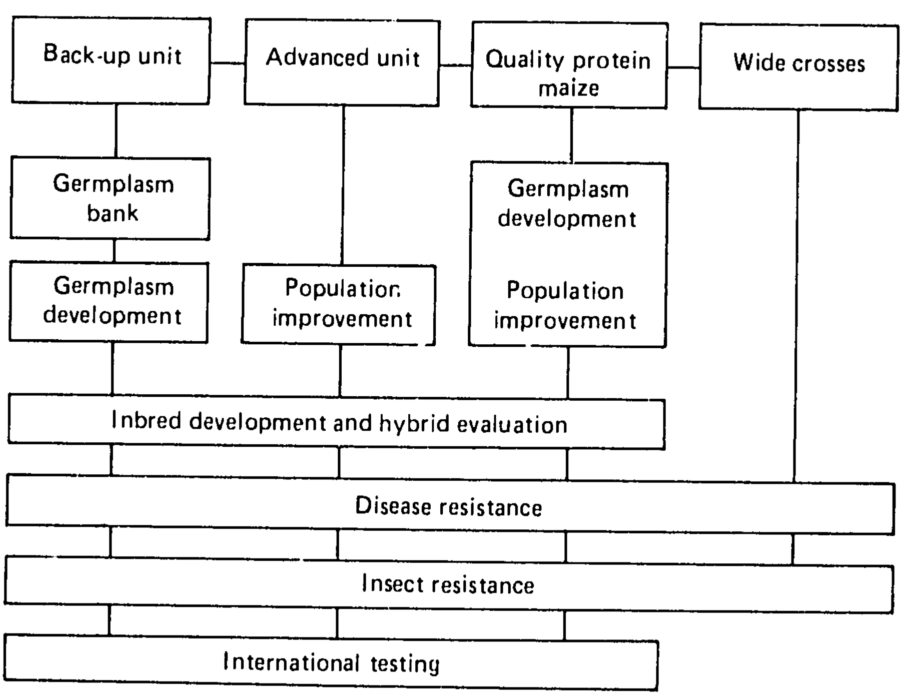

Figure 2. Maize germplasm development program, CIMMYT, Mexico

Since it would be impossible for CIMMYT to supply varieties for each of the numerous ecological zones found in developing countries, germplasm is developed that is suitable for large areas termed "mega-environments," which encompass many smaller areas that are distinct but similar in some characteristics, such as elevation. As indicated in Figure 3, the germplasm complexes that are developed for these mega-environments (the lowland tropics, for example) are subdivided into three maturity groups, which are further broken down according to grain color (yellow or white) and type (flint or dent). Once this germplasm has reached a certain stage of development, it is distributed to national program researchers, who make further refinements and adapt it to the precise growing conditions of the farmers whom they serve.

CIMMYT's maize germplasm development program has a funnel-shaped structure similar to that of most other breeding programs for major crops (Figure 4). At the top of the funnel is the germplasm bank, in which are maintained some 14,000 accessions. From this broad genetic base, over the past 15 years or so, we have developed a series of gene pools or complexes for various mega-environments. These pools are improved by means of half-sib family selection under fairly mild selection pressure so that their variability is not greatly reduced.

From the best fraction of the pools are drawn populations, which are subjected to more intense selection pressure in a modified full-sib recurrent selection scheme. An important feature of this scheme is that selected full-sib progenies are tested in five or six different environments to broaden the adaptation of the populations. As a result of this testing, and the half-sib selection scheme, the variability of the germplasm is gradually reduced and its uniformity increased. The next stage is the development of experimental varieties, which are then tested in multilocational trials. Based upon trial results, elite varieties are selected; these are among the intermediate goods most commonly used by national programs in developing countries.

Elevation	Lowland tropics (0-1000 m)			Midaltitude tropics (1000-1500 m)		Highland tropics (1500-2000 m)		Subtropical (0-1000 m)		Temperate (0-1000 m)	
	Early	Intermediate	Late	Early	Late	Early	Late	Early	Late	Early	Intermediate
Days to maturity	90	100	110-120	110-120	150-180	150-170	180-240	100-110	120-140	100-115	120-150
Number of gene pools	4	4	4	4	5	Floury 4 Flint Dent 4	Floury 4 Flint Dent 4	4	4	2	2

Figure 3. Mega environments for CIMMYT maize germplasm

A vital component of this maize improvement scheme is CIMMYT's international testing network, which is both an integral part of the germplasm development work and a mechanism for distributing that germplasm. One of the three sets of trials that make up the testing network is the International Progeny Testing Trials (IPTTs). Some 250 full-sib families generated from the populations are tested at six locations. The cooperators who conduct the IPTTs select the families that perform best under their conditions and provide CIMMYT with data on their performance.

This information is used in two ways. On the basis of IPTT results, superior progenies are selected to form a population for the next cycle of testing; experimental varieties are then developed. From Population 27, for example, seven varieties were formed in 1982 (Figure 5). Six of these varieties were developed on the basis of full-sib progeny performance at one of the six test locations; among those varieties was Los Baños 8227, which was developed from the progenies of Population 27 that performed best at Los Baños, Philippines. The seventh variety, Across 8227, was formed according to the performance of the progenies across all locations. As mentioned previously, these varieties are then subjected to extensive multilocational testing, which is done through Experimental Variety Trials (EVTs) and Elite Variety Trials (ELVTs).

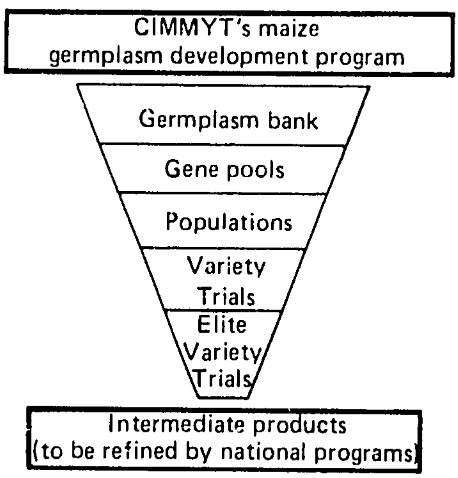

Figure 4. The maize germplasm development program, CIMMYT, Mexico

As a check on the progress of this maize improvement scheme, we measure the gains per cycle brought about in each population by recurrent selection. The percent of gain varies, of course, from one population to another, but the average is 3.44% (Table 1). These gains are measured routinely to determine whether we are continuing to make progress through multilocational testing of the full-sib progenies.

An even more important test of progress is the degree to which CIMMYT germplasm is being accepted and used by national programs. So far, 112 varieties or hybrids containing CIMMYT germplasm have been released in some 30 developing countries. Most of these releases have been varieties based in some way upon materials distributed through our international maize testing system. Some national programs, however, have used CIMMYT germplasm to develop inbred lines with which they have made hybrid combinations. Since CIMMYT's maize program is geared primarily toward variety development through recurrent selection, we are often asked how the program can serve national researchers who are interested in hybrids. We cater to their needs in two ways. The first is that information is compiled about inbreeding depression and heterotic patterns for both gene pools and populations. This information would be of obvious value to, for example, a breeder in Kenya who wanted to know how particular materials would interact with other and how they would hold up under inbreeding.

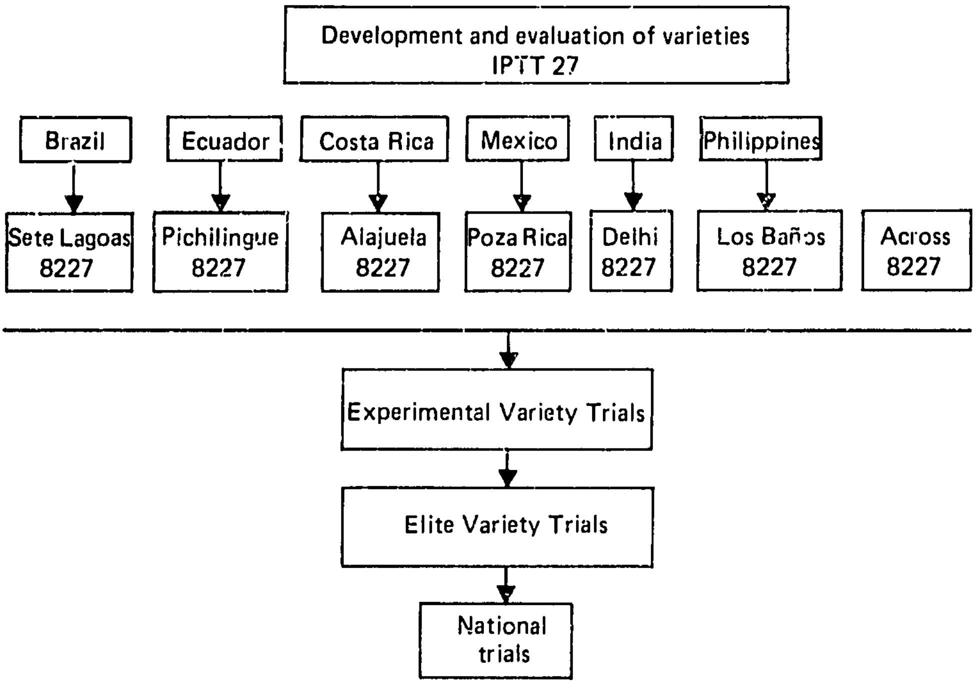

Figure 5. The seven varieties formed from CIMMYT maize Population 24, 1982

Table 1. Gains following two to three cycles of selection in 13 maize populations, CIMMYT, Mexico

Pop.	Population name	Cycles of improvement	Total gain (°/o)	Gain/cycle (°/o)
21	Tuxpeño-1	2	4.4	2.20
22	Mezcla Tropical Blanco	3	4.3	1.44
23	Blanco Cristalino-1	3	6.6*	2.20
24	Ant. x Ver.-181	3	10.6**	3.50
25	(Mix. Col. Gpo. 1) x Eto	2	4.8	2.40
26	Mezcla Amarilla	2	6.2	3.10
27	Amarillo Cristalino	3	13.6**	4.50
28	Amarillo Dentado	2	5.9	2.90
29	Tuxpeño Caribe	2	5.4	2.70
32	ETO Blanco	2	1.5	0.75
35	Ant. x Rep. Dom.	2	8.1*	4.05
36	Cogollero	2	19.7**	9.80
43	La Posta	3	15.7**	5.20
$\overline{x}$			7.9**	3.44

*, ** Significant at the 0.05 and 0.01 levels of probability, respectively

The second way in which we assist hybrid development in national programs is in the production of early generation inbred lines during the improvement of pools under mild selection and of populations under more intense selection pressure. At every cycle of population improvement, and every third cycle of improvement in the pools, the superior materials are selected and taken through a couple of generations of inbreeding. These products are then made available to national programs (Figure 6).

The primary goal of many national researchers that already have or expect to initiate hybrid programs is the development of single-cross or conventional hybrids. We are convinced that in many cases these researchers would stand a better chance of success by concentrating on nonconventional hybrids, such as family top-cross and variety hybrids. These generally yield less than conventional hybrids, but they are much easier to produce. However, the development of any sort of hybrid, whether conventional or nonconventional, is an easy task compared with its production, and finally its appearance in farmers' fields. This is a fact that needs to be considered by national programs before heavy investments are made in hybrid development.

Research Techniques

As will be clear from the foregoing discussion, CIMMYT focuses on practical plant breeding rather than basic research. Even so, in developing germplasm for national programs, we also devise, as a by-product of this work, various research techniques that make our program more efficient and are of interest to many national researchers as well. Some examples of these research by-products are

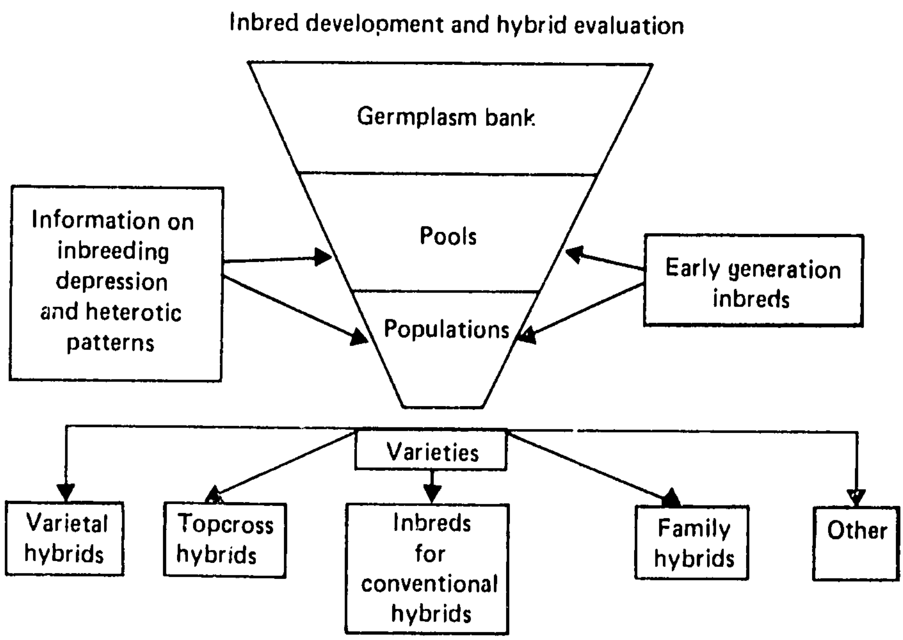

Figure 6. The production of early generation, inbred maize lines for use by national programs for hybrid development, CIMMYT, Mexico

techniques for mass production of inoculum and mass rearing of insects, breeding methodologies for developing hard-endosperm opaque-2 maize and procedures for rapid analysis of grain quality.

On-Farm Research

Over the years, CIMMYT has also developed a set of methodologies for on-farm research. We do not ourselves conduct this research any more than we develop and deliver varieties directly to farmers, but we assist national programs in organizing their own on-farm research efforts. The urgent need for this type of work is plainly evident from the wide gap that generally exists between national average maize yields (about 1 t/ha in most African countries) and those of variety trials conducted on experiment stations, where yields of 5 to 7 t/ha are not uncommon.

What we hope our colleagues in national programs can accomplish through on-farm research is the identification of those factors responsible for this yield gap and the development of recommendations that will enable farmers to narrow the gap by increasing their productivity. Obviously, this type of research cannot be the exclusive domain of any one discipline, but must include the combined efforts of several groups. The complex problems with which farmers are faced must be confronted by both biological and social scientists who are capable of integrating experiment station and on-farm research. Extension agents must also be closely involved in this enterprise, since they will be primarily responsible for transferring recommended technologies to farmers.

On-farm work can also yield secondary benefits for increasing the overall effectiveness of national research and extension efforts. One of the most important of these benefits is that of bringing together researchers from various disciplines with extension personnel and farmers; in this way on-farm research opens a flow of information that can be invaluable in helping national researchers direct their programs more effectively. Far from replacing or encroaching upon the territory of experiment station research or extension, on-farm research can give greater focus to these activities by pinpointing maize production problems and solutions.

Training

In addition to supplying national programs with various research products, CIMMYT also assists them in improving the most valuable resource they have, namely the researchers themselves. This is done through various types of in-country and in-service training. Typical of the in-country maize training activities are two to four-week courses, for which CIMMYT supplies specialists to cover a specific subject (such as seed production), which is of primary concern to the national program.

Many other training opportunities are available at our headquarters in Mexico. Visiting scientists from national programs come to work with our staff for a period of two or three months on problems of mutual interest. Predoctoral fellows, who have finished their university course work, may do their research at CIMMYT. So can postdocotral fellows, who can become more closely involved in our research program while they are working independently on problems that are of special interest to them.

The great majority of CIMMYT maize trainees, however, participate in one of our six-month in-service courses. There are courses in production agronomy, maize improvement, experiment station management and maize protein evaluation. The production agronomy course is extremely comprehensive, providing classroom instruction in various aspects of breeding, statistics, physiology and agronomy. In addition, participants become familiar with artificial inoculation and other techniques that are used in experiment station research; they also gain valuable experience in conducting research under the less-than-optimum conditions in farmers' fields.

Regional Programs

To ensure that the goods and services offered by CIMMYT's maize program are meeting our clients' needs, it is critical that we maintain strong links and effective communication with national programs. This purpose is accomplished to some degree through our international testing system and training programs. But the most effective way we have found for strengthening and giving continuity to our ties with national researchers is through bilateral projects and regional programs.

Of the latter there are six, one each for Central America and the Caribbean, the Andean region, West Africa, East Africa, the Middle East/North Africa, eastern and southern Africa and Asia (Figure 7). These regional programs are staffed by one or more maize specialists, whose job is to support the work of national scientists. Because of the diversity of the maize specialists' task, their position seems difficult and certainly unusual to many people. We are often asked how it is possible for a plant breeder to be stationed in a place where he does not even have a breeding nursery. The answer to that question lies in the difference between his work and that of other breeders. Rather than conduct their own research, the regional specialists (not all of whom are plant breeders; there are also agronomists, economists and other specialists) participate in the research of as many as a dozen national programs. For most of the specialists who are breeders, the nurseries of the national programs in a sense substitute for their own. The

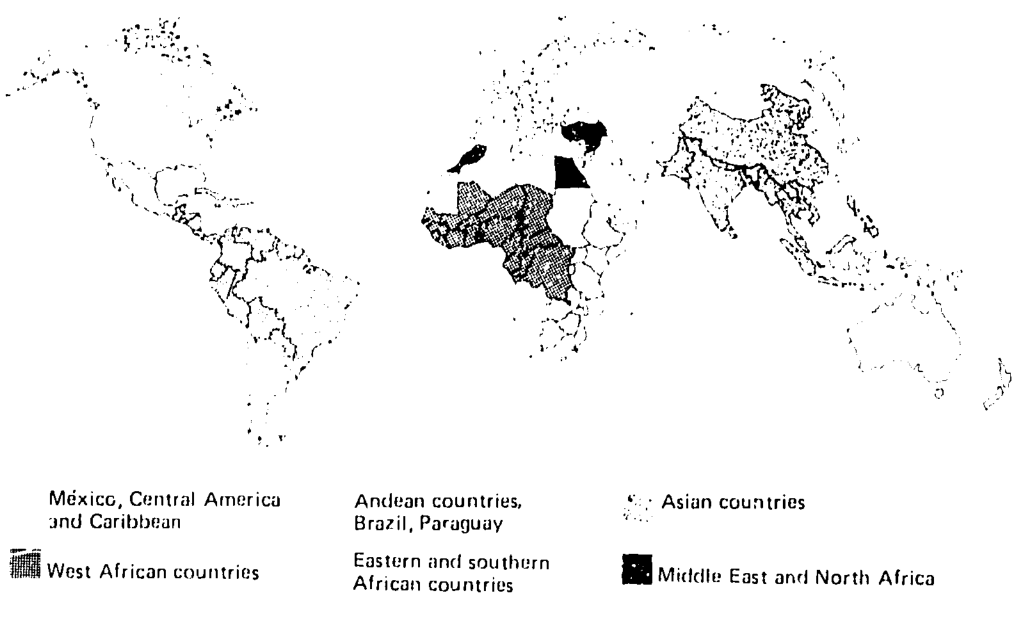

Figure 7. CIMMYT Regional Maize Programs

exceptions are those few regional staff members who conduct some germplasm improvement work on specific region-wide problems, such as downy mildew in Southeast Asia and maize streak virus in West Africa.

The regional staff members also support the work of national researchers by helping them identify and meet germplasm, training and other needs. A substantial share of their time goes into organizing in-country training and various regional activities, such as this workshop. These events give national scientists opportunities to exchange ideas and research results with one another and with staff members from CIMMYT headquarters and other organizations.

Another task that illustrates the value of the maize specialists to national programs is their assistance in on-farm research. Scientists who are new to this type of research are sometimes surprised to find that on-farm trials may have a coefficient of variation as high as 40% and still provide much valuable information; the trials are useful, however, only if someone visits the site in addition to examining the data. Such visits are one service provided by the regional specialists. And generally, because they remain in close touch with this and other national program activities, they can form an accurate picture of national program needs and determine how to draw upon CIMMYT resources to help in meeting those needs.

Discussion

Question: What are the steps that must be followed for a successful on-farm research program?

Dr. Cantrell: First, to begin on-farm research, you must start with the resources you have. There are four points to guide you in setting up the program. Use the same design you use for on-station programs, although you must expect large CVs with the on-farm experiments. Add such inputs as fertilizer when you begin to see progress. Compare local germplasm and management with improved germplasm and management on as large a number of farms as possible. And, very important, move to farmer-managed trials as soon as you can. It takes time to gain farmers' confidence, but it can be done. And it must be done, as on-farm trials are essential in agricultural research.

II. Breeding

Evaluation of Population Improvement in the Kenya Maize Breeding Methods Study

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Abstract

The maize (Zea mays L.) breeding methods study in Kenya was initiated in 1964 to compare the efficiency of various methods for improving yield. A minimum of ten years of selection was completed in each experiment, and some procedures continue today because of their efficacy in line or population development. Following selection, there were three years of evaluation, including both direct and indirect effects of selection. Intrapopulation improvement was conducted, using three variations of mass selection, including two plant densities and two levels of selection intensity. Five variations of ear-to-row selection included comparison of number of generations of random mating prior to beginning selection, plant density, male plant elimination and number of entries in the selection trial. Other methods compared were half-sib, S_1 and full-sib recurrent selection. The most consistent improvement was found with ear-to-row selection, with rates of gain of nearly 3% per cycle. Interpopulation improvement was studied, using reciprocal recurrent selection, S_1 and ear-to-row selection in the parental populations. Gains in the variety crosses were evaluated by making up the series over all cycles of selection. Gains using reciprocal recurrent selection were near 7% per cycle. Ear-to-row selection, in contrast, resulted in little gain in the variety crosses, although improvement was realized in the parental populations. Inbred lines were developed from cycles 2, 3 and 4 of the reciprocal recurrent selection experiments in Kitale Synthetic II and Ecuador 573. The lines of each cycle were advanced to S_3, when they were crossed in all possible combinations. Yields of the best three-way crosses were predicted, and the best 36 or so were actually made and evaluated. The best three-way crosses were entered into the East African Maize Variety Trials, where they generally outyielded other entries at mid- and high-altitude sites. Significant gains were noted in lodging resistance. Two lines from cycle 2 and one from cycle 3 are now involved in production in Kenya, and three cycle 2 lines are used commercially in Tanzania. A singularly high-yielding cycle 4 line was identified from Ecuador 573, but is probably not yet found in commercial hybrids. Gains in the best three-way crosses exceeded gains in the population crosses over the time of development by 2 to 5%; uniformity in seed production and in farmers' fields enhanced the attractiveness of the three-way cross over the population cross. A highly prolific hybrid, such as EAH6302, should be quite useful in intercropping conditions when planted at densities of 25,000 plants/ha. At the recommended densities of 44,000 plants/ha, it had fewer barren plants that the older hybrids.

The maize (*Zea mays* L.) breeding methods study in Kenya was designed to compare the efficiency of various recurrent selection methodologies for the improvement of yield (5).

Comparisons of intrapopulation improvement methods included:

- Mass selection with variants of selection intensity and plant density;

- Modified ear-to-row selection (9) with variations of number of generations of random mating, plant density, male plant selection and number of entries;
- S_1 selection;
- Half-sib selection with three testers, the parent population *per se*, a low-yielding population and a low-yielding inbred line, and
- Full-sib selection (2,3).

Three methods of interpopulation improvement were studied, ear-to-row selection in two parental populations with subsequent variety cross production, S_1 selection in the two parental populations and reciprocal recurrent selection. Results of the study have provided significant information on direct effects of selection, correlated responses of other agronomic variables and an indication of inbreeding shown in the cycle 5 or 10 populations.

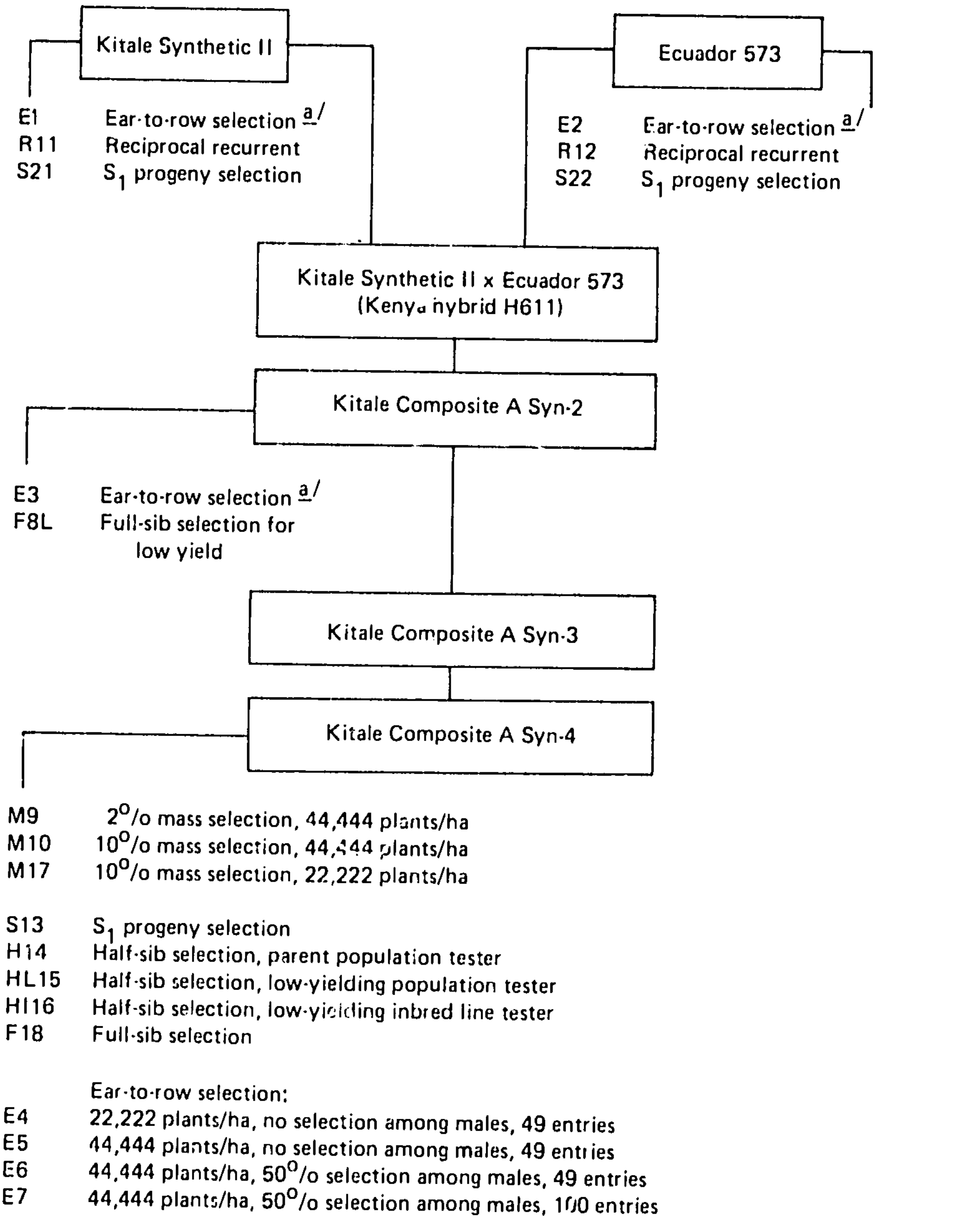
Materials and Methods

Three populations were used in the breeding methods study. Kitale Synthetic II (KSII) was developed by Harrison (7) from Kitale Station maize. Ecuador 573 (Ec573) was a land race introduced from Ecuador that combined well with KSII. The variety cross, designated H611, was used as a commercial hybrid for a time in Kenya. Kitale Composite A (KCA) was the randomly mated variety cross. The general scheme of the methods study, specific experiment designations and variants of the selection techniques are shown in Figure 1. Details of the techniques used are given by Darrah and Mukuru (1).

The evaluation of the selection progress was completed following ten years of selection in all but two of the experiments, the mass selection experiment at reduced plant density (after seven cycles) and the half-sib selection experiment, using an inbred line tester (after four cycles). Four separate evaluation trials were grown. The mass and ear-to-row intrapopulation experiments (M9, M10, M17 and E3 to E7) were evaluated in 14 environments over a two-year period, using a randomized complete block design. The S_1, half-sib and full-sib selection experiments (S13, H14, HL15, HI16 and F18) were similarly evaluated. The interpopulation selection experiments (E1, E2, S21, S22, R11 and R12) were evaluated in a triple-square lattice design of 81 entries at six environments in a single year. An additional evaluation of the effects of selection at different plant densities in the mass and ear-to-row selection experiments was made, but is not reported here.

Evaluation trials utilized a 33-plant plot obtained from three rows of nine hills that were planted with three seeds in the end hills and two seeds in each of the others. Thinning reduced the stand to two plants in the end hills and one in the others, e.g., 11 plants per row. Hill spacing was 75 cm by 30 cm. Fertilizer application included nitrogen at 160 kg/ha and phosphorus (P_2O_5) at 80 kg/ha; no potassium was applied because soils in the evaluation areas were adequate in potassium availability. Weed control was obtained by application of Atrazine and 2-4,D in a pre-emergent surface spraying. Stalk borers were controlled by application of 5% DDT powder in the whorl of the plants when they were approximately 50 cm high.

Data were recorded for grain yield and moisture, number of plants per plot, number of lodged plants (root and stalk lodging), number of ears with bare tips, number of usable ears, number of diseased ears, number of days to 50% anthesis, ear height, and presence of



[a] Same procedure as for E6

Figure 1. Outline of the maize breeding methods study, Kenya

blight (*Helminthosporium turcicum* Pass.) and rust (*Puccinia sorghi* Schw). Disease was rated on a scale of 1 to 5 (1 = a resistant plant, 5 = a susceptible plant). Yields were converted to quintals per hectare (1 quintal = 45.4 kg), and adjusted to 12.5% moisture content and mean stand. Adjustments for stand differences were minimal because most plots had above 90% stand. Lodging, usable ears and diseased ears were expressed as a percent of the counted stand. Bare tips were expressed as a percent of the number of usable ears. Days to flowering and blight and rust rating were done on a plot basis. Ear height was measured on ten random competitive plants per plot and means were calculated for further analyses.

Analyses of variance were completed for each experiment, with the entry x environment term used to test differences among entries. Least-squares regression techniques were used to compute gain from selection and correlated responses. Where the experimental design was a lattice, only the yield means were adjusted for block differences; the analysis for all other characters was completed as for a randomized complete block design experiment. The diallel crosses of the cycle 10 mass and ear-to-row selection populations and the cycle 5 S_1, half-sib and full-sib selection populations were analyzed using Griffing's Method 4 (crosses only), Model 1, fixed effects analysis (6).

Trial Results

Intrapopulation improvement by mass and ear-to-row selection

Mass selection using a 2% selection intensity (M9) resulted in the highest yield gain (2.68% per year), but was not statistically different from mass selection at 10% selection intensity (M10: 1.92% per year) (Table 1). Gain from selection at reduced plant density (M17: 22,222 plants/ha) was similar to that obtained at the same selection intensity at normal plant density (M10: 44,444 plants/ha). Significant correlated responses occurred in M9 and M10 for increased frequency of bare tips, usable ears, diseased ears and ear height. The increase in frequency of bare tips was about 6% per year, while the increase in diseased ears was just over 2% per year. It is likely that the increased yield resulted in a longer ear, the tip of which extended beyond the husk. Thus, the bare tips were exposed to birds and insects, which damaged the ears; this resulted in a greater incidence of fungal ear diseases.

Significant increases in days to flowering occurred in M9, and ear height increased in M9 and M10. However, the changes were of little practical importance over the 10 years of selection. The net results would be a two-day delay in flowering for M9 and 11 to 17-cm increases in ear height. Past evaluations (3) of M9 and M10 had suggested rates of increase of ear height up to twice that found in this evaluation.

M17 was initiated using cycle 5 of M10 as cycle 0. Seven cycles of selection were evaluated in this trial. Because of the different starting point and fewer cycles of selection, a greater linear response coefficient was needed for statistical significance than for M9 or M10. The only significant correlated response found was for increased ear height, and that response was between that found for M9 and for M10 (0.58% per year).

All of the ear-to-row selection experiments resulted in significant yield gains, ranging from 1.77% per year for E3 to 4.79% per year for E7 (Table 1). All experiments showed significant correlated responses of increased frequency of bare tips, increased number of usable ears, and for all but E7, increased frequency of diseased ears. The increase in frequency of bare tips, for example, 1% in E4 and over 14% in E6, suggests that selection against bare tips would be important in a breeding program designed to produce material for farmer use. Increases in yield were associated with increases in usable ears, but that was likely due to a reduction of barren plants because of the low mean frequency of usable ears (54.8%). This value was much lower than expected and may reflect a more severe discarding of diseased or nonusable ears than had taken place previously. Significant increases in days to flowering occurred for E3 and E7 only. E3 and E4 also had significant increases in ear height. Again, the changes in days to flowering and ear height were relatively small, even though statistically significant. In part, this differentiation was possible because of the accuracy of the measurement of the variables, as compared to a character such as lodging; lodging commonly has coefficients of variation exceeding 100%, versus 4% to 7% for days to flowering and ear height.

The ear-to-row selection experiments were set up to test certain variants of the technique applied. Selection in E3 was initiated after one generation of random mating (Syn 2) of the variety cross. Compared to E6, which used the same procedure, except for including three generations of random mating of the variety cross, E3 made progress at a rate that was significantly less (P = 0.01) than that of E6 (1.77% versus 4.79% per year). Selection in E4 was done at half the plant density (22,222 plants/ha) of E5; all other aspects were the same. E5 had a significantly greater rate of gain (P = 0.05) than E4 (3.07% versus 1.90% per year). Neither of these experiments included selection among the male plants.

The contrast of experiments E5 and E6 evaluated the effect of selective elimination of 50% of the male plants before anthesis. No significant difference in yield gain was found for male plant selection. Selection prior to anthesis can only be made for lodging, diseased plants, tassel emergence and ear height. However, no significant differences were found for any of these characteristics, except for an increased blight rating in E5. A higher frequency of plant elimination might be effective, but sufficient pollen for full seed set must be insured.

Forty-nine entries were grown in each cycle of E6, whereas 100 entries were grown for E7. Both experiments included male plant elimination, but this was not shown to be a significant contributor to yield improvement. Gain per year for E7 was 4.79% which was significantly greater (P = 0.01) than that obtained for E6 (3.10%). E7 also showed a significant reduction in lodging of 1% (percent of lodging percent) per year and a significant decrease in days to flower of 0.2% per year; although the latter is relatively small, it is in the right direction. The reduction of lodging must be a reflection of greater harvest from standing plants versus losses from plants that lodge before grain filling is completed or plants that suffer losses from predators, such as rodents, that have access to ears on the ground.

A diallel set of variety crosses, including all of the KCA mass and ear-to-row selection experiments, was made using the cycle 10 populations, or the equivalent cycle 5 population in the case of M17. Inbreeding or random population drift can be discerned by analysis of the diallel, because either one or more of the variety crosses will differ and this will be reflected in the specific combining-ability effects (s_{ij}). General combining-ability effects (g_i) should reflect average changes in additive genetic effects over the several

Table 1. Comparison of predicted gains from selection for yield in Kitale Composite A (KCA), using ear-to-row (E) and mass (M) selection

Selection experiment[a]	Cycles	Selection variant: Genr'n random mating	Plants /ha	Male sel'n (%)	No. of entries	Plants selected (%)	Least-squares gain from selection on per year basis: Yield (q/ha)	Lodging (%)	Bare tips (%)	Usable ears (%)	Diseased ears (%)	Days to flower (no.)	Ear height (%)	Blight rating[b]	Rust rating[b]
KCA(E3)	10	1	44,444	50	49	10	0.68** 1.77%	0.03	0.44** 3.75%	0.90** 1.64%	0.26** 2.50%	-0.16** -.14%	0.46** 0.19%	0.000	0.007* 0.60%
KCA(E4)	10	3	22,222	None	49	10	0.73** 1.90%	0.25	1.29** 10.98%	1.41** 2.68%	0.43** 4.13%	0.05	0.63** 0.26	-0.002	-0.002
KCA(E5)	10	3	44,444	None	49	10	1.18** 3.07%	0.01	0.78** 6.69%	1.30** 2.37%	0.42** 4.02%	-0.04	0.29	0.007* 0.59%	-0.004
KCA(E6)	10	3	44,444	50	49	10	1.19** 3.10%	-0.11	1.73** 14.76%	1.13** 2.06%	0.27** 2.58%	-0.07	-0.05	-0.001	0.003
KCA(E7)	10	3	44,444	50	100	10	1.83** 4.79%	-0.65** -1.15%	0.50** 4.30%	2.04** 3.72%	0.09	-0.18** -0.16%	0.11	0.000	-0.000
KCA(M9)[c]	10	3	44,444	--	250 plots	2	1.03** 2.68%	-0.26	0.74** 6.28%	0.80** 1.47%	0.22* 2.15%	0.25** 0.22%	1.72** 0.70%	-0.003	-0.004
KCA(M10)[c]	12	3	44,444	--	50 plots	10	0.74** 1.92%	-0.18	0.67** 5.74%	0.55** 1.01%	0.25** 2.38%	0.05	1.13** 0.46%	-0.005	-0.001
Predicted cycle 0 for E3 to E7, M9 and M10							38.3	57.0	11.7	54.8	10.4	113.7	244.2	1.13	1.18
KCA(M17)[c/d]	7	3	22,222	--	50 plots	10	0.66* 1.52%	0.54	0.58	0.21	0.30	0.02	1.44** 0.58%	0.011	0.000
Predicted cycle 0 for M17							43.3	52.1	14.6	59.1	10.9	114.3	248.8	1.10	1.20

a/ Evaluation grown at 14 sites; days to flower recorded at only nine sites
b/ Rating scale 1 to 5 (1 = resistant, 5 = susceptible)
c/ Fifty plants per plot; total number of ears selected 250 for all mass selection experiments
d/ KCA(M17)C_0 = KCA(M10)C_5
* ** Significantly different from 0.0 at P = 0.05 and P = 0.01, respectively

crosses. Significant positive g_i yield effects were found for E3 (2.8 q/ha) and E7 (3.5 q/ha) (Table 2). These effects were not significantly different from each other, but were significantly greater than the effects for E4 and E5. E7 also had a g_i effect significantly greater then that of E6 (1.2 q/ha). All three mass selection experiments had significant negative g_i effects, with that of M10 (-3.8 q/ha) being significantly less than that of M9 or M17. The high g_i effect for E7 agrees with its high rate of gain from selection, but the significant positive effect found for E3 is associated with the lowest rate of gain from selection among the ear-to-row experiments. The mass selection experiment populations did not combine well with the ear-to-row populations: they did particularly poorly in crosses among themselves.

Two statistically significant s_{ij} effects were found, -4.5 q/ha for E5 x E6 and 3.1 q/ha for E6 x E7. The latter was the highest-yielding cross in the diallel (59.6 q/ha), suggesting that some heterogeneity existed between the two populations. The poor performance of the E5 x E6 cross may have been due to sampling error: it was not associated with any pattern and the gains from selection for yield were similar. Overall, there is little to suggest either a significant amount of inbreeding or that random drift occurred by cycle 10.

Ear-to-row selection with 100 entries in the selection trials (E7) was clearly the procedure of choice. Any possible effect of inbreeding was minimized because the number of effective parents was nearly twice that of any other method studied (8.3). Because of that, it might be possible to further increase rates of gain by decreasing the selection intensity to 7.5% or to grow 144 entries and select 5% per cycle. Either procedure would result in about the same number of effective parents as E3 to E6.

Intrapopulation improvement by S_1, half-sib and full-sib selection

The comparable ear-to-row selection experiment, E7, was included in this evaluation of gain. E7 had a significant gain of 3.47% per year (Table 3), quite a bit less than estimated in the mass and ear-to-row evaluation (4.79% per year). However, the actual rates of gain were much closer (1.83 versus 1.62 q/ha per year). Part of the difference can be attributed to the overall lower yield predicted for cycle 0 in the former evaluation (38.3 q/ha) in contrast to this evaluation (46.6 q/ha). The rate of gain for E7 was the second highest among the methods included in this evaluation. Comparing the rates of gain, the rate for E7 significantly exceeded rates of gain for S13, H14, HL15 and HI16. The rate of gain for E7 was very similar to that of F18 (3.47 versus 3.59% per year).

S_1 selection (S13) had high predicted gains based on the selection trials, but this gain was not realized. Although gain was significant, it was only 0.86% per year, less than a quarter of that achieved with E7 or F18. Gain in S13 was not different from that obtained in H14 or HL15, but was significantly less than that of E7 or F18.

Since the predicted gains from the selection trials were based on S_1 progenies, S13 was also evaluated, based on a bulk of random S_1 ears made from each cycle. The rate of gain for the selfed populations far exceeded that obtained anywhere else in the evaluations, 17.6% per year. That high rate was based on a predicted cycle 0 mean of 17.9 q/ha, which was substantially lower than that used for the S13 cycles *per se*. After ten years of selection, the regressed cycle 10 values were identical for S13 *per se* and S13 selfed. Further evaluation of these populations will be needed to study the inbreeding depression changes found over cycles. These data suggest that inbreeding depression has been significantly decreased from S_0 to S_1.

Table 2. Yield (q/ha) diallel analysis of Kitale Composite A (KCA), ear-to-row (E) and mass (M) selecition cycle 10 populations (cross means shown above the diagonal, general combining ability effects (g_i) on the diagonal and specific combining ability effects (s_{ij}) below the diagonal)

Selection experiment	Cycles	Selection variant: Genr'n random mating	Plants /ha	Male sel'n (°/o)	No. of entries	Plants selected (°/o)	$E3C_{10}$	$E4C_{10}$	$E5C_{10}$	$E6C_{10}$	$E7C_{10}$	$M9C_{10}$	$M10C_{10}$	$M17C_5$
KCA(E3)	10	1	44,444	50	49	10	2.8**	54.8	56.5	53.0	55.2	53.2	53.0	53.0
KCA(E4)	10	3	22,222	None	49	10	0.1	0.2	52.2	53.8	54.1	51.1	48.0	49.3
KCA(E5)	10	3	44,444	None	49	10	2.5	0.8	-0.5	47.9	55.5	47.8	46.6	52.6
KCA(E6)	10	3	44,444	50	49	10	-2.7	0.7	-4.5*	1.2	59.6	53.9	49.6	52.6
KCA(E7)	10	3	44,444	50	100	10	-2.8	-1.4	0.7	3.1*	3.5**	55.0	52.0	51.9
KCA(M9)[a/]	10	3	44,444	--	250 plots	2	0.4	0.9	-1.7	2.7	1.5	-1.7*	44.7	46.0
KCA(M10)[a/]	10	3	44,444	--	50 plots	10	2.3	-0.2	-0.9	-0.6	0.5	-1.5	-3.8**	46.7
KCA(M17)[b/]	5	3	22,222	--	50 plots	10	0.2	-1.0	3.0	1.3	-1.7	-2.3	0.4	-1.7*
Cross means							54.1	51.9	51.3	52.8	54.8	50.2	48.5	50.3

a/ Fifty plants per plot; total number of ears selected 250 for all mass selection experiments

b/ $KCA(M17)C_0 = KCA(M10)C_5$

*, ** Significantly different from 0.0 at $P = 0.05$ and $P = 0.01$, respectively

LSD 0.05 $(g_i - g_j) = 2.1$, LSD 0.05 $(s_{ij} - s_{kl}) = 4.6$, LSD 0.05 among crosses $= 5.2$, LSD 0.05 among cross means ≈ 2.0

Table 3. Comparison of predicted gains from selection for yield in Kitale Composite A (KCA); using eat-to-row (E), S_1 (S), half-sib (H) and full-sib (F) selection

Selection experiment[a/]	Cycles	Selection or evaluation variant	Least-squares gain from selection on per year basis								
			Yield (q/ha)	Lodging (%)	Bare tips (%)	Usable ears (%)	Diseased ears (%)	Days to flower (no.)	Ear height (%)	Blight rating b/	Rust rating b/
KCA(E7)[c/]	10	100 entries, 10% selection intensity	1.62** 3.47%	-0.16	-0.00	1.34** 2.06%	0.13	-0.08* -0.07%	0.79* 0.34%	0.004	0.001
KCA(S13)	5		0.40* 0.86%	-0.02	0.16	1.55** 2.38%	0.18	-0.15** -0.14%	-0.75* -0.33%	0.006	0.001
KCA(H14)	5	Population *per se* tester	0.75** 1.60%	0.69** -1.36%	0.09	1.33** 2.05%	-0.02	-0.14** -0.12%	-1.45** -0.62%	0.007	0.003
KCA(HL15)	5	Low-yielding population tester	0.73** 1.56%	0.22	0.48** 2.73%	2.00** 3.09%	0.49** 4.50%	-0.15** -0.13%	-0.81* -0.35%	-0.001	0.001
KCA(HI16)	4	Low-yielding inbred line tester	-0.47* -1.02%	0.35	-0.35	0.49	0.26* 2.37%	0.11** 0.10%	-1.28** -0.55%	-0.001	-0.002
KCA(F18)	5		1.67** 3.59%	-1.11** -2.18%	1.35** 7.75%	1.74** 2.68%	0.09	-0.01	-0.37	-0.001	-0.004
Predicted cycle 0 for above			46.6	51.1	17.4	64.9	10.9	112.1	231.5	1.14	1.19
KCA(S13)S_1	5	KCA(S13) populations selfed	3.16** 17.60%	-1.04** -1.66%	0.77** 6.60%	4.21** 11.79%	0.26	-0.33** -0.29%	0.08	-0.004	-0.007
Predicted cycle 0 for KCA(S13)S_1			17.9	63.0	11.6	35.7	11.5	113.6	216.1	1.21	1.29
KCA(HL15) X	5	KCA(HK15) x population tester	0.83** 1.95%	0.53	-0.35	1.28** 1.93%	0.41** 4.83%	0.01	-0.17	-0.007	-0.009
Predicted cycle 0 for KCA(HL15)			43.8	53.7	11.8	66.2	8.4	111.5	227.2	1.19	1.28
KCA(HI16) X	4	KCA(HI16) x inbred tester	0.61* 1.14%	-0.40	-0.13	0.96** 1.35%	-0.04	0.19** 0.17%	0.29	0.005	-0.010
Predicted cycle 0 for KCA(HI16) X			53.0	52.0	13.9	70.9	11.0	111.4	226.0	1.10	1.16

a/ Evaluation grown at 14 sites; days to flower recorded at only nine sites
b/ Rating scale 1 to 5 (1 = resistant, 5 = susceptible)
c/ Two cycles in two years versus one cycle in two years for other methods of selection
*, ** Significantly different from 0.0 at P = 0.05 and P = 0.01, respectively

Half-sib selection included three variations of the tester. H14 used the parent population as the tester, HL15 used a low-yielding population derived from KCA as the tester, and HI16 used a low-yielding inbred line extracted from the low-yielding population as the tester. Only four cycles of HI16 were available for evaluation because of the time required to develop the inbred tester. Responses for H14 and HL15 were similarly significant at 1.6% gain in yield per year. H14 and HL15 both had significantly higher rates of gain than HI16, which had a significant yield loss (1.02% per year). Gains predicted from selection trials for the test cross were not reflected in gains in the population *per se*.

For the HL15 and HI16 half-sib selection experiments, each cycle of selection was crossed to the appropriate tester for comparison with the cycles *per se*. Because the tester for H14 was the current cycle of the experiment, no difference would be expected between the cycles and the cycles crossed with the tester. Gains from selection in HL15 and from HL15 crossed with the low-yielding population tester were similar (1.56% and 1.95% per year, respectively), although the latter had a lower predicted cycle 0 (43.8 versus 46.6 q/ha). In this case, the gain in the test cross was reflected in gain in the population *per se*.

There were many correlated responses with other agronomic characters. Selection in F18 resulted in a significant decrease in lodging (2.18% per year) with increases in bare tips (7.75% per year) and usable ears (2.68% per year). The association of higher yield and reduced lodging losses would apply as discussed for ear-to-row selection.

Selection in H14 resulted in a significant decrease in lodging (1.36%). Diseased ears increased significantly in HL15 and HI16, but not in other experiments. S13, H14, HL15 and HI16 had small but significant decreases in days to flowering and ear height. These four experiments all had a selfing or test-crossing phase in which one-third of the potential rows for either selfing or test crossing were eliminated prior to anthesis. Selection for earliness of flowering and reduced ear height could account for the reductions observed. F18 had only a yield-test season followed by recombination, which was accomplished by paired-row diallel crosses of remnant selfed seed of selected entries. A balanced set of ears for yield testing was taken directly from reciprocal crosses made in the recombination nursery. Thus, there was not the same opportunity for nursery selection as there had been for S13, H14, HL15 or HI16.

A diallel set of variety crosses formed from the cycle 10 population of E7, the cycle 5 populations of S13, H14, HL15 and F18, and the cycle 4 population of HI16 was evaluated to examine divergence of the selection experiments. Higher yields were achieved from these variety crosses than from those of the ear-to-row and mass selection experiments grown in similar environments (64.3 versus 51.7 q/ha, respectively). The g_i effect for S13 was significant and negative (-2.3 q/ha); that for HL15 was significant and positive (3.3 q/ha) (Table 4). The remaining g_i effects were not significantly different from zero.

In contrast to the mass and ear-to-row selection experiment diallel, several significant s_{ij} effects were found. Most experiments had one significant positive and one significant negative effect. E7 had two of each, positive for crosses with HL15 and HI16 and negative for crosses with H14 and F18.

Table 4. Yield (q/ha) diallel analysis of Kitale Composite A (KCA), ear-to-row (E, cycle 10), S_1 (S), Half-sib (H) and full-sib (F) cycle 5 populations. (cross means shown above the diagonal, general combining ability effects (g_i) on the diagonal and specific combining-ability effects (s_{ij}) below the diagonal)

Selection experiment	Cycles	Selection or evaluation variant	$E7C_{10}$	$S13C_5$	$H14C_5$	$HL15C_5$	$HI16C_4$	$F18C_5$
KCA(E7)[a]	10	100 entries, 10% selection intensity	-0.5	58.0	61.9	70.3	69.1	60.2
KCA(S13)	5		-3.5*	-2.3*	63.0	66.7	60.3	64.6
KCA(H14)	5	Population *per se* tester	-1.3	1.6	-0.6	66.7	58.7	68.8
KCA(HL15)	5	Low-yielding population tester	3.2*	1.3	-0.3	3.3**	62.1	69.1
KCA(HI16)	4	Low-yielding inbred line tester	6.8**	-0.3	-3.5*	-4.0**	-1.5	65.4
KCA(F18)	5		-5.2**	0.9	3.5*	-0.2	1.0	1.6
Cross means			63.9	62.5	63.8	67.0	63.1	65.6

a/ Two cycles in two years versus one cycle in two years for other methods of selection

*, ** Significantly different from 0.0 at P = 0.05 and P = 0.01, respectively

LSD 0.05 ($g_i - g_j$) = 2.7, LSD 0.05 ($s_{ij} - s_{kl}$) = 3.8, LSD 0.05 among crosses = 5.4, LSD 0.05 among cross means = 2.4

This suggests that H14 and F18 were selected for similar favorable alleles, while HL15 and HI16 had different alleles selected. That would agree with the use of a specific tester for those experiments. The presence of several significant s_{ij} effects suggests divergence of the selection experiments and a greater effect of inbreeding.

Interpopulation improvement by ear-to-row, S_1 and reciprocal recurrent selection

Ear-to-row, S_1 and reciprocal recurrent selection were each done in KSII and Ec573 for ten years. Table 5 shows the gains resulting from selection in the parental populations and gains in the variety crosses resulting from crossing respective cycles of each pair of experiments.

No significant change in yield was realized by selection in KSII. Responses were positive for ear-to-row selection, but negative for S_1 and reciprocal recurrent selection. KSII was a well-adapted population that had already undergone one cycle of half-sib selection (4). It is possible that genetic variability for yield was insufficient for selection progress under the conditons in which the experiment was grown. A significant lodging reduction was found for R11, as well as a small but significant reduction in days to flowering. All three KSII selection experiments had a significant increase in diseased ears, averaging over 4% per year. The predicted cycle 0 yield was 47.0 q/ha.

Selection in Ec573 resulted in a significant 4.60% per year yield increase by the ear-to-row method and a 3.33% per year increase by the S_1 method. Reciprocal recurrent selection did not affect the yield of Ec573. E2 showed a significant increase in usable ears and significant decreases in days to flowering and blight rating. S22 had a 1.89% per year decrease in lodging, and increases of 3.75% per year for bare tips and 4.55% per year for usable ears. Although R12 had no yield response, it showed a 9.48% per year drop in bare tips, 2.88% per year increase in usable ears, significant small decreases in days to flowering and ear height, and over 2% per year decreases for both blight and rust ratings. The predicted cycle 0 yield was 38.0 q/ha.

Heterosis of the predicted cycle 0 cross of KSII and Ec573 was 49.6% over the mid-parent. Gain of the ear-to-row variety cross over 10 cycles was negative and not significant. Only the frequency of bare tips showed a correlated response to selections of -4.45% per year, which was probably associated with a lack of yield increase. The variety cross derived from S_1 selection in the parental populations also failed to show any yield gain. The only significantly correlated response was an increase in usable ears of 1.24% per year.

H611(R), the variety cross produced using reciprocal recurrent selection, had a significant yield gain of 2.75% per year or 5.5% per cycle. Previous evaluations (2,3) reported gains of 7 to 10% per cycle, with approximately the same predicted cycle 0 yield level (60 q/ha). In addition, all of the significant correlated responses were in the right directions—lodging was reduced at a rate of 2.36% per year, bare tips decreased 6.90% per year, usable ears increased 1.92% per year and days to flowering decreased 0.35% per year. Other selection experiments had yield gains associated with undesirable increases in bare tips and diseased ears.

Table 5. Comparison of predicted gains from selection for yield in Kitale Synthetic II (KSII), Ecuador 573 (Ec573) and their variety cross (H611), using ear-to-row (E), S_1 (S) and reciprocal recurrent selection (R)

Selection experiment	Cycles	Least-squares gain from selection on per year basis								
		Yield (q/ha)	Lodging (%)	Bare tips (%)	Usable ears (%)	Diseased ears (%)	Days to flower (no.)	Ear height (%)	Blight rating b/	Rust rating b/
KSII(E1) c/	10	0.14	-0.13	0.29	0.40	0.46** 4.07%	0.27*	0.50	-0.010	-0.009
KSII(S21)	5	-0.37	-0.10	-0.03	1.09** 1.66	0.55 4.99%	0.03	0.13	-0.009	0.004
KSII(R11)	5	-0.49	-1.17** -1.86%	-0.22	0.56	0.42* 3.74%	-0.17* -0.26%	-0.47	-0.000	0 023** 2.74%
Predicted cycle 0		47.0	64.0	8.0	65.6	11.1	100.7	219.0	0.86	0.83
Ec573(E2) c/	10	1.75** 4.60%	-0.52	0.22	1.18** 1.80%	0.14	-0.48** -0.45%	-0.69	-0.018* -1.69%	-0.003
Ec573(S22)	5	1.27** 3.33%	-1.18** -1.89%	0.58** 3.76%	2.97** 4.55%	0.25	0.14	0.13	-0.012	-0.008
Ec573(R12)	5	0.66	-0.66	-1.46** -8.48%	1.88** 2.88%	-0.12	-0.25** -0.23%	-1.49** -0.63%	-0.027** -2.53%	-0.018* -2.10%
Predicted cycle 0		38.0	62.5	15.4	65.2	5.6	107.0	235.6	1.07	0.86
H611(E) c/	10	-0.44	-0.11	-0.73** -4.45%	-0.39	0.08	0.03	0.44	0.000	0.008
H611(S)	5	0.46	-0.64	-0.04	0.97* 1.24%	0.18	0.11	0.37	-0.007	-0.005
H611(R)	5	1.75** 2.75%	-1.49** -2.36%	-1.12** -6.90%	1.50** 1.92%	-0.24	-0.36** -0.35%	-0.32	0.002	-0.003
Predicted cycle 0		63.6	62.9	16.3	78.3	6.4	101.6	229.4	0.82	0.79
H611(R)F_2	5	1.46** 3.12%	-2.00** -3.04%	-0.32	1.79** 2.42%	-0.34	-0.53** -0.51%	-1.03	-0.009	0.000
Predicted cycle 0		46.7	66.7	12.2	73.7	9.6	104.3	230.5	0.91	0.87
KCA(E7) c/	10	1.59** 3.19%	0.24	0.29	1.61** 2.30%	0.26	-0.07	1.13* 0.51%	-0.011	-0.013
Predicted cycle 0		49.6	57.4	11.1	69.9	7.2	102.3	223.9	0.93	0.83

a/ Evaluation grown at six sites; data for lodging, ear height, blight and rust recorded at only five sites
b/ Rating scale 1 to 5 (1 = resistant, 5 = susceptible)
c/ Two cycles in two years versus one cycle in two years for other methods of selection
*, ** Significantly different from 0.0 at P = 0.05 and P = 0.01, respectively

Darrah and Mukuru (1) pointed out the possibility of using the advanced generation of a variety cross, such as H611(R), for immediate farmer yield improvement until a seed industry could be developed that would be capable of producing a sufficient quantity of crosses. The F_2 generation of each cycle of H611(R) was included in the evaluation trial, along with E7 for comparison. Yield increased in H611(R)F_2 at 3.12% per year; this was based on a predicted cycle 0 value of 46.7 versus 63.6 q/ha for H611(R). Some bias occurs in percentage results where comparisons are made with differing initial points. The actual predicted gains for the variety cross and its F_2 were 1.75 and 1.46 q/ha per year, respectively. The result is a slight increase in the difference between the cross and its F_2 over cycles of selection. E7 closely paralleled the F_2 response with a gain of 1.59 q/ha per year and a predicted cycle 0 of 49.8 q/ha. The F_2 also showed a significant reduction of lodging (2.36% per year), an increase in frequency of usable ears (2.42% per year) and a decrease in days to flowering (0.51% per year). If a variety cross or cross of lines extracted from heterotic populations were eventually desired, the F_2 or further advanced generation would be an acceptable initial product for release to farmers. No advantage over the F_2 was realized by the use of ear-to-row selection in KCA.

The heterotic response of the H611 variety crosses was planned to be examined by partitioning the gains in each parent and adding these to predict the cross. If only additive effects were present, the individual parent population gains should predict the cross performance. Table 6 gives the parent population gains measured against cycle 0. For H611(E), a gain of 0.2 q/ha was found in KSII and a gain of 1.9 q/ha in Ec573. The cycle 10 cross would be predicted to exceed the cycle 0 cross by 2.1 q/ha, but the actual gain was -5.9 q/ha. Although none of the gains were statistically different, a trend is suggested.

Table 6. Contributions from parental yield improvement (q/ha), judged in crosses with cycle 0, to variety-cross hybrids, using ear-to-row (E), S_1 (S) and reciprocal recurrent (R) selection

Ecuador 573	Kitale Synthetic II								
	$E1C_0$	$E1C_{10}$	Gain	$S21C_0$	$S21C_5$	Gain	$R11C_0$	$R11C_5$	Gain
$E2C_0$	68.3	68.5	0.2	..	..	..	..	..	..
$E2C_{10}$	70.2	62.4	..	..	..	..	..	..	..
Gain	1.9	..	2.1 vs. -5.9 actual	..	..	..	..	..	..
$S22C_0$	..	..	..	68.3	64.6	-3.7	..	..	..
$S22C_5$	..	..	..	77.4	63.2	..	..	..	..
Gain	..	..	..	9.1	..	5.4 vs. -5.1 actual	..	..	..
$R12C_0$	..	..	..	..	..	..	68.3	72.4	4.1
$R12C_5$	..	..	..	..	..	..	71.6	79.5	..
Gain	..	..	..	..	..	..	3.3	..	7.4 vs. 11.2* actual

* Gain significant at $P = 0.05$

The observed gain due to S_1 selection in KSII was -3.7 q/ha, and that of Ec573 was 9.1 q/ha. The predicted cycle 5 variety cross was 5.4 q/ha above the cycle 0 cross, whereas the observed value was 5.1 q/ha below the cycle 0 cross. Again, these differences only indicate a trend because there was no statistical significance. For both H611(E) and H611(S), selection probably decreased the heterotic response of the variety crosses, possibly because the same favorable alleles were selected in both populations.

The observed gain in KSII, using reciprocal recurrent selection, was 4.1 q/ha, and in Ec573, 3.3 q/ha. The cycle 5 variety cross would be predicted to exceed the cycle 0 cross by 7.4 q/ha; the observed difference was 11.2 q/ha (significant at P = 0.05). Selection based on variety cross performance *per se* increased the heterotic response of the hybrid.

Evaluation of cycle 8 populations from reciprocal recurrent selection and lines extracted from cycles 2, 3 and 4 of Ec573 (R12)

An evaluation of the cycle 8 reciprocal recurrent selection populations and lines extracted from earlier cycles was grown in five environments in 1983 (Table 7). Results indicated a 7.6% yield advantage of R12C5 over R12C2 (commercial version) in crosses with (A x F). The cycle 8 yield advantage was 16.6% for the same cross (87.8 q/ha). Significant decreases in bare tips and days to flowering also occurred with the cycle 8 cross.

A cross involving extracted lines R12C3-93 and R12C3-82 with the female single cross (D x G) yielded significantly more (94.2 q/ha) than any current commercial cross (closed pedigrees). When measured against KSIII, R12C8 outyielded R12C2 (commercial version) by a significant 15.9%.

Table 7. Evaluation of cycle 8 populations from reciprocal recurrent selection and lines extracted from cycles 2, 3 and 4 of Ecuador 573 (R12)[a]

Entry	Yield (q/ha)	Stand (%)	Lodging (%)	Bare tips (%)	Usable ears (%)	Diseased ears (%)	Days to flower (no.)	Ear height (cm)
(A x F)Ec573(R12)C2	75.3	96.8	64.7	9.6	84.5	7.8	95.7	230.7
(A x F)Ec573(R12)C5	81.0	94.7	65.8	6.1	95.1	7.8	96.4	226.9
(A x F)Ec573(R12)C8	87.8	96.5	53.4	2.7	94.5	5.4	93.8	216.4
(A x F)(R12C2-50 x R12C3-93)	80.3	97.9	67.5	6.6	90.0	6.4	95.5	229.7
(A x F)(R12C2-50 x R12C4-82)	77.7	96.8	70.2	4.9	94.6	8.0	96.5	221.4
(F x G)(R12C3-93 x R12C4-82)	88.3	96.7	62.4	23.3	99.5	7.3	98.0	234.3
(D x G)(R12C3-93 x R12C4-82)	94.2	97.7	63.8	19.2	101.3	8.1	96.8	226.2
KSIII x R12C2	76.6	93.9	63.9	12.7	93.3	5.2	98.8	237.4
KSIII x R12C8	88.8	97.4	53.2	10.6	95.5	2.8	99.1	229.9
KSII(R11)C8 x R12C8	98.7	95.9	48.5	14.1	98.2	5.2	97.9	233.4
Mean	84.9	96.4	61.3	11.8	94.6	6.4	96.9	228.6
LSD 0.05	10.4	1.6	10.9	4.5	8.0	NS	1.5	NS
CV% (based on G x E)	19.3	2.6	28.0	64.9	13.5		2.4	

[a] Evaluation grown at five sites

The highest-yielding cross in the evaluation was R11C8 x R12C8 at 98.7 q/ha; it also had the lowest frequency of lodging (48.5%). Commercial hybrid producers in East Africa should be able to make use of the advanced cycles of this cross to realize significant gains over currently available hybrids.

Conclusions

Ear-to-row or full-sib selection with 100 entries in the selection trials would be the recommended intrapopulation improvement method. Care must be taken to reduce the frequency of bare tips that occurs with improved yielding ability. If half-sib selection is to be used, the choice of the tester is critical to the utility of the selected population. The tester selected should have good combining ability with the population under selection, as the test cross is what will be most improved. Half-sib selection should be targeted more at specific combining ability than at general combining ability.

Reciprocal recurrent selection is clearly the method of choice if heterosis exists between the populations to be improved. If hybrid production capability is lacking, the F_2 of the improved cross will suffice for an improved farmer variety until that capability is developed.

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Discussion

Dr. Kirkby: Would the effectiveness of selection methods depend on the facilities available?

Dr. Darrah: To some extent, but in the maize population improvement study in Kenya, relatively simple facilities were utilized in the beginning. However, the different environments selected were sufficiently close together that proper supervision was possible, ensuring appropriate management.

Mr. Prior: The experiments were conducted using high levels of nitrogen. Would you have obtained similar results if you had used levels nearer the low levels used by the farmers?

Dr. Darrah: No, those genotypes with higher yield potential would not have been well differentiated. It is unlikely that there would have been the same interaction of variety performance at both high and low fertility levels. For selection trials, higher fertility levels may be needed to distinguish yield differences among genotypes.

Dr. Manwiller: What population size did you use in the selection methods study?

Dr. Darrah: Initially the effective population size was 36. At the University of Missouri, 12 x 12 lattices are being utilized, although 100 entries would suffice. If fewer than 50 entries are used, there will likely be problems of genetic drift.

Dr. Khadr: You state that equal gains from selection were obtained in both the ear-to-row and full-sib selection methods. Did you expect that at the beginning?

Dr. Darrah: Yes, we did. For bigger seed, materials were planted at half the recommended plant density. To obtain enough seed, full sibs were produced reciprocally (the two ears were bulked). However, individual circumstances need to be considered.

Mr. Ndambuki: The population size in Kitale Synthetic II and Ecuador 573 was low, and there was an increase in yield up to cycle 8. Would you expect this to continue, given the initial low population size?

Dr. Darrah: It is expected that there will be further gains if selection is conducted under very favorable environments. However, higher population sizes and selection intensities need to be utilized.

Mr. Debelo: Reciprocal recurrent selection requires highly trained personnel and considerable facilities. What do you suggest when the personnel are not well trained and facilities are limited?

Dr. Darrah: If a hybrid seed industry is not available, it is advisable to use ear-to-row selection. For maximizing variety crosses, two populations may be set up reciprocally, with the F_2 initially utilized as a variety. If one of the populations is exotic, half-sib selection may be used with the local population as a tester.

Breeding for Drought Tolerance in Maize

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Abstract

There is an urgent need for maize varieties capable of better production under water stress, particularly in sub-Saharan Africa where drought is claiming thousands of lives each year. The most critical moisture-stress periods for growth and yield in maize are from tasseling and silking to grain filling. Drought resistance is the degree to which one genotype is more productive in a given water-stress environment than another genotype, and is usually accomplished by one or more of three mechanisms, drought escape, drought avoidance or drought tolerance. The breeding approach chosen for improving drought resistance in maize depends on the nature of the moisture-stress environment, of which there are three types, those having stored moisture, those characterized by variable moisture and those having optimum moisture with occasional short drought periods. The differences in plant breeding strategies for stress conditions are often determined by the severity of the problem, the ability to select for the stress condition and the resources available to the plant breeder. A widely accepted strategy is to select for yield under a nonstress condition, and then evaluate those selections under a diverse array of drought-prone environments. A second strategy is to select for yield under stress conditions, preferably after determining that a variety has reasonable yield potential under more optimum conditions. A third strategy is the utilization of a number of physiological, biochemical and morphological indicators or traits, known or suspected to be drought responsive. Morphological traits include leaf firing, shedding, rolling and angle changes, height reduction and root factors. The physiological and biochemical traits include plant modifications to water-stress conditions. Genetic improvement of drought tolerance is a component of many maize breeding programs, but a simple, workable scheme has not yet been determined. The need for drought-tolerant varieties and hybrids throughout many of the maize-producing regions of the world demands that breeders use all of the techniques at their disposal to improve drought tolerance in maize.

The need to improve crops genetically by the breeding of varieties for better production under water stress is urgent. The drought in sub-Saharan Africa is claiming thousands of lives each year; most of the area has experienced drought for three consecutive years. Momen *et al.* (18) state that there is evidence that climate may be more variable in the future, and point out the need for cultivars that can withstand more rigorous conditions.

Periodic drought, caused by irregular rainfall distribution and worsened by soils with low water-holding capacities and plow pans which reduce rooting depth, causes sizeable reductions in maize yields. Average annual loss in tropical maize production may be 15%, according to Fischer *et al.* (13). Actually, drought probably has an even greater influence, in that many farmers do not apply fertilizer or other inputs as readily in drought-prone areas.

Maize is often classified into only three maturity groups, early, medium and late, but it has many growth stages, as identified by Sprague (26). Both maturity and growth stage are at some point in time greatly affected by drought. The growth stages identified are planting to emergence, early vegetative growth (from rapid stem elongation to tasseling), tasseling, silking and pollination, and finally grain production (from fertilization to physiological maturity). Of these stages, the most critical moisture-stress periods for growth and yield are from tasseling and silking to grain filling (10,22). Water deficits for only one to two days during tasseling and pollination may cause as much as 22% reduction in yield (13). Denmead and Shaw (12) observed that moisture stress at silking reduced grain yield by 50%; moisture stress after silking reduced yield by 21%.

Irrigation at such critical periods may overcome the drought stress. Quizenberry (21) reports that, at the critical periods, as little as 10 mm of additional soil moisture over maintenance levels may increase maize yields by 18 to 44 kg/ha. Additionally, Stickler (27) noted that plot population could be increased with subsequent higher yields with adequate moisture; under moisture stress, lower populations gave higher yields.

Drought resistance is the degree to which one genotype is more productive in a given water-stress environment than another genotype, and is usually described under three mechanisms, drought escape, drought avoidance or drought tolerance. Drought escape is the ability of a plant to complete its life cycle before severe soil and plant water deficits occur. Drought avoidance is the plant's ability to endure drought by maintaining high tissue water potential or manifesting a relatively small reduction in tissue water potential under conditions of increasing soil-moisture deficit. Drought tolerance is the ability of the plant tissue to sustain a smaller reduction in physiological or metabolic activities as its water potential decreases. Most of the drought resistance in crop plants is due to avoidance, and the traits are mostly xeromorphic, i.e., they are developed by the plant as a result of moisture stress, for example, an epicuticular wax layer. These traits should have high heritability in a moisture-stress environment, and therefore selection should be more successful in moisture-deficit environments (11).

Darrell and Clark (11) have divided plant responses to drought into two categories according to stage of plant development, the preflowering or early-season response, whose symptoms are leaf rolling, leaf bleaching, leaf firing and delayed silking or flowering, and the postflowering or grain-filling response, whose symptoms include premature senescence, stalk lodging and poor grain filling. They observed that hybrids have been shown to be more preflowering tolerant than are inbred lines

The nature of the moisture-stress environment determines the breeding approach for improving maize for that environment. The water-stress environments can be roughly classified as follows:

- Stored-moisture environment—In this environment, the crop completes its entire life cycle on soil moisture stored during a prior wet season. Such an environment is characterized by distinct wet and dry seasons, and is particularly sensitive to any genetic, climatic or cultural factor favoring moisture utilization. Breeding strategies for this type of environment favor selecting for metabolic efficiency (21) among shorter, earlier maturing materials with improved morphological features for retarding water loss.

- Variable-moisture environment—In this environment, the crop is grown during the period of the year when moisture is intermittent. Variable rainfall patterns usually result in alternating periods of adequate soil-moisture availability and drought conditions; the ability to survive prolonged drought with rapid growth following rainfall is desirable. The "latente" maize studied by Castleberry and LeRette (7) apparently has the ability to maintain itself in a near dormant state under early water stress and then respond rapidly to irrigation or rainfall. The variable-moisture environment is more difficult to breed for than the stored-moisture environment, and unfortunately is the one most representative of eastern, central and southern African countries. Breeding strategies for this type of environment favor the selection of plants with high photosynthetic rates, sensitive stomatal responses, dense or deep root systems and osmotic adjustment mechanisms for maintaining cell turgor (21).

- Optimum-moisture environment—In this environment, the crop has adequate moisture during most of its life cycle, with only occasional short drought periods. Such environments are usually characterized by high-input, high-management farming systems and the drought, though rare, can be severe in its economic impact. Since the combination of high yield under optimum conditions and drought tolerance is difficult to achieve, this environment is the most difficult to breed for in a direct way. Generally, indirect selection by wide testing before release of new material is the accepted practice. Breeding strategies for these conditions include selecting for root development, osmotic regulation and stomatal closure (21).

Breeding Strategies for Drought Tolerance

The differences in plant breeding strategies for stress conditions, such as drought, are often determined by the severity of the problem, the ability to select for the stress condition and the resources available to the plant breeder. A widely accepted strategy is to select for yield under a nonstress condition, and then evaluate those selections under a diverse array of environments including, in this case, drought-prone environments (5). This approach assumes that drought-tolerance genes are present in high-yielding material, and that some combination will contain adequate genes for both traits. Work by Russell (23) has shown that this approach has developed superior maize hybrids in the USA.

A second strategy is to select for yield under stress conditions, preferably after determining that a variety has reasonable yield potential under more optimum conditions (5). One problem with selection under the stress environment is that the genotype x environment interaction is more difficult to distinguish, due to the generally low yields in such an environment. Examples of progress in selecting maize for drought tolerance are reported by Fischer *et al.* (13). Three cycles of selection in Colombia in the wet season gave gains of 10.5% per cycle for the wet season and 0.8% for the dry season; the three-cycle dry-season selection had gains of 7.5% per cycle for the wet season and 2.5% for the dry season.

A third strategy, which perhaps is a modification of the stress-environment selection approach, is the utilization of a number of physiological, biochemical and morphological indicators or traits, known or suspected to be drought responsive (20). These traits are often examined only under greenhouse and laboratory conditions, and the lack of definitive correlations with field response has hampered their widespread use. However, since they offer a way of examining large amounts of breeding material, their potential use is of great importance. Seetharama *et al.* (25) noted that, for sorghum, lack of progress could be due to the fact that cultivars utilize a multiplicity of drought avoidance or tolerance mechanisms, some of which concomitantly reduce photosynthesis. They also noted that screening technologies were not sufficiently developed for routine evaluation.

Drought resistance is a complex character, but it can be measured by the use of many physiological, morphological and biochemical traits. Seetharama *et al.* (25) reported that, as drought affects many plant-growth processes, consideration of a single character has not provided any consistent results. Christiansen and Lewis (9) advised that, initially, the plant breeder should be prepared to search all available sources of existing germplasm, with yield taking second place to the identification of superior sources of drought resistance. They further pointed out that two breeding approaches are available to the plant breeder when attempting to develop varieties with better yield in moisture-deficit environments, the development of varieties with adaptation to a wide range of environmental conditions or the development of varieties that are highly adapted only to a moisture-stress environment.

Selection Traits for Drought Tolerance

Morphological traits

Preflowering drought-stress traits include leaf firing, leaf shedding, leaf rolling, leaf-angle changes, height reduction and root factors. Leaf rolling or leaf shedding (leaf-area reduction) is a common way of reducing water loss. Leaf enlargement following drought stress is considered to be a good indicator of drought tolerance, and has the further advantage of being relatively easy to evaluate. The senescence of older leaves is a method for dehydration avoidance in the plant. Narrower leaves may also reduce water loss, and since normally photosynthesis utilizes only a small fraction of incident irradiation, narrower leaves should not cause losses in yield. Reduced tassel size may also fit into this category. Leaf-angle changes may reduce water loss by providing more shading of lower leaves and by reducing canopy temperatures. Height changes do not necessarily influence drought tolerance, although in general a more favorable ratio of reproductive to vegetative parts is desirable.

Changes in the root system may be desirable under drought conditions. Increased root density or root depth may permit greater utilization of available soil water. Care should be exercised, however, that selection does not result in greater transpiration losses or in abnormal root/shoot ratios. Darrell and Clark (11) observed that postflowering drought-stress traits included premature plant senescence, stalk lodging and poor grain filling. A predisposition to stalk rot pathogens generally accompanied earlier drought stress.

Physiological and biochemical traits

These traits represent plant modifications to water stress conditions. In some cases they may be obvious in their benefit; in others, they only indicate a response and are not of direct benefit.

Pollen shed or anthesis and silk emergence must be synchronized if effective pollination is to occur. This synchronization is altered greatly by drought stress, often with silking being delayed beyond pollen shed. Johnson and Herrero (16) showed that, under control, mild stress and severe stress conditions, there was a 0.6, 3.8 and 4.5-day delay in silk emergence, respectively. All treatments began pollen shed about 3.5 days after tassel emergence. Positive silk elongation ceased at about -9 bars in droughted plants and at about -14 bars in well-watered plants, measured at similar ear-leaf potentials. Pollen viability was only moderately affected by drought, but it was affected by high temperatures. Troyer and Brown (30,31) noted that physiological silk delay was usually caused by a lack of moisture to the developing ear. Selection for synchrony under drought stress should be an important part of a drought-tolerance breeding program.

Barlow *et al.* (3) found that, when the soil-water potential was decreased from -0.35 to -2.50 bars, leaf elongation rates decreased by 44% while soluble carbohydrates increased 42%; dry matter accumulation and transpiration decreased 26 and 24%, respectively. Osmotic adjustment influencing leaf and cell-water potential is important in the ability of plants to survive drought stress. Acevedo *et al.* (1) have shown that, in response to moderate water stress, seasonal osmotic adjustment occurs in field-grown sorghum, maize and soybeans.

Estimation of critical water-stress levels by cellular (membrane) integrity, measured by electrolyte leakages, appears to be a relevant criterion for selection for drought and heat tolerance. According to Sullivan and Ross (28), the degree of membrane stability to stress, as evaluated by ion leakages, correlates well with other plant responses to water stress. Mwale and Myers (19) determined leaf electrolyte leakage following water stress for several US maize inbreds and their F_1s and F_2s. They observed significant differences between cultivars grown under nondrought conditions, but not between those grown under drought stress. Leakage values were generally lower following drought stress, indicating osmotic adjustment.

Stomatal behavior, or more particularly the timing and completeness of stomatal closure during water stress and following water relief, is an important characteristic. Hiron and Wright (15) reported that water stress is one of the factors which induces stomatal closure. They also noted that, in plants which had been allowed to wilt and were then watered, the stomata remained closed for several days, even when there was a rapid recovery of full turgidity.

Beardsell and Cohen (4) indicated that abscisic acid (ABA) increases under water stress, inhibiting transpiration and inducing stomatal closure. Sharp reductions in photosynthesis and sharp increases in leaf-diffusion resistance at specific water potentials could be the result of ABA-induced stomatal closure (32). Larque-Saavedra and Wain (17) used a latente hybrid, developed by Muñoz in Mexico, that was believed to be drought tolerant, and two European cultivars, Anjcn 210 and LG11, which had not been bred for drought tolerance, to compare levels of ABA in detached leaves. The amount of free ABA in detached, nonwilted maize leaves in the latente hybrid was found to be more than four times that of the other two. After subjecting the detached leaves to water stress, the level of ABA increased in all varieties.

Ackerson (2) studied a US Corn Belt hybrid and a latente hybrid developed by Castleberry and LeRette (8) and found that levels of ABA were higher in the latente hybrid, particularly under stress during the vegetative and intermediate grain-filling stages. ABA accumulation was coincident with more rapid stomatal closure and lowered conductance. Photosynthetic activity was also affected by water stress, in part because of losses in leaf area, but also because of the closing of stomata with a consequent loss of CO_2 uptake. The drought interrelationship between photosynthesis and translocation has been studied by Boyer and McPherson (6), with the conclusion that photosynthesis is the critical factor in determining yield, assuming that pollination and fertilization have occurred. Johnson and Herrero (16) have listed the plant growth processes in order of decreasing sensitivity to drought—cell and leaf enlargement, floral development, photosynthesis and transpiration, respiration and translocation.

The accumulation in leaf tissue of metabolites, such as proline and betaine, also seems to be a response to drought-stress conditions. Hanson *et al.* (14) suggest that the extent of proline accumulation reflects the degree of internal water deficit, as evidenced by the decline in leaf-water potential. Mwale and Myers (19) evaluated six F_1 maize hybrids, their F_2s and their inbred parents for proline accumulation, and found a broad-sense heritability of 0.70.

Pathological presence may also be used to indicate drought stress in maize. Schneider and Pendery (24) reported that, at the end of the growing season, the incidence of corn stalk rots in field plants exposed to mild water stress during the pretassel, post-pollination, or grain-filling stages were 60.3, 25.3 and 7.7%, respectively; the nonstressed control had 24.7% disease. The resistance to water flow between roots and leaves was approximately doubled in stressed, infected plants, and it was thus concluded that a water deficit during the early part of the growing season had a predisposing effect toward disease development.

Table 1. Characteristics of three maize breeding programs for drought tolerance

	Breeding program		
Characteristic	BSSS(R)[a]	CIMMYT	Castleberry-LeRette[b]
Genetic goal	Improved populations	Improved varieties	Commercial hybrids
Germplasm source	Elite line composites	Tuxpeño-1	Line x line (Michoacan 21 composites)
Stage of selection	Half-sib test crosses	Full-sib families	Inbreeding
Stress environment	Multiple environment	Limited irrigation	Limited irrigation
Selection criteria	Yield, agro · ·nic index	Growth, firing, synchrony, yield	Firing, synchrony, ear, root
Secondary evaluation	Line development	Multiple environment	Multiple environment

[a] Iowa State University, Ames, Iowa, USA
[b] Dekalb Agricultural Research, Inc., Dekalb, Illinois, USA
Source: Castleberry (7)

Genetic improvement of drought tolerance in maize is a component of many breeding programs. Table 1 shows the characteristics of three different types of breeding programs which have produced drought-tolerant materials.

Troyer (29) suggests several selection criteria in breeding for drought tolerance, to select for early flowering, against silk delay, for maximum leaf area, against tassel blast and for a long filling period. He also emphasizes that selection under high plant densities provides an opportunity to breed for drought tolerance in nondrought environments.

Conclusions

In summary, much is known about the responses of maize to drought, and also about specific characteristics that have a relationship to drought tolerance. Several strategies have been developed for breeding for drought tolerance. However, the interrelationship of all of this knowledge into a simple, workable scheme for maize-breeding programs has not yet been determined. Breeders might select for yield stability over a wide geographic area, or they might provide a high-yield option, together with options that maximize yields under those stress conditons which have a high probability of occurrence.

At present, some combination of the above programs, with the additional input of any specific physiological or morphological indicators, should be practiced. The need for drought-tolerant varieties and hybrids throughout many of the maize-producing regions of the world, particularly in eastern, central and southern Africa, demands that breeders use all of the techniques at their disposal to improve drought tolerance in maize.

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Discussion

Dr. Darrah: Was it common to find transgressive segregation like the F_1 of B73 x MO17, which had higher proline levels, i.e., was less drought tolerant than either parent?

Dr. Myers: Some crosses showed transgressive segregation, while others followed the predicted pattern of the selfed generations being intermediate to the two parents.

Dr. Patel: Nematode damage to roots also causes proline accumulation, does it not?

Dr. Myers: That is true. Anything which increases water stress within the plant will cause proline to accumulate.

Question: Is there a "rough and ready" method for screening for drought tolerance in a national program?

Dr. Myers: The proline accumulation technique is simple enough that it can be used within a national program for screening a limited number of materials, such as the key inbreds and F_1 hybrids.

Development and Evaluation of Maize Hybrids in Zambia

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Abstract

In Zambia, where maize is the primary staple food crop, the maize research program is working to collect, screen and develop materials with useful agronomic characteristics, develop a range of new genotypes to meet the needs of different types of farmers, improve and maintain the purity of existing commercially grown hybrids and varieties, test commercially grown hybrids and varieties from other countries to determine suitability for import, and identify agronomic practices that give the highest and most stable yields for the soils, climates and hybrids and varieties found in Zambia. The emphasis of the program is to provide for two immediate needs, earlier maturing hybrids and varieties better adapted to Zambian conditions, and the staff, physical facilities and genetic resources to allow for continuous improvement over a long period. Since 1978, hybrid maize development has focused on the improvement of Zambia's principal hybrid, SR52, as well as on the development of new, earlier maturing drought-tolerant hybrids. In 1983, SR52 was re-released under the new name of MM752. It has shown a yield increase of 20% over the old SR52, and by 1986-87 should completely replace it. The development of new hybrids suitable for the country is now the major emphasis of the program. Excellent progress has been made, with seven new hybrids released in 1984. Inbred lines are being tested according to five approaches. Preliminary results indicate that these approaches are successful in maintaining or improving yield, even though selection emphasis is largely on other traits, earliness, drought tolerance and streak resistance, all of which have been substantially improved. It also appears that the most promising lines are coming from the conversion of yellow inbreds into white and from the extraction of inbreds from diverse populations.

Maize hybrids have been widely grown in Zambia since independence in 1964. In the beginning, the major commercially produced hybrid was SR52, although SR11 and SR13 were also grown on limited areas for a short time. Zambia's maize breeding program also began with independence, with the main objective being that of maintaining and increasing the parent lines of SR52 in order to begin hybrid seed production. However, there were difficulties, because the male parent was a poor producer of pollen. Therefore, a program of test crossing was begun in 1966 to select an inbred line or variety with high yield and easy maintenance, which would readily cross with SR52. Over 500 different varieties and inbred lines, collected both within Zambia and from outside the country, were included in this crossing program. By 1968, this number was reduced to six, and in 1969 inbred line 63J 347 was selected as the male parent for a three-way cross, with SR52 as the female. The new hybrid was released in 1970 as Zambian Hybrid 1 (ZH1).

A long-term breeding program was initiated in 1965, following the Zambian maize breeder's attendance at the First, Second and Third East African Cereals Research Conferences.

The methods of recurrent selection were described in detail at these three conferences and were adopted for Zambia's long-term maize breeding program. The aim of the program was to produce a variety that would be higher yielding than the currently grown SR11, SR13 and SR52, and suitable for the requirements of both small farmers and the more productive commercial farming enterprises.

Two maize populations were formed between 1966 and 1969. The first, Zambian Composite A (ZCA), was made up of Hickory King plus 17 inbred lines from the Zambian hybrid development program; the second, Zambian Composite Z (ZCZ), came from material originating in Central America, an area ecologically similar to Zambia. ZCA was released for commercial production in 1971. Following the initial release, recurrent selection resulted in a yield increase of approximately 10% in two years. Two more composites were formed between 1968 and 1970, Zambia Yellow Composite and Zambian Short-Season Composite.

Unfortunately, during the period 1971 to 1978, most research emphasis was on activities other than straightforward hybrid and variety development. This included work on protein quality, cytoplasmic male sterility, dwarf brachytic genes and the testing of foreign hybrids and varieties. The development and improvement of new populations was not carried on in any sizeable way. This lack of continuous effort for the improvement of key populations was one of the main reasons that only one local single-cross hybrid was in production in Zambia for over 20 years, despite the big demand for a diversity of maize hybrids and varieties.

As a result of cooperation between Zambia's Ministry of Agriculture and Water Development and the Maize Research Institute of Yugoslavia, the breeding situation changed in 1979. The program became more comprehensive, with an attempt to improve the existing genotypes of maize, particularly SR52, as well as to develop new genotypes to meet the wide range of requirements of various types of farmers in areas with varying environmental conditions. Financial support for this program was provided by GRZ (Government of the Republic of Zambia), Yugoslavia, FAO, SIDA (the Swedish International Development Agency) and USAID. A large introduction program has also been carried out by the Yugoslavian Maize Research Institute through their farm in Mazabuka. Zambia has benefited greatly from this assistance.

Objectives

Considering the importance of maize as the primary staple food crop in Zambia, the main objective of the current maize research program is to contribute to increased and more stable maize production in the country. More specifically, the objectives are:

- Collect, screen and develop source materials which possess useful agronomic characteristics, including high yield potential, stability, tolerance to the principle diseases and insects, suitable maturities and desirable plant and grain type;
- Develop a range of new genotypes of maize capable of meeting the needs of different types of farmers, of improved composites for subsistence farmers in remote areas, of top crosses and double crosses for subsistence and emergent farmers and of three-way crosses and single crosses for emergent and commercial farmers;
- Improve existing commercially grown hybrids and varieties by modification of parents or selection within the variety;

- Maintain (through cooperation with ZAMSEED) the purity of commercially grown genotypes of maize;

- Test commercially grown maize hybrids and varieties from other countries to compare newly developed genotypes with the best foreign hybrids of the same types to determine the suitability of such hybrids for import, if necessary, and

- Identify agronomic practices which give the highest and most stable yields for the soils, climates and hybrids (and varieties) found in Zambia.

The emphasis of the program is to provide for two immediate needs, earlier maturing hybrids and varieties better adapted to Zambian conditions, and the staff, physical facilities and genetic resources to allow for continuous improvements over a long period.

Research Results

Since 1978, hybrid maize development in Zambia has focused on the improvement of the main existing hybrid, SR52, and on the development of new, earlier maturing, drought-tolerant hybrids.

Replacement of Zambian SR52 by MM752

The accomplishment of the greatest immediate benefit to Zambia has been the yield improvement of the contaminated Zambian version of SR52. Both parents were highly contaminated, causing noticeable unevenness and morphological variation, as well as yield reduction, when compared to the Zimbabwe version of SR52. In 1978-79, results of yield trials conducted at six locations to compare SR52 seed from different producers confirmed the high level of variability, even among single seed lots (Table 1). Obviously, in a single-cross hybrid, there should be little variation among plants or seed lots. During the

Village mango trees and plantings of maize and pumpkin, Luangwa Valley, Zambia

growing period, it was impossible to distinguish between plants of the correct type and off-type plants in either parent; at harvest, only 5% of the cobs of SC5522 (male) and 23% of the cobs of N3233 (female) corresponded to the correct type. It is not surprising that this degree of contamination caused the Zambian SR52 to be about 15% lower in yield than the Zimbabwe version.

The contamination of the parents of SR52 occurred because of improper maintenance of breeders' and basic (registered) seed. Specifically, basic seed of both parents had recirculated for over 15 years, and there had been essentially no production of hand-pollinated breeders' seed. Fortunately, basic seed of the females and males were never produced on the same farm and were properly isolated from other maize, so that the contamination within the inbreds apparently came from residual variation and mutation rather than from outcrossing. However, without a system of maintenance involving hand-pollination, this contamination was not kept within acceptable limits.

Considering the nature of the contamination, a simple ear-to-row method of line purification was utilized. In 1978-79, about 2000 true-to-type ears were selected from basic seed of each parent and were planted ear-to-row. At tasseling, five plants of each of 200 selected rows were hand-pollinated in each parent. During the 1979 dry season, three rows each of 100 selected families were planted. The best 20 families were then selected at tasseling, giving a total of 60 rows. Selected families were ranked from 1 to 20 on the basis of plant phenotype. Five plants were selfed within a row, and 20 plants were crossed with the family in the other parent which had the same rank. These crosses were planted in a yield trial at two locations in the rainy season of 1979-80. At the same time,

Table 1. Results of yield trials of the hybrid maize variety SR52 at six locations, using seed produced by six different growers, Zambia, 1978-79

Grower	Yield (t/ha)						
	Mt. Makulu	Kabwe	Msekera	Magoye	Moch.	Kaoma	Mean
Mortizan	9.29	3.81	7.58	5.35	5.24	2.84	5.69
Hantuba	10.26	6.19	9.09	5.32	5.38	2.41	6.44
Coventry	8.44	5.68	7.28	5.47	5.44	3.05	5.89
Lublinkof	10.37	3.41	7.63	4.68	5.09	3.37	5.76
van Devanter	10.54	6.83	9.88	5.96	5.38	2.89	6.91
Nakumba	10.07	7.85	8.33	5.65	5.85	2.31	6.68
Mean	10.14	6.01	8.51	5.40	5.46	2.91	6.41
SR52 (Zimbabwe) (check)	12.01	8.30	9.80	5.40	5.81	3.50	7.47
CV%							13.40
SE/M							0.35
LSD(0.05)							1.01
LSD(0.01)							1.36

the five selfed ears of each of the 20 families were planted for further selfing. Detailed records of phenotype were collected on all selected families. F_1 progenies of the 20 families were all roughly equal to each other and to the Zimbabwe SR52. Therefore, on the basis of phenotype, and to a lesser degree on yield, five of the female families and three of the male families appeared identical. These families were mixed together within each parent to serve as the source for further breeders' seed increases.

In the dry season of 1980, 60 kg of seed each of both male and female parents were produced by hand-pollination. Further testing of the new SR52 was conducted during 1980-81 and 1981-82 at five locations, showing an increase of 20% over the old SR52; there was no statistically significant difference between it and the Zimbabwe SR52 (Table 2). This new version was released in 1983 under the name Mount Makulu 752 (MM752). The number 7 stands for FAO group 700, and the 52 was retained in the name to show its connection with SR52. Roughly 10,000 hectares were planted with MM752 during the 1984-85 season, and more than 100,000 hectares are expected for 1985-86. By 1986-87, MM752 will have completely replaced SR52 in Zambia.

MM752 is the only hybrid currently being produced in its maturity group. It gives excellent yield under good conditions, and is suitable for any farmer (small or commercial) who can plant at the beginning of the rains, in an area of adequate moisture with at least 150 growing days, and with a reasonable amount of fertilizer. It generally needs at least 200 kg/ha basal compound (D or X, 10-20-10 and 20-10-5 N, P_2O_5 and K_2O, respectively), plus 200 kg/ha topdressing (ammonium nitrate at 34% N or urea at 46% N).

Development of new hybrids

Development of new maize hybrids suitable for the country is now the major emphasis of the research program, and it is recognized that

Table 2. Comparisons of yields of the hybrid maize varieties MM752 and SR52 (Zambia), 1980-81 and 1981-82

Variety	Yield (t/ha)[a/]					
	Mt. Makulu	Mazabuka	Magoye	Msekera	Kabwe	Mean
MM752	5.59	4.50	5.83	10.64	10.38	7.39
SR52(Zambia)	4.57	3.94	4.61	9.51	8.01	6.13
SR52(Zimbabwe)	5.43	4.72	6.61	0.29	10.61	7.75
Mean	5.20	4.39	5.68	6.81	9.56	7.09
% increase of MM762 over SR52(Zambia)	22	14	26	12	29	20
SE/M						0.20
LSD(0.05)						0.64
LSD(0.01)						0.90
LSD(0.001)						1.31

a/ Average of the two years

several types of hybrids are necessary for different agroecological areas and different levels of management. Three major areas are defined on the basis of total rainfall, length of growing season and mean temperature. Zone I is the northern, high-rainfall area, Zone II, the intermediate-rainfall area in the central part of the country, and Zone III, the hot, dry valleys of the Zambezi and Luangwa rivers. Hybrid types, topcrosses, double crosses, three-way crosses and highly productive single crosses are needed with a range of 90 to 180 days to physiological maturity.

The development of new maize hybrids began in 1978-79, with the main emphasis on earlier maturity, drought tolerance and disease resistance. Excellent progress has been made, with several new hybrids identified that have excelled in three years of testing. These hybrids are crosses of

Table 3. Yield of the National Maize Variety Trial in 12 environments representing the three agroclimatic zones of Zambia, 1984

Entry	Zone I (6 environments)		Zone II (5 environments)		Zone III (1 environment)		Mean (12 environments)	
	Yield (t/ha)	% of MM752	Yield (t/ha)	% of MM752	Yield (t/ha)	% of MM752	Yield (t/ha)	% of MM752
MM601	6.07	107	9.79	112	6.84	120	7.68	110
MM752	5.69	100	8.73	100	5.72	100	6.96	100
MME602	5.70	100	8.75	100	4.99	87	6.91	99
MM502	6.09	107	8.52	98	3.76	66	6.91	99
MM501	5.71	100	8.44	97	6.02	105	6.88	99
MM603	5.90	104	8.13	93	5.78	101	6.82	98
R215	5.04	89	8.92	102	4.47	78	6.61	95
RS52(Zambia)	5.07	89	8.28	95	5.64	99	6.46	93
PNR473	4.98	88	8.45	97	4.40	77	6.38	92
CS4141	4.89	86	8.15	93	6.00	105	6.34	91
SR52(Zimbabwe)	4.97	87	7.98	91	5.69	99	6.28	90
MME503	4.89	86	8.31	95	4.48	78	6.28	90
ZH1	4.63	81	7.40	85	4.00	70	5.73	82
ZUCA	4.95	87	6.13	70	5.73	100	5.51	79
EV8076	4.72	83	6.49	74	4.15	73	5.41	78
Pop. 10	4.23	74	6.69	77	4.73	83	5.30	76
Across 7844	3.84	67	6.79	78	4.68	82	5.14	74
Across 7843	3.75	66	5.95	68	5.16	90	4.78	69
Mean	5.06	89	7.88	90	5.12	90	6.24	90
SE/M	0.35		0.35		0.59			
CV%	11.69		7.50		14.99			
LSD(0.05)	0.98		0.99		1.66			
LSD(0.01)	1.31		1.31		–			
LSD(0.001)	1.69		1.70		–			

elite inbreds which were obtained from the Maize Research Institute of Yugoslavia during advanced stages of inbreeding and then selected for adaptation to Zambia. Seven hybrids developed from these inbreds and the parents of MM752 were released during 1984 (MM501, MM502, MM504, MM601, MM603, MM604 and MM606).

Yields of the new hybrids are listed in Tables 3 and 4; descriptions of other charcteristics appear in Table 5. The yield of MM601 was exceptionally good in all three zones; the yields of all of the others were competitive with MM752 and the popular Zimbabwe hybrid, R215. All of them mature 5 to 25 days earlier than SR52 and are more drought tolerant, both because of the early maturity and because of better synchronization between pollen shed and silking. These new hybrids are also more streak resistant than SR52, MM752 and R215. They should be of great benefit to both large- and small-scale farmers who are currently growing SR52 but cannot plant on time, or who are farming in areas of low rainfall. Certified seed of most of the newly developed hybrids will be available for farmers during the 1985-86 season.

Excellent single, double and three-way crosses have now been developed, but some very promising top-cross hybrids are also being tested. In 1983-84, two first-year trials were conducted at two locations to test combining ability of some selected half-sib families of composites undergoing recurrent selection. Fifteen families, representing eight populations, were crossed with two inbred testers (ZPL9 and ZPL12), and the resulting 30 top crosses were

Table 4. Yields of the advanced maize hybrid trials, Zambia, 1981 to 1984[a]

Entry	1981-82		1982-83		1983-84		Mean	
	Yield (t/ha)	% of SR52 (Zim)	Yield (t/ha)	% of SR52 (Zim)	Yield (t/ha)	% of SR52 (Zim)	Yield (t/ha)	% of SR52 (Zim)
MM601	8.13	94	6.74	129	7.50	160	7.46	120
MM604	7.69	88	6.70	128	7.10	151	7.16	115
MM603	7.31	84	6.24	119	6.82	145	6.79	109
R215	6.95	80	6.70	128	6.43	137	6.69	108
MM504	6.30	72	6.50	124	6.50	138	6.43	104
MM606	6.90	79	6.00	115	6.20	132	6.37	103
MM501	5.71	66	7.30	140	6.10	130	6.37	103
PNR473	6.90	79	6.50	124	5.62	120	6.34	102
SR52(Zimbabwe)	8.69	100	5.23	100	4.70	100	6.21	100
SR52(Zambia)	6.94	80	4.45	85	4.47	95	5.29	85
Mean	7.15	82	6.24	119	6.14	1.31	6.51	105
SE/M	0.43		0.38		0.45		0.41	
LSD(0.05)	0.95		0.26		0.82		0.85	
LSD(0.01)	1.40		1.25		1.23		1.31	
LSD(0.001)	1.78		1.63		1.69		1.70	

[a] Average of two environments

compared with four standard check hybrids (R215, PNR473, MM502 and MM752) and four open-pollinated varieties (Pirsabak (2) 7930, Across 7844, ZUCA, and EV8076) (Table 6). All selected families showed good combining ability with both testers.

The top crosses were markedly superior in yield to the varieties, with several top crosses having equal or better yield than the best hybrid checks (e.g., Across 7644-117 x L9, Across 7644-117 x L12, PR7832-241 and PR7832-256 x L12). The level of heterozygosity of the top crosses is much higher than that of the inbred-line hybrids, but yields are similar. The stability and adaptability of top crosses make them very suitable for the small-scale sector, and considering the yields of those tested in this trial, it is clear that an effort should be made to release some top-cross hybrids as soon as possible.

Development of inbred lines
The main source of inbred lines in the program has been breeding material from the Yugoslavian Maize Research Institute which is being tested on the research farm in Mazabuka, Zambia.

This breeding material represents collections from over 14 maize-growing countries, Zambian local collections and composites, and CIMMYT and IITA varieties. The numbers of lines screened each year in the rainy and dry seasons are shown in Table 7.

Five different approaches to inbred-line development have been used in Zambia:

- Conversion of yellow inbreds to white;
- Improvement of established inbreds;
- Selfing of genetically diverse breeding populations;
- Recombination of related inbreds, and
- Introduction of foreign elite inbreds.

During 1983-84, there was preliminary testing of 105 new inbred lines representing these different approaches. The number of tested lines and the average yield within each category are shown in Table 8. Some new hybrid combinations showed significantly higher yield than the check hybrids, with the remainder yielding about the same as the checks.

Table 5. Plant characteristics of newly developed maize hybrids, Zambia, 1984

Hybrid	Hybrid type[a]	Grain type[b]	Ear ht. (cm)	Plant ht. (cm)	Days to 50% silk	Days to Maturity	Resistance score Streak[c]	Resistance score Cob rot[c]	Resistance score Drought
MM501	SC	SD	84	180	65	125	2.1	3.7	Exc.
MM502	SC	SD	84	200	69	135	1.5	4.1	Exc.
MM504	TC	SD	86	200	66	130	2.2	4.4	Good
MM601	SC	SD	110	210	69	135	2.4	4.6	Good
MM603	TC	SD	100	200	69	140	2.5	4.7	Good
MM604	TC	SD	100	210	70	145	2.7	4.7	Good
MM606	DC	SD	100	200	68	140	2.9	4.7	Good
MM752	SC	D	120	210	76	150	3.1	5.0	Poor

a/ SC = single cross, DC = double cross, TC = three-way cross
b/ SD = semident, D = dent
c/ Scoring scale 1 to 5 (1 = resistant, 5 = susceptible)

Table 6. Yields of half-sib selected families crossed with two inbred testers at two locations, Zambia, 1983-84

Family	Yield (t/ha) ZPL9 (tester)	ZPL12 (tester)	Mean
Tlaltizapan 7644-18	4.93	8.10	6.52
Tlaltizapan 7644-19	4.52	8.66	6.59
Tlaltizapan 7644-67	3.40	6.16	4.78
Across 7644-117	6.61	8.66	7.65
Across 7644-128	5.51	8.21	6.86
Poza Rica 7832-241	4.22	9.23	6.72
Poza Rica 7832-256	5.14	9.63	7.38
Alajuela 7725-168	5.17	9.44	7.03
Alajuela 7725-189	3.17	8.66	5.91
ZUCA 232	3.70	8.28	5.99
ZCA 269	4.24	8.15	6.20
La Cal. 7728-83	4.73	7.48	6.11
La Cal. 7726-84	4.65	7.63	6.14
Tocumen 7728-136	4.13	6.03	5.08
Tocumen 7728-140	4.69	5.07	4.88
Average	4.59	7.96	6.26
Open-pollinated checks			
P(2)7930	1.98	4.45	3.22
Across 7844	1.56	4.52	3.04
ZUCA	2.97	6.78	4.88
EV8076	4.28	6.95	5.62
Average	2.70	5.68	4.19
Hybrid checks			
R215	6.11	8.76	7.43
PNR473	4.55	6.68	5.61
MM502	4.69	8.97	6.83
SR62	2.37	6.57	4.47
Average	4.43	7.75	6.09
Grand Mean	4.23	7.52	5.87
CV%	30	25	
LSD(0.05)	2.16	3.07	
LSD(0.01)	2.89	--	

These tests were preliminary and were not adequate to identify any specific hybrid as superior to the checks. They did, however, indicate that the methods of inbred development being used were successful in maintaining or improving yield, even though most of the selection emphasis was on early maturity, drought tolerance and streak resistance. The improvements in these latter three characters have been substantial, indicating that the program should be continued with the approaches currently being used. It is apparent that the combining ability of L12 is generally higher than that of L9, and there are indications that the most promising lines are coming from the conversion of yellow inbreds into white and the extraction of inbreds from diverse populations. Further information on the effectiveness of the different approaches will be available during 1984-85, as a result of tests on the combining ability of 575 inbreds representing 115 lines from each of the five groups.

Conclusions

If the maize breeding program in Zambia continues with the same intensity, it should soon be possible to develop hybrids for each agroecological zone and each level of management. They should be much superior to the currently grown SR52, or even the recently released new hybrids. Although much progress has been made, the maize program is only at the beginning of the ultimate achievements that can be realized in Zambia. The development and improvement of maize hybrids have resulted in major yield gains in the United States, Europe and some African countries, and better-adapted hybrids should also revolutionize maize production in Zambia.

Table 7. Inbred line development, Zambia, 1978-79 to 1984-85

Season	No. planted lines S_0 to S_6 Rainy season	Dry season	No. selected lines Rainy season	Dry season	No. Tested lines
1978-79	5578	2950	959	856	—
1979-80	3580	5020	640	580	109
1980-81	5450	5540	380	680	38
1981-82	2467	6350	608	1080	58
1982-83	9839	6100	1872	1870	60
1983-84	11431	8630	2481	2180	105
1984-85	17600	—	—	—	575

Table 8. Number of tested lines and yields of five different sources of inbred line development, Zambia

Source	ZPL12 No. Tested lines	ZPL12 Yield (t/ha)	ZPL9 No. tested lines	ZPL9 Yield (t/ha)
Conversion of yellow into white inbreds	9	9.83	—	—
Improvement of established inbreds	9	7.37	10	8.33
Genetically diverse populations	6	9.86	—	—
Recombination of related inbreds	29	7.62	18	5.87
Introduction of foreign inbreds	21	8.30	3	6.73
Checks				
MM502		8.71		
R215		8.05		
PNR473		6.76		
SR52		6.40		
CV%		12		11
LSD(0.05)		1.54		1.48
LSD(0.01)		2.06		1.97
LSD(0.001)		2.69		2.58

Discussion

Dr. Nissly: In developing hybrids for large-scale farmers and for small-scale farmers, do you consider different criteria?

Dr. Ristanovic: The types of varieties recommended for different types of farmers depend on the level of heterogeneity in the hybrid. For example, three-way and varietal-cross hybrids, rather than single crosses, would be recommended for use by the subsistence farmers whose level of husbandry is low.

Dr. Sprague: Pirsabak (2) 7930, which you mentioned, was developed as a result of selections made in Pakistan, and it was supplied to Zambia by CIMMYT. This is a good example of cooperation between programs in the exchange of materials.

Progress in Breeding for Resistance to the Maize Streak Virus Disease

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Abstract

*Reliable techniques for the mass rearing of the vector (*Cicadulina *spp.) of maize streak virus were developed at IITA. Streak resistant sources were identified and others introduced, and large-scale field screening made possible the development of populations, varieties and inbred lines with high levels of streak resistance. Both recurrent selection and conversion by backcrossing were used. National programs are participating in the selection of superior genotypes for their own use. Streak-resistant varieties are being miltiplied and have been released to farmers in several African countries.*

Maize streak virus disease (MSV) is considered one of the most important maize diseases in sub-Saharan Africa. It occurs both in the forest and in savanna zones, and from sea level up to 1800 meters in elevation. The magnitude of yield loss due to MSV varies from season to season, depending on the percent of infected plants and the growth stage at time of infection. Severe outbreaks often occur in combination with late planting and in second-season maize. In 1983, epidemics of maize streak virus were reported from the savanna zone of several countries in West Africa and caused substantial yield losses, which were further aggravated by erratic rainfall distribution. In 1984, also, high incidence of streak was reported from the savanna zones of West Africa.

Yield losses of up to 100% have been measured in experiments at the International Institute of Tropical Agriculture (IITA) in Nigeria, under artificial streak epiphytotics. Reliable methods for mass rearing of the vector (*Cicadulina* spp.) and for screening large numbers of genotypes have been developed (1,2 3,7). Although yield losses due to MSV can be controlled to some extent by agronomic practices, such as timely planting and seed treatment with systemic insecticides, a much more reliable strategy would be the introduction of MSV-tolerant, high-yielding, well-adapted varieties. Streak resistance is an important component of yield stability of maize varieties in streak-prone areas. It also has an impact on such crop demands as fertilization and weed control; farmers are less reluctant to invest in these inputs if they know that their crop will not succumb to diseases.

In this presentation, reliable methods of screening for streak resistance will be described briefly, and an overview given of the progress in streak-resistance breeding.

Development of Screening Techniques

Erratic natural occurrence of MSV makes it very difficult to make genetic gains by routine field selection. Artificial rearing methods were therefore developed at IITA, starting with the mass rearing of *Cicadulina triangula* leafhoppers. The leafhoppers were initially reared in cages on young plants, fed on plants infected with MSV and then released from the cages into large greenhouses. These methods were improved and techniques developed to uniformly infest large populations of maize plants in breeding nurseries in the field (6,7). The process for mass rearing cicadulina leafhoppers is shown in Figure 1.

It is now possible to release about 200,000 leafhoppers per week in the field, enough to infest about 50,000 plants with viruliferous insects. The screening technique has been described in detail by Dabrowski (3). The infestation is very uniform, which minimizes the chances of "escapes" in the field. Susceptible check rows are planted at regular intervals in order to monitor the uniformity of the infestation.

Identification of Sources of Streak Resistance

In 1975, streak resistance was found in the maize population TZ-Y, which was partly based on yellow segregants from Tuxpeño Planta Baja. A number of lines were developed through continuous selfing under artificial streak infection. One of these lines, IB32, has subsequently been used extensively at IITA as a donor for streak resistance.

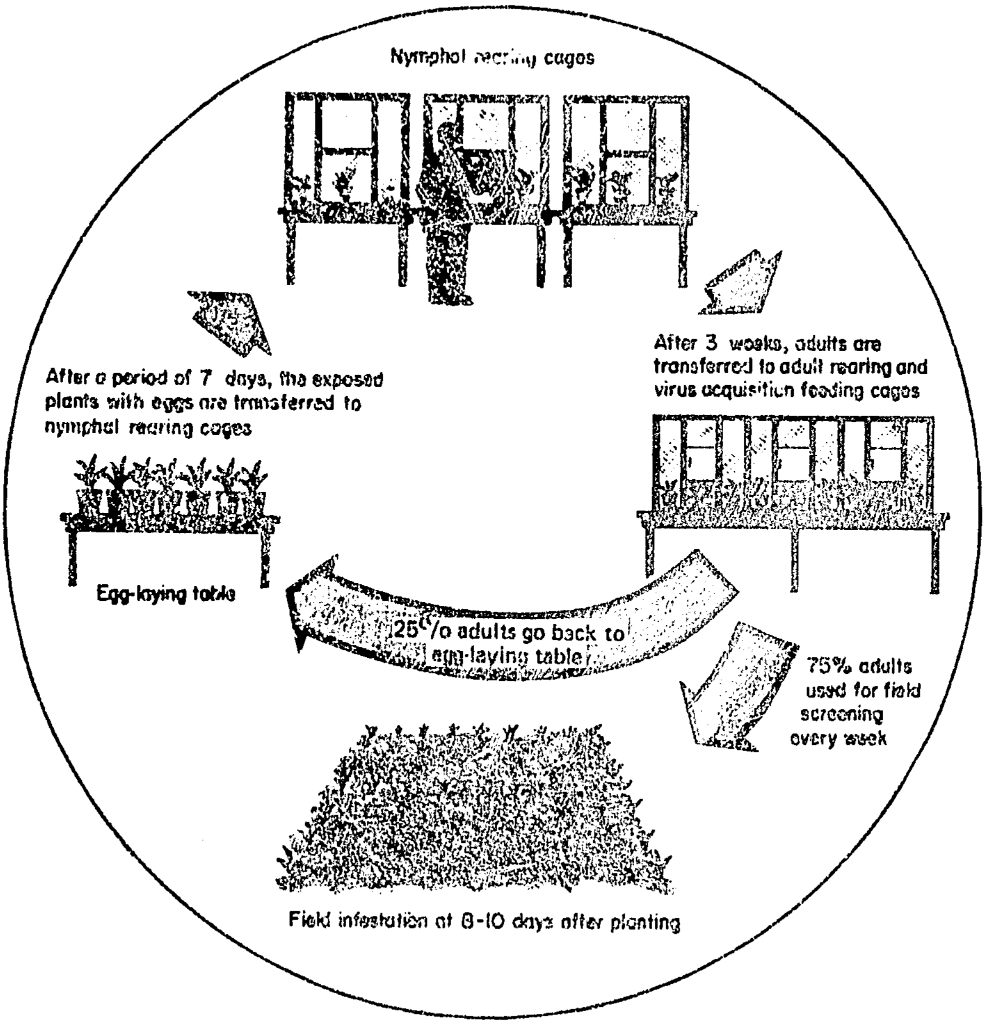

Figure 1. Diagram for mass rearing *Cicadulina triangula*, IITA, Ibadan, Nigeria

In 1976, streak resistance was also verified in the variety La Revolution from Reunion Island and in Tuxpeño x Ilonga composite from Tanzania. In 1977, both white and yellow-grain populations were established, based on TZ-Y; they were called TZSR(W) and TZSR(Y), respectively. These populations had good streak resistance, but a rather narrow genetic base and certain limitations, one of which was poor standability.

In 1982, streak resistance was verified in uniform streak nurseries at IITA in the populations tropical late white dent (Pop. 10), tropical intermediate white flint (Pop. 11) and tropical yellow flint-dent (Pop. 12). The populations were developed in a cooperative effort between the national programs of Tanzania and Zaire and CIMMYT.

A study of the inheritance of streak resistance in IB32, using generation mean analysis (5), has suggested that only about three major genes are involved in controlling streak resistance; modifier genes also play a role in disease expression. The streak resistance in La Revolution is monogenic. Field observations indicate that streak resistance developed at IITA also holds up in East Africa.

In the evaluation of breeding materials, efforts were made to select plants with a high level of tolerance to MSV. The following scale of 0 to 5 was used for evaluating tolerance:

0 = no symptoms
1 = very few streaks on leaves
2 = light streaking on older leaves, gradually decreasing on young leaves
3 = moderate streaking on old and young leaves, slight stunting
4 = severe streaking on 60% of leaf area, plants stunted
5 = severe streaking on 75% of leaf area, plants severely stunted or dead

Plants of category 0 were eliminated, as that category could include escapes.

Development of Streak-Resistant Populations and Varieties

The rather simply inherited resistance and the screening techniques, which provide uniform streak challenge, have made it possible to make rapid progress in the development of streak-resistant materials. Table 1 lists the populations which are currently being improved for streak resistance and agronomic characters through recurrent full-sib selection in cooperation with national programs.

TZSR-W-1 and TZSR-Y-1
Because of the agronomic limitations and the narrow genetic base of TZSR(W) and TZSR(Y), other materials were introgressed into these populations. TZSR(W) was crossed with TZB and TZPB from IITA and with 1974 experimental varieties originating from Populations 21 and 22 from CIMMYT. TZSR(Y) was crossed with Poza Rica 7428 (CIMMYT), the Nigerian variety 096EP6 and IB32 x La Revolution (a cross between two sources of streak resistance).

Half-sib families were formed under streak pressure in both populations during the dry season of 1979-80. In the following season, the half-sib families were tested at five locations in Nigeria and one location in Upper Volta (Burkina Faso). The best 50 families of each population were recombined to form TZSR-W-1 and TZSR-Y-1. Full-sib recurrent selection was initiated in 1981, with the cooperation of African national programs.

La Posta
La Posta (Pop. 43) is a late white dent of Tuxpeño background. The population has shown good performance in the lowland tropics of Latin America, West Africa and parts of East Africa. Various selections from

this population have been released to farmers and are widely distributed in several African countries, e.g., Ghana, Benin, Togo and Swaziland.

La Posta is in high demand by national programs on the African continent. Therefore, it was decided in 1980 to transfer the center of population improvement for La Posta from Mexico to IITA, Nigeria, with major emphasis on streak resistance. However, recurrent selection for yield and other agronomic characters was carried out at the same time, in order to continue to develop new superior varieties and improve the population.

Early-maturing lowland populations (TZESR-W, TZESR-Y and Pool 16)
For adaptability to areas with short rainfall duration in many parts of Africa, early-maturing populations have been developed. Since streak incidence in the second season in the bimodal rainfall distribution areas in West Africa is usually higher than in the first rainy season, such varieties must possess streak resistance.

Two early maturing, streak-resistant populations, TZESR-W and TZESR-Y, were initiated in 1977 by crossing early maturing materials, mainly originating from Upper Volta, with TZSR(W) and TZSR(Y). These crosses were advanced to S_3 under streak in subsequent seasons. Selected S_3 lines were then recombined to form the two early maturing populations, which were tested for yield on a family basis in Nigeria in 1981. In 1982, recurrent full-sib selection for yield and other agronomic characters was started in cooperation with national programs; the level of streak resistance of the selected families was monitored at IITA. TZESR-Y is currently being handled in the Semi-Arid Food Grains Development Project (SAFGRAD) in Burkina Faso.

Through the regional testing activities of the SAFGRAD project, Pool 16, developed at CIMMYT, was identified as promising and early maturing under semiarid conditions. Population improvement was initiated by the SAFGRAD project, but in order to incorporate streak resistance into this material, the center of improvement was transferred to IITA. Pool 16 is an early maturing white dent, while TZESR-W has white flint grain. Pool 16 was crossed to TZSR-W-1, and the resulting population has been backcrossed four times to Pool 16. Priority is being given to recovering the genes for the typical plant type and earliness, as well as for improving the streak-resistance level.

Midaltitude population (TZMSR)
TZMSR combines a high level of resistance to maize streak virus with resistance to *P. sorghi* (rust) and

Table 1. Streak-resistant populations under selection, IITA, Nigeria, 1985

Population	Description	Adaptation
TZSR-W-1	Late white flint	Lowland forest and savanna
TZSR-Y-1	Late yellow flint	Lowland forest and savanna
La Posta (Pop. 43)	Late white dent	Lowland tropics
TZMSR-W	Late white flint-dent	Midaltitude
TZUT-W	Intermediate white flint-dent	Savanna
TZUT-Y	Intermediate yellow flint-dent	Savanna
TZESR-W	Early white flint	Lowland forest and savanna
TZESR-Y	Early yellow flint-dent	Lowland forest and savanna
Pool 16	Early white dent	Lowland forest and savanna

H. turcicum (blight), major diseases in the African midaltitude ecology. It is derived from crosses of well-adapted maize varieties and hybrids from eastern, southern and central Africa that have streak-resistance sources. It is late maturing and has the white grain preferred by consumers in many countries of Africa. A combined half-sib and S_1 selection breeding procedure was followed for a number of generations, screening the materials for streak resistance under artificial infestation at Ibadan and for highland blight and rust in Jos (1300 meters altitude).

By 1982, when a good level of resistance to streak and highland blight and rust had been achieved, full-sib progenies from the population were subjected to international testing in Cameroon, Nigeria, Zambia and Zimbabwe. Experimental varieties synthesized from the best families in these trials are currently being evaluated in African countries that have midaltitude ecologies.

Intermediate-maturing lowland populations (TZUT-W, TZUT-Y)
These populations were developed with the objective of combining the efficient plant type of US Corn Belt varieties with tropical materials. They have performed well in the savanna zones of West Africa and have a good level of streak resistance.

In addition to the work on these populations, improvement of materials with combined resistance to maize streak virus and downy mildew is also being pursued.

Breeding for Streak Resistance through Backcrossing

A different approach in breeding for streak resistance is the conversion of elite varieties by backcrossing. The prerequisites of a successful backcross program are fulfilled in the case of resistance to maize streak virus. Well-adapted varieties of decided superiority in the majority of their characters are available, as are heritable sources of resistance. Also, suitable screening techniques exist for identifying plants carrying resistance.

Table 2. Source populations of experimental varieties used for conversion to streak-resistance, IITA, Nigeria, 1985

Source population	Pop. no.	Description	Backcross generation
Tuxpeño-1	21	Late white dent	BC_2
Mezcla Tropical Blanca	22	Late white semident	BC_4
Amarillo Dentado	28	Late yellow dent	BC_4
Tuxpeño Caribe	29	Late white dent	BC_4
Blanco Cristalino-2	30	Early white flint	BC_4
Amarillo Cristalino-2	31	Early yellow flint	BC_4
Antigua x Republica Dominicana	35	Intermediate yellow dent	BC_4
La Posta	43	Late white dent	BC_4
American Early Dent x Tuxpeño	44	Late white dent	BC_4
Blanco Dentado-2	49	Intermediate white dent	BC_2
White Flint QPM	62	White quality protein maize	BC_3
Yellow Dent QPM	66	Yellow dent quality protein maiz	BC_2

National programs in Africa have identified varieties with good performance in the CIMMYT-coordinated international testing program. These varieties are being used in various ways in national breeding programs, and some have been released to farmers. Therefore, a conversion program was initiated for quick delivery of elite germplasm with streak resistance. Table 2 describes the source populations from which these varieties were extracted. Experimental varieties from populations with different plant types, maturities and grain types were used that would be suitable for the various farming situations on the continent.

Figure 2 illustrates the breeding approach used, a backcrossing scheme that takes advantage of the on-going efforts in population improvement of the source populations. The most recent experimental variety with proven performance from each population is used as a recurrent parent in each backcross generation. Approximately 4,000 plants are screened for streak resistance, and the progenies from about 100 selected plants are planted ear-to-row the following season. Precaution is taken to sample enough plants of the recurrent parent to adequately recover the gene frequencies characteristic of the variety under improvement. Various modifications of this scheme are used.

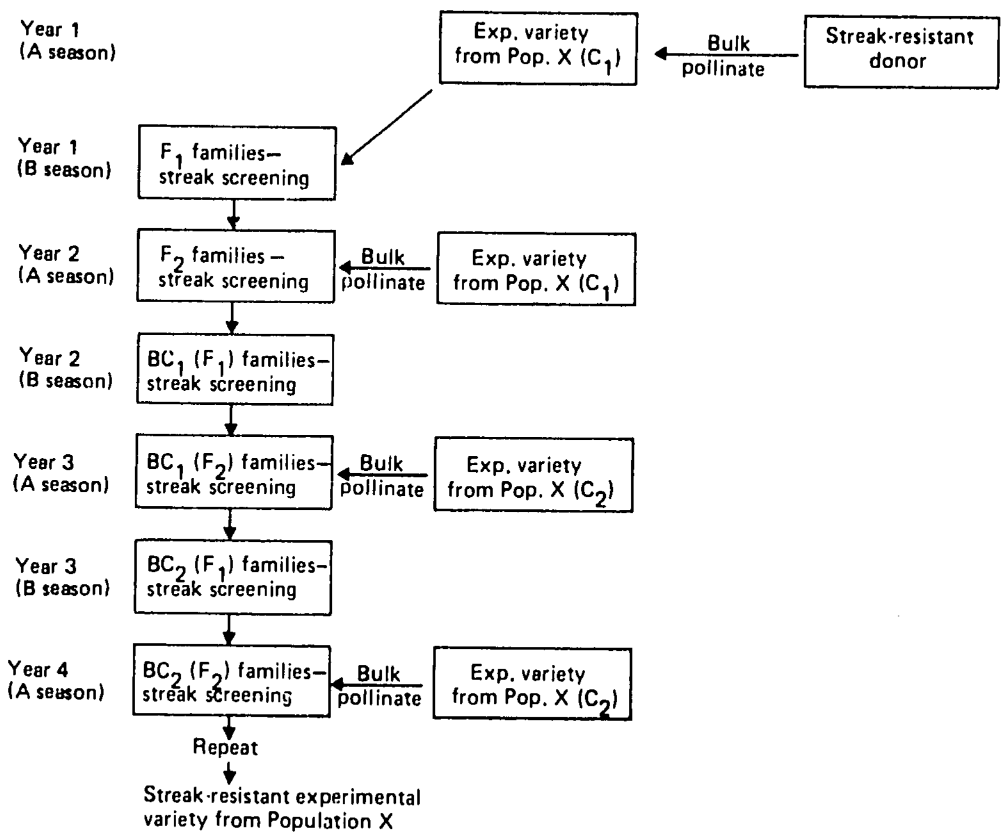

Figure 2. Scheme used for converting experimental varieties from Advanced Unit populations undergoing improvement for streak resistance, IITA, Nigeria

For instance, the F_1 generation is not always advanced to F_2 before making the next backcross.

Table 3 presents a comparison of streak-resistant conversions and the recurrent parents under artificial streak infection at IITA. The streak conversions were five to eight times higher yielding than their unconverted counterparts; they were also superior in other agronomic characters under this very heavy streak infection. Table 4 demonstrates that yield potential was not sacrificed. When the streak-resistant varieties were compared with their normal counterparts without streak, the yield levels were very similar.

Table 3. Comparison between streak-resistant conversions and their non-streak-resistant counterparts in EVT-LSR(W) and (Y) under streak, IITA, Nigeria, 1983

Trial	Variety	Grain yield (kg/ha)	Days to silk	Plant ht. (cm)	Ear ht. (cm)	Streak score [a]
EVT-LSR(W)	Poza Rica 7822	901	63	132	74	5.0
	Poza Rica 7822-SR BC_2	7040	56	215	113	2.3
EVT-LSR(W)	Across 7729	1087	62	140	72	5.0
	Across 7729-SR BC_2	7050	54	212	107	2.3
EVT-LSR(W)	Poza Rica 7843	1502	60	165	80	5.0
EVT-LSR(W)	Poza Rica 7843-SR BC_2	7400	55	242	128	2.5
EVT-LSR(Y)	Across 7728	857	61	113	76	4.8
	Across 7728-SR BC_2	6743	55	234	133	2.3
EVT-LSR(Y)	Tocumen (1) 7835	1435	58	120	54	3.5
EVT-LSR(Y)	Tocumen (1) 7835-SR BC_2	5118	50	206	103	1.3

[a] Scoring scale 1 to 5 (1 = resistant, 5 = susceptible)

Table 4. Comparisons of streak-resistant conversions and normal counterparts of five varieties, tested under negligible streak at Ikenne, Ilorin and Samaru, Nigeria, 1983

Variety	Grain yield (kg/ha)	Yield index [a]	Days to silk	Plant ht. [b] (cm)	Ear ht. [b] (cm)
Poza Rica 7822	6572	100	56	229	116
Poza Rica 7822-SR BC_2	6601	100	56	226	119
Across 7729	5811	100	[illegible]	218	166
Across 7729-SR BC_2	6495	112	55	220	110
Poza Rica 7843	6964	100	58	238	134
Poza Rica 7843-SR BC_2	6638	95	56	243	129
Across 7728	5743	100	57	219	114
Across 7728-SR BC_2	6391	111	57	231	129
Tocumen (1) 7835	5086	100	51	206	100
Tocumen (1) 7835-SR BC_2	5497	108	51	197	96

[a] 100 = non-streak-resistant variety
[b] Data from Samaru and Gusau only

Breeding for Streak Resistance in Hybrids

In addition to these efforts in the development and improvement of populations and open-pollinated varieties, IITA has embarked on a substantial hybrid project. Streak-resistant inbred lines and hybrids have been developed by using the populations mentioned above as sources for streak resistance. The inbred lines are available to national programs upon request.

Cooperation with National Programs

In order to give national programs the opportunity to evaluate the streak-resistant materials, trials are organized and dispatched from IITA to African cooperators. These trials include populations and varieties derived from the streak-resistant populations and the streak conversions developed by backcrossing. The researchers in national programs request seed of the best-performing varieties and make further selection under local conditions; these varieties are then either used directly or integrated in various ways into the national breeding programs.

Population improvement of streak-resistant populations includes the following steps:

- International testing of 250 families;
- Selection within families at IITA;
- Recombination of best families, and
- Formation of new families.

As an example, Table 5 summarizes the results from the progeny testing of La Posta in 1982. The 250 full-sibs were arranged in a 16 x 16 simple lattice and tested along with six local checks in six different countries. The ten best families were selected at each location and across locations for the formation of experimental varieties.

Table 6 shows the percentage of selected families of La Posta with plants having streak resistance after

Table 6. Improvement of streak resistance within La Posta, IITA, Nigeria, 1980 to 1984

Year	Families with resistant plants (%)
1980	4.6
1982	26.9
1984	100.0

Table 5. Grain yield of IPTT 43 (La Posta), 1982

	Yield (t/ha)						
Progeny testing	Honduras (Catamacas)	Ivory Coast (Ferko)	Nicaragua (Santa Rosa)	Nigeria (Ikenne)	Thailand (Suwan)	Zimbabwe (Gwebe)	Mean (6 locations)
Selected families	7.87	9.64	6.25	7.08	8.56	9.15	7.45
Population mean	6.63	7.83	4.89	5.12	6.62	6.67	6.29
Best check	5.51	9.31	5.40	5.44	7.25	12.35	7.54
CV	13.70	11.70	17.30	16.60	11.80	13.10	—

three cycles of selection. The families were selected for yield and other agronomic characters; efforts were made to include families that had plants with streak resistance, if their yield was average or above. In 1984, the 250 families from the latest cycle of selection were distributed to six different countries. Some plants with streak resistance were found in all families that were screened at IITA. The best plants within each family were selfed. The S_1 lines will be screened and advanced to S_2 before they are recombined for the next cycle of selection. It is expected that the population will be uniformly streak resistant by 1986, and that all future varieties derived from this population will be streak resistant.

Table 7 presents results from the testing of early maturing streak-resistant varieties in 1984. The streak-resistant varieties were earlier and higher yielding than the mean of the best check across 17 African locations. Table 8 summarizes the results of the first late, white, streak-resistance variety trial, which was conducted in 1984.

Table 7. Results of testing early streak-resistant varieties in Elite Variety Trials in 17 locations in Africa, 1984

Variety	Grain type	Grain yield (kg/ha)	Days to silk	Grain moisture (%)	Plant ht. (cm)
EV 8335-SR	YD	4570	54	21	183
M. Gaike-82 TZESR-W	WF	4220	53	20	190
Ikenne-82 TZESR-W	WF	4140	53	20	187
Gusau-82 TZESR-W	WF	3950	53	20	189
EV 8331-SR	YF	3830	50	19	167
Pool 16 Gusau-81 (RE)	WD	3810	50	20	163
EV 8330-SR	WF	3720	51	20	168
Best check	–	3660	55	20	197

Table 8. Results of testing late white streak-resistant varieties in Elite Variety Trials in 14 different locations in five countries, 1984 (streak incidence negligible)

Variety	Grain yield T/ha	Grain yield % best check	Days to silk	Plant ht. (cm)	Ear ht. (cm)
EV 8343-SR BC_3	5.3	113	60	216	114
EV 8329-SR BC_3	5.3	113	59	201	103
EV 8322-SR BC_3	5.2	111	61	206	110
Sekou 81 TZSR-W-1	5.1	109	61	218	117
Ejura 81 TZSR-W-1	5.0	107	60	205	112
Across 81 TZSR-W-1	4.9	104	61	207	110
Bertoua 81 TZSR-W-1	4.6	98	60	202	110
Mean (SR var.)	5.1	109	60	208	111
Gusau 81 TZB (RE) [a/]	5.0	107	61	209	115
Best check [b/]	4.7	100	61	209	110

[a/] RE = reference entry
[b/] Different check used at each location

Streak-resistant experimental varieties with good agronomic characters of various maturity groups and plant types are now available to national programs in the various agroclimatic zones of Africa. Some of these varieties have been released to farmers and are being multiplied in several African countries. Once the streak-resistant varieties are widely distributed, they should greatly increase the stability of maize production on the African continent.

Acknowledgements

The author wishes to acknowledge the work of the breeders, entomologists and pathologists in the CIMMYT/IITA maize improvement program at IITA. The progress reported here is a result of their joint effort.

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Discussion

Mr. Olver: Is streak resistance monogenic?

Dr. Bjarnason: Resistant materials from Reunion Island have been found to be monogenic. However, there are at least three major genes involved in the resistance based on IB32.

Mr. Mulamba: Some streak-resistant materials have been found to be susceptible to downy mildew. Are there any efforts to combine streak and downy mildew resistance?

Dr. Bjarnason: There are already materials with resistance to both streak and downy mildew in the breeding program at IITA.

Dr. Manwiller: Have you observed any differences in the races of streak virus?

Dr. Bjarnason: We have not observed any differences in the virus in terms of race, and resistant materials from IITA have held up well in East Africa (Tanzania) and vice versa.

Dr. Gibson: Tanzania and Zambia have been very successful in selecting for streak resistance by the method you have suggested, that is, by selecting plants which were infected early and developed only broken symptoms on the lower leaves, with little increase in these symptoms on the upper leaves. Although you have not found that the BC_2 of the streak-resistant conversions of CIMMYT populations have lower yields than the original populations, they generally do appear to be slightly lower yielding under our conditions. I don't see this as a serious problem since there is still adequate variability for selection for our local conditions. However, it will be an advantage to have an improvement in streak resistance in our own region.

Dr. Bjarnason: I agree; it is useful to select in the different regions, and yield should not be sacrificed in these conversions.

CIMMYT's Maize Improvement Role in East, Central and Southern Africa

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Abstract

Although maize is an alien crop of recent origin, it is the most important staple food crop in sub-Saharan Africa. However, production has remained stagnant at about 1 t/ha over the last two decades, and in some countries, production has actually declined in absolute terms. The relative poor performance of maize in sub-Saharan Africa stems from complex interactions of natural and man-made disasters, official neglect of agriculture, the population explosion, drought, problems of soil fertility, pests and diseases, the absence of improved technology, the practice of growing maize as a subsistence crop, poor trading opportunities with the developed countries and the colonial legacy of agricultural development, which stressed the production of cash crops for external markets. In 1980, the Lagos Plan of Action, adopted by African leaders, set 1985 as the target year for eliminating hunger from the African continent. According to an FAO forecast, 21 African countries will face more severe food shortages in 1985 than they faced in 1984, one of the worst famine years in Africa's recent history. However there is optimism that improved maize varieties and hybrids, as well as improved production practices, exist for increasing maize production in the region. To realize this potential, there is a need for location-specific research by multidisciplinary teams within the national research programs. International centers, such as CIMMYT and IITA, are also determined to intensify their maize research efforts in the region, in collaboration with the national programs and other interested agencies.

Africa is the only continent in which Malthus's grim prediction that food production would not be able to keep pace with population growth seems to be a reality. According to FAO statistics, food production in Africa during the 1970s increased at only 1.8% per year; population increase was almost 3% per year. Between 1971 and 1980, food production per capita fell by 11%; food imports more than doubled in volume, but at a sevenfold increase in cost.

The 1980s have been worse. FAO predicts that 21 African countries will face more severe food shortages in 1985 than they faced in 1984, one of the worst famine years in Africa's recent history. Paradoxically, 1985 was set as the target year of the Lagos Plan of Action, which was adopted by African leaders in 1980 for eliminating hunger from the continent.

Maize is the most important staple food crop in sub-Saharan Africa. However, production over the last 20 years remained stagnant at about 1 t/ha, and in certain countries production per capita actually declined. During the same period, for the world as a whole, maize production increased at an annual rate of 3.4%.

In the 1970s, there was a yield decline in maize of 1% annually in sub-Saharan Africa. In the developed countries, maize production increased by 3.8% annually, with yield increases accounting for three-quarters of that increase. In the developing countries, production increased by 2.5% annually, with area expansion contributing to one-half of the production increases. In absolute terms, maize yields have increased about 0.3 t/ha in developing countries over the last two decades, as compared to an increase of nearly 2 t/ha in developed countries. In other words, yields in developing countries increased at less than half the rate of those of developed countries.

Now, however, there is optimism that improved maize hybrids, varieties and production practices exist for increasing maize yields in sub-Saharan Africa. African farming systems are complex, and the development of suitable maize varieties and production technologies will require strong national research programs, with multidisciplinary teams conducting location-specific research.

The Importance of Maize in Sub-Saharan Africa

For the period 1978 to 1980, average maize production in the developing countries was 118 million tons, of which 11% was produced in sub-Saharan Africa. Nigeria, Malawi, Zimbabwe, Kenya and Ethiopia each produced between 1 and 2 million tons per year, and twenty other countries produced from 100,000 to 1 million tons. All of the countries cultivated at least 100,000 hectares of maize.

From 1978 to 1980, eastern and southern African countries grew 8.6 million hectares of maize, with a total production of 8.9 million tons; this was 7% of total world area, but only 2% of world production. Similarly, western African countries grew 5.9 million hectares and produced 4.5 million tons, 5 and 1% of world area and production, respectively. The figures for North Africa were 1.2 million hectares and 3.4 million tons, 1 and 0.9% of total world area and production, respectively (Table 1).

Table 1. World maize area, yield and production by region, 1978 to 1980

	Area (million ha)	Yield (t/ha)	Production (million tons)	Percent of total area	Percent of total production
Developing world	70.4	1.7	118.1	58	31
Eastern and southern Africa	8.6	1.0	8.9	7	2
Western Africa	5.9	0.8	4.5	5	1
North Africa	1.2	2.8	3.4	1	0.9
Mideast countries of Asia	1.2	1.9	2.4	1	0.6
South Asia	7.0	1.1	7.7	6	2
Southeast Asia and Pacific	8.2	1.3	10.6	7	3
East Asia	12.8	3.1	39.2	11	10
Mexico, Central American and Caribbean	9.4	1.3	12.6	8	3
Andean region	1.9	1.4	2.8	2	0.7
Southern Cone	14.3	1.8	26.0	12	0.7
Developed world	51.2	5.1	260.3	42	69
Developed market economies	42.2	5.5	221.3	35	59
Eastern Europe and USSR	8.9	3.5	39.1	7	10
Total world	121.6	3.1	378.4	100	100

Source: World Maize Facts and Trends, CIMMYT Report One, 1981, CIMMYT, Mexico.

The average annual total maize production (1974 to 1982) for the Multinational Programming and Operational Centre for Eastern and Southern Africa States (MULPOC), a group of 18 countries, was as follows:

Kenya	2.0 million tons
Zimbabwe	1.3 million tons
Malawi	1.2 million tons
Ethiopia	1.1 million tons
Tanzania	0.9 million tons
Zambia	0.8 million tons
Remaining 12 countries	1.6 million tons

Maize has become the main food crop for laborers in the towns as well as for rural peasants, because of the ease of storage and handling and the simple preparation of porridge and other dishes. Small patches of maize are often grown near the home for eating as roasting ears. For certain countries (e.g., Zimbabwe, Malawi and Kenya), it is an important source of foreign exchange earnings, while for others it is the most important staple food crop.

The History of Maize Research in Eastern and Southern Africa

The first attempts to breed maize in eastern and southern Africa took place in Rhodesia (now Zimbabwe) and Kenya, and were designed to benefit the commercial European farmers. In 1949, Zimbabwe became the first country after the USA to release hybrids for commercial production. Interest in maize breeding in East and West Africa in general, and in Kenya in particular, was stimulated by the occurrence of *Puccinia polysora*, tropical corn rust, in West Africa in 1951. In the search for resistance, many collections were made, principally from Latin America, but also from the rest of the world. No particular consideration was given to the yield potential of the varieties into which resistance was transferred. Kenya released its first hybrid in 1964. The introduction of Ecuador 573 from Latin America, and its outstanding combining ability with Kitale Synthetic II, led to a breakthrough in commercial hybrid production in Kenya.

The Current Status of Maize Research

Currently, maize research in sub-Saharan Africa is conducted principally by national agricultural research programs, assisted by international research centers, such as CIMMYT and IITA, bilateral agencies, some private companies and missionary groups. In some countries, universities play an important role in basic maize research.

In certain countries of the region, research trials average 5 to 6 t/ha and occasionally reach 12 t/ha. In Zimbabwe, Kenya and Zambia, 50 to 80% of the small farmers grow hybrids, but national average yield levels are a low 1 to 1.5 t/ha. Large-scale farmers average 4 to 6 t/ha.

The Kenya Seed Company is presently in the process of increasing seed of three hybrids, designated as Pwani 1, 2 and 3, for possible release in the low coastal areas. Tanzania is producing its own hybrids by recycling inbred lines that had been developed in Kitale, Kenya. Malawi is also producing three hybrids, namely MH12, MH13 and NSCM41. The National Seed Company of Malawi was able to obtain the inbred lines of NSCM41 from Ciba Geigy and pays a royalty for producing the F_1 in Malawi. However, the adoption of hybrids in Malawi is still low.

Zambia has been growing SR52 for a long time; consequently, the parental lines have become contaminated. In 1983, Zambia released a new version of SR52, after successfully cleaning up the parental lines. This new hybrid is designated as MM752. In 1984, they successfully released seven additional earlier maturing, drought-tolerant hybrids and two open-pollinated varieties. All of the major maize-producing countries of the region have developed or are in the process of developing new hybrids and varieties. The others are screening a large number of materials obtained from CIMMYT, IITA and other sources, to identify those that combine well for hybrid production and for direct utilization as varieties *per se*.

Constraints to Maize Production

Generally speaking, Africa's food crisis stems from the complex interactions of natural and man-made disasters, including official neglect of agriculture, rapidly expanding poulation, drought, problems of soil fertility, pests and diseases, the absence of improved technology, the practice of growing maize as a subsistence crop, and poor trading opportunities with the developed countries. Also, as a legacy of Africa's colonial years, the emphasis in agriculture has been on the production of cash crops, such as coffee and tea, for external markets, rather than food crops, such as maize. The major constraints limiting maize production in sub-Saharan Africa can thus be broadly classified as environmental, biological, agronomic, socioeconomic and governmental.

Environmental factors

The major environmental factors affecting maize production are climate and soils. Climatic factors include rainfall, temperature and sunshine. The amount, distribution and reliability of rainfall are equally important. On the equator, there are two rainy seasons a year, as the convergence zone moves backwards and forwards across the equator.

The high-potential maize-growing areas of western Kenya, Uganda, Ethiopia and the lake region of Tanzania have long rainy seasons and utilize maize varieties averaging 200 days to maturity. The midaltitude areas of Ethiopia, Angola, Zambia, Zimbabwe, Malawi, Mozambique and Madagascar have extensive areas suited to intermediate-maturity maize. The lowlands of Tanzania, Kenya, Ethiopia, Zambia, Zimbabwe, Malawi, Mozambique, Botswana, Swaziland, Lesotho, Somalia and Djibouti are characterized by short and erratic rains; these areas require early maturing maize varieties. In the high mountains of Lesotho, cold-tolerant maize varieties are needed, due to the short growing period between killing frosts.

The threshold temperature for growing maize is about 10°C, with the rate of growth proportional to the number of degrees above this figure up to 30°C. Much of sub-Saharan Africa enjoys favorable temperatures for maize growing. Temperature and rainfall are usually associated with altitude, with cooler temperatures and more reliable rainfall at higher altitudes. For example, while Kitale maize varieties take 230 days to mature at 1500 to 2000 meters elevation, it takes 13 months to mature at 2700 meters.

Maize has the highest yield potential in the semitropics in those areas where temperatures are comparatively cool and there is plenty of sunshine. On the equator there is little variation from the 12-hour day length; hence, there is less time per day for photosynthesis than there is in the temperate regions. Coastal areas also have low yields due to unfavorable combinations of high temperatures and low sunshine. The high incidence of diseases and pests in the coastal areas is due to the combination of high temperatures and high humidity.

A large proportion of the soils in sub-Saharan Africa have a low pH, although not below 5.5, the critical level for maize. In those regions with high rainfall and high temperatures, there is a problem of soil acidity which may be related to iron and aluminum toxicity. Nitrogen is the major limiting nutrient, followed by phosphorus; sulfur is usually more deficient than potassium. Potash is deficient mainly in coastal areas.

Biological factors

Diseases—The following are the main maize diseases in sub-Saharan Africa:

- *Helminthosporium turcicum*—mostly above 1000 to 1500 meters elevation;
- *Helminthosporium maydis*—below 1000 meters;
- *Puccinia sorghi*—1000 to 1500 meters;
- *Puccinia polysora*—below 1000 meters;
- *Fusarium* and *Diplodia* spp. (ear and stalk rots)—damage varies from country to country and from year to year, and
- *Cicadulina mbila* (maize streak virus)—the incidence of maize streak virus fluctuates from season to season and from area to area. The virus is more serious in areas with two seasons of maize per year, or where there is an alternate host in the dry season, such as grasses and sugarcane. Severity of attack increases with late planting, as the vector population builds up over time. (This writer has seen a severe infestation of streak virus on highland maize grown at an elevation of 2300 meters in Burundi; this shows that the disease can endanger maize production at all altitudes in sub-Saharan Africa.)

Insects—The two serious groups of insects that attack maize in Africa are stalk borers and storage pests. Of the stalk boring insects, the principal ones are:

- *Busseola fusca*—the main borer in highland maize;
- *Sesamia calamistis*—a problem in lowland and coastal areas;
- *Chilo partellus*—a problem in low elevations;
- *Spodoptera exempta* (army worm)—a cause of complete devastation in some areas and some years;
- *Agrotis* spp. (cutworms)—insects which attack seedlings, and
- *Heliothis armigera* (earworms)—insects which feed on the leaf.

The two serious primary storage pests are *Sitophilus* spp. (maize weevil) and *Sitoroga cerealella* (grain moth). *Prostephanus trancatus* (the larger grain borer) is now causing alarm in Tanzania and along the southern borders of Kenya.

In general, disease and pest losses are lowest in the cool highlands and highest in the hot lowlands and humid coastal areas.

Agronomic factors

In many sub-Saharan countries, the maize production practices followed by small-scale farmers are inadequate. Principal among these poor husbandry practices are late planting, low planting density, insufficient and late weeding and inadequate and late application of fertilizers, herbicides and insecticides.

Socioeconomic factors

Some examples of socioeconomic factors limiting maize production are the lack of funds, labor and manpower, the lack of availability of inputs and their high price, and post-harvest losses due to a lack of proper storage facilities.

Governmental policy

The lack of proper seed production and distribution systems and the absence of sound marketing and pricing policies, coupled with inadequate research and production policies, hinder maize production in many sub-Saharan African countries.

CIMMYT's Mandate

CIMMYT is responsible for assisting in raising the productivity of the resources committed to maize by farmers in the developing countries. Operationally, the center concentrates on providing national programs with improved germplasm, as well as with assistance in breeding methods, training and some material needs. National programs are ultimately responsible for developing improved technologies for their farmers.

Improved germplasm

Improved germplasm is defined in terms of yield dependability (stable performance in the face of drought, diseases, insects and other hazards), yield responsiveness and maturity (for avoiding hazards, intensifying cropping systems, satisfying new demands or exploiting the potential of longer-season environments).

The stages in maize germplasm management and improvement followed by CIMMYT are shown in Figure 1. The scheme provides for continuous population improvement, with the best fraction siphoned off to provide an experimental variety for immediate utilization or for furthering hybrid development. New accessions are continuously fed into the corresponding pools to broaden the germplasm base.

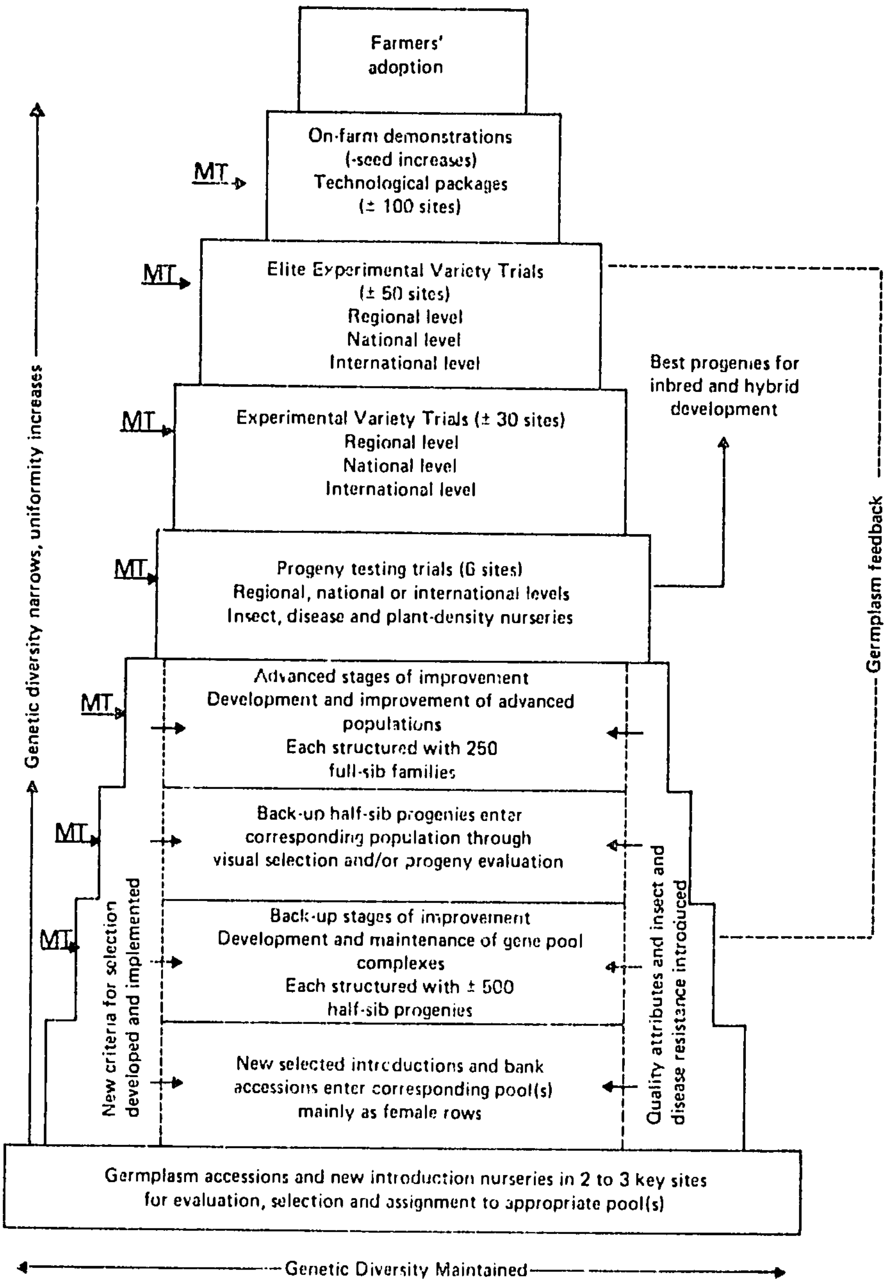
Figure 2 presents the population improvement scheme utilized in the CIMMYT maize program. The progeny trial and regeneration system is designed in such a way that national program scientists are full partners in the breeding process. The selection of superior families is carried out by national programs in close collaboration with CIMMYT scientists.

The various gene pools and corresponding populations assembled and classified by CIMMYT are shown in Tables 2a and 2b. There are 33 normal and 13 quality protein gene pools; there are 22 normal and 10 quality protein advanced populations. Since some advanced populations were constituted before a corresponding gene pool was developed, all populations do not necessarily have a corresponding gene pool.

Trials distributed in the East African regional program—CIMMYT's East African Regional Maize Program was formally established in September 1982, with headquarters in Nairobi, Kenya. CIMMYT's regional programs for wheat and economics had been in existence since 1975 and 1976, respectively. Although the maize program is the newest in the region, there has been interaction with regional maize scientists in germplasm testing, training and consultancy services since 1974. The following chart shows the number of maize trials distributed in eastern and southern African countries between 1974 and 1984:

Year	74	75	76	77	78	79	80	81	82	83	84	Total
No. of trials	16	23	32	20	74	75	134	99	94	164	84	755

Performance of CIMMYT materials in sub-Saharan Africa—Tables 3, 4 and 5 show the relative performance of CIMMYT varieties in eastern, southern, central and western African countries, respectively. Most varieties did better than the best local checks. This was more evident in those areas where the growing conditions were less than optimum for the maximum potential genotypic expression of hybrids, such as SR52. In its proper environment, SR52 is an outstanding hybrid, but its performance is very poor in marginal areas. The small-scale farmers who grow most of the maize in developing countries do not necessarily have an optimum environment or favorable growing conditions. They are the ones who need help most, and CIMMYT's maize improvement program is targeted especially to those farmers.



MT = multilocation tests

Figure 1. Stages in maize germplasm management and improvement, CIMMYT, Mexico

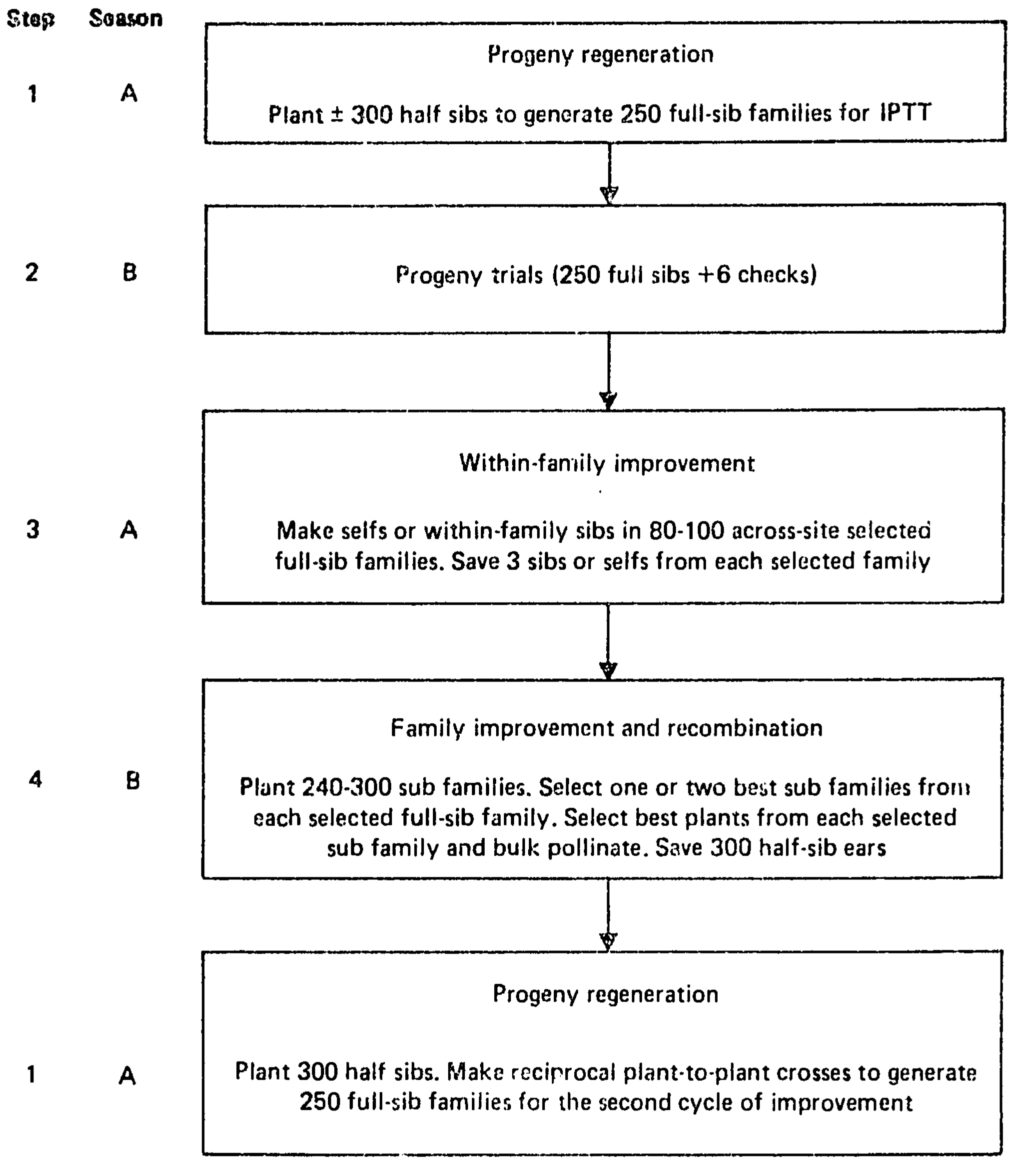


Figure 2. Population improvement scheme breeding sequence, CIMMYT, Mexico

Table 2a. Maize gene pools and corresponding populations in CIMMYT's maize improvement scheme, CIMMYT, Mexico

Pool no.	Pool name	Pop. no.	Population name
1	Highland early white floury	..	Blanco Harinoso Precoz
2	Highland late white floury	..	— —
3	Highland early yellow floury	..	Amarillo Harinoso Precoz
4	Highland late yellow floury	..	Chillos x Varios
5	Highland early white morocho	..	— —
6	Highland early yellow morocho	..	— —
7	Highland late white morocho	..	— —
8	Highland late yellow morocho	..	— —
9	Highland late white dent	..	— —
15	Tropical early white flint	30	Blanco Cristalino-2
16	Tropical early white dent	..	— —
17	Tropical early yellow flint	31	Amarillo Cristalino-2
18	Tropical early yellow dent	..	— —
19	Tropical intermediate white flint	..	— —
20	Tropical intermediate white dent	49	Blanco Dentado-2
21	Tropical intermediate yellow flint	26	Mezcla Amarilla
22	Tropical intermediate yellow dent	35	Antigua-Republica Dominicana
23	Tropical late white flint	..	— —
24	Tropical late white dent	32	ETO Blanco
		21	Tuxpeño
		22	Mezcla Tropical Blanca
		29	Tuxpeño Caribe
		43	La Posta
25	Tropical late yellow flint	27	Amarillo Cristalino-1
26	Tropical late yellow dent	24	Antigua-Veracruz 181
		28	Amarillo Dentado
		36	Cogollero
27	Temperate-subtropical early white flint	..	— —
28	Temperate-subtropical early white dent	..	— —
29	Temperate-subtropical early yellow flint	46	Templado Amarillo Cristalino
30	Temperate-subtropical early yellow dent	48	Compuesto de Hungría
31	Temperate-subtropical intermediate white flint	34	Blanco Subtropical
32	Temperate-subtropical intermediate white dent	44	AED-Tuxpeño
		42	ETO-Illinois
		47	Templado Blanco Dentado
33	Temperate-subtropical intermediate yellow flint	33	Amarillo Subtropical
34	Temperate-subtropical intermediate yellow dent	45	Amarillo del Bajio
..	Northern temperate range gene pool (NTR)		
..	Southern temperate range gene pool (STR)		
..	Intermediate temperate range gene pool (ITR)		
..	CIMMYT-German gene pool		

Table 2b. Tropical and subtropical quality protein maize (QPM) gene pools and corresponding populations in CIMMYT's maize improvement scheme, CIMMYT, Mexico

Pool no.	Pool name	Pop. no.	Population name
15 QPM	Tropical early white flint QPM	62	White flint QPM
17 QPM	Tropical early yellow flint QPM	61	Early yellow flint QPM
18 QPM	Tropical early yellow dent QPM	66	Yellow dent QPM
23 QPM	Tropical late white flint QPM	62	White flint QPM
24 QPM	Tropical late white dent QPM	63	Blanco Dentado-1 QPM
24 QPM	Tropical late white dent QPM	64	Blanco Dentado-2 QPM
25 QPM	Tropical late yellow flint QPM	65	Yellow flint QPM
26 QPM	Tropical late yellow dent QPM	66	Yellow dent QPM
27 QPM	Subtropical early white flint QPM	67	Templado Blanco Cristalino QPM
29 QPM	Subtropical early yellow flint QPM	69	Templado Amarillo QPM
31 QPM	Subtropical intermediate white flint QPM	67	Templado Blanco Cristalino QPM
32 QPM	Subtropical intermediate white dent QPM	68	Templado Blanco Dentado QPM
33 QPM	Subtropical intermediate yellow flint QPM	69	Templado Amarillo QPM
34 QPM	Subtropical intermediate yellow dent QPM	70	Templado Amarillo Dentado QPM

Table 3. Performance of CIMMYT materials in East and southern Africa

Country	Year	Location	Elevation (m)	Latitude	Best CIMMYT variety	Yield (kg/ha)	Best local check	Yield (kg/ha)
Angola	1982	Chilongo	1700	12°44'S	PR8022	8818	SAM	5109
					Piura (1) 7836	6608	HTCA2	6423
					Across 7844 RE	5829	HTCA2	5112
Botswana	1977	Good Hope	100	25°29'S	Lowaquine 7635	3587	RECOP	2971
		Cabole			Pirbasak (1) 7642	4987	Kalahari	4420
	1970	Sabela	1150	24°34'S	Ferke (1) 7622	3295	Check	2706
Burundi	1980	Bosso	1400	–	Across 7842	7349	Igaroma	5253
		Imbo	830	3°11'S	Across 7729	5671	CFS-5	4717
		Mosso	1260	4°00'S	TL7844	7585	CPS-4×SR-52	6547
		Imbo	830	3°11'S	Across 7843	7467	IMBU	4907
Ethiopia	1978	Alemaya	1990	–	SIDS7634	7130	Check	5997
		Awassa	1400	–	Across 7522	8733	Check	6836
		Bako	1650	9° 8'N	Blanco Cristalino-2	4636	OP512	3821
		Nazareth	1550	8°30'N	Across 7723	6114	SNAYE	3942
Malawi	1979	Chitedze	1150	14° S	TL7044	6579	UCA C_2	6179
		Ngabu	100	–	Tocuman 7728	5791	PNR353 (HYS)	5301
				–	San Andres 7721	5005	PNR353	3751
	1980	Chitedze	1150	14° S	TL7044	8532	CX-H41	10018
		Bvumbwe	1150	–	Across 7643	6902	Check	7113
				–	Across 7627	6506	Check	5790
	1982	Mbawa	1500	–	Guaymas (1) 8022	5818	CCC C.	5636

Table 3. (continued)

Country	Year	Location	Elevation (m)	Latitude	Best CIMMYT variety	Yield (kg/ha)	Best local check	Yield (kg/ha)
Mozambique	1977	Sussundenga	635	19°20'S	Pichilingo 7429	4646	SR52	3597
					Suwan 7528	5929	SR52	5626
		Umbeluzi	12	26°03'S	Delhi 7622 (1)	4024	Silver Mine	2582
	1978	Umbeluzi	12	26°03'S	Ilonga 7721 (1)	4715	La Posta	3200
					Chiquisaca 7728	3933	SR52	1873
					La Granja 7525	4661	SR52	3321
					087734	4091	Sahara	1962
	1979	Umbeluzi	12	26°03'S	TL7633	2631	Silver King	1435
					Maracay 7522	3498	Kalahari	1693
	1980	Lioma	670	15°10'S	TL7844	6626	SR52	7776
		Nampula	432	15° 9'S	Sete Lagoas 7824	3424	SR52	2930
	1982	Chirembe	-	–	Santa Rosa 8022	5572	VAR.2 (Mukulu)	4467
Somalia	1973	Afgoy	83	2° 8'N	Gemeiza 7644 (2)	5935	Local variety	4446
Swaziland	1976	Malkerns	650	26°35'S	Across 7433	3580	Check	2902
	1978	Malkerns	650	26°35'S	Los Baños 7643	4314	SR52	3263
	1979	Malkerns	650	26°35'S	Across 7632	8570	SR52	9195
	1980	Mangcango	1300	26°31'S	Cotaxtla 7844	5528	SR52	5221
Tanzania	1975	Ilonga	506	6°42'S	Cuyuta 7430	4773	Local check	3935
	1976	Lambo	1268	3°14'S	Across 7542	6889	Local check	4589
	1977	Lambo	1268	3°14'S	Pirsabak 7942 (3)	10755	UCA	13559
	1979	Ilonga	506	6°42'S	TL7644	4668	EXP7993	2103
	1980	Ilonga	506	6°42'S	Across 7843	5144	Check	4859
		Lambo	1268	3°14'S	Sakha 7842 (1)	7593	UCA	8217
	1982	Ilonga	506	6°42'S	La Maquina 8022	5772	EV8076	4624
Uganda	1976	Kawanda	1208	0°25'N	La Maquina 7422	5327	Check	4769
Zambia	1981	Mansa	1259	11° 6'S	PR7921	4698	SR52	4854
			–	–	Kisenga 7729	4622	SR52	4854
Zimbabwe	1982	Harare	1506	–	PR8022	9379	ZS225	12177
		Chiredzi	429	–	Ferke (1) 8023	7721	ZS225	9393
		Kadoma	1155	–	Across 8045	5663	ZS202	6155
					Swat (1) 8047	5341	ZS225	6165

Table 4. Performance of CIMMYT materials in central Africa

Country	Year	Location	Elevation (m)	Latitude	Best CIMMYT variety	Yield (kg/ha)	Best local check	Yield (kg/ha)
Cameroun	1982	Ekona	400	4°N	Ferke (1) 8023	6933	Ekona Synthetic	5511
					Chuquisaca (1) 7822	6644	Ekona White	5081
Central Africa Republic	1976	Soumbe	521	6°30'N	OB7328	3061	Local check	2718
	1982	Soumbe	521	6°30'N	PR8022	7830	Damba	4523
Zaire	1975	Kaniama	949	7°25'S	ETO x Tuxpeño	9911	Local check	9112
	1976	Kisanga	1187	11°44'S	Across 7422	6508	Check	6266
		Kaniama	949	7°25'S	La Maquina 7422	8193	Check	8119
	1977	Gandajika	780	6°45'S	Ferke 7529	8213	Salongo 11	6736
					Pichilingue 7429	7873	Kasai-I	6746
	1978	Gandajika	780	6°45'S	Across 7843	7127	Tuxpeño x ETO	4927
		Kisanga	1187	11°44'S	San Ramon 7528	8187	Kasai-I	8039
	1979	Kaniama	949	7°25'S	PR7643	7340	Tuxpeño x ETO	6672
	1982	Kaniama	949	7°25'S	PR8032	6790	Kasai-I	5745
		Kisanga	1187	11°44'S	Ferke (1) 8022	7174	PNM-1	6708

Table 5. Performance of CIMMYT materials in West Africa

Country	Year	Location	Elevation (m)	Latitude	Best CIMMYT variety	Yield (kg/ha)	Best local check	Yield (kg/ha)
Benin	1981	Sekou	80	6°20'N	Maracay 7921	5748	TZPB	4577
					PR8022	4442	TZPB	2502
	1982	Niouli	105	6°42'N	Ferke (1) 8023	4195	TZPB	3203
Ghana	1975	Nyankpala	185	9°29'N	Cuyuta 7429	3022	Composite 4	2034
	1976	Kwadaso	270	2°45'N	Guaymas 7522	4422	Check	3227
	1977	Kwadaso	270	2°45'N	Delhi 7622 (1)	3776	Composite 4	2442
	1978	Pokoasa	50	5°41'N	Across 7529	5242	La Posta	4970
	1979	Nyankpala	185	9°29'N	PR7843	5129	Comp-W	3260
					Santa Cruz 7835	4044	Golden Cristal	2598
	1980	Ejura	232	7°23'N	PR7822	5685	Composite 4	4338
	1982	Ejura	232	7°23'N	Piura (1) 7926	6217	Golden Cristal EVBO	5077
Guinea Bissau	1982	Canamac	8.5	12°21'N	Sete Lagoas 7931	6156	Check	3702
					PR8032	6204	Check	3136
Ivory Coast	1975	Ferke	330	9°36'N	ETO x Tuxpeño	8146	CJB	5724
					La Maquina 7422	8741	CJB	6191
	1975	Ferke	330	9°36'N	Across 7524	5236	IRAT81	4524
	1979	Ferke	330	9°36'N	Ferke (1) 7822	7213	Tuxpeño (C11)	6528
					Across 7728	7368	IRAT81	6329
					La Maquina 7843	7741	IRAT81	7424
		Bouake	360	7°41'N	PR7643	6451	IRAT81	4981
	1980	Ferke	330	9°35'N	PR7929	6982	IRAT81	6742
Liberia	1982	Suakoko	–	–	Los Diamantes 7921 (1)	4575	Check	3549
					Across 8023	2198	Check	1409
Mali	1979	Sotuba	500	12°40'N	Tocumen 7835 (1)	4997	IRAT85	4358
					PR7729	5636	Boni	4746
					Gomeiza 7644 (2)	6001	Sanguerini	5134
	1982	Tierouala	–	–	Ferke (1) 8023	5721	Check	5164
Nigeria	1977	Ibadan	220	7°30'N	Ferke 7629 (1)	7039	Local variety	4788
					La Molina 7432	5089	Local variety	4603
	1978	Ikene	53	6°52'N	San Andres 7630 (2)	5873	TZPB (S_1) C_7	5160
		Ibadan	220	7°30'N	TL7633	4073	TZPB (S_1) C_7	3484
	1980	Ikene	53	6°52'N	PR7931	4462	TZUT	3584
	1981	Gusali			PR7926	5427	TZEUX174	5160
		Mokwa	1318	10° 0'N	Across 7843	5825	TZSRW-1	5633
	1982	Gusau	2400	12°10'N	Alajuela 8032	6375	Pirsabak 7930	4627
Senegal	1978	Sefa	10	12°47'N	Ferke 7529 (1)	4849	BDS111	4374
					Cali 7623	4590	2MIO	3597
	1980	Sefa	10	12°47'N	Across 7627	4074	Check	4048
					Pichilingue 7726	5242	Check	3728
	1982	Sefa	10	12°47'N	Across 7929	5814	HVB-1	5462
					Piura (1) 7926	5176	BDS111	4686
Sierra Leone	1979	Njala	54	8° 0'N	PR7822	4572	Local variety	3322
		Rokupr	8	9° 0'N	Across 7728	3577	Western YLEX Nigeria	2049
Togo	1982	Sucral	400	9°30'N	San Andres 8043	5637	Local check	4175
			400	6°30'N	Mexico 8049	4375	Kepole	3660
		Djama Cope	–	–	PR8023	4950	Kepole	4318
		Adeta	--	–	PR8032	4582	La Posta	3588
		Sotouboua	380	8° 3'N	Suwan 8035	4584	La Posta	3971
Upper Volta (Burkina Fasso)	1976	Farakoba	420	11° 6'N	067442	5068	Check	3364
					PR7422	6048	Check	5046
	1979	Farakoba	420	11° 6'N	Across 7635	4655	Syn. Massayomba	3671
	1981	Farakoba	420	11° 6'N	La Maquina 7928	3861	Irat. 100	2960
		Kamboinse	300	12°28'N	PR7931	7759	TZPB	7036

Materials based on CIMMYT germplasm released by national programs—Table 6 lists some examples of maize varieties based on CIMMYT germplasm that have been released by seven sub-Saharan African countries. Almost all of the varieties are adapted to lowland tropical growing conditions except those of Lesotho, which are for the highlands. The four highland maize materials were reported to have had 75% adoption by Lesotho farmers within two to three years.

Materials identified for possible release by national programs—Table 7 shows a number of maize varieties derived from CIMMYT germplasm that are being reselected and extensively tested for possible release in six countries.

Breeding methods

Seed maintenance and multiplication of open-pollinated varieties—The procedures involved in the production of hybrid seed and the maintenance of parental lines are well documented. However, adequate documentation on the development, maintenance and multiplication of improved open-pollinated varieties is lacking. Millions of hectares of land in the developing world are devoted to open-pollinated varieties, because such varieties are well suited to the vast regions where traditional agricultural practices are still the rule. Open-pollinated varieties have a distinct advantage where seed distribution is difficult and costly. The seed of open-pollinated varieties can be saved by the farmer from year to year and can move from farmer to farmer.

Table 6. Materials based on CIMMYT germplasm released by national programs in Africa

Country	Source population	Population name	Variety	National program name
Ivory Coast	22	Tuxpeño Caribe	Poza Rica 7529	Poza Rica 7529
	22	Mezcla Tropical Blanca	La Maquina 7422	La Maquina 7422
	21	Tuxpeño-1	Tuxpeño-1	Tuxpeño-1
Lesotho	Pool 4	Highland early yellow flint	–	Highland early yellow
	Pool 2	Highland early white dent	–	Highland white dent
	Pool 1	Highland early white flint	–	Highland white flint
	Pool 6	Highland intermediate white floury	–	Highland white floury
Malawi	21	Tuxpeño	Tuxpeño C_{11}	Tuxpeño
Swaziland	43	La Posta	Across 7443	Across 7443
Tanzania	21	Tuxpeño-1	EV8076	Staha
	30	Blanco Cristalino-2	EV8188	Kito
	21	Tuxpeño-1	EV7992	Kilima
Zaire	21	Tuxpeño-1	Tuxpeño-1	Salongo 2
	21 x 25	Tuxpeño-1 x COL, GPO1 x ETO	Shaba Safi	PNM-1
	21 x 32	Tuxpeño-1 x ETO Blanco	Tuxpeño-1 x Eto	Kasai-1
	21 x 32	Tuxpeño-1 x ETO Blanco	Tuxpeño-1 x Eto x Shaba Safi	Shaba-1
	43 x 44	La Posta x American Early Dent	–	VC9
	44 x 21	American Early Dent x Tuxpeño	–	VC80
	44			
Zambia	30	Blanco Cristalino-2	Pirsabak (2) 7930	MMV400
	21	Tuxpeño-1	EV8076	MMV600

Exchange of germplasm among national programs is also easier with open-pollinated varieties than with closed pedigree maize materials that involve property rights.

In the past, many released materials were variable in agronomic attributes and lacked phenotypic appeal; this was largely a result of a somewhat loose definition of variety. More recently, variety has been redefined as an assemblage of the superior fraction of uniform and stable phenotypes of an improved population in a given improvement cycle. Once a variety has reached the release stage, it should be described for salient attributes for the area of its adaptation. Characters such as adaptation, plant height, maturity and grain color and texture should be considered in varietal description. Each variety should also possess some distinct genetic features which can be used to distinguish it from other varieties. Table 8 lists those characters that may be considered in describing a variety.

Evaluation and varietal release systems vary with national programs. In most cases, conditions on experiment stations and in farmers' fields are so different that any assessment of variety performance without conducting on-farm trials are unreliable. The evaluation system employed should facilitate identification of superior

Table 7. CIMMYT materials under consideration for release by African national programs

Country	Source population	Population name	Variety
Burundi	43	La Posta	Ferke 7643
	43	La Posta	Across 7643
	43	La Posta	Across 7843
Ghana	43	La Posta	Poza Rica 7843
	43	La Posta	Ejura (1) 7843
Kenya	49 x 32	Tuxpeño Planta Baja x ETO Blanco	Pwani Hybrid
	30	Blanco Cristalino-2	Pirsabak (1) 7930
	30	Blanco Cristalino-2	Pirsabak (2) 7930
Malawi	44	American Early Dent x Tuxpeño	Across 7844
	44	American Early Dent x Tuxpeño	Kisanga 7844
	30	Blanco Cristalino-2	Pirsabak (1) 7930
	30	Blanco Cristalino-2	Jutiapa 7930
Mozambique	43	La Posta	OB7643
	34	Blanco Subtropical	OB7734
	28	Amarillo Dentado	Monica
	22	Mezcla Tropical Blanca	Makulu
	43	La Posta QPM	La Posta QPM
	40	White QPM	PR7740
	49	Tuxpeño C_{17}	Mexico 8049
Zambia	43	La Posta	Across 7843
	44	American Early Dent x Tuxpeño	TL7844
	44	American Early Dent x Tuxpeño	Across 7844

varieties as rapidly as possible and involve simultaneous tests on several sites at experiment stations and in farmers' fields, along with appropriate checks. Figure 3 illustrates the sequence of such a program.

The maintenance and seed production of open-pollinated varieties of maize can be easily managed through three stages of seed multiplication, namely, breeders' seed, foundation seed and certified seed. The breeders' seed field should show the least amount of variation, and the certified seed field the most; the foundation seed is intermediate between the two. The responsibility for maintaining the purity of breeders' seed should rest with the breeder himself. The certification standards should be fixed carefully for various stages of seed multiplication, so as to provide quality control but not hamper seed production and distribution. Alternative procedures for the maintenance and production of breeders' seed are shown in Figure 4.

Table 8. Characteristics that may be considered in the description of a variety

Plant part	Characteristic	
	Qualitative	Quantitative
Stem	Color	Height Number of nodes Number of tillers
Leaves	Color Color of central vein Color of leaf sheath Pubescence of sheath	Total number Number of leaves above ear Leaf angle Width of ear leaf Length of ear leaf
Tassel	Color of glumes Color of anthers Compact or open	Length of peduncle Length of central axis Number of branches Days 50°/o plants with pollen
Ear	Color of stigmas Color of dry husks Husk pubescence Husk texture Ear shape Kernel row arrangement Cob color	Number per plant Insertion angle Length of ear peduncle Number of kernel rows Length Diameter Weight Shelling percentage Cob diameter
Seed	Color of pericarp Color of aleurone Color of endosperm Texture (dent, flint, etc.)	Length Width 1000-grain weight Thickness

Source: Development, maintenance and seed multiplication of open-pollinated maize varieties. 1984. CIMMYT, Mexico.

Training

A major function of the CIMMYT maize program is that of training and staff development. Since it takes 10 to 15 years of training and experience beyond high school to develop agricultural research scientists, this investment in human resources does not produce immediate results; therefore, it is a difficult task for developing countries.

The main objective of CIMMYT's training program is to assume a supportive and complementary role to national maize research programs. One of the primary objectives is to help fortify the capacity of collaborating national programs to conduct effective research on maize improvement and production. CIMMYT's maize program provides the following types of training:

* In-service training—This type of training is offered to national program scientists who are actively engaged in maize improvement, production and experiment station management. The five-month course takes place in Mexico.

* Visiting scientists—This offer is extended to senior-level research collaborators with national leadership responsibilities. The visits range from one week to three months, and training includes orientation, discussion and review of research methodologies.

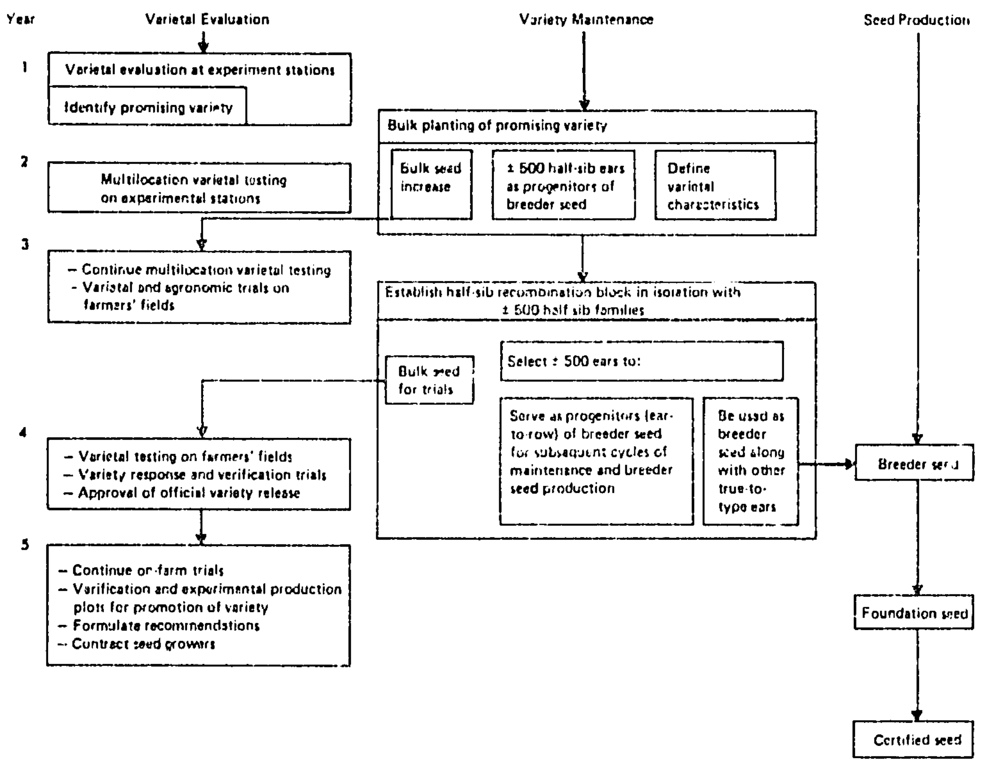


Figure 3. Sequence of events in varietal evaluation and maintenance and a seed production program

Source: Development, maintenance and seed multiplication of open-pollinated maize varieties. 1984. CIMMYT, Mexico.

- Pre- and post-doctoral fellowship programs—Pre-doctoral fellowships provide thesis research opportunities for selected candidates. Post-doctoral fellows come to CIMMYT to develop their professional scientific knowledge in maize research. This program also serves as a way for CIMMYT to screen and identify potential staff.

- Associate scientists—This program serves as a link between the respective national programs and CIMMYT. The salaries of these scientists, who stay at CIMMYT for a year or more, are frequently paid by their own governments.

- In-country training—A number of regional and national training programs are conducted periodically in selected countries and regions. The advantage of this kind of training is that a large number of participants can take part. This type of training is meant to complement the in-service training offered in Mexico.

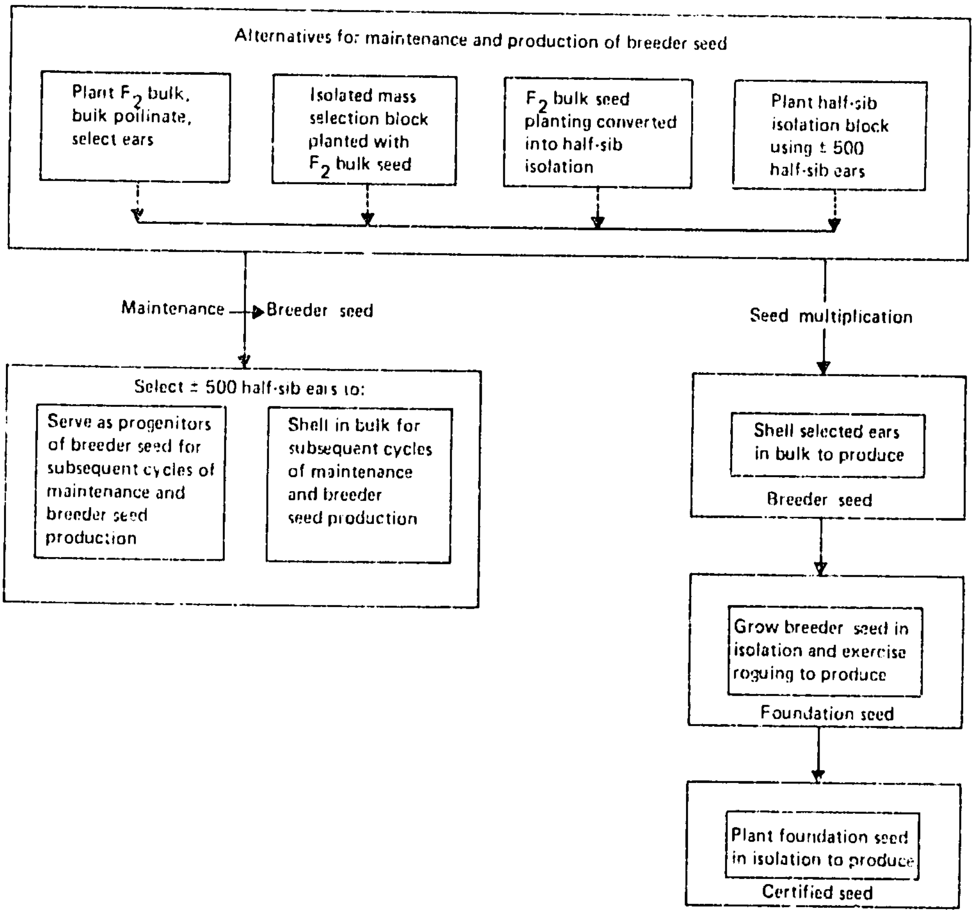


Figure 4. Maintenance and seed production of an open-pollinated maize variety

Source: Development, maintenance and seed multiplication of open-pollinated maize varieties. 1984. CIMMYT, Mexico.

- Conferences and workshops—Such meetings bring together researchers, development assistance agency officials and others for improving communication between CIMMYT and its collaborators, both at headquarters and in regional offices. National scientists are invited to present papers, share ideas and discuss priorities.

Table 9 shows the number of CIMMYT maize trainees, visiting scientists and pre- and post-doctoral fellows from eastern and southern African countries between 1974 and 1984.

Other training-related activities—In 1982, along with CIMMYT scientists, the national maize research coordinators of Ethiopia and Kenya visited the Zambia and Malawi maize research programs. All associated expenses were paid by CIMMYT. Similarly, one of the senior maize breeders of Zambia visited the Tanzania maize program, along with the CIMMYT team. As a result of such tours, the maize scientists of these countries have started exchanging germplasm. It is hoped that such activities will be continued in the future if funds are available.

CIMMYT staff members attempt to visit each national program once or twice a year to hold discussions with national scientists, former CIMMYT trainees and other agencies engaged in maize research. Field discussions and demonstrations in areas of mutual interest, such as note-taking, scores for measuring disease and insect damage, harvesting procedures and yield determination are covered. Such personal contacts have been found to be a valuable training method.

CIMMYT maize staff also actively participate in regional and/or national-level seminars and workshops and often present papers. To a limited extent, they also participate in maize research project identification, preparation and implementation when requested by national programs.

Material assistance to national programs

The budget of CIMMYT's East African Regional Maize Program is very limited. However, a genuine attempt has been made and will continue to be made to provide certain essential items needed by national programs. To this effect, CIMMYT has donated pollinating bags, grain moisture meters, field scale balances, fertilizers, herbicides, steel tape measures, knapsack sprayers and even motorcycles and vehicles in exceptional cases. This modest effort partially offsets foreign exchange restrictions faced by almost all national programs in Africa.

Table 9. Maize trainees, visiting scientists, and pre- and post-doctoral fellows from eastern and southern African countries, CIMMYT, Mexico, 1974 to 1984

Program and country	Year		Number
In-service trainees			
Botswana	1978-80		2
Burundi	1984		1[a]
Ethiopia	1974-83		7
Kenya	1975-84		19[a]
Lesotho	1983		1
Mozambique	1981		3
Malawi	1975-84		8[a]
Rwanda	1978-84		2
Somalia	1984		3
Swaziland	1980		1
Tanzania	1977-84		30[a]
Transkei	1980		1
Uganda	1981-82		2
Zaire	1978-80		11
Zambia	1977-84		12[a]
		Total	103
Visiting scientists			
Botswana	1981		1
Ethiopia	1977-84		7
Kenya	1981-84		6
Lesotho	1982		1
Malawi	1982		1
Mozambique	1981-84		2
Uganda	1984		1[b]
Zambia	1983		3
Zimbabwe	1982		1
		Total	23
Pre-doctoral fellows			
Tanzania	1981-82		2
Zimbabwe	1974-75		1
Post-doctoral fellow			
Zaire	1981-82		1
In-country training			
Malawi	1984		38

a/ Includes candidates accepted for March to June 1985
b/ Departed in February 1985

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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.

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.

Reference

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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 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% (12). The yield-depressing effect of maize diseases is, therefore, among the principal causes of the instability of maize production in Africa (7).

Latitude, altitude and vegetation type are the principal physioclimatic factors for stratifying maize ecologies in Africa. There are six major ecologies:

- Lowland tropical rain forest—mostly between 10°N and 10°S latitudes, with altitudes below 1000 meters (parts of Tanzania and coastal Kenya);
- Lowland tropical savanna—between 10° and 15°N latitude, with altitudes of less than 1000 meters (the eastern belt from Ethiopia to Mozambique and the southern belt from Mozambique to Angola);
- Tropical, midaltitude—between 1000 and 1500 meters altitude (mainly eastern and southern Africa and parts of central Africa);
- Tropical highlands—between 1500 and 2000 meters altitude (mainly the eastern and southern parts of central Africa);
- Subtropical/Mediterranean--above and below 23°N and 23°S latitudes, respectively, and
- Tropical desert, irrigated—mainly between 15° and 23°N latitude and parts of eastern and southern Africa.

Major Maize Diseases

Maize is subject to attack by some diseases wherever the crop is grown. The two most important factors that influence ecological stratification, namely temperature and rainfall, also govern the distribution of maize diseases in Africa. For instance, subtropical or temperate diseases like *Helminthosporium turcicum* leaf blight and *Puccinia sorghi* rust occur in the cool environment of the tropical highlands, whereas their heat-loving counterparts, *H. maydis* and *P. polysora*, prevail in the lowland tropics. Furthermore, even within the lowland zone, the higher relative humidity of the rain forest belt of West Africa facilitates the occurrence of more diseases than in the drier savanna. Since temperature does not limit year-round maize production in tropical Africa, seasons are differentiated principally by rainfall pattern. Differences in rainfall (total annual precipitation and distribution), temperature regimes, relative humidity, cumulative inoculum potential and the overall climatic influence on vector behavior affect disease distribution between seasons within the same ecology.

Maize diseases can be classified in several ways. The system used here combines elements of host-plant development with easily recognizable symptom-characteristics. Over thirty diseases have been recorded on maize in Africa, many of which are of little or no practical significance in its production. Only the major, commonly encountered diseases will be reviewed here.

Seedling rots and other seedling diseases

Maize seeds are subject to infection by fungi, causing seed rots and diseases of the seedlings, often referred to as damping-off. These fungi are soil and/or seed borne. The symptom of seed rot is the complete decay of the seed before or at time of germination. Seedling diseases, usually called seedling blight, may occur in several forms. Some commonly encountered symptoms are those of brown water-soaked lesions on the roots, the twisting of the shoot (*Pockkah boeng*) and stunting or progressive wilting and eventual death, beginning at the tip of seedling leaves. These diseases are favored by planting in wet, poorly drained or cold soils, by mechanical injury to the seed coat and by very deep planting.

Fungi that incite ear or kernel rots are also common agents of seed rots and seedling diseases. *Fusarium* spp., especially *F. moniliforme*, are the most frequently occurring fungi found on seeds across all the maize-growing ecologies in Africa. Other commonly occurring seed-borne fungi are *Macrophomina phaseoli, Nigrospora oryzae, Botryodiplodia theobromae, Helminthosporium maydis* and *Diplodia maydis*. *F. roseum* occurs in the highlands. *Aspergillus* and *Penicillum* may also be important, especially if the seed is wet when harvested and stored. The most important group of soil-borne pathogens are various species of *Pythium*.

Seed rot and seedling diseases can be controlled by planting good-quality seed in warm soil. Factors that predispose seed and seedlings to diseases can be corrected or eliminated by the avoidance of excessive mechanical damage through careful processing of seed, planting mature seed, storing seed at relatively low temperatures and humidity, and planting when soils are warm and favorable to seed germination and growth. Chemical seed treatment, i.e., with Captan or Thiram, protects against invasion by soil-borne fungi.

Local-spot foliar diseases

Local-spot leaf diseases are the most frequently occurring maize diseases. They are principally caused by fungi and are common in areas of warm temperatures and ample moisture in the form of rain or heavy dew. When severe, they depress yield by reducing the photosynthetic leaf area and predispose the plants to root and stalk rots. Yield losses are particularly pronounced when the plants are severely infected in the early growth stages.

Helminthosporium leaf blights—These are the most prevalent and potentially most damaging of the leaf-spot diseases of maize. The two common species are southern leaf blight and northern leaf blight.

Southern leaf blight occurs in warm humid areas of the lowland tropics (20° to 32°C). It is caused by the fungus *Helminthosporium maydis* Misik and Miyake (*Cochliobolus heterostrophus* Drechs.). The synonyms of the fungus are *Drechslera maydis* and *Bipolaris maydis*. The disease is characterized by tan, roughly rectangular lesions, with the longer side being parallel to the leaf axis. They range in size from 1.9 to 2.7 cm long by 0.6 to 1.2 cm wide.

There are two races of the fungus. Race O is the most common and is not specific on any type of cytoplasm; it usually attacks only leaves. Race T occurs on plants having the Texas (T) type of cytoplasm that confers male sterility to the plant. On such maize varieties, not only the leaf blades are infected, but also the sheath, husk, shank and cob. The lesions incited by Race T are larger and less rectangular; they are more spindle shaped or elliptical. They usually have dark reddish brown borders.

Northern leaf blight is caused by *Trichometasphaeria turcica* (Luttrell) and appears in cool, humid climates, such as those of the subtropics or the tropical highlands. The characteristic symptoms are large boat-shaped, grayish green lesions (5 to 10 cm long and about 1.3 cm wide); they later turn tan. The temperature range of 18° to 27°C favors disease development. *H. maydis* and *H. turcicum* overseason as mycelium and spores (conidia) on infected leaves of the previous-season crop and on stored grain. The disease is spread by means of conidia, and under ideal weather conditions the disease cycle is completed in 60 to 72 hours. The conidia can also be transformed into chlamydospores (resting spores).

Rusts

The maize rusts are fungal diseases caused by the *Puccinia* species. Rusts occur primarily on the leaves and any above-ground green tissue. They are characterized by the presence of roughly circular, golden yellow to brown raised structures (pustules), which when mature erupt to release powdery spores. There are two major species, which like the leaf blights are distinguishable on the basis of ecological adaptation (temperature preferences).

Polysora rust—This type of rust is caused by *P. polysora*. It occurs in warm, humid environments; elevations above 1220 meters are unfavorable for disease development. The pustules are light brown and round or oval. They are usually found on the upper surfaces of the leaves, with the leaf epidermis remaining intact over the pustules for a long period. The uredospores are yellowish to golden, and also round to oval. No alternate host has been recorded for the fungus, but it has a number of collateral grass hosts. Perennation is by uredospores. Teliospores are rare and of little importance in the disease cycle.

Sorghi rust—This rust is caused by *S. sorghi*. The disease is prevalent in cool environmnts, such as in the highlands of eastern and southern Africa and parts of central Africa. The pustules are more elongated and darker than those caused by *P. polysora*. Pustules appear on both upper and lower leaf surfaces and break through the epidermis relatively early as compared to those of polysora rust. *P. sorghi* has a complete life cycle (macrocyclic), which passes through an alternate host, the barberry (*Oxalis* sp.). However, as with polysora rust, the uredospore is the chief means of disease spread.

Curvularia leaf spot—Curvularia leaf spot is found throughout the tropics, but thrives in warm, humid environments. The disease is caused by the fungus *Curvularia pallescens* or *C. lunata*. The spots are usually small and circular (1 to 6 mm in diameter) with a gray center and a brown border, beyond which there is often a chlorotic background. On very susceptible varieties, the disease is also found on the sheath and husks. Curvularia leaf spot is perennated by conidia that survive on maize debris; the conidia are also responsible for the secondary spread of the disease during the growing season.

Physoderma brown spot—Brown spot is common in hot, humid climates, especially when land is continuously planted to maize. It is caused by the fungus *Physoderma maydis* Miyake. The first signs of the disease are tiny yellowish spots (0.1 to 1.5 mm in diameter) on the leaves; these spots later turn brown. The early stage of the disease can easily be confused with rust, but the brownish yellow powder produced in rust is not present. On the leaf sheath, midrib and stalk, the spots are chocolate brown. High disease severity may lead to leaf and stalk breakage, particularly in windy areas.

Economic significance and control of leaf diseases

Leaf diseases, particularly leaf blights and rusts, usually appear first on the lower leaves; the disease progresses upward, until in severe cases nearly all of the leaves of the plant become heavily infected. The presence of a large number of spots robs the plant of the much-needed green leaf tissue for photosynthesis, and therefore of high productivity. Ears of severely infected plants are light. The earlier the plant is infected, the greater the ultimate yield loss; severely infected seedlings may die prematurely.

Although leaf diseases can be controlled by the use of fungicides, the practice is not economically feasible, and frequent rainfall can necessitate frequent spraying. Host-plant resistance is the simplest and most cost-effective method of control. The improved maize varieties offered by the international centers (IITA and CIMMYT) have high levels of resistance to most of these diseases. Stable quantitative resistance, i.e., the appearance of few spots, is emphasized in the breeding program. A simply inherited qualitative resistance to *H. maydis* has proved very effective and stable (2). It is being utilized by seed companies in the USA. Many of the improved varieties available in national programs in eastern and southern Africa have high levels of resistance to *H. turcicum*, deriving largely from some early introductions, such as Ecuador 573. Resistance to curvularia leaf spot and physoderma brown spot has been progressively improved through a gradual elimination of sensitive plants during the breeding process.

Systemic foliar diseases

For this category of diseases, infection is not restricted to the primary point of infection or to the tissue within the infected leaf. Rather, leaves that develop later will contain the pathogen and express the characteristic symptoms of the disease. All of the maize diseases induced by viruses and virus-like pathogens are systemic. Maize streak, maize mottle/chlorotic stunt and maize dwarf mosaic are presently the major virus diseases of economic significance in tropical Africa. Downy mildew is also a very important systemic disease that is caused by a fungus. Yield loss through systemic diseases is proportional to the number of plants infected, as such plants die prematurely or remain virtually unproductive.

Maize streak virus disease—Maize streak virus (MSV) disease was first recorded in South Africa in 1901. It is now widely distributed in Africa and occurs in diverse ecologies, from sea level up to 2000 meters and in the forest belt as well as on the savanna. The disease is still virtually restricted to the African continent and the neighboring islands in the Indian Ocean (14). Maize streak is most commonly observed on irrigated crops and off-season crops, such as maize planted late in the main season or as a second-season crop in the two-season ecology in the West Africa forest zone. The disease is spread by several species of leafhoppers belonging to the genus *Cicadulina*. No other method of spread is known.

Leaves of plants infected with MSV show broken to almost continuous chlorotic lines along the veins and over the leaf surface. Only new growth develops these symptoms; there are normally green leaves at the base of the diseased plant. This allows estimation of the growth stage of the plant at time of infection. Plants infected at an early growth stage become stunted and produce poor ears. Fajemisin *et al.* (9) identified the major components of yield loss in MSV-infected plants as plant loss due to early infection (within ten days after emergence), resulting in low plant stand and subsequent reduced harvestable ears, and less vigorous growth in late-infected plants. Late infection is characterized by shorter plants, narrow stem diameter, smaller leaf size, delayed flowering, nonsynchronization of pollen shed with silking and small, poorly filled ears.

Chemical control with Furadan can achieve some control of streak disease, although this is neither reliable nor cost effective. The most economically feasible method of control is the planting of resistant varieties. Over the past ten years, IITA has emphasized the development of streak-resistant varieties as an approach to improved productivity of maize in Africa (8). This has been made possible through the evolution of a simple and reliable screening technique, utilizing large-scale, controlled infestation of maize seedlings with viruliferous leafhoppers (3,4). Through collaboration between IITA and CIMMYT, varieties with improved plant type, high yield and resistance to MSV have been developed which meet the needs of farmers and consumers in the principal maize ecologies of Africa (1,8,10,15). Under severe streak pressure, these streak-resistant varieties have yields three times higher than those of their streak-susceptible counterparts.

Similarly, streak-resistant maize hybrids have been developed for lowland and midaltitude ecologies (13). National programs in Africa are now aware of streak resistance sources, and by 1984 more than 30 countries had proven the effectiveness of this resistance.

Maize mottle/chlorotic stunt—Maize mottle/chlorotic stunt (MMCS) is caused by a virus which is also transmitted by *Cicadulina* leafhoppers. The symptoms of the disease include a shorter plant due to shortened internodes, leaf mottling with or without purpling, shoot bending, nonextrusion of anthers, causing functional male sterility, false prolificacy (multiple ear shoots) and poorly developed ears. This disease is as widely distributed as MSV. Symptoms similar to MMCS are prevalent in the midaltitude areas of southern Africa, particularly in Zambia and Zimbabwe. Almost all of the elite inbred lines being used in this region are susceptible to a disease suspected to be MMCS; further research is needed.

Generally, streak-resistant varieties have high levels of resistance to MMCS. This is a result of selection against the disease in MSV disease nurseries, since both diseases are spread by *Cicadulina* leafhoppers. However, work is now underway at IITA to investigate MMCS and embark on independent screening for resistance to the virus.

Maize dwarf mosaic—Symptoms of maize dwarf mosaic (MDM) first appear on the youngest leaves as an irregular, light and dark mosaic, which may develop into narrow streaks along the veins that appear as dark green islands on a chlorotic background. As the plant matures, leaves become yellowish green. Plants with these symptoms are sometimes stunted and have excessive tillering, multiple ear shoots and poor seed set. Leaves often turn purple as the plant approaches maturity. The disease is caused by a virus that can be transmitted mechanically by at least 12 species of aphids, including the maize leaf aphid (*Rhopalosiphum maydis*). The disease is common in the midaltitude ecology. The streak-resistant varieties have also been reported to resist MDMV (12).

Downy mildew—Downy mildew constitutes perhaps the most serious maize disease wherever it occurs. The disease is caused by fungi of the generas *Peronosclerospora* and *Sclerophthora* and is very important in several countries in Asia. Downy mildew has also been reported in some countries in Africa, including Zaire, Nigeria, Mozambique, South Africa, Zambia, Somalia, Sudan and Ivory Coast.

Infected plants show some form of chlorosis, which is uniform or striped, depending on the pathogen involved.

Systemically infected plants are stunted, spindly and brittle, with erect, narrow, chlorotic leaves. Infected plants may display a leafy proliferation of the tassels; such leafy masses constitute the so-called "crazy top" symptom. In late-infected plants, ear shoots tend to be numerous, elongated and have leafy appendages; they are usually barren.

Chemical control of downy mildew can be achieved by treating the seed with Apron SD 35 at 3 g/kg of seed. Also, varieties with downy mildew resistance (DMR) have been developed by IITA and CIMMYT. Since maize in some African countries is attacked by both streak and downy mildew, varieties that combine resistance to the two diseases have been developed at IITA. These DMRSR varieties produce good yields under severe attacks of either downy mildew or streak, as well as of combined attack by the two diseases (11).

Stalk and ear rots

Stalk and root rots are universal. Some stalk rot occurs in every field where maize is grown. When conditions favor rapid disease development, infected plants may die several weeks before the ears are fully mature; this results in ears that are poorly filled and in chaffy kernels. Indirect yield losses also occur through stalk breakage and root lodging, making harvesting difficult and causing many fallen ears to rot. Losses vary from season to season and from region to region, but throughout Africa stalk rot incidence of 5 to 40% is common.

Maize is susceptible to some ear-rotting pathogens. They cause reduction in the yield and quality of grain. Some of them, especially *Aspergillus flavus* and *Fusarium moniliforme*, produce mycotoxins which reduce the nutritive value of the grain (5); others cause various forms of discoloration, which directly reduces the market value of the grain. Losses due to ear and kernel rots are considerable but vary widely. Delayed harvesting and improper drying and storage methods increase the level of ear rot infection.

Rots are caused by a complex of species of fungi and bacteria that attack plants approaching maturity. *Pythium* and some bacteria commonly attack maize before silking. The most common fungi causing rots of root, stalk and ear in Africa are *Fusarium moniliforme*, *Diplodia maydis*, *Botriodiplodia theobromae* (= *D. natalensis*), *Macrophomina phaseoli* (*Sclerotium bataticola*) and *Rhizoctonia solani*. The rots induced by these pathogens can be distinguished by the color of the rot, the consistency of the rotten stalk, and of course by the identification of the causal agent.

Fusarium rot is found wherever maize is grown in Africa, lowland forest, lowland savanna and from medium to high altitudes. The infected stalk is of various shades of pink, and the grain is pink or has whitish streaks. Rots induced by *Diplodia* are common in cool environments, such as the tropical highlands of eastern and southern Africa. The stalk is brown, and infected ears have bleached husks that are stuck together with a fungal mass. *B. theobromae* is common in the humid lowlands. Infected stalks are brown, and the grains are dark colored. *Macrophomina* causes charcoal rot, characterized by internodes consisting of vascular strands surrounded by numerous dark sclerotia. Infected grains are dark colored. Charcoal rot occurs in dry environments, such as in the savanna and in the second season in the forest belt. *R. solani* causes a rotting of the shoot, which causes leaf drying and rotten stalks and ears. It is commonly encountered in very wet equatorial forests. It has been found in Gabon, Liberia, Cameroon and Nigeria.

Cephalosporium maydis causes a disease called late wilt in maize. The first symptom of late wilt is the moderately rapid wilting of the leaves, beginning at tasseling. Leaves turn dull green and then become dry. Vascular bundles in the stalk turn brown. Later, the lower part of the stalk becomes dry, shrunken and hollow. These stalk symptoms may be modified by secondary organisms that cause a wet rot. Late wilt is a very serious maize disease in Egypt and other dry areas.

Maize plants vary in the extent of susceptibility to the rot agents. Where available, resistant varieties should be grown. Yield losses can be reduced substantially by timely harvesting of the crop and by proper grain drying and storage.

Striga infestation
Maize is prone to attack by *Striga*, a genus of parasitic seed plant commonly referred to as witchweed Severe localized infestation of maize fields has been observed in many African countries, particularly in the savanna belt of western and central Africa, in Benin, Nigeria, Mali and Cameroon. The spread of *Striga* is of major concern because maize production has become more widespread in the savanna belt, replacing sorghum and millet in many areas where rainfall is adequate. *Striga* has also been observed to be of economic significance in parts of eastern and southern Africa where sorghum cultivation is prevalent.

By feeding directly on the maize plant, *Striga* deprives it of essential nutrients, metabolites and water. *Striga* damage on maize is reflected by drought-like symptoms (wilting and leaf firing), stunting, poor pollen production and poor ear development, all of which contribute to drastic yield reductions. This weed is difficult to eradicate by conventional means for two reasons. It produces many seeds that retain their viability in the soil for many years and germinate only in the presence of the host plant, and postemergence weed control is ineffective, because by the time *Striga* weeds emerge, considerable damage has already been done to the maize plant.

Over the past three years, IITA has carried out intensive field screening and evaluation of inbred lines and hybrid combinations under heavy *Striga* infestation at Mokwa in the southern Guinea savanna zone of Nigeria, and some inbreds and hybrids that demonstrate consistent resistance/tolerance have been developed (16). Further research and the development of a simple and reliable screening technique is urgently needed. *Striga hermonthica* is the most important *Striga* species encountered in the lowland ecology of West Africa. In a survey conducted in parts of West Africa in 1984, Parkinson observed five *Striga* species (18). This finding has serious implications for the development of stable resistance/tolerance to *Striga*.

Diseases in Variety Development

Influence of diseases in maize improvement: Historical perspective
The role of maize diseases in catalyzing the variety development process in Africa has been tremendous. The inter- and intra-continental spread of *Puccinia polysora* in the late 1940s and early 1950s, for example, led to the establishment of regional maize improvement centers in East and West Africa, namely EAAFRO (East African Agricultural and Forestry Research Organization) in Kenya and Uganda and WAMRRU (West African Maize Rust Research Unit) in Nigeria. These two regional centers facilitated the birth of national programs in East and West Africa. Through the introduction of maize germplasm from Central America and the Caribbean, and the

subsequent development of synthetics and composites, research efforts have helped to nullify the threat posed by polysora rust epidemics (19).

Perhaps the greatest development in the past 15 years has been the recognition of maize streak virus disease as a production hazard in many countries in Africa. Before the 1970s, streak was considered of economic importance only in southern Africa (20,21,22,23). As a result of the emergence of national programs and the need to grow off-season maize through irrigation for the acceleration of the varietal development process, as well as the increase in maize cultivation in various regions of all African countries, an increased incidence of streak has been observed. The disease has gradually moved into the major growing season. This has motivated IITA to carry out research into the development of a simple and reliable screening technique for the breeding of streak-resistant maize (8,17). This streak-resistant (SR) maize is being used by many African countries, either as varieties *per se* or as resistance sources (12).

Due to the recognition of maize streak as an enemy to increased maize productivity in Africa, IITA and CIMMYT have collaborated for a more effective solution of problems affecting maize production over the past five years. Streak-resistant maize has been developed for every major ecology in Africa, and some experimental varieties with proven performance in the CIMMYT international testing program are being converted to streak-resistant versions (1,10). Also, the center for global improvement of La Posta (Pop. 43) has been moved from Mexico to Nigeria to allow for integration of streak resistance with tropical adaptation.

The past 10 to 15 years have witnessed the emergence of the threat of downy mildew to maize production in some African countries. This problem was first recognized in Zaire in about 1973 (PNM Annual Report, 1973), and then in Nigeria (6). The disease is important in South Africa, and it has also been reported in Somalia, Sudan, Mozambique, Zambia and Ivory Coast. Downy mildew-resistant (DMR) varieties have been developed in the CIMMYT Asian Regional Program. IITA has utilized the Asian DMR varieties to develop maize with combined resistance to downy mildew and streak virus. High-yielding, streak-resistant maize hybrids are being developed at IITA for the various maize ecologies in Africa (14).

Future efforts in developing maize varieties with combined resistance to the major economically important diseases in Africa will be concentrated on maize mottle/chlorotic stunt, *Striga* and stalk and ear rots.

Development of techniques for disease-resistance screening

After establishing priority for detailed research activities on a particular disease, based on its socioeconomic significance, the next step is to evolve effective control measures. Because of its economic feasibility for the farmer, host-plant resistance is explored. It is desirable to screen as many cultivars as possible for sources of resistance, but the first phase of the screening should involve adapted varieties in order to hasten adoption. The rate of progress in developing effective, stable and durable resistant cultivars depends largely on the use of reliable screening techniques. There are two broad groups of screening procedures, the hot-spot technique and the controlled infection technique.

Hot-spot technique—This method involves the use of a location that is known for its high level of infection/infestation for that particular pathogen/pest. It is generally used for soil-borne diseases like root and stalk rots and *Striga* infestation. Such locations are often referred to as sick plots. The hot-spot technique is also used for pathogens which have a local concentration of alternative hosts or other means of perennation; this is true of downy mildews. It is a feasible technique for diseases of local distribution and hence of quarantine importance. Even for diseases of widespread distribution, such as rust and blight, a hot-spot approach is used where environmental conditions lead to the natural development of the disease in epiphytotic proportions. The success of this technique depends on the consistent expression of epiphytotic potential of the location in question. The advantage is that wild types of the pathogen form are used, thereby assuring durability of the resistance so developed.

Controlled infection technique—This is an intensive method which can be practiced in the laboratory, in the greenhouse or in the field. It utilizes knowledge of pathogen behavior, host physiology and the prevailing environment. Controlled infection methods vary in their complexity. They can be as simple as that for blight (*H. turcicum* and *H. maydis*), whereby naturally infected leaves are dried and pulverized and then introduced into the leaf whorls of maize seedlings, or they can be as complex as that for streak-resistance screening. In this latter case, the *Cicadulina* leafhoppers are reared and fed on streak-infected maize plants to allow the acquisition of the virus. The viruliferous insects are then dispensed into the leaf whorl of young maize seedlings (7 to 10 days old). Between these two extremes are several other forms of controlled infection methods, including the production of spores of the pathogen, e.g., rust and blight leaf spots, and the inoculation of the plants with the spore suspension, either by spraying or through syringe injection. Stalk rots and ear rots are induced by inoculating the stalk or ear with toothpicks dipped in a pathogen medium.

The effectiveness of a controlled infection method depends on a thorough understanding of the host, the pathogen and the environment. In insect-borne diseases, knowledge of the ecology and population dynamics of the vector in the geographical zone of interest is also vital (3,4). In selecting the pathogen/vector isolates for mass culturing/rearing, it is important to utilize forms that will assure the durability of the resistance.

Disease rating methods

Diagnosis and assessment of plant diseases are two of the most important functions of plant pathologists. Diagnosis of the more common diseases is based on the identification of the pathogen and/or symptoms, using methods that are universally known and accepted. Disease assessment methods, on the other hand, have received much less attention.

Disease resistance is the relative measure of disease on a cultivar as compared to the amount of disease on other cultivars subjected to the same environmental conditions and given the same quantity of initial inoculum. A very reliable method of disease assessment is therefore a prerequisite for the effective screening of cultivars for resistance. Three parameters are considered in disease assessment, incidence, intensity/severity and crop yield.

Incidence is the quickest and easiest parameter to measure. It is expressed as the total number or the percentage of infected plants. The limitation of incidence for measuring disease is that it can only be correlated with loss in diseases where the presence of the disease means the total loss of the infected plants, e.g., wilts and downy mildew. In other diseases, where the mere presence of the disease symptom does not mean premature death and a resulting loss of the plants, the time of infection and the degree of attack determine the effect of the disease on the productivity of the plant. For example, late infection of maize by streak virus, e.g., after eight weeks, has little or no effect on yield. Incidence *per se* has no significance in this case. Therefore, the actual area of damaged plant tissue must be assessed.

Disease severity is specific to the plant, whereas incidence relates to a plant population or to an area. Disease severity or intensity is expressed as the place where it falls in the range between no disease and complete disease, i.e., by dividing the range of 0 to 100% into a number of categories or classes. The subdivisions may be for entire parts of the plant, such as total leaf area for rust and blight or the whole ear for ear rot, or it may be for a portion of the plant, such as the ear leaf or the second to fourth internodes for stalk rot. Careful scoring is necessary for reliable, reproducible results. If the number of distinguishing classes is too small, the key will have no discriminative capacity; if the number is too large, too much time is lost in deciding which grade best matches the plant or plant part observed.

All methods of assessment of disease severity are subjective to some extent, since they are the results of visual judgment. A commonly used scale is that of 0 to 5, a form of which is presented in Table 1.

Two tools for rating for intensity are commonly used:

- Disease scale—a verbal and numerical description of the classes to be distinguished, and
- Standard diagram or pictorial disease scale—the percentage of the leaf, stalk, or fruit area infected.

In both cases, the observer has to visualize the area the lesions (including the surrounding chlorosis) would cover if they could be gathered together, and then estimate this area as a percentage of the total area of the plant tissue being assessed.

Before the adoption of material for general usage, it is desirable that experiments be carried out to correlate the amount of disease shown by the disease assessment method with actual crop loss. Also, the method must be related to the phenology (growth stage or development) of the host. Scoring must not be delayed until a time when it would be impossible to record differential responses among the various cultivars being assessed, as then the increase in disease would no longer have any significant effect on crop productivity.

Table 1. Scoring scale used for assessing disease severity

Numerical designation[a]	Disease class/interval (%o infection)	Description of infection	Host-plant disease reaction
0	0	None	Immune (or escape)
1	0– 10	Slight	Highly resistant
2	10– 25	Mild	Resistant
3	25– 50	Moderate	Moderately susceptible
4	50– 75	Heavy	Susceptible
5	75–100	Very heavy	Very susceptible

[a] Further subdivisions can also be used, i.e., 1.5, 2.5, 3.5, 4.5

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Discussion

Dr. Kirkby: My comment is related to *Striga*. You stated that the conventional weed-science approach to the control of *Striga* is not feasible. If by "conventional approach" you mean reliance upon herbicides, then I agree with you. Other agronomic methods are known to assist in control; even small farmers in Kenya know that rotation with cotton reduces infestation of the subsequent maize or sorghum crop (cotton induces suicidal germination). It is also widely recognized that the use of fertilizers results in the suppression of *Striga*. Perhaps we should learn from the experience of sorghum breeders, who have been concerned with selection for resistance to *Striga* much longer than have maize breeders. Dr. Ramaiah's breeding work in the ICRISAT/Burkino Faso program has successfully demonstrated resistance in a number of materials, but this resistance has not always held up across environments. It appears that an integrated approach to the management of this weed is needed, with a pathology-type breeding effort combined with cultural control methods. This kind of interdisciplinary approach to *Striga* control is being developed by national sorghum researchers in Ethiopia and in Kenya.

Dr. Darrah: You now have *Striga*-resistant varieties. Have you gone further in identifying the mechanism or mechanisms involved?

Dr. Fajemisin: We have not yet investigated the mechanism, but the resistant maize is able to tolerate some *Striga* infestation without showing symptoms of stress, such as wilting, leaf firing and stunting.

Mr. Malithano: When do you consider a disease to be of economic importance?

Dr. Fajemisin: Starting with farmers' plots with different planting dates, you monitor the incidence and severity of disease and correlate this with loss in yield for each disease.

Mrs. Sibale: How available is IITA for helping national pathologists in identifying local pathological problems?

Dr. Fajemisin: We can help in various ways, such as through training, publication of field guides, country visits and exchanges of scientists.

Mr. Marandu: From the map of Africa that you showed, it appeared that downy mildew is restricted to certain countries. Is the disease localized?

Dr. Fajemisin: Yes, it is, and the rate of movement is reduced if the moisture content of seed is kept below 13%.

Maize Resistance to Stalk Borers [*Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae)]: Some Aspects of Insect Responses to the Plant and Implications for Breeders

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Abstract

*Maize plants exhibit much variability in terms of moth preference for oviposition and larval colonization. Studies on the relationship between the stalk borer [*Chilo partellus *(Swinhoe)] and the maize plant indicate that factors such as plant surface trichomes and plant exudates influence adult oviposition on the plants. The neonate larvae also are able to discern between acceptable and unacceptable plants for feeding and colonization. Knowledge of such variability and the effect on *C. partellus *colonization patterns can be useful in plant breeding strategies for the development of maize genotypes resistant to stalk borers.*

Maize is the third most important cereal (after wheat and rice) in the world. In African countries, it is perhaps the single most important food crop, and yet their production levels are among the lowest in the world. One of the major constraints limiting production in Africa are insect pests, particularly the stalk borer. Strategies to reduce this constraint have, in the past, relied mainly on the use of chemical pesticides. The use of such pesticides without regard to the complexities of the ecosystem, particularly the population dynamics of the pest and its natural enemies, has been one of the basic shortcomings of this control strategy. In Africa, a large proportion of the total land area under maize cultivation (70 to 80% in Kenya) is held by small-scale subsistence farmers. For such farmers, it is not economically or logistically feasible to use chemical pesticides. Therefore, they must depend on a more fundamental approach to pest management, such as the use of insect-resistant cultivars.

The Maize-Stalk Borer Complex

The stalk borer complex in Africa is quite wide. However, four major species, [*Chilo partellus* (Swinhoe), *Busseola fusca* (Fuller), *Sesamia calamistis* (Hmps.) and *Eldana saccharina* (Walker)], are the most important in distribution and predominance. The damage symptoms of these pests are similar; the early instar larvae feed on leaf or leaf sheath tissue, while later instar larvae bore into the stems. On young plants, stalk borer feeding on leaf tissue may cause a reduction in the photosynthetic area, and extensive infestation may cause the destruction of the growing tissue with the resulting "dead heart" condition. On older plants, the larvae penetrate and tunnel through the stem piths. Extensive tunneling in the peduncle may result in poor pollen development and poor pollination. Tunneling in the lower stem or shank damages stem piths and vascular tissue. This type of damage may interfere with the transport of metabolites and cause stalk weakening and breakage.

Little is known of the extent of loss caused by stalk borers, mainly because of the extreme variability in maize yields, due to climate, variety, type of agricultural system, plant growth stage and timing of the pest attack. In Kenya, however, Walker (7) and Warui and Kuria (8) estimated that average annual losses due to stalk borers are about 18%.

The problem of stalk borers for subsistance farmers presents a challenge to agricultural researchers to develop control tactics that do not rely on costly and often unavailable pesticides. Host-plant resistance is one control tactic that appears to offer great promise. Host-plant resistance comes as a package in the seed of the variety, and utilizes mechanisms which afford adequate protection to the plant through its vulnerable stages.

Maize Resistance to Stalk Borers: ICIPE's Research Objective

In late 1979, a project to develop maize resistance to stalk borers was initiated at the International Centre for Insect Physiology and Ecology (ICIPE), with funds from USAID and the British ODA to be used for:

- Evaluating maize genotypes for sources of resistance to stalk borers;
- Identifying the biochemical, biophysical and/or other characteristics of maize plants which influence stalk borer responses and cause plant susceptibility or resistance, and
- Identifying the genetic bases of the resistance expressed, in order to enable breeders to formulate appropriate breeding strategies.

Chilo partellus is used as the model in these studies as it is most widespread. It is also the predominant species in the Mbita Point area where ICIPE is located.

Evaluation of maize germplasm for sources of resistance

In 1980-81, about 460 families of maize from CIMMYT that had shown some resistance to *Ostrinia nubilalis* (Hubner) and *Diatraea grandiosella* (Dyar) were tested with some elite materials from Kenya and elsewhere. Materials showing high levels of resistance were selected for detailed study. In 1984, the following groups of maize genotypes were also tested for their levels of resistance or susceptibility to the stalk borer *C. partellus*:

- Group I—MP704, MP702 and MP701 which were developed in Mississippi, USA. These are inbred lines and were reported to have resistance against the Southwestern corn borers *D. grandiosella* and *Spodoptera frugiperda* (J.E. Smith).

- Group II—CI31A, B75, B85, B86 and OH43, which originated in the USDA Corn Insects Research Laboratories at Ankeny, Iowa, USA. These were reported to be resistant to the European corn borer *O. nubilalis*.

- Group III—ICZ1-CM and ICZ2-CM, which originated in the International Disease Resistance Nursery at Cornell University, New York, USA, and Population 27, CIMMYT maize; all were received through CIMMYT. ICZ1-CM and ICZ2-CM were family selections that showed some resistance to *Chilo partellus* in preliminary studies at Mbita. ICZ2-CM was used as the resistant check in this study.

- Group IV—Inbred A and Katumani, which originated from Kenya germplasm. Katumani is a locally grown variety. Inbred A was used as the susceptible check.

The evaluation process took into consideration adult moth responses, as well as larval damage. A radial planting design was used to monitor *C. partellus* adult oviposition preference among the maize genotypes in a choice situation. This design gives each plant an equal chance for selection for oviposition by the moths. The plants were enclosed in a cage (6 x 6 x 2.5 meters) of nylon net (6 meshes/cm) to exclude ovipositing larvae from the field population. Twenty ovipositing moths were released in the center of the cage, and the number of eggs laid on each plant was counted every other day. The 20 moths were replenished each week with fresh ovipositing females. The test period covered the second to the tenth weeks after plant emergence.

For evaluating larval establishment and damage to the maize genotypes, plants were infested with a specified number of *C. partellus* larvae or eggs at the blackhead stage, 3 to 4 weeks after emergence. A scale of 1 to 9 (1 = no damage, 9 = severe foliar damage) (4) was used to evaluate the degree of foliar damage four weeks after infestation. At harvest, stalk breakage and ear drop were monitored. Stalks of harvested plants were split open and borer tunnels were measured. In a parallel study, field plants at 4 to 5 weeks were infested with ten first instar larvae each. All egg masses were removed from the plants before and after infestation. Twenty-eight days after infestation, the plants were dissected and all immature forms of *C. partellus* were recovered and their developmental stages recorded.

Table 1 shows oviposition distribution on the various maize genotypes. From these observations, the maize genotypes were categorized according to *C. partellus* preference for oviposition:

- Nonpreferred—ICZ1-CM, B75, B85 and MP701
- Moderately nonpreferred—MP704, CI31A, MP702 and B86
- Preferred—ICZ2-CM, Katumani, Inbred A and OH43

Table 1. Oviposition by *Chilo partellus* on different maize genotypes presented in radial rows around a circle within a cage in the field, ICIPE, Kenya, 1984

Genotype	Source	o/o eggs laid [a/] (mean ± SE)
Inbred A	Keny	10.8 ± 1.8
Katumani	Kenya	15.2 ± 3.3
ICZI–CM	CIMMYT	2.5 ± 1.4
ICZ2–CM	CIMMYT	17.9 ± 4.3
CI31A	Iowa	6.9 ± 1.4
OH43	Iowa	10.7 ± 2.3
B75	Iowa	4.2 ± 0.9
B85	Iowa	4.4 ± 3.1
B86	Iowa	9.8 ± 3.4
MP701	Mississippi	4.5 ± 0.6
MP702	Mississippi	8.2 ± 1.4
MP704	Mississippi	6.8 ± 3.3

[a/] Percent of total number of eggs laid on all genotypes during the period 5 to 9 weeks after plant emergence

Table 2 summarizes some of the measurements of primary damage by *C. partellus*, as well as damage expression among the maize genotypes. Foliar damage ranged from 2.6 in MP702 to 8.3 in Inbred A. Percentage of dead heart was highest in CI31A; most of the genotypes had no symptoms of this condition. Mean stem tunnel length per plant ranged from 22.8 cm in MP704 to 53.9 cm in Inbred A. CI31A could not be compared for this factor, since most of the plants died before harvest. Based on the mean values of foliar damage assessment, the genotypes were categorized as resistant, moderately resistant and susceptible:

- Resistant—MP702, MP704, MP701, ICZ1-CM, ICZ2-CM and possibly Katumani
- Moderately resistant—OH43, B85, B86 and B75
- Susceptible—CI31A and Inbred A

Katumani suffered little foliar damage in this experiment, apparently because of its rapid growth. It tasseled soon after infestation, and thus larvae were not able to establish themselves on leaf tissue. Earlier infested Katumani plants showed higher levels of foliar damage.

Foliar damage was caused mainly by *C. partellus*. Therefore, resistance to foliar damage indicated resistance to *C. partellus* at the whorl stage of plant development. Stem damage was caused by both *C. partellus* and *E. saccharina*, which usually appear on maize plants at Mbita during the early flowering stage. Stem tunneling and its subsequent expressions, e.g., broken tassels, ear drop and stalk breakage (Table 2), were used to categorize genotypes as to resistance levels:

- Resistant—MP704, MP702, ICZ2-CM and MP701
- Moderately resistant—B87, B75, B86 and ICZ1-CM
- Susceptible—OH43, Katumani, Inbred A and CI31A

Table 2. Primary damage by *Chilo partellus* larvae and expressions on twelve maize genotypes, ICIPE, Kenya, 1984

Genotype	Mean foliar lesions [a]	% dead hearts	Stem tunneling [a]	% stem breakage [a]
MP704	2.90 a	0	22.8 a	14.3 a
MP702	2.60 a	0	28.2 ab	16.0 ab
MP701	3.35 a	0	24.8 a	30.3 ad
ICZ2-CM	3.45 ab	2.5	37.2 b	17.8 abc
B85	5.08 cd	0	35.7 ab	34.4 bcd
ICZ1-CM	3.48 ab	0	38.4 b	27.5 abc
Katumani	3.10 a	0	40.6 bc	40.4 cde
B75	6.73 ef	37.5	39.0 b	23.5 abc
B86	6.35 de	15.0	38.0 b	31.0 ad
PH43	4.80 bc	0	39.9 b	37.5 cde
Inbred A	8.25 g	57.5	53.9 c	48.7 de
CI31A	7.88 fg	45.0	[b]	54.5 e

[a] Figures followed by the same letters not significantly different at the 5% level of probability, according to the DMRT

[b] Plants completely destroyed before harvest

Larval establishment and development after 28 days of infestation was highest in B85, with 50% larval recovery, and least in MP704, with only 2.5% recovery (Table 3). Also, 44.7% of the *C. partellus* recovered from B85 were in the pupal stage; no pupae were recovered from MP704 and MP701. It thus appears that MP704 has a high level of resistance to *C. partellus* infestation and larval survival.

The Iowa materials (Group II) were all reported to have moderate to high levels of DIMBOA in their leaf tissues and were highly resistant to *O. nubilalis* infestation. Their susceptibility to *C. partellus* infestation suggests that DIMBOA may not be a factor in maize resistance to *C. partellus*, and that the factor determining this resistance and that to *O. nubilalis* may be different.

Behavioral responses of *C. partellus* adults and larvae to resistant and susceptible maize genotypes

Observations of *C. partellus* oviposition behavior on maize indicate that they prefer plants 3 to 4 weeks after emergence. The moths usually oviposit on the lower leaves (1,3,5). Other factors observed as influencing oviposition were leaf surface trichomes and plant exudates (water of guttation). The moths appeared to favor smooth surfaces for oviposition. On maize plants, the underside of the leaves was the preferred oviposition site. Plants with high trichome density were less preferred. Considering that *C. partellus* moths lay eggs arranged in flat and partially overlapping masses, surfaces with irregularities such as hairs would be a hindrance (5). Oviposition on the underside of the leaf also may help to

Table 3. Larval establishment and development of *Chilo partellus* on twelve maize genotypes, ICIPE, Kenya, 1984[a]

Genotype	No. recovered per plant [b]	o/o below 4th instar	o/o pupae
MP704	0.87 a	25.0	0
MP702	1.32 ab	5.3	10.5
MP701	1.59 b	20.7	0
ICZ2-CM	1.71 bc	0	5.7
B85	2.34 c	3.0	9.0
ICZ1-CM	1.53 b	20.7	6.9
Katumani	1.51 b	6.9	6.9
B75	1.77 bc	0	44.7
B86	1.84 bc	17.0	2.1
CM143	2.23 c	6.5	14.3
Inbred A	2.08 c	3.7	9.3
CI31A	1.37 ab	22.7	9.1
SE	0.16	—	—

[a] 10 larvae were released per plant; larvae and pupae were recovered 28 days after the release of neonates, and data analyzed after transformation by $\sqrt{X + .05}$

[b] Figures followed by the same letter not significantly different at the 5o/o level, according to the DMRT

protect the eggs from direct sunlight and excessive heat and so prevents dessication. However, more detailed knowledge of the moth behavior pattern which leads to plant acceptance and subsequent oviposition is necessary for a thorough understanding of the role of plant characters on oviposition.

Detailed observations of *C. partellus* oviposition preferences under controlled conditions indicate the importance of distance-perceivable characters, such as water vapor and plant odor, as well as contact-perceivable characters, such as plant surface trichomes and waxes.

Despite moth preference for oviposition on lower leaves, the newly emerged larvae do not feed until they arrive in the whorl, where they may later become established (2). Emerging larvae are therefore faced with the task of migrating to the feeding sites, a journey which seems to be a critical phase in larval survival and establishment on the plant. This suggests that suitability to neonate larval feeding is not a major determining factor in the choice of ovipositing sites. Any plant characteristic which slows down the larval movement or causes larvae to leave the plant exposes them to the dangers of increased predation and environmental factors, such as heavy rain and excessive wind or heat (6).

Resistance to *C. partellus* in maize may result simply from the failure of the larvae to reach the whorls, due to the presence or absence of certain plant characteristics. Such characteristics may be influenced by genotype and are therefore open to manipulation through breeding processes. Observations on *C. partellus* neonate larval behavior at the eclosion sites (leaf surfaces) of 3- to 4-week-old plants indicate different patterns of acceptance of such surfaces. For convenience, larval behavior on the leaf surfaces have been categorized as follows:

Table 4. Mean percentage of acceptance by *Chilo partellus* larvae of different maize lines, ICIPE, Kenya, 1984

Maize line	Larval acceptance (o/o) [a]			
	High	Low	Tentative	Rejection
Whole plants				
Inbred A	67.34 (55.15)a [b]	7.88 (16.33)ah	15.56 (23.31)ah	9.24 (17.66)h
Inbred G	25.00 (29.95)h	26.22 (30.81)a	9.45 (17.95)h	35.55 (36.65)a
ICZ1-CM	36.60 (39.00)ah	21.46 (27.60)ah	18.53 (25.55)ah	15.27 (23.02)h
ICZ2-CM	29.50 (32.91)h	13.31 (21.44)ah	21.90 (27.89)ah	33.89 (35.62)a
Artificial/modified plants				
Inbred A^{-x} [c]	22.00 (28.03)h	24.55 (29.74)a	39.26 (38.80)a	9.24 (17.68)h
Artificial plant	29.30 (32.79)h	5.14 (13.15)h	26.22 (30.80)ah	38.41 (38.28)a
SE	4.55	3.76	3.97	2.97

a/ Figures followed by the same letters not significantly different at the 1o/o level
b/ Figures in parentheses are means of angular transformations
c/ Inbred A^{-x} = inbred A plants with leaf margins removed

- High acceptance—The larvae move in the direction of the axil, reaching it within ten minutes of release
- Low acceptance—The larvae roam the leaf surface for 11 to 30 minutes before reaching the axil
- Tentative acceptance—The larvae roam the leaf surface for more than 30 minutes; they sometimes repeatedly spin on and off the plant
- Rejection—The larvae spin off the plant within 15 minutes of release

Analyses of these behavior patterns on leaf surfaces showed significant differences among the maize genotypes in terms of larval acceptance (Table 4). There was a trichome density gradient along the leaf margins of all genotypes; areas near the axils were generally free of trichomes, and trichome length and density increased toward the leaf tip. The larvae appeared to use this feature to locate the leaf axil. On the most acceptable plant (Inbred A), larval arrival at the leaf axils diminished significantly when the leaf margin trichomes were removed. The percentage of successful larval establishment, food consumption, growth and development were also lower on the more resistant ICZ2-CM genotype. These factors appeared to be directly correlated.

Studies are in progress to isolate those factors within the plant responsible for the responses of *C. partellus* adults and larvae and which determine plant resistance or susceptibility. A good knowledge of a number of insect/plant interactions and how they can be modified is essential. These interactions include:

- Signals emanating from host plants (e.g., color, odor, shape, surface texture, etc.) and insect responses to such signals;
- Suitability of the host plant for the feeding, growth and development of the insect, and the insect's ability to exploit it;
- Suitability of the host plant for shelter and escape from natural enemies of the insect, and
- Reaction of the host plant to insect infestation.

For the development of reliable breeding procedures, research is essential on how these interactions can be modified by breeding and by agronomic factors. Only then can a successful search for durable resistance to stalk borers be incorporated into maize improvement programs.

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Discussion

Dr. Gelaw: It has been mentioned that some of the materials you are working with have poor genetic backgrounds and are not of any immediate value to national programs. Why don't you concentrate your work on more adapted germplasms?

Dr. Ampofo: ICIPE does not try to develop useable varieties, but rather to identify resistant sources which the national programs can then incorporate into their own material. ICIPE is now planning to contact national programs and to cooperate with them more directly than it has in the past.

Dr. Darrah: It is not surprising that you found materials high in DIMBOA to be no more resistant to *Chilo* than other materials. DIMBOA is associated with resistance to the leaf feeding of the first generation of the European corn borer, but not to the damage caused by the second generation borer.

Ethiopian delegate: ICIPE has chosen to work on *Chilo*, which is not our most important pest. Why aren't you working on other pests?

Dr. Ampofo: We are working on *Chilo partellus* because it is a very widespread pest in this region. Our resources are too limited to work on a variety of pests.

Mr. Ndambuki: The Kitale Research Station furnished ICIPE with Kenya hybrid lines to screen for resistance. The results were very useful in our breeding programs.

The Maize Pathology Program in Zambia

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Abstract

Maize in Zambia is attacked by a wide range of diseases caused by fungi, bacteria and viruses. Due to limitations in staff and resources, the maize program is focusing on only the ones that are most important and widespread, maize streak virus, ear rots and leaf diseases (blight and rust). Various field screening techniques were tested for maize streak, and it was found that the planting of infector rows four weeks before the test rows led to high levels of MSV infection. Large numbers of breeding progenies, germplasm materials and hybrid combinations have been screened, and eight have been found less susceptible across ten locations in the country. A trial on the control of MSV by various insecticide treatments showed no significant differences, possibly because the vectors had built up on alternate weed hosts and the maize plants had already been injected with virus before the vectors were killed. Ear rots, which lead to grain loss as well as to the presence of mycotoxins in both human and animal food, constitute a health threat in Zambia. To select for resistance, maize ears are inoculated in the field with fungus, and disease reactions are scored for individual ears. Three germplasm lines have shown less susceptibility to ear rots, and they will be used to incorporate resistance into maize hybrids and varieties. Research has just begun on the leaf diseases, and testing is being carried out to determine the best methods for screening for resistance to these diseases.

The maize crop in Zambia is subject to a number of diseases caused by fungi, bacteria and viruses. Yearly losses range from 3 to 30%, but in some localized areas, one or more diseases may become acute and destroy a considerably higher proportion of the crop. Because of limitations in staff and resources, systematic work has been initiated on only the most important and widespread of the diseases, streak virus, ear rots, blight and rust.

Maize Streak Virus (MSV)

Streak disease in maize is found in all the maize-growing areas of southern Africa and is widely distributed in other parts of Africa. It also occurs in Mauritius, Madagascar and parts of Asia (van Rensburg and Kuhu, 1977). MSV is not seed transmitted in maize, nor is it transmissible by sap inoculation. The sole method of transmission is by the insect vectors, of which *Cicadulina mbila* (Naude) is the most important in southern Africa.

The first symptoms in the diseased maize seedlings is the appearance of small, spherical, chlorotic spots on the youngest leaves three to six days after inoculation has taken place. All leaves formed after inoculation with the virus display the symptoms, while leaves below the place of inoculation are unaffected. When the disease is fully developed, the leaves of infected plants are covered with narrow, continuous, chlorotic streaks that sometimes fuse laterally, so that virtually the whole leaf has a chlorotic appearance.

Widespread, severe incidence of MSV has been reported from Luapula and Western, Northwestern, Northern and Central provinces of Zambia. The parents in the seed maize crop of SR52 have often been severely affected with

MSV in the major maize-growing areas of the country. Therefore, systematic work was initiated in 1980 to develop screening methods, identify resistant sources and utilize them in developing high-yielding, MSV-resistant maize hybrids, composites and varieties.

Screening techniques

In order to develop reliable screening techniques, avoid disease escape and secure an even distribution of inoculum and vector populations, various field screening techniques were tested. It was evident from the results obtained that the planting of infector rows four weeks before the test rows led to high levels of MSV infection Inoculation with viruliferous insects helped to avoid the possible escape of plants in the field.

Screening activities

During the last four years, large numbers of breeding progenies, germplasm materials and hybrid combinations have been screened, using the above technique, to identify sources of resistance to MSV. The results are summarized in Table 1. Except for the 1981-82 season, when weather conditions were not favorable, the screening has been successful. Most of the local germplasm has shown moderate-to-high susceptibility. Twenty-three single ear selections have proved consistently less susceptible over the four seasons. Among them, 12 entries were tested in a multilocational program at ten locations in Zambia: eight were found less susceptible across all of the locations.

The streak-resistant cultivars 1566/1 and 1567/1 were used as parents to develop hybrids, of which four, 1566/1 x Se, 1567/1 x Se, 1566/1 x L12 and 1567/1 x L12, have been found to be both high yielding and highly resistant to MSV. Work is in progress to further test these materials for release to farmers as an alternative to SR52 in areas where streak is a major problem.

Insecticide control

A trial on the control of MSV by insecticides was initiated after reports were received that Furadan applications had reduced streak virus incidence in Ghana and Zimbabwe by reducing the vector population. Six trials were held with soil and seed being treated with Deltanet, Miral and Furadan in different formulations. Untreated seed and seed treated by the Zambia Seed Company were used as controls. The trial utilized a randomized complete block design with three replications and six 5-meter rows. The results, which are summarized in Table 2, indicate that the different treatments led to no significant differences in any of the three parameters being tested, percent virus infection, severity of virus infection and yield between different treatments. A possible explanation for this is that the vectors had built up on alternate weed hosts, and the maize plants had already been injected with virus before the vectors were killed.

Ear Rots

Maize is susceptible to a number of ear and kernel rots, some of which are widely distributed. During 1974, when unusual weather conditions prevailed throughout Zambia, abnormal rain and low temperatures during flowering and maize harvest led to an exceptionally high incidence of ear rots. They were damaging in two ways: first, there was considerable grain loss, and second, the staple diet of the entire nation was endangered by the presence of mycotoxins. The main source of animal feed was similarly contaminated. Past meteorological data indicate that such weather conditons are unlikely to occur throughout the country more than twice a century. However, even that is a sufficiently high frequency to constitute a permanent threat to the well-being of the people of Zambia.

Ear rots are caused by a group of fungi, the most important being *Diplodia zeae*, *D. macrospora*, *Fusarium graminearum* and *F. moniliforme*. Systematic work was initiated in 1980 to test the effect of these organisms on seed viability, and a large number of germplasm and breeding materials have been screened.

Table 1. Results of four years of screening to identify sources of resistance to maize streak virus, Zambia, 1980 to 1984

Material	Number of lines in different reaction categories (o/o virus infection)					Total no. of lines
	0o/o	1-10o/o	11-25o/o	26-60o/o	61-100o/o	
1980-81 season						
Local collections	5	10	44	36	9	104
Hybrid combinations	37	51	45	14	2	149
Breeding progenies from IITA	127	25	66	45	10	273
Total	169	86	155	95	21	525
1981-82 season						
MSV-resistant selections	41	42	7	1	0	91
Hybrid combinations	85	44	11	0	0	140
Inbred lines	447	63	30	24	6	570
Total	573	149	48	25	6	801
1982-83 season						
MSV-resistant selections	23	47	98	166	18	352
Hybrid combinations	0	0	6	23	41	70
Germplasm	0	1	1	17	56	75
Swaziland material	0	0	0	1	22	23
CIMMYT material	0	2	5	3	3	13
Total	23	50	110	210	140	533
1983-84 season						
Multilocation testing	0	8	4	0	0	12
MSV-resistant selections	67	245	29	4	0	345
Hybrid combinations	0	4	8	6	2	20
Open-pollinated maize trial	0	7	11	10	3	31
Early maize trial	0	1	7	2	0	10
Total	67	265	59	22	5	418
Grand total	832	550	372	352	172	2278

Maize kernels were collected separately for fusarium and diplodia infection from the previous crop, with apparently clean maize of the same variety used as the control. Visual assessment was made of the kernels, which had been placed on moist filter papers in plastic petriplates and incubated at 25°C. Results indicated that there was a complete loss in viability of the diplodia-infected maize: only 1.5% of the fusarium-infected kernels germinated. The clean maize had 97.8% germination.

Screening techniques

In order to distinguish between resistant and susceptible cultivars, a factorial experiment with four replications was conducted to determine the most appropriate method and stage of inoculation of maize ears. They were inoculated in the field with *Diplodia macrospora* and *Fusarium graminearum*, and disease reactions on individual ears were scored. A scale of 1 to 5 was used (1 = no infection, 5 = very severe infection). Cob rot infection was found to be greater when inoculations were made around pollination time, rather than two weeks after pollination. Diplodia infection was most severe when inoculation was done with a toothpick at the base of the ear. Inoculating the tip of the ear with a syringe was more effective for fusarium infection.

Screening activities

The screening activities carried out from 1980 to 1984 are briefly summarized in Table 3. There were only three germplasm lines which showed less susceptibility in the initial screening. For the segregation of this material for various characters, including resistance in subsequent screenings, single ear selections were made to purify the material. Consistently moderately resistant lines were identified each season and tested under the multilocation testing

Table 2. Reaction to six soil and seed insecticide treatments for maize streak virus, Zambia

Treatment	Virus infection[a] (%)	Virus infection score[b]	Yield (kg/ha)
Deltanet SD	47.63	3.40	419
Deltanet 3G	47.23	3.25	631
Deltanet 400 EC	35.77	3.53	479
Miral 10 G	36.53	3.50	526
Furadan liquid	36.27	3.52	514
Furadan 10G	43.77	3.40	789
Zamseed check	46.30	3.64	592
Clean seed check	39.60	3.92	500
SEm ±	5.81	0.14	105.92
CV%	24.16	7.11	33.01
Significance	NS	NS	NS

a/ Percentage of plants infected in the middle two rows of each plot
b/ Visual scoring scale 1 to 5 (1 = no symptoms, 5 = severe symptoms) (average of 30 plants in middle two rows)

program. These lines will be utilized in the breeding program to incorporate ear rot resistance in elite maize hybrids and varieties.

Leaf Diseases

Among several leaf diseases affecting maize in Zambia, the following five diseases greatly limit yield under severe epiphytotic conditons:

- Turcicum leaf blight (*Helminthosporium turcicum*)
- Maydis leaf blight (*Helminthosporium maydis*)
- Common maize rust (*Puccinia sorghi*)

Table 3. Results of four years of screening to identify sources of resistance to cob rot in maize, Zambia, 1980 to 1984

Material	Number of lines in different reaction categories[a]					Total lines
	1	2	3	4	5	
1980-81 season						
Local germplasm	3	27	26	21	26	103
Breeding progenies	0	3	10	11	89	113
Hybrid combinations	0	17	70	51	11	149
Elite inbreds	0	0	1	10	57	68
Total	3	47	107	93	183	433
1981-82 season						
Streak selections	0	0	2	42	47	91
National maize variety trial	0	0	12	11	0	23
Experimental hybrids	0	0	20	48	0	68
Inbred lines	0	0	12	31	58	101
Germplasm lines	0	0	2	61	78	141
Total	0	0	48	193	183	424
1982-83 season						
Cob rot selections	0	4	9	82	134	229
Resistant hybrid combinations	0	1	5	13	[illegible]	33
Elite hybrids	0	17	39	13	1	70
Swaziland germplasm	0	0	3	12	7	22
Total	0	23	59	143	203	428
1983-84 season						
Multilocation trial	0	9	3	0	0	12
Cob rot resistant selection	0	10	68	15	0	93
Hybrid trial	0	1	2	3	14	20
Open-pollinated maize trial	0	0	0	2	29	31
Early maize trial	0	0	0	0	10	10
Total	0	20	73	20	53	166
Grand total	3	90	287	449	622	1451

[a] Scoring scale 1 to 5 (1 = no infection, 5 = very severe infection)

- Southern (Polysora) rust (*Puccinia polysori*)
- Leopard spot (vector unknown)

Screening techniques
Because of staff limitations, active research has only been initiated on these leaf diseases this season. An experiment has been conducted to determine the best method of inoculation, the optimum growth stage of the plant and the varietal interaction for infestations of turcium leaf blight and common maize rust for screening purposes. Several attempts made to isolate the causal agent for leopard spot have been unsuccessful; this may mean that it is a physiological disorder.

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Discussion

Mr. Olver: Do you inoculate varieties of different maturities at different times?

Dr. Rao: Yes, we generally inoculate at pollination time.

Mr. Olver: Do you standardize the environment, for example, by irrigation, after inoculation?

Dr. Rao: Yes, we have found that sprinkler irrigation after inoculation gives the right environment for disease establishment.

Dr. Moshi: When does the leopard spot disease occur during the growth of the maize plant? Does it affect all of the leaves of the plant, and how does yield loss occur?

Dr. Rao: It can occur anytime after three weeks from planting. Grain yield is reduced through a reduction of the total leaf area.

Mr. Malithano: What was the objective of the experiment in which you used various insecticides?

Dr. Rao: Reports from Ghana and other places suggested that Furadan could control the incidence of maize streak. However, our results did not confirm this. It appears that the insect had already infected the plants before it got the lethal dose of the insecticide.

Mr. Ochieng: Is it possible to incorporate multiple resistance into a given genotype by inoculating the same plant with several pathogens/strains? If so, which fungus species could one treat in this way without risk of interaction?

Dr. Rao: It is possible to inoculate for multiple resistance to different diseases, for example, fusarium and diplodia, but it is better to identify resistant sources for each disease and introduce them independently.

V. Seed Production

Kenya Seed Company: Growing for the Future

C. Ndegwa, N.K. arap Tum and F. Ndambuki, Kenya Seed Company Limited, Kitale, Kenya

Abstract

The Kenya Seed Company was begun in 1956 for the production and marketing of agricultural seed. Maize seed now constitutes its largest crop, with a volume of 14,000 tons in 1984. For production of certified seed, Kenya Seed contracts with selected growers, of which 35% are government farms and 65% are individual growers. The company supplies basic seed to the growers, who grow the hybrids with the assistance of qualified field supervisors; the superivsors register the crop for certification with the National Seed Quality Control Service. After the seed has been harvested it is dried on the cob, shelled, cleaned and processed. It is then ready for distribution to farmers by the Grain Growers' Cooperative Union and stockists. Currently, Kenya Seed produces ten hybrids and two open-pollinated varieties for the various agroclimatic areas of the country. Breeder seed for these varieties comes from three national agricultural research stations, as well as Kenya Seed Company's small but effective research program on maize breeding and improvement. As a result of that program, Pioneer X105A, HG14C, H625 and the recently released H5012 have been introduced on the market for the benefit of Kenya farmers.

The Kenya Seed Company Limited (KSC) was started almost 30 years ago as an enterprise for the production and marketing of seed for maize, wheat, barley, sorghum, sunflower, horticultural crops and pasture. It has expanded its volume of seed maize production from 300 tons in 1963 to 14,000 tons in 1984, and maize seed now constitutes the largest single crop produced by Kenya Seed.

Kenya Seed was privately owned when it was inaugurated in 1956; now, however, the Government of Kenya holds 51% of the shares through the Agricultural Development Corporation (ADC), a parastate corporation charged with the responsibility of promoting the development of agriculture in Kenya. Twenty-seven percent of the shares are held by the Kenya Grain Growers' Cooperative Union, and the rest are held by individuals.

Seed Production and Distribution

The Kenya Seed Company contracts with selected growers for the production of certified seed. Approximately 35% of the certified hybrid maize seed is produced on ADC farms, which are located mainly in the Trans Nzoia District. Individual farmers produce 65% of the seed in the Trans Nzoia and Uasin Gishu districts. The company supplies basic seed to the growers, who produce the various hybrids with the asistance of qualified field supervisors; the supervisors register the crops for certification (according to OECD regulations) with the National Seed Quality Control Service.

After the seed maize has been harvested by the growers, it is dried on the cob, shelled, cleaned and processed. It is then ready for distribution to various parts of Kenya, as well as to neighboring countries if there is a surplus. The bulk of the seed is distributed to farmers through branches of the Kenya Farmers' Association, whose stores will, in the future, be managed by the Kenya Grain Growers' Cooperative Union. The Kenya Grain Growers' Cooperative Union is a farmer cooperative, supplying inputs and marketing produce, and it will now also serve as the main marketing agent for Kenya Seed Company. Stockists are also appointed to further distribute seed so that it is more convenient to small-scale farmers.

Currently, the Kenya Seed Company produces ten different hybrids and two open-pollinated varieties suitable for the four agroclimatic areas in Kenya. In 1984, it also produced seven new experimental hybrids on a small scale for use in field trials. These new hybrids, along with the older varieties, are available to farmers for the following regions:

- High-altitude, high-rainfall areas, which are located mainly west of the Rift Valley, and are the most important maize-growing areas in Kenya. The late-maturity hybrids adapted to this area are H611, H612, H613, H614 and H625, and the experimental hybrids are H8102 and H8108. These hybrids require 750 to 1200 mm of rainfall per year over a period of 6 to 8 months.

- Bimodal rainfall zone, which comprises most of central Kenya. It has 650 to 1200 mm of rainfall distributed over two distinct seasons (often referred to as the long and the short rains). There are areas in the Rift Valley and Nyanza Province which also fit this category, especially in the lake basin. The medium-maturity hybrids suitable for these areas include H511, H512, H622 and H632, and the experimental hybrids are H5012 and H82M1.

- The bimodal but erratic-rainfall areas east of the Rift Valley, with precipitation averaging 635 mm per year. The varieties most suitable for this marginal maize-producing area are Katumani Composite B and the experimental Makueni Composite; several KSC three-way or double-cross hybrids are being tested.

- The high-temperature, high-rainfall, high-humidity coastal zone, which has two distinct seasons, the wet and the dry. The varieties most suitable for this area are Pioneer X105A, Coast Composite and the experimental hybrids, Pwani 1, 2 and 3.

Maintenance Breeding

In order to produce all of these improved hybrids and composites, the company depends on breeder seed from the National Agricultural Research Stations, Kitale for late-maturity seed, Katumani for seed for the marginal areas and Mtwapa/Msabaha for seed for the coastal zone. Once released, the inbred lines, populations and synthetics are maintained at the Kenya Seed Company Research Department at Endebess in the Kitale area. Since 1970, the company has had a small but effective research program on maize breeding and improvement; as a result of this program, Pioneer X105A, H614C, H625 and the recently released H5012 have been introduced on the market for the benefit of Kenya farmers. The results achieved so far are encouraging, and the program will be further expanded.

The seven experimental hybrids, which are being produced in small quantities, will be sold to interested farmers for commercial field trials. This will give feedback to the Kenya Seed Company Research Department and the National Agricultural Research Station as to where further improvement is needed. Figure 1 shows the information which

KENYA SEED COMPANY LIMITED
RESEARCH DEPARTMENT

PRE-RELEASE RECOMMENDATION FOR NEW EXPERIMENTAL HYBRIDS

A team of plant breeders in Kenya Seed Company Limited have developed seven new hybrids. Small amounts of seed of each of these hybrids will be offered for sale to interested farmers to try out at various parts of the country. These new hybrids have high potential yields. We are confident that the improved hybrids will enable farmers to increase their yields, better their profits and provide more food security for the nation as well as their families. We are proud of our achievement in this regard.

15 years ago Kenya Seed Company committed itself to a programme of genetic research and hybrid improvement, an undertaking that demanded an investment of both time and money. Today we can see some results from this programme in the form of the new hybrids.

We invite farmers to purchase these new hybrids for at most 10°/o of their maize crop and observe the difference.

As long as we can improve upon hybrid performance the odds of increasing your yields and profit will be that much more in your favour.

Below are the hybrids you can select for your location. We are sure these will increase your profits.

SEVEN NEW HYBRIDS

	H8108 (Kitale)	H8102 (Kitale)	H5012 (Embu)	82MI (Embu)	Pwani H1 (Mombasa)	Pwani H2 (Hola)	Pwani H3 (Mombasa)
Approx. days to 50°/o tassel	110	110	70	74	66	69	66
Approx. days to maturity	200	200	160	160	120	120	120
Adaptability	1	1	2	1	1	2	1
Standability	2	2	2	2	1	2	1
Blight resistance	1	1	1	1	1	1	1
Rust resistance	1	1	1	1	1	1	1
Hust cover	2	2	3	3	1	2	2
Ear height	Tall	Tall	Medium	Medium	Short	Short	Short
Yield potential	High	V.high	High	V.high	High	High	High

Scale: 1–5 (1 = excellent, 2 = very good, 3 = good, 4 = fair, 5 = poor)

Figure 1. Prerelease information made available to farmers on new experimental hybrids, Kenya Seed Company

is made available to farmers on new experimental varieties.

The initial stages of seed multiplication are conducted in selfing or sibbing blocks sown with various lines on an ear-to-row basis. The inbred lines are established under normal cultural conditions with adequate amounts of fertilizer and crop protectors; roguing is carried out at least three times before and after controlled hand-pollination. The practice as adapted for older lines is inter-row sib pollination, a method which has helped in the development of vigorous lines for further seed increase. The Hazelden method of check plotting each ear has minimized problems of contamination; a row is planted from a portion of each ear of breeder seed and observations are made in the early stages on such characters as trueness to variety. Only the best ears which pass the check plot test continue to the second multiplication stage. A committee made up of government breeders, Kenya Seed Company breeders, the National Seed Quality Control Service (NSQCS) and senior seed production officers of Kenya Seed assesses the quality of lines approved for further seed production.

The remainder of the seed of the approved ears is planted ear-to-row in isolation in 400-meter rows. Plants are checked and inspected by both the company production staff and the NSQCS. At this stage, super elite seed is produced. After the required quantities of super elite seed are available, single crosses are formed; they will ultimately be used to produce the final hybrids. Under normal circumstances, both of these stages take place on the company farm at Endebess. The final stage of multiplication is the production of certified seed. The hybrids under experimental production for seed

Excessively tall Kenya maize at 2150 meters elevation

distribution include variety crosses, three-way crosses and double crosses; currently, only one single-cross hybrid is under experimental production.

Future Programs, Problems and Opportunities

The Kenya Seed Company Research Department has one of the richest stores of germplasm in the country. Line development from its own composites, synthetics and populations, together with those from the National Agricultural Research Station, CIMMYT and the USA, will contribute greatly to the maize breeding program. Kenya Seed has a breeding plan for shortening the Kenya maize plant, as well as a project for strengthening the root and stalk of the plant as a means to elevate harvest index.

By the end of this century, Kenya will need about 2.8 million tons of maize grain each year to feed an estimated population of 28 million. Assuming that arable land planted with maize will remain at about 1 million hectares, all maize producers will have to grow improved maize cultivars with good cultural practices (timely planting of high-quality hybrid seed and the application of appropriate fertilizers). To meet the need for improved seed, therefore, the Kenya Seed Company will need to double its seed production and distribution capacity by the year 2000.

Acknowledgements

The Kenya Seed Company acknowledges the cooperation of government researchers and the technical guidance provided by USAID and CIMMYT staff in Kenya. The authors of this paper wish to thank Kenya Seed Managing Director, B. Gakenyo, for permitting them to present this paper, and CIMMYT and USAID for their invitation and financial assistance for attending this workshop.

Discussion

Dr. Kadir: How do you overcome the problems associated with seed production in contract farmers' fields?

Mr. Ndegwa: The farmers provide all inputs and labor, but they are assisted by Kenya Seed field staff.

Dr. Fajemisin: How does the seed certification scheme operate?

Mr. Ndegwa: The seed crop is registered with the National Seed Quality Control Services, and they monitor all stages of production.

Dr. Rao: How often do you go back to breeder seed to check the proper maintenance of the seed?

Mr. Ndambuki: It is not usually necessary to do this, because seed is properly maintained by the Kenya Seed Company. However, we did have to go back to breeder seed in the case of one of our open-pollinated varieties. Also, we have annual comparisons of new seed from the government program and the company seed stock.

Zambia Seed Company: The Maize Seed Situation in Zambia

W.M. Chibasa, Zamseed, Lusaka, Zambia

Abstract

Since 1981, the Zambia Seed Company (Zamseed) has been responsible for the production, procurement and distribution of maize seed, as well as all other agricultural and horticultural seed in Zambia. The seed is produced by farmers in the Zambia Seed Producers' Association under predetermined hectarages and conditions. Quality control and certification is conducted by the Seed Control and Certification Institute. Maize is Zambia's most important crop, and since 1983 the maize situation has changed for the better as a result of the release of the hybrid MM752, an improved version of SR52. Today Zambian farmers have available a range of varieties that should give them the flexibility to plant maize up to the last two weeks in December and still obtain reasonable yields. The viability of Zamseed is now being threatened by the costs arising from the necessity to both produce and store the parent lines of SR52 and produce and supply the new maize varieties. The present seed situation in Zambia is generally adequate, although increased attention needs to be given to better storage at district and provincial levels, improved marketing, and education of farmers and extension as to the value of the new varieties, as well as to the distribution of the new hybrids and the utilization of current stocks of the older varieties.

The Zambia Seed Company (Zamseed) has had the responsibility of producing (through multiplication), procuring (through importation when necessary) and distributing maize seed, as well as all other agricultural and horticultural seed in Zambia since 1981. Until that time, the production of seed was organized by the seed services (now the Seed Control and Certification Institute (SCCI))of the Zambia Seed Producers' Association (ZSPA), and the seed was marketed by Namboard, the National Agricultural Marketing Board. The farmers' unions now market agricultural seed, acquring it from the provincial centers and distributing it to the rural depots.

Maize is the most important crop in Zambia. It is grown in most regions, except for some exceptionally wet, dry or infertile areas where sorghum, millet or cassava are more adapted. The importance of maize is reflected in the volume of production and the sales of maize seed as compared to other agricultural crop seeds (Tables 1 and 2). It is estimated that if purchased maize seed were used for planting all of the land now under maize, Zamseed would have to produce and market 15,750 tons of seed annually.

Seed Production

Zamseed carries out the production of maize seed through contracts with ZSPA members who grow basic and certified seed under predetermined hectarages and conditions; some 5,000 hectares are grown annually. For convenience, the production of seed is confined to the major maize-growing areas of Mazabuka, Lusaka, Chisamba, Mkushi, Kabwe and Chipata. The number of growers involved fluctuates between 150 and 200. Quality control and certification is conducted by the SCCI, under the jurisdiction of the Permanent Secretary of the Ministry of Agriculture and Water Development

(MAWD). Seed certification is carried out according to OECD regulations, while ISTA rules govern laboratory testing. The specifics relating to maize seed production are presented by Wellving (1), and quality control for certification is covered by the Agricultural (Seeds) Act, CAP 352, of the laws of the Republic of Zambia.

It is generally accepted that agricultural research and extension should promote that which is most beneficial to the farmer. However, Zamseed and its marketing agencies must also be viable business enterprises in order to continue to serve the farmer; they are responsible to the farmer, but they also depend on

Table 1. Production (and importation) of maize seed compared to other agricultural seeds, Zambia Seed Company Limited, 1981 to 1984

Type of seed (all varieties)	Number of bags			
	1981	1982	1983	1984
Maize (50-kg bags)	193,615	78,848	100,403	123,352
Sunflower (25-kg bags)	5,831	12,422	19,788	32,958
Soybeans (50-kg bags)	8,652	8,938	8,893	10,314
Groundnuts (40-kg bags)	841	1,490	766	1,412[a]
Sugarbeans (50-kg bags)	2,325	2,448	574	351
Wheat (50-kg bags)	..	13,252	8,570	4,903
Sorghum (50-kg bags)	..	..	..	1,710
Imported maize				
R215 (50-kg bags)	..	..	30,000	..
PNR473 (50-kg bags)	..	..	..	20,000
CG4141 (50-kg bags)	..	..	..	10,000

a/ 30-kg bags

Table 2. Sales of maize seed compared with other agricultural seeds, Zambia Seed Company Limited, 1981 to 1984

Type of seed (all varieties)	Number of bags			
	1981	1982	1983[a]	1984[b]
Maize (50-kg bags)	174,106	167,008	133,000	138,000
Sunflower (25-kg bags)	16,478	8,423	6,326	7,665
Soybeans (50-kg bags)	4,481	6,302	6,660	14,982
Sugarbeans (50-kg bags)	322	552	1,133	320
Groundnuts (40-kg bags)	..	1,097	17	309
Wheat (50-kg bags)	2,631	1,265	3,575	7,067
Sorghum (50-kg bags)	..	..	458	2,417

a/ Sales for 11 months

b/ Namboard also sold about 10,000 50-kg bags of seed maize; this quantity is not included in the figure for the year him for their survival. This must be borne in mind when seed production and distribution is discussed.

The Maize Situation in Zambia

As has already been mentioned in the Zambian papers presented here, hybrid varieties dominate commercial and semicommercial maize production in the country, and they will probably continue to do so. However, it is hoped that open-pollinated varieties will soon begin to play a more important role in maize production (2).

Between 1961 and 1970, seed was available in Zambia for the cultivars SR52 (a single cross), SR11 and SR13 (double crosses), Hickory King (open-pollinated) and ZUCA (a composite). From 1971 to 1982, only SR52 and ZH1 (a top cross) were being utilized. During this latter period, occasional importations of other cultivars were made to augment seed produced within the country.

In 1983 the maize situation in Zambia changed for the better with the release of MM752, an improved version of

Table 3. Tentative maize variety recommendations for Serenje District, Central Province, Zambia Seed Company Limited, 1985-86

Planting date	Expected yield[a]	First choice	Second choice
November	High	MM752	SR52
	Medium	MM603	MM752
		MM604	SR52
		MM606	
	Low	MMV600	MM603
			MM604
			MM606
December (first two weeks)	High	MM601	MM603
			MM604
			MM606
	Medium	MM603	MMV600
		MM604	
		MM606	
	Low	MMV600	MM603
			MM604
			MM606
December (last two weeks)	Medium	MM603	MMV600
		MM604	
		MM603	
	Low	MMV600	MM603
			MM604
			MM606

a/ High yield = eight 90-kg bags/lima, medium = six 90-kg/lima, low = four 90-kg bags/lima

Note: Implication for Zamseed is that at least seven varieties will need to be delivered to Serenje. Are the farmers ready?

SR52. The new commercial hybrids MM501, 502, 504, 601, 603 and 604 were released in April of 1984; the open-pollinated varieties MMV400 and MMV600 were released in July 1984 and the double-cross MM606, at the end of 1984. Today, at least in theory, Zambia has a range of varieties which should give the farmer the flexibility to plant maize up to the last two weeks in December and still obtain reasonable yields (Table 3).

Present estimates show that between 500,000 and 760,000 hectares are planted to maize in Zambia each year. Maize seed sales for the period 1981 to 1984 show that, on the average, only 306,000 hectares were planted with seed purchased from designated outlets. Table 4 shows the 1982-83 estimates of maize hectarage, production, seed sales and area planted to certified hybrid seed. The tables presented here indicate that, except for the 1981-82 agricultural season, which appears to have been an anomaly, the supply of maize seed has been more than adequate.

The Future of the Seed Industry in Zambia

The development and release of eight new maize hybrids and two open-pollinated varieties has dramatically changed the situation in the production, and more especially, the distribution of maize seed. The viability of Zamseed is now being threatened as a result of the costs incurred in both the production and storage of the parent lines of SR52 and the production and supply of the new maize varieties. Table 5 describes the maize varieties available for 1985-86 and the zones for which they are recommended for either early or late plantings. It can be seen that most of the new varieties have wide

Table 4. Estimates of maize area, production, seed sales and area planted to certified hybrid seed for 1982-83, Zambia

Province	Area (000 ha)	Total production (000 90-kg bags)	Marketed (000 90-kg bags)	Yield (90-kg bags/ha)	Seed sold (000 50-kg bags)	Area planted (000 ha)	
						Hybrid[a]	Other[b]
National	564	12,800	8,875	22.7	160	304	260
Central	160	4,000	3,000	25.0	35	70	90
Southern	120	4,100	3,200	34.2	53	106	14
Eastern	200	3,200	1,700	16.0	33	66	134
Lusaka	38	600	400	15.8	9	18	20
Northern	25	550	400	22.0	13	25	..
Western	9	110	45	12.2	3	6	3
Copper Belt	6	120	50	20.0	4	6	..
Northwestern	4	70	45	18.0	3	4	..
Luapula	3	50	35	16.7	2	3	..
Total 1983-84	503	9,671	6,606	19.2	130	266	237

a/ Estimate based on 25 kg seed per ha
b/ Estimated by substracting area planted to hybrid from total area

Source: Paul Gibson, June 1984

adaptability and provide the farmer with flexibility as regards planting date, which will depend on the varying dates of the onset of the rains and the duration of the rainy season.

Zamseed is suggesting the following combinations of varieties for the three agricultural zones:

Zone I (high rainfall)	SR52 and MM752 or MM606 and MMV600
Zone II (inter-mediate rainfall)	MM752 and SR52 or MM601 and MM604 or MM606
Zone III (low rainfall)	MM504 and MMV400

To a large extent, the availability of seed will be influenced by the cost of seed production, a factor that is determined by seed yields of the various varieties. If the weather is favorable, Zamseed will not have to import early maturing maize varieties, as they have in the past. However, to improve overall maize production in the country, it will be necessary to increase sales so that the area planted to farmer-retained maize seed can be reduced.

The maize seed situation in Zambia is generally adequate, although increased attention needs to be given to:

- Improved storage at provincial and district levels;
- Improved marketing to reach the farmers who plant retained seed (this constitutes 50% of the total hectares planted to maize annually);
- Education of farmers and extension as to the value of the new varieties, and
- Distribution of new hybrids and the utilization of current stocks of the older varieties.

References

1. Department of Agriculture, 1984. Seed Production Handbook of Zambia. A.H.A. Wellving, ed. Lusaka, Zambia.

2. Ristanovic, D., P. Gibson and K.N. Rao. Development and Evaluation of Maize Hybrids in Zambia. (These proceedings.)

Table 5. Description of maize varieties available from Zambia Seed Company Limited for 1985-86

Variety	Type[a]	Days to maturity[b]	Kernel type[c]	Drought tol.	Streak res.	Cob rot res.	Recommended zones[d] Early planting	Late planting
MMV400	OP	100-120	F	Exc.	Good	Good	III	II S
MM504	TC	130-135	SD	Exc.	Good	Good	II S, III	I, II, III
MM601	SC	130-135	SD	Good	Good	Good	II	I, II
MM603	TC	135-140	SD	Good	Exc.	Good	II	I, II
MM604	TC	130-135	SD	Good	Good	Good	II	I, II
MM606	DC	130-135	SD	Good	Good	Good	I, II	I, II
MMV600	OP	130-135	SF	Fair	Exc.	Good	I, II N	I
MM752	SC	150-155	D	Poor	Poor	Poor	I, II	Not rec.
SR52	SC	150-155	D	Poor	Poor	Poor	I, II	Not rec.

a/ OP = open-pollinated variety, SC = single-cross hybrid, DC = double-cross hybrid, TC = three-way cross hybrid

b/ Days to maturity = the number of days from planting to physiological maturity, the number of days is relative, being less in a low-rainfall or low-elevation situation, and more in a high-rainfall or high-elevation environment

c/ F = flint, D = dent, SD = semident, SF = semiflint

d/ Zone I is the high-rainfall area (>1,000 mm), including Northern, Northwestern, Copper Belt, Luapula provinces and parts of Central Province

Zone II is the intermediate-rainfall area (<1,000, >800 mm), including most of Eastern, Central, Luapula, Lusaka and Western provinces, the northern part of this zone (II N) is similar to Zone I and the southern part of zone (IIS) is similar to Zone III

Zone III is the low-rainfall, drought-prone Zambezi and Luangwa valleys, plus parts of Western Province

Note: These descriptions are provisional, based on current data, and [illegible] be revised as further information becomes available

5

Field Visits

Visit to Golden Valley

W. Mwale (reporter), Mount Makulu Research Station, Chilanga, Zambia

On March 12, the workshop delegates drove north of Lusaka to see the Golden Valley maize trials with Dr. Ristanovic, Zambia Maize Team Coordinator. He explained that, depending on climatic conditions, rainfall and altitude, Zambia is divided into three maize growing zones. The 35 to 40 trials being conducted at Golden Valley include National Maize Variety Trials for Zones I and II and National Maize Variety Trials and Advanced Maize Variety Trials for Zone III. There are also 17 trials to test combining ability of new hybrids, CIMMYT trials, commercial maize trials and open-pollinated maize trials. Zambia now has 579 new combinations of hybrids, and work on modified single crosses is in progress.

For developing inbred lines, Dr. Ristanovic stated that sister crosses have produced excellent lines for good seed in Zambia; most Zambian hybrids have SR52 as parents. Program emphasis is on the selection of plants for good prolificacy and ear placement. The FAO maturity group system for hybrids and open-pollinated varieties is utilized, and Zambia presently has groups ranging between 400 and 700. Lines with 100, 130, 145 and 160 days to maturity are available, and

Dr. Gelaw examines maize plant with conference delegates at Golden Valley

emphasis is being given to selection for streak and drought resistance. In most trials, hybrids with good performance in commercial production within Zambia and surrounding countries are used as checks, for example, PNR473, CG4141, R215 and SR52 (from both Zambia and Zimbabwe).

Dr. Sprague observed that the stand seemed shorter than in previous years; Dr. Gibson answered that probably that was the result of less sunshine than normal. Under that condition, the hybrid MM601 was reported as being better adapted than SR52. Mrs. Sibale mentioned the presence of stunted plants; stalk borer was reported as the most likely suspect. A suggestion from Dr. Darral was that when trials are separated as to plant height, shorter varieties can be planted at higher densities. Dr. Gibson stated that there would be more emphasis on lowering plant height in the future; presently, every variety is compared to the tall SR52.

It was observed that early hybrids have a tendency for prolificacy. The new Zambian hybrid MM502 is prolific, as well as being very adaptable and the most resistant to maize streak. Dr. Gibson mentioned that MM502 has not been well accepted in Zambia, because it is a back-cross conversion from one yellow parent and so is creamy white. Why, he asked, should Zambia import yellow maize and refuse a creamy white hybrid? A good choice for small-scale farmers is the recently developed line MMV400; it is very early maturing and needs less management than hybrids.

Dr. Gibson discussed the commercial soybean crop, which is planted in rotation with maize in the trials. This has been found to be a successful procedure, as the soybeans can be sold and the money returned into the program. Dr. Sprague mentioned the variations in the soybean stands, and wondered whether the darker green patches were an indication of higher levels of nitrogen. Mr. McPhillips stated that generally fertilizer was not applied to soybeans; the variations were due to water logging in the low spots in the fields. Mr. Prior stated that poor land preparation was also a factor; it had been delayed as a result of the rains and a lack of funds to buy diesel fuel. Dr. Sprague asked whether tilth was improved after a crop of soybeans, and was told that it was.

The group then proceeded to Dr. Gibson's plot of the open-pollinated variety A7844. They discussed the amount of streak infection present in the population, and how to select for resistant plants. Dr. Fajemisin of IITA pointed out that those plants with few and broken lines of infection should be selected as they show resistance. Dr. Gibson said that while the population was still susceptible to streak, resistant materials had been incorporated into it; he mentioned that the late planting had been found to encourage streak infection. He reported that they get better yields out of their own reselections in the families than they do by using resistant lines from IITA; simple half-sib selection has led to good improvement.

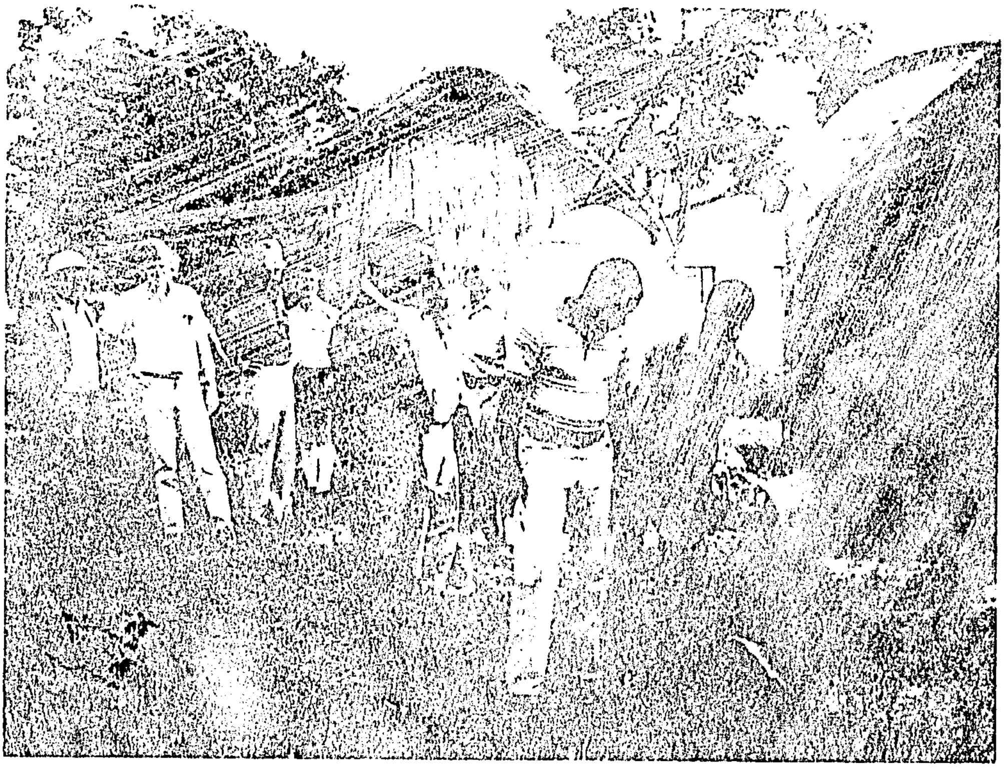
Visit to Mount Makulu Research Station, Chilanga, and the Maize Research Institute Farm, Mazabuka

R.Watts (reporter), Mount Makulu Research Station, Chilanga, Zambia

On March 14, the workshop delegates spent a full day visiting various agricultural sites south of Lusaka. The purpose of the visit was to see on-going maize research, as well as Zambian agriculture in general. Hybrid maize seed production was seen at both the Maize Research Institute and at the farm of Lionel Coventry, a commercial farmer. On the way, delegates saw examples of small-scale maize production, and were able to get an impression of the potential of the Kafue flood plain area as they drove through part of the 9,000-hectare Nakambala Sugar Estate.

Mount Makulu Research Station

Mount Makulu is the headquarters of the research branch of the Ministry of Agriculture and Water Development (MAWD), and houses the Maize Research Team. It is used to only a limited extent for breeding work and trials, because dust from the nearby cement factory makes the soils very alkaline (pH > 7). Therefore, the station is not representative of most of Zambia, and so is unsuitable for trials. Delegates were shown demonstration plots of maize, rainfed wheat, sorghum and sunflower, as well as the National Maize Variety Trial.



Examples of maize storage systems, Mount Makulu Research Station

The Maize Research Institute Farm

The Maize Research Institute (MRI) farm in Mazabuka was purchased in 1980 by the Maize Research Institute of Yugoslavia as a winter nursery multiplication center for increasing the rate of development of new hybrid varieties. The purchase took place after a search through a number of tropical and subtropical countries. Zambia was chosen because of the availability of suitable land with some irrigation capacity; the area also offers good conditions for growing maize and for screening against a range of diseases. A cooperative agreement was signed by Zambia and Yugoslavia, and it is an excellent example of mutual assistance. Breeding material is freely exchanged between the two countries, and Yugoslavian material has been incorporated into some of the new Zambian hybrids. Seven Zambians have been trained at the Institute.

The Yugoslavian Maize Research Institute at Zemun Polje, outside Belgrade, is an important center for maize research and has a staff of about 400. Some 145 Zemun Polje maize hybrids have already been released, and seed has been exported to Europe, North Africa and the USSR. Yugoslavia, being a nonaligned nation, has wide contacts with both Western and Eastern Block countries, and agriculturists from developing countries are particularly welcome in the training programs, which are conducted at the International Maize Training Center. Yugoslavian experts are also assisting a number of countries, including Zambia, Angola and Mozambique.

Conference delegates examine maize grown at the MRI farm at Mazabuka

The Mazabuka farm consists of 2,500 hectares, of which 500 are arable; the remainder are used for ranching. Maize is grown on a three-year rotation, with two years of pasture between the maize crops. As a result of the severe droughts experienced from 1981 to 1984, plans have been made to extend the irrigated area from the present 15 to 100 hectares.

MRI is now beginning to grow two warm-season crops in Zambia, so that the following three generations can be produced in each 12-month period:

Crop 1—October to January (in Zambia)
Crop 2—January to May (in Zambia)
Crop 3—May to September (in Yugoslavia)

Dr. Vladimir Trifunovic, former director of the Institute and now adviser to the Director General, explained the work of the MRI farm to the workshop delegates. The manager of the fa n is stationed in Zambia, and seven to eight supporting staff come from Yugoslavia during the maize-growing season each year. There are also 40 permanent Zambian workers, who are supplemented by over 100 part-time workers at harvest time. Zambian staff live in villages around the station, and are given enough free seed to plant about 3 hectares of maize per family. In addition to the yellow maize hybrids and inbred lines grown for the Yugoslavian program, a large part of the farm is used for growing seed on contract for the Zambia Seed Company. In particular, the MRI farm undertakes much of the basic seed multiplication.

One of the most interesting aspects of the MRI in Yugoslavia is that it is reported to be 98% self-financing. It is also a major foreign exchange earner, since two-thirds of its ZP certified maize seed is exported. For many African countries, the financing of research and the generation of foreign exchange are parallel problems. There may well be value in making certain aspects of research the responsibility of self-financing institutes, such as the MRI, and maize breeding might be a particularly good area, especially when there is a possibility for export. The Zimbabwe research program has already developed along these lines, and the Kenya Seed Company is financing its own maize research. One disadvantage of such a program could be that the commercialization of research might lead to an undue emphasis on hybrids. Zambia is striving to develop open-pollinated varieties for use in remote areas and for farmers with insufficient capital to buy new hybrid seed each year.

Commercial Seed Production on the Lionel Coventry Farm

The tour ended with a visit to the Coventry farm, which is situated on flat land along the Kafue River. Delegates inspected an excellent seed crop of the MM604 hybrid (MM502 x N3) developed at Mount Makulu. This is the first commercial production of the hybrid, and a yield of 4.5 to 5 t/ha is forecast; the female parent is the prolific hybrid MM502, which has two or more ears per plant. Although Mr. Coventry planted ten female rows to three male rows, instead of the recommended 4:2 ratio, pollination appears to be reasonable. However, he has been discouraged by the slow pollination of the crop, which in drier years could lead to problems in synchronization. More research is needed on recommended ratios for new hybrids.

Visit to Small-Scale Farmers, Chipapa, Lusaka District

A.F.E. Palmer (reporter), Maize Program, CIMMYT, Mexico

On Saturday, March 16, after the visit to the Zambia Seed Company facilities in Lusaka, a group of participants visited some on-farm trials at Chipapa in Lusaka District. The guide was Alex Njobo, an agricultural economist in the Adaptive Research Planning Team (ARPT) for Lusaka Province. Three on-farm locations were visited, and the following types of trials were seen:

- A trial comparing an early variety (MM400) for earlier food supply and the farmer's variety. MM400 had received fertilizer; the farmer's variety had not.
- A variety trial with the local variety interplanted with sorghum. Bird damage had been a severe problem. Two different planting dates had been used, but the second planting had been lost, due to goats at one location and to birds at another.
- A trial testing alternative crops, such as sunflower and beans, since maize is often planted late. While birds do not constitute a problem for early planted maize, they frequently do for late plantings.

Farmers around Chipapa frequently grow maize at low plant populations, and they intercrop maize with sorghum and squash. There was debate at the sites as to why farmers grow their local varieties even though they give inferior yields; one obvious reason was food preference. There was also discussion as to the best use of limited fertilizer resources for hybrids or local varieties.

One farmer did not use fertilizer on open-pollinated varieties, as he thought the grain could not be kept for seed after using fertilizer. This appeared to be an extension of the concept that fertilizer is only used on hybrids, which cannot be kept for use as seed.

Chipapa farmer discusses his experimental maize plot with conference delegates

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Closing Ceremonies

Conclusion of the First Eastern, Central and Southern Africa Regional Maize Workshop

The Honourable D. Munkombwe, MP, Minister of State, Ministry of Agriculture and Water Development, Zambia

It is an honor and a privilege for me to have been asked to close this First Eastern, Central and Southern Africa Regional Maize Workshop, which has been attended by distinguished scientists from both within and without the region. I am particularly pleased that this first workshop has been held here in Zambia; it is indeed an honor for our country.

Needless to say, a workshop of this nature is of paramount importance in fostering cooperation on a regional and international basis. We in the region need to cooperate among ourselves if we are going to succeed in developing agriculture in our countries. I see this workshop as a step towards further interaction and cooperation among our agricultural scientists, those on whom we rely for increasing the productivity of agriculture.

Since this workshop opened, I have been following the deliberations with keen interest, and I wish to inform you that I am pleased with the progress made in identifying issues and problems that commonly affect the region. I understand that you have resolved to hold a workshop of this nature on a biennial basis, rotating host countries. I welcome this proposal wholeheartedly, because it will ensure the continuity of the cooperation that has been established here.

It is important to note that maize research alone cannot bring about the desired production levels necessary to meet self-sufficiency in our region or individual countries; there is a need to integrate the efforts of all those involved in the process of food production. To this end, I would like to urge that future maize workshops be organized with a view to integrating crop breeding, production and processing, so that many of the issues that affect maize can be addressed simultaneously. This will help ensure that appropriate solutions be applied to all types of problems which are faced by the maize farmer.

I hope that the resolutions made at this workshop will not be allowed to gather dust on your shelves. Not only would this undermine the efforts of all of you gathered here; it would also undermine the efforts of your various countries. As you return home, you should ensure that action is taken on those resolutions that are relevant to your situations. I would like to urge that your chairman designate a person or persons to follow up on the implementation of the resolutions and set the stage for the next workshop, which I understand our colleagues from Burundi and Zimbabwe have offered to host.

Those who will be charged with the responsibility of organizing the second workshop may wish to learn from the experience gained from this one, to avoid any mistakes which may have been made here. For instance, there should be facilities for the translation of the papers presented and discussions held at the workshop.

I would not be doing justice to my place here if I did not pay tribute to all of those who have made it possible for this workshop to be held here in Lusaka, especially the organizing committee, CIMMYT and the

Government of the Republic of Zambia. I also wish to thank IITA, USAID-REDSO and IDRC. In addition, there are a number of companies in Zambia which have generously contributed to the success of the workshop. Last but not least, I would like to thank the management and employees of this hotel for their hospitality.

Too often we forget the people who work so tirelessly behind the scenes at workshops, conferences or seminars of this kind. Therefore, I want to express special appreciation to the secretarial staff, drivers and others without whom this workshop could not have functioned so smoothly.

I would like to wish each and every one of you a safe return to your respective countries and organizations.

Now it is my honor and privilege to declare officially closed this First Eastern, Central and Southern Africa Regional Maize Workshop.

The Delegates' Response to the Honourable Minister

A. Mpabanzi, Institut de Recherche Agronomique et Zootechnique de la CEPGL (Burundi, Rwanda a Zaire), Gitega, Burundi

It is an honor for me to be chosen to respond to the Honourable Minister on behalf of the delegates to the First Eastern, Central and Southern Africa Regional Maize Workshop.

First, I would like to thank the Zambian people through their Honourable Minister of Agriculture and Water Development for their special hospitality to us. We will always remember it.

I also wish to thank Their Excellencies, the Ministers, for taking time out from their many duties to their country for opening the workshop and then for participating in this closing ceremony. This is an indication of their deep interest and determination to encourage maize research, so that eventually everyone in this region will have enough to eat.

We have been pleased with the presentations and discussions that have taken place in the workshop, and also with having been able to visit some of the Zambian research stations. We have all learned from our Zambian experiences, and I hope that we can utilize this knowledge in our respective countries.

It has been a privilege to have among us the eminent scientists who came to share their experiences with us. Our thanks are extended to those who have made this workshop possible, the Government of Zambia, CIMMYT and others who have already been named. We are especially grateful to Dr. Gelaw of CIMMYT's East African Maize Program for working so tirelessly in organizing this maize workshop. To our friends on the Zambian research team, thank you for welcoming us to your beautiful country and for making our visit so worthwhile.

We will not forget the international organizations, who sponsored the attendance of many of us at this workshop. We hope that now, when the governments of the African nations are faced with tremendous financial problems, the international organizations will continue their assistance to us as they have in the past.

We are looking forward to the second maize workshop, but we will never forget this first one in Zambia. The things that we have learned here will keep us busy, so that at the next meeting, we will have much to report.

Again, Honourable Minister, thank you on behalf of all of the workshop participants.

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Appendix I

Varieties, Composites and Hybrids Released by African National Programs

Country and variety name	Type, source and origin of germplasm
Angola	
ZPSC852b	Single cross
SAM3	Synthetic
Burundi	
Kitale Composite A	Kitale, Kenya
Igarama-4	Improved local highland maize
GPS4 x SR52	
Bambu	Rwanda
GPS5	Synthetic from Gandajika, Zaire
Across 7843 (to be released in 1985)	CIMMYT Pop. 43
Ethiopia	
Composites (mainly)	Open pollinated
Kenya	
Kitale Synthetic II (1961)	Open pollinated
H611 (1964)	Variety cross KSII x Ec573
H622 (1965)	Double cross
H632 (1965)	Three-way cross
H612 (1966)	Topcross

Characteristics	Comments
White dent grain, late, tall	Similar to SR52
Yellow flint grain, broad adaptation	Yield potential > 7 t/ha, moderately tolerant to *H. turcicum*
Late (220 days to maturity), plant height 2.5 m, adaptation 1800-2600 m	Yield potential 7 t/ha, prone to lodging, farmer resistance because of lateness which does not permit a good second-crop pea crop
Adaptation 1200-2600 m	Yield potential 5.5 t/ha
Adaptation 1200-1800 m	Yield potential 6.5 t/ha
Adaptation 1200-1800 m	Yield potential 5 t/ha
Adaptation 800-1200 m	Yield potential 4.7 t/ha
Adaptation 800-1200 m	Yield potential 7.5 t/ha
Intermediate and high rainfall adaptation	Yield potential 80-100 q/ha, prone to lodging, resistant to *H. turcicum* and *P. sorghi*; in the late 1970s a program was initiated to develop early maturing varieties for escape from moisture stress
Flat white grain, late (105 days to maturity), adaptation 1700-2200 m	Outyielded maize grown at the time 10-20%, released to farmers west of the Rift Valley
Late (105 days to maturity), tall plant height, adaptation 1800-2400 m	High yield potential, prone to lodging
Late (100 days to maturity), adaptation 1000-1700 m	Yield potential 3.1 t/ha, susceptible to MSV
Late (100 days to maturity), adaptation 1000-1700 m	Yield potential 2.8 t/ha, susceptible to MSV
Late (90 days to maturity), adaptation 1500-2100 m	Yield potential 3.8 t/ha

Appendix I (continued)

Country and variety name	Type, source and origin of germplasm
Katumani Composite B (1967)	Katumani V x Katumani VI
H511 (1967)	Variety cross
H512 (1970)	Variety cross
H611C (1971)	Variety cross
H613 (1972)	Topcross
Coast Maize Composite (1974)	Open pollinated
H614 (1976)	Topcross
Embu Composite 3 (1980)	Composite of 5 local varieties
H625 (1981)	Double cross
Kenya Seed Company	
H8102 (to be released)	The company cannot release pedigrees
H5012 (to be released)	
82MI (to be released)	
Pwani H1 (to be released)	
Pwani H2 (to be released)	
Pwani H3 (to be released)	

Characteristics	Comments
Early (65 days to maturity), adaptation 500-1600 m	
Intermediate (60-70 days to maturity), adaptation 1000-1700 m	Yield potential 2.6 t/ha, susceptible to headsmut and MSV
Intermediate (65-80 days to maturity), adaptation 1000-1700 m	Yield potential 3.1 t/ha, susceptible to headsmut and MSV
Late (105 days to maturity), tall plant height, adaptation 1800-2400 m	Yield potential 3.8 t/ha, prone to lodging
Late (100 days to maturity), adaptation 1500-2100 m	Yield potential 3.8 t/ha
Intermediate (80 days to maturity), adaptation 0-1000 m	On-farm yield 1.8 t/ha (compares favorably with H511 and H512), susceptible to *P. sorghi* rust
Late (100 days to maturity), adaptation 1500-2100 m	Yield potential 3.9 t/ha
Intermediate	
Late (95 days to maturity), adaptation 1500-2100 m	Yield potential 4.4 t/ha
Late (200 days to maturity), high ear placement, high-altitude adaptation	Very high yield potential, blight and rust resistant
Late (160 days to maturity), medium ear placement, midaltitude adaptation	High yield potential, blight and rust resistant
Late (160 days to maturity), medium ear placement, midaltitude adaptation	Very high yield potential, blight and rust resistant
Late (120 days to maturity), low ear placement, coastal adaptation	High yield potential, excellent standability and husk cover, blight and rust resistant
Late (120 days to maturity), low ear placement, coastal adaptation	High yield potential, blight and rust resistant
Late (120 days to maturity), low ear placement, coastal adaptation	High yield potential, excellent standability, blight and rust resistant

Appendix I (continued)

Country and variety name	Type, source and origin of germplasm
Lesotho	
Highland early yellow	CIMMYT Pool 4
Highland white dent	CIMMYT Pool 2
Highland white flint	CIMMYT Pool 1
Highland white floury	CIMMYT Pool 6
Madagascar	
Plata 264 (proposed for release)	Fianarantsoa synthetic x Tuléar synthetic
266	Polyhybrid, H632 x (SR11 x SR13)
377	Polyhybrid, TV23 x 266
378	Three-way cross (NAW5867 x C2806D) x D160F
321 (proposed for release)	
375 (proposed for release)	
383 (proposed for release)	Intervarietal hybrid, 374 x 377
374 (proposed for release)	Polyhybrid, HD9 x TV13
384 (proposed for release)	Polyhybrid
387 (proposed for release)	Polyhybrid
322 (proposed for release)	Double cross A435 x (21A x B2785)
375 (proposed for release)	Intervarietal hybrid, 374 x 266
325 (proposed for release)	Double cross HD1 = (F2834T x E680) x (A435 x Pa109)
341 (proposed for release)	Double cross (F2834T x AJ54)
380 (proposed for release)	Complex hybrid, 21A x 264

Characteristics	Comments
Flint grain	
Early maturity	There has been 75% farmer adoption of these varieties in 2-3 years
Early maturity	
Intermediate maturity	
White grain	
White grain	
White grain	
White-yellow grain	Mean yield 8 t/ha on-station
Yellow grain	
Yellow grain	
Yellow grain	
Yellow grain	
Yellow grain	
Yellow grain	
Yellow grain	
Yellow grain	

Appendix I (continued)

Country and variety name	Type, source and origin of germplasm
Malawi	
SV17 (mid-1960s)	Synthetic
SV28 (mid-1960s)	Synthetic
SV37 (mid-1960s)	Synthetic
LH (mid-1960s)	Local hybrid
Chitedze Composite A (mid-1970s)	
Chitedze Composite B	Formed from exotic materials
Ukiriguru Composite A (mid-1970s)	Tanzania
Ukiriguru Composite B	Tanzania
Chitedze Composite C	Chain crossing of 19 CIMMYT materials and SR52
MH12	
MH13	
NSCM41	CIBA-Geigy hybrid
CXH66 (after 1977)	
CXH74 (after 1977)	
CXH43 (after 1977)	
Tuxpeño	CIMMYT Pop. 21 C_{11}
Mauritius	
UR22 (1981)	Three-way cross, United 530 (French single cross) x R22 (inbred line derived from Rodriguez local variety)
UR14 (1982)	Three-way cross, United 530 (French single cross) x R14 (Rodriguez local variety)
Others (not yet named)	Three-way cross, Gheppio (French single cross) x inbred lines derived from Rodriguez local varieties

Characteristics	Comments
Lakeshore area adaptation	Released for low-potential areas, farmer dissatisfaction because of height
Tall	Some progress in ear height reduction
Tall	Released for high-potential areas, farmer dissatisfaction because of height
Tall	Some progress in ear height reduction
White semiflint grain, intermediate maturity, adaptation 500-1500 m	
	Malawi pays royalty to produce F_1s
	High yield potential
	High yield potential
	High yield potential
Lowland, tropical adaptation	Released for Karonga Agricultural Development Division
Yellow grain, early maturity, short plant height	Recommended for planting in sugarcane interrows
Yellow grain, short plant height	Recommended for planting in sugarcane interrows
Early maturity, short plant height	In process of release

Appendix I (continued)

Country and variety name	Type, source and origin of germplasm
Mozambique	
Three varieties based on CIMMYT germplasm (soon to be released)	
Obregon 7643 (soon to be released)	
HZPSC852b	
Reunion	
IRAT 143	Complex hybrid Revolution variety x INRA 508
IRAT 279	Complex hybrid Revolution variety x 137TN
Revolution (IRAT 292)	Local Reunion variety
Rwanda	
Golden Corn (1951)	Zaire
Bambu (1959)	Zaire
Katumani (1972)	Kenya
Nyirakagoli (1975)	Local variety
Somalia	
Afgoi Composite (1976)	Afgoi Composite Yellow, composed of Somali land races, Guatemalan flint and US hybrids
Somtux (Somalian Tuxpeño) (1980)	Half-sib crosses of Afgoi Composite x Tanzanian Tuxpeño
ISOMA (Improved Somtux)	Multivarietal hybrid, Pop. B.RBS.

Characteristics	Comments
	In experimental production
Yellow grain, early maturity, short plant height	High yield potential, tolerant to MSV, MMV and MStrV
Yellow grain, late maturity, tall plant height	High yield potential, very tolerant to MSV, MMV and MStrV
Yellow grain, late maturity, tall plant height	Medium yield potential, very tolerant to MSV, MMV and MStrV
Intermediate maturity, tall plant height, midaltitude adaptation, needs sufficient rainfall (at high altitudes the growing cycle is long, under dry conditions the stalk is weak and susceptible to stalk borers)	Farmer and miller dissatisfaction because of hard grain, but still recommended because of productivity and intermediate maturity
Early maturity	Good yield potential, good resistance to diseases, prone to lodging, planted around Lake Kiva
Large grain, sweet flavor, early maturity	
Hard grain	
White flint grain, late (110-120 days to maturity)	Yield potential 5.7 t/ha, genetic purity lost due to lack of continuity in the breeding program
White semident grain, late (110-120 days to maturity)	Yield potential 5-6 t/ha, genetic purity lost
	Yield potential 5.7 t/ha, planned for release after multilocation testing

Appendix I (continued)

Country and variety name	Type, source and origin of germplasm
Swaziland	
NPPK (official name NPP x K64R) (1979-80)	Parents Natal Potchefstroom Pearl, South African open-pollinated variety, and K64R, USA
PNR95 (1981-82) (produced in South Africa since 1969)	Topcross Parents improved versions of those above
Across 7443 (1981-82)	Open pollinated CIMMYT Pop. 43, La Posta
CG4141 (1982-83)	Three-way cross SX1 (female) x CL6 (male inbred, an excellent pollen producer)
(Not yet named)	Double cross (7584 x 7583) x (7560 x 7597)
Tx 379	A1-20 (female single cross) x A1-6 x A1-3 (male inbred)
Tanzania	
116302 (1977)	[KSII (R11)C_2 - 5 x KSII (R11)C_2 - 30] Ec573 (R12)C_2 - 50 Developed at Kitale, Kenya, and tested throughout East Africa
H614 (1977)	(AXF) x Ec573 C_2
Staha (previously EV8076) (1983)	Open-pollinated variety of Pop. 76 comprised of Ilonga Composite, 50%, Tuxpeño-1 (CIMMYT), 45%, and Katumbili, 5%
Kilima (previously EV7992) (1983)	Open-pollinated variety of Pop. 92 comprised of Ukiriguru Composite A, 90%, and Tuxpeño-1 (CIMMYT), 10%
Kito (previously EV8188)(1983)	Open-pollinated variety of Pop. 88 formed from Blanco Cristalino-2 (Pop. 30), CIMMYT

Characteristics	Comments
White dent grain, medium to early maturity, medium plant height	Good drought resistance, problems of husk cover, ear placement and barren stalks (K64R is sensitive to low pH)
Small white flint grain, late maturity, tall plant height, lowland tropical adaptation	High yield potential under irrigation, breeding attention being given to improved husk cover
Tall plant height	Vigorous plant growth
Short plant height, upright leaves	
	In 1979 an improved version was developed using an advanced generation of the male parent (AXF) x Ec573 C_5
Late, adaptation 0-900 m	
Late, adaptation 900-1500 m	
White flint grain, intermediate (90 days to maturity at Ilonga), adaptation 1300 m	

Appendix I (continued)

Country and variety name	Type, source and origin of germplasm
Uganda	
White Star (previously 5314 Rust Resistant Muratha 58) (1960)	EFRO29 (Colombia) x local Muratha (ex-Kenya)
Western Queen (MH59) (1960)	KR54 (ex-Kenya) x K8 (local Kawanda 8)
Kawanda Composite A (1971)	Contains 36 varieties and hybrids
Kawanda Composite B	Contains 24 varieties and hybrids
Zaire	
Shaba Safi (1969)	
PNM 1 (1973-74)	Tuxpeño-1 (CIMMYT) x COL. GPO1 x ETO (Pop. 21 x 25)
Kasai 1 (1974-75)	Open pollinated Tuxpeño-1 x ETO Blanco (CIMMYT) (Pop. 21 x 32)
Shaba 1 (1975)	Open pollinated Tuxpeño-1 x ETO Blanco (CIMMYT) x Shaba Safi (Pop. 21 x 32)
Salongo 2 (1975)	Open pollinated Original 10 families of Tuxpeño-1, cycle 11 (CIMMYT) (Pop. 21)
VC9	La Posta x American Early Dent (CIMMYT) (Pop. 43 x 44)
VC80	American Early Dent x Tuxpeño-1 (CIMMYT) (Pop. 44 x 21)
Zambia	
Zambian Composite A	
Zambian Yellow Composite	
Zambian Short-Season Composite (1968-1970)	
ZH1 (1970)	Three-way cross 633 347 (male) x SR52 (female)

Characteristics	Comments
Late (115 days to maturity)	
Late (101 days to maturity)	No longer produced as so susceptible to MSV
Late (133 days to maturity)	Ready in 1977 but not yet released due to lack of seed multiplication facilities

White flat dent grain, late (120 days to maturity), plant height 198 cm, ear height 110 cm, mid- and low-altitude adaptation	Yield potential 8 t/ha, some flintiness in the grain
White flat dent grain, late (180 days to maturity), plant height 235 cm, ear height 128 cm, high-altitude adaptation	Yield potential 9 t/ha
White flat dent grain, plant height 228 cm, ear height 123 cm, mid- and low-altitude adaptation	Yield potential 8 t/ha

Appendix I (continued)

Country and variety name	Type, source and origin of germplasm
Zambian Composite 2	Central American materials
MMV400	Blanco Cristalino-2 (CIMMYT) (Pop. 30) (Pirsabak (2) 7930)
MMV600	Tuxpeño-1 (CIMMYT) (Pop. 21)(EV8076)
MM752 (1983)	Single cross
Hybrids released in 1984 (all are crosses of elite inbreds from MRI, Yugoslavia, and selected for adaptation in Zambia)	
MM501	Single cross
MM502	Single cross
MM504	Three-way cross
MM601	Single cross
MM603	Three-way cross
MM604	Three-way cross
MM606	Double cross

Characterisitcs	Comments
Dent grain, late (150 days to maturity), plant height 210 cm, ear height 120 cm	High yield under good conditions, suitable for any type of farmer planting at beginning of rains in areas of adequate moisture with at least a 150-day growing season and using a reasonable amount of fertilizer; by 1986-87 will have completely replaced SR52 in Zambia; susceptible to ear rot
Semident grain, late (125 days to maturity), plant height 180 cm, ear height 84 cm	Yield potential 6.4 t/ha, resistant to drought, quite resistant to MSV
Semident grain, late (135 days to maturity), plant height 2 m, ear height 84 cm	Yield potential 6.8 t/ha, excellent resistance to drought, good resistance to MSV, quite susceptible to ear rot
Semident grain, late (130 days to maturity), plant height 2 m, ear height 86 cm	Yield potential 6.4 t/ha, good resistance to drought, quite resistant to MSV
Semident grain, late (135 days to maturity), plant height 210 cm, ear height 110 cm	Yield potential 7.5 t/ha, good resistance to drought, fair resistance to MSV, susceptible to ear rot
Semident grain, late (140 days to maturity), plant height 2 m, ear height 1 m	Yield potential 6.8 t/ha, good resistance to drought, susceptible to ear rot
Semident grain, late (145 days to maturity), plant height 210 cm, ear height 1 m	Yield potential 7.2 t/ha, good resistance to drought, susceptible to ear rot
Semident grain, late (140 days to maturity), plant height 2 m, ear height 1 m	Yield potential 6.4 t/ha, good resistance to drought, susceptible to ear rot

Appendix I (continued)

Country and variety name	Type, source and origin of germplasm
Zimbabwe	
SR52	Single cross N3-2-3-3 (female, inbred from Salisbury White) x SC5522 (male, inbred from Southern Cross)
ZS107	Single cross N3-2-3-3 (female) x NAW5885 (male, inbred from NPP, South Africa)
ZS206	Modified single cross RL17 x EL77P (females, yellow conversions of N3-2-3-3) x HS253P (male, yellow conversion of SC5522)
R215	Three-way cross N3-2-3-3 x NAW5885 x 2 Kba (*H. triticum*-resistant version of K64R)
R201	Three-way cross N3-2-3-3 x NAW5885 x K64R (conversion of Kansas line K64)
R200	Three-way cross NAW5885 x MW5813 (Mexican germplasm) x K64R
ZS225	N3-2-3-3 x 2N3d (backcross version of N3-2-3-3) x FR17P (French inbred recycled with NAW5885)
ZS202	Modified single cross RL17 x EL77P x CK3P (from US hybrid Coker 16)

(Zimbabwe did not indicate characteristics or comments for their released varieties)

Appendix II

Participants, First Eastern, Central and Southern Africa Regional Maize Workshop, Lusaka, Zambia, March 10-17, 1985

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