CIMMYT's Work for Maize Systems and Farmers in Sub-Saharan Africa

Center Commisioned External Review (CCER)
14-24 April 2004

Western Kenyan farmer participating in conducting CIMMYT on-farm trials

CIMMYT MR

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INTERNATIONAL MAIZE AND WHEAT IMPROVEMENT CENTER

CIMMYT® (www.cimmyt.org) is an internationally funded, nonprofit, scientific research and training organization. Headquartered in Mexico, CIMMYT works with agricultural research institutions worldwide to improve the productivity, profitability, and sustainability of maize and wheat systems for poor farmers in developing countries. It is one of 16 food and environmental organizations known as the Future Harvest Centers. Located around the world, the Future Harvest Centers conduct research in partnership with farmers, scientists, and policymakers to help alleviate poverty and increase food security while protecting natural resources. The centers are supported by the Consultative Group on International Agricultural Research (CGIAR) (www.cgiar.org), whose members include nearly 60 countries, private foundations, and regional and international organizations. Financial support for CIMMYT's research agenda also comes from many other sources, including foundations, development banks, and public and private agencies.

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Executive Summary

The occasion of an external review of CIMMYT's work on maize and maize systems in Africa serves as an excellent opportunity for our scientists and administrators to take stock and synthesize the fruits of our efforts over the past five to ten years. For the most part, we have many positive accomplishments to report, but given the continuing and growing gap between food production and food requirements in sub-Saharan Africa (SSA), we can hardly claim that the challenge of providing food security and improving livelihoods has been met and overcome. Our work and relative research priorities, as this briefing booklet will show, have evolved together with changing research and socioeconomic environments, and with our increased understanding of what farmers and national agricultural research systems need and how we can help provide it.

The first two chapters explain some of the changes that have occurred at CIMMYT as well as in the maize research environment in SSA. CIMMYT is now implementing the results of a comprehensive year-long strategic planning process to position the Center and orient its mission for the next 10-15 years. The new strategy builds on CIMMYT's core strengths in maize and wheat improvement, and maize and wheat systems, while placing an increased emphasis on improving people's livelihoods and effective partnerships. Key to this philosophical reorientation is a physical reorientation that, under CIMMYT's new structure, will headquarter the new African Livelihoods program and its maize and wheat activities in Nairobi, and bolster other SSA offices, thereby strengthening our presence and effectiveness in the continent. This reorientation is timely, as Chapter 2 pointedly notes the difficult policy and donor milieu in which we now operate.

Chapter 3 provides an overview of the structure and staffing for the Center's work over the past five years, based on the "Food and Sustainable Livelihoods for Sub-Saharan Africa Regional Project," outlined in CIMMYT's 1998-2003 mid-term plan. It lays out the themes and goals of six sub-projects, which are reported on later in this briefing booklet. Also recounted is our history in working with a variety of regional organizations.

Chapters 4 and 5 review the most prominent abiotic and biotic stresses facing maize farmers in SSA, and CIMMYT project activities and products geared to help overcome these constraints. High on the list of abiotic constraints are drought and poor soil fertility, which CIMMYT tackles from several angles including development of stress tolerant germplasm and related breeding methodologies, research to understand plant drought-response mechanisms, and farmer participatory research on crop, soil, and water management strategies, including risk management. This work is further leveraged through the use of networks and capacity building activities. Exciting drought tolerant varieties have been developed through the application of a wide range of tools ranging from innovative mother-baby trials to marker-assisted selection at the molecular level. The potential impact is further heightened when such germplasm is integrated with the "Best Bets" technology options generated by our soil fertility management research.

Significant biotic stresses include northern leaf blight, maize streak virus, and gray leaf spot. Key among insect pests are stem borers and postharvest pests (weevils and the larger grain borer). Finally, the parasitic weed *Striga* exacts heavy yield losses, often from resource poor farmers who cannot afford to apply adequate amounts of fertilizer. CIMMYT's germplasm improvement efforts on this front have produced noteworthy results, especially for disease tolerance and a revolutionary technology (seed coating for adapted herbicide resistant maize varieties) to control *Striga* in farmers' fields. Work on insect pests has introduced a new technology, genetically modified Bt maize, to CIMMYT and Africa (the IRMA project), along with the complex technical and societal issues that accompany it. Considerable progress has been made on these fronts while the end-products are making their way through the development pipeline.

Chapter 6 addresses CIMMYT's work on highland maize, which has taken on added significance with the Center's new mission. Highland maize growing areas are typically densely populated and disproportionately poor. The biggest constraint to increased production is predominance of unimproved maize varieties. Extensive screening and characterization efforts have been undertaken to identify exceptional local materials. These can also contribute to efforts aimed at breeding improved hybrids and open-pollinated varieties (OPVs) that meet the unique requirements of these regions and their farmers.

Chapter 7 goes right to the heart of the "better livelihoods" mandate as it reviews work to improve the nutritional characteristics of maize for SSA. Quality Protein Maize (QPM) heads the list of accomplishments in this area, as it is bred into stress resistant varieties that meet the needs of local farmers. Work has recently been initiated in conjunction with the World Bank's Harvest Plus Challenge Program to boost micronutrient levels in maize, specifically iron, zinc, and beta-carotene.

The gap between research and impact is a critical one. Chapters 8 and 9 review our efforts to bridge this gap by stimulating, and even building, seed markets and avenues for distribution, and by helping NARS in SSA strengthen their human and institutional capacities. Access to improved seed is essential for improving the lives of maize farmers in SSA. CIMMYT is moving on many fronts to address this issue, including grass roots approaches such as mother-baby trials to stir interest and involvement in improved varieties, to community-based seed production, which increases access to seed while improving farmers' incomes. Work at the policy and business levels is breaking down constraints to a more vital and competitive seed market. By improving the flow of information about new varieties, CIMMYT hopes to stimulate interest, experimentation, and adoption of improved maize by clients ranging from NARS scientists to farmers. For long-term sustainable progress, capacity building is a must, and the final chapter looks at the severe constraints and the positive actions CIMMYT is taking on this issue. Indeed CIMMYT spends 33% of its budget on training and networking activities.

It is hoped this briefing booklet will provide a succinct overview of CIMMYT's work in SSA, and the challenges we face daily in trying to improve the livelihoods of our brothers and sisters in the region. By virtue of the booklets brevity, not every issue and activity can be presented completely and with the attention they deserve. We therefore invite the review team, during our interactions to seek out those details and less obvious linkages and we look forward to assisting with that task. We also eagerly anticipate the review team's report and its findings on what we are doing right and suggestions on how we can do things better.

1. A New CIMMYT and a New African Maize Program

During 2003, CIMMYT underwent an in-depth strategic planning process involving a wide range of stakeholders, donors, and research partners. CIMMYT sought to examine the continuing relevance of its mission, define how to position itself to meet the needs for agricultural knowledge and technology over the next 10-15 years, and determine the most appropriate organizational structure and operating modalities.

The new strategy builds on CIMMYT's core strengths in maize and wheat improvement, and maize and wheat systems. The Center retains its foci on the seed as one of the most effective means to disseminate improved technology, and on cropping systems amenable to farmers' practices, that complement the improved varieties and enhance sustainability. What's new with the Strategic Plan is an increased emphasis on improving people's livelihoods by working with partners to ensure the technology gets to the farmers; a new structure that brings eco-regional priorities to the forefront; more visibility to networks and more focus on effective collaboration to better leverage the Center's strengths; and a commitment to improved knowledge management and sharing.

So, what has changed insofar as CIMMYT's work in sub-Saharan Africa? Nothing and everything.

Nothing has changed in terms of the major research targets: the biotic and abiotic stresses that steal away farmers' harvests. Research continues on soil fertility and risk management to help resource-poor farmers make the most of (and conserve) their scant assets, and on examination and development of seed production and distribution systems, particularly for smallholders and those in biophysically and socioeconomically marginal environments. Our research portfolio reflects priorities that are well matched to farmers' needs, as the following examples highlight (and as described in more detail in Chapter 3).

A major commitment has been made to combating the parasitic weed *Striga*, a particular scourge to smallholders who cannot afford adequate fertilizer, which inflicts damage in the billions of dollars annually. Stem borers, cited by Kenyan farmers as the foremost field pest are also foremost among CIMMYT's priorities in developing insect resistant maize. On the abiotic side, drought is one of the biggest problems faced by regional farmers, leading to perennial food shortages. Here CIMMYT scientists are pursuing solutions using the full range of tools in their toolbox, from mother-baby trials of drought tolerant maize at the village level with participating farmers, through conservation agriculture techniques that concentrate water and reduce its loss from fields, to marker assisted selection at the molecular level in CIMMYT biotechnology labs. Innovative approaches and networks have also been brought to bear on poor soil fertility, which brings on a host of other problems in its wake. Socioeconomics has been part of the mix, not only for impacts assessment, but also for identifying production and market constraints, including the crucial issue of seed production and distribution.

In all our activities, we have been working with a wide range of partners including national maize research and extension programs, universities, private seed companies, non-governmental organizations, and farming communities. We have had a very strong emphasis on working closely with our prime clients, the NARS and farmers, for the last 20 years in Africa. This has diversified over the last 3-6 years to more work with a range of intermediate partners such as extension services, NGOs, and seed companies, and very recently to input and policy support. We tried to address the great challenge posed to capacity building of NARS through formal and in-service training, and through networks that provide significant amounts of operational funds to NARS activities.

So what *has* changed? For one thing, the general environment in which CIMMYT works. The approach of the international community to helping those living in rural areas of developing countries has shifted from producing adequate food to a far broader agenda in the 1990s of improving livelihoods of the resource poor, in which the role of agricultural research and development, and even agriculture, can get lost. NARS and particularly extension services have witnessed a continuing downward trend in their budgets. Funding for international agricultural research generally in Africa has also been in decline. Much of this funding has been diverted to development efforts aimed at better dispersing the benefits achieved through research, and to food aid crisis alleviation (as policy decisions and uncertainties have discouraged food production). This comes at the expense and risk of creating yet more dependency. However, there are some signs that influential donors (e.g., World Bank, DFID, USAID) and more importantly African governments (through NEPAD) are again recognizing that investments to strengthen agriculture is the only way for most of sub-Saharan Africa to grow and develop economically. Therefore, we expect many new opportunities to arise for the wider CIMMYT-partner alliance and its products for sub-Saharan Africa in the next few years.

Another major change at the institutional level was the creation in January 2004 of CIMMYT's African Livelihoods Program as one of six programs developed to implement our new Strategic Plan. It represents a concerted effort to address changes in needs and the environment in Africa. As the name implies, the African Livelihoods Program is focused solely on sub-Saharan Africa, and will be headquartered in the continent (at our Nairobi office) to be closer to "where the action is." It is expected to be somewhat more autonomous from HQ than CIMMYT regional offices were in the past, with more decision-making made in and for Africa. It will take advantage of links with strong partner programs and (where funds allow) address special needs, which may best be handled through bilateral agreements.

The African Livelihoods Program rightly focuses on improving rural livelihoods through a broad range of maize system interventions, be they better nutrition (i.e., QPM), better profitability (intercropping/ multicropping systems, access to technology and knowledge), or better and more sustainable land use (conservation agriculture techniques). This integrated approach emphasizes the use of interdisciplinary teams that bring their expertise to bear on specific problems. Perhaps the key item in improving livelihoods is producing impact at the grassroots level. Projects will go beyond being satisfied with variety and technology development to explore how to reach farmers with these improvements. CIMMYT cannot do this alone, hence the new determination to focus on effective partnerships and networks to "deliver the goods" to farmers.

To sum up, while CIMMYT's research foci have been on target in sub-Saharan Africa—and much of that research agenda will not change—the time has come and we are well placed to better deliver the benefits of this work to the people and nations of the region. We are confident that the new African Livelihoods Program will do just that.

2. Changes in the External Environment for Maize Research in Eastern and Southern Africa

Food production[1] in eastern and southern Africa, as in the rest of sub-Saharan Africa (SSA), has not kept up with population growth. Nevertheless, agricultural research has made significant contributions to food production and economic stability. In the late 1990s, an estimated 47% of all maize areas in SSA and 58% in eastern and southern Africa was planted to modern maize varieties[2] (Morris 2001), and every 1% yield increase in agricultural productivity—where it occurred—was estimated to reduce poverty by 0.6% (Thirtle et al. 2001).

During the past two decades, the external environment for agricultural research and production at large has changed significantly, resulting in more malnourished children and more people living on less than US$1 per day in SSA (Rosegrant et al. 2001). The factors behind these distressing trends include unfavorable weather conditions; declining public investments in agricultural research, education, and infrastructure development; unfavorable trade policies; changing donor priorities; poor governance; and major public health problems. Other factors include changes in the demand for technology and information as they pertain to farmers' demands versus the politically defined objectives for agricultural development; changes in research tools and processes as they relate to use of technology and information, and the debate on the roles of public and private sectors.

Most of eastern and southern Africa has experienced frequent drought, floods, or mid-season dry spells resulting in yield instability, serious food shortages, and recurring famines. Apart from their devastating effect on livelihoods, climatic calamities have also contributed to shifting the focus of donors from longer-term development efforts to short-term interventions, which alleviate the immediate problem of food and input shortages, but, in many instances, serve to weaken more sustainable distribution and marketing systems. As an example, 26% of the development assistance of the USA to SSA in 1999 was allocated to emergency relief, whereas only 2% was allocated to agricultural development (Johnson and Hazell 2002).

Faced with fiscal crises and donor pressure, countries in eastern and southern Africa accepted Structural Adjustment Programs (SAPs), which attempted to prescribe the roles of the public and private sectors. As a result, public financial support for education, research, extension, credit schemes, and infrastructure development has decreased. Meanwhile, private investment, which is supposedly more efficient but mostly targeted at favored environments and social groups, has not filled the void left by the retreat of the public sector (Fan and Rao 2003).

Before the onset of SAPs in eastern and southern Africa, the public sector heavily subsidized institutions that coordinated grain marketing with seed, fertilizer, and credit delivery. Acceptance of SAPs led to the abolition of these subsidies and withdrawal of parastatals, but little-to-no economic growth in SSA (Fan and Rao 2003). Credit opportunities have disappeared and the cost of inputs at the farm level has increased. Indeed, a 25-30% decrease in inorganic fertilizer use on arable land can be observed between 1991 and 2000 in eastern and southern African countries that underwent SAPs but were undisturbed by political unrest (FAOSTAT, 2003). Reduced investment in rural infrastructure has contributed to increased supply and marketing costs culminating in reductions in profit margins for both farmers and traders. Furthermore, the high risk associated with serving resource-poor farmers in a highly variable socioeconomic and biophysical environment has left a vacuum in agricultural marketing and input supply to areas outside of major cities and trading centers.

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[1] In most countries in eastern and southern Africa food equates to maize.
[2] Modern maize includes improved open-pollinated varieties and hybrids.

Globalization has also seen small-scale farmers marginalized with the decline in the world relative prices for traditional export commodities (e.g., coffee, cotton, tea, and tobacco), and alternative income opportunities failing to emerge. At the same time, urban markets in many major cities have been flooded with imported and donated goods from other countries. Africa's share in agricultural trade during the past 30 years has fallen from 8% to 3%. Today, less than 1% of foreign direct investment in the developing world goes to SSA.

Donor support to agricultural research shifted significantly in the 1990s to other areas such as governance, and social and environmental issues. For instance, USAID support for agricultural research in Africa declined by 42%. Of its overall aid, EU decreased agricultural aid to developing countries from 12% to 4% between 1987 and1998, while agriculture's share of total World Bank lending declined from 26% to less than 10% from 1980 to 2000 (Pardei and Beintema 2001).

Like the rest of SSA, eastern and southern Africa is currently afflicted with severe health problems, bordering on crises, including HIV/AIDS, malaria, and tuberculosis. In SSA, 9% of all adults (15–49 years) are living with HIV/AIDS (UNDP 2002). In many countries, trained staff and income-generating adults at the peak of their professional capabilities have died, exacting a heavy toll on the agricultural sector. Political instability, civil conflicts, and/or corruption only add to this worrisome mix.

Maize will continue to be crucial to food security in eastern and southern Africa. This will require continued investment in agricultural and maize research. The recent entry of the New Partnership for Africa's Development (NEPAD), the Forum for Agricultural Research (FARA), and Sub-Regional Organizations (SROs) into agricultural research augurs well for maize and agricultural research in general.

Ministers of Agriculture attending a Ministerial Meeting in Maputo, Mozambique in July 2003, issued the Maputo Declaration on NEPAD, which committed them to increase their respective investments in agriculture to 10% of total government expenditure. If this is realized, then maize and agricultural research generally should benefit, as well as rural infrastructure. Donors are also putting agriculture and agricultural research back on their agendas and are pledging to support NEPAD, FARA, and SROs. At the national level, farmers' institutions should be strengthened to enable them to exert political pressure for increased public investments in agricultural research, rural infrastructure, and market institutions.

The technologies generated by maize research will need to be adopted by small-scale farmers in order to lessen poverty and ensure food security. For this to occur, as it did prior to the 1990s, small-scale farmers will need to be provided with reduced farm-gate costs, and increased access to modern maize seed, fertilizer, credit, and markets.

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3. CIMMYT in Sub-Saharan Africa: Recent Background, Staffing, Structure, and Activities

Background

Maize is the number one starch staple food crop produced and consumed in eastern and southern Africa, where CIMMYT concentrates its activities. In sub-Saharan Africa as a whole, maize ranks about even with cassava. Maize is the foundation of the region's food security and economic stability. Analyses of past trends indicate that the importance of maize in the region will likely continue to grow. Maize grows well in subhumid and some semiarid agroecologies in SSA and it responds well to improved management and inputs, including improved soil fertility and water availability. Additionally, it is easy to harvest, store, and process, and it is popular among consumers, making it food of choice for hundreds of millions of Africans. Wheat is also an important food, especially for urban consumers. Because most wheat must be imported using foreign currency, its significance extends beyond the area planted or quantity produced in Africa.

The environment for the production of smallholder maize and associated legume food crops in Africa has drastically changed during the last decade. Declining soil fertility, increasing pressures from pests such as stem borers and parasitic weeds (*Striga hermonthica and S. asiatica*), highly variable rainfall, and climatic change all have increased the risk farming families take when allocating scarce resources (cash, labor, seed, and mineral and organic fertilizers) to maize and other crops they grow for food and income. Governments have reduced their support for inputs and product marketing, while the private sector has struggled to fill the gap, and credit is no longer available to most smallholder farming communities. Consequently, smallholder farmers are confronted with many difficulties including the high cost and scarcity of inputs, unreliable production conditions, and uncertain product markets.

Staffing and Structure

To address the problems faced in SSA's diverse environments, CIMMYT has continuously based staff in sub-Saharan Africa since the mid-1970s. In 2003, CIMMYT employed 18 international staff at its offices in Nairobi, Kenya; Harare, Zimbabwe; Addis Ababa, Ethiopia; and Lilongwe, Malawi. Support has been provided by about 60 locally hired staff. No staff have been based in West Africa since 1997, but the Center previously maintained offices in Ghana, Ivory Coast, and Nigeria. Additionally, CIMMYT works closely with NARS in North Africa, especially on wheat, through its offices in Aleppo, Syria; and Ankara, Turkey. Many activities—ranging from germplasm development to biotechnology and GIS—are undertaken at CIMMYT headquarters in Mexico, but are targeted for Africa and developed and tested with partners from SSA. CIMMYT's work in SSA has generally fallen under the auspices of more than 20 special projects funded by a variety of donors[1]. Some core and core restricted support has been available, mainly with funds from the UK's DFID. The estimated expenditure by CIMMYT in Africa for 2002 was more than US$15 million.

CIMMYT has a long history of working with regional organizations in SSA. In eastern Africa, the East and Central Africa Maize and Wheat Network (ECAMAW), which operates under the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) and is coordinated by staff working out of the CIMMYT offices at ILRI, Addis Ababa, Ethiopia and ICRAF, Nairobi, Kenya. In addition to coordinating ECAMAW, the center was the implementing agency for the Maize and Wheat Improvement Research Network (MWIRNET) for SADC, on behalf of the Southern African Centre for Cooperation in Agricultural Research and Training (SACCAR), during 1995–2000. Currently, the development of stress tolerant and more nutritious maize varieties (SADLF and QPM projects), and a maize seed promotion initiative funded by USAID are closely linked to SADC. We look forward to continued links with ASARECA, SADC-FANR, and FARA, including those forged through the Africa Challenge Program.

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1 See Annex A for a complete list of CIMMYT donor funded projects active in sub-Saharan Africa during 2003.

Under the CIMMYT Medium Term Plan (1998 to 2003), most of the Center's activities in SSA were grouped into one large regional project, "Food and Sustainable Livelihoods for Sub-Saharan Africa." Crop- specific or disciplinary programs (Maize, Wheat, Biotechnology, Economics, Natural Resources), on the other hand, provided staffing and resources.

The goal of the Food and Sustainable Livelihoods for sub-Saharan Africa regional program was to enhance the development and deployment of efficient, productive, and sustainable maize and wheat technologies and systems, including germplasm with resistance to pests and diseases and tolerance to environmental stresses, and the development of natural resource management technologies and human resources. The project drew the donor-funded projects together into an integrated program of research, networking, training, and extension, involving multiple partners in the region, to address five aspects of food security and livelihood development:

1. Track and understand biophysical and socioeconomic change in the maize and wheat systems of sub-Saharan Africa and formulate strategies to address the implications.
2. Develop and disseminate maize and wheat germplasm that possesses durable resistance to pests and diseases and tolerance to environmental stresses.
3. Develop and promote more sustainable crop production systems, focusing on soil fertility maintenance and water and pest management, while conserving natural resources and increasing productivity.
4. Formulate policy recommendations and research priorities for improving maize and wheat farming systems in sub-Saharan Africa.
5. Build local and national capacities though training and networking, to address 1-4.

Activities

The regional project helped set priorities, encouraged synergies and integration among an array of donor projects and partner organizations, and presented research results to parties that could use them. It operated through six thematic subprojects with the following activities:

SP 1: Development of maize germplasm adapted to biotic and abiotic constraints

Development of maize germplasm adapted to biotic and abiotic stresses in SSA, through a range of funded projects in the region, including (i) characterization of the region for maize stresses, using GIS, models, and crop distribution data; (ii) development and evaluation of maize germplasm for resistance to *Striga (including herbicide resistance for seed treatment)* and stem borers, and tolerance to drought and low-N, and for early maturity; (iii) development of nutritionally rich maize cultivars (QPM, micronutrients) adapted to regional biotic and abiotic stresses; (iv) establishment of collaborative maize breeding programs with NARSs through exchange of germplasm in regional trials, and through exchange of technical information; (v) development of maize germplasm adapted to highlands; and (vi) standardization of contracts and material transfer agreements for germplasm and intellectual property issues.

SP 2: Deployment of maize germplasm adapted to sub-Saharan Africa

Deployment of maize germplasm adapted to SSA, including (1) on-farm evaluation of new maize hybrids and OPVs; (2) establishment, with NARSs, of seed production activities; (3) seed delivery and seed testing procedures; (4) promotion of farmer participatory methods for the improvement and deployment of maize; (5) demonstration of the nutritional value of QPM through animal feeding trials; and (6) economic analysis of on-farm experiments.

SP 3: Development and deployment of wheat germplasm

Development and deployment of wheat germplasm adapted to SSA, including (1) shuttle breeding program between Ethiopia and CIMMYT-Mexico for durum wheat; (2) regional collaboration through the exchange of wheat germplasm and information; and (3) on-farm demonstrations of new wheat varieties utilizing farmer participatory approaches.

SP 4: Understanding and promoting sustainable maize and wheat-based systems:
Promotion of sustainable maize- and wheat-based systems in SSA, involving (1) investigating long-term trends in productivity and sustainability of cropping systems; (2) studying the dynamics of nutrients in smallholder fields, measuring organic efficiency of N inputs, and determining "best bet" soil fertility improvement technologies; (3) identifying and evaluating soil and moisture conservation technologies and integrating appropriate methods with soil fertility management practices; (4) evaluating organic practices for the control of *Striga*; (5) evaluating herbicide-coated seed of herbicide-resistant maize for *Striga* control, devising strategies to manage the development of herbicide resistance, and evaluating integrated approaches to *Striga* control; (6) developing NARS' capacity to undertake economic evaluation, priority setting, and policy research for "best bet" management technologies; and (7) synthesizing information on "best bet" technologies and preparing management brochures, research reports, and a newsletter.

SP 5: Enhancing human resources and partnerships devoted to maize and wheat cropping systems
Enhancing human resources and partnerships by (1) identifying training opportunities for graduate students; (2) establishing links with other training institutions in the region; (3) developing training materials; (4) developing and presenting short courses for scientists/personnel of NARS, NGOs, regulatory agencies, seed companies, extension services and farmers; NARS scientists; (5) organizing and conducting regional maize and wheat conferences; and (6) facilitating networks on crop improvement and crop systems research and development.

SP 6: Impact assessment and socioeconomic analysis of maize and wheat technology
Impact assessment and socioeconomic analysis, including (1) studies to describe, understand and document socioeconomic change in maize and wheat production systems; (2) studies to assess economic profitability of improved germplasm and new natural resource and crop management technologies; (3) develop policy information and advocacy on items 1 and 2; and (4) support capacity building efforts of NARS socioeconomists through regional networking and training.

The expected outputs from this work for 2002-2005 are as follows:

- At least 20-30 high yielding maize cultivars, including cultivars with enhanced nutritional quality and herbicide resistance, with resistance to biotic stresses (e.g., MSV, GLS, Turcicum, *Striga*, and stem borers) and tolerance to abiotic stresses (drought, low-N and low pH).
- A comprehensive maize germplasm development and evaluation program fully implemented with partners in eastern and southern Africa.
- More than 800 on-farm testing sites developed in collaboration with public extension agencies, NGOs, and universities to screen maize germplasm for drought and low-N tolerance.
- Maize seed provided to NGOs for production and distribution in Angola, Ethiopia, Malawi, Mozambique, and Zimbabwe.
- New wheat cultivars (2 durum, 10 bread wheat) with water-logging adaptation developed for Ethiopia and with rust resistance, for eastern Africa.
- "Best bet" soil fertility technologies identified and disseminated to 5,000 farm advisers and 40,000 farmers.
- Policy guidelines and economic information developed on soil fertility issues.
- Improved farming systems developed and tested with farmers: five alternate crop management options, and N-management strategies for maize and legumes in Ethiopia, Kenya, Malawi, Tanzania, Uganda, Zambia, and Zimbabwe.
- In western Kenya, 5,000 farmers participating in *Striga* management demonstrations.
- In western Kenya, commercialization and adoption by smallholders of a low-cost but highly effective technology for *Striga* control in maize involving low-dose herbicide seed-coating on herbicide-resistant varieties.
- Trained maize and wheat researchers.
- Impact studies looking at the impacts of improved maize and wheat production technologies for resource-poor farmers.
- Policy briefs and recommendations that encourage improved maize and wheat production systems in the region.
- Key NARS networks managed, allowing more efficient use of staff and funds.

- At least 5% of farmers growing maize resistant to stem borers in Kenya and in other interested countries.
- At least five farmer associations growing seed of improved maize OPVs in western Kenya and Uganda.
- QPM and other enhanced maize available and widely used by farmers in region.
- Drought tolerant maize OPVs and hybrids, and relevant information on management, widely used on smallholder farms in southern Africa.
- Soil moisture conservation strategies with drought tolerant varieties tested and adapted with farmers in Ethiopia, Kenya, and Tanzania.

Achievements

Recent achievements include the release by many national programs (through seed companies and NGOs) of maize OPVs and hybrids that are tolerant to the region's abiotic and biotic stresses. Well-adapted wheat varieties were released in eastern Africa. New natural resource management (NRM) information was generated, particularly about soil fertility, weed management, and conservation tillage. Preliminary evidence was obtained about the uptake of certain NRM technologies by farmers. Several initiatives looked at how we can better focus our work on meeting client needs and providing the support they require, including the explicit incorporation of a poverty focus into maize seed product development and delivery and soil fertility management research, improved adoption and impact studies, policy and private sector support for NRM, and upgrading NARS' skills in areas such as natural resource economics.

As of 1 January 2004, the regional project structure was replaced by a new program structure at CIMMYT. Staffing and resources for SSA are now allocated through the new African Livelihoods Program, which encompasses all activities that were conducted within the former CIMMYT regional project.

4. Overcoming Abiotic Stresses through Breeding and Crop and Risk Management

Background

Maize is grown almost entirely under rainfed conditions in eastern and southern Africa, and farmers have limited cash for purchased inputs. Yields are well below their potential of 4.5-7.0 t/ha, due to a combination of low-yielding varieties, suboptimal agronomic practices, and abiotic and biotic stresses. Drought and low soil fertility (particularly nitrogen [N]) are among the major factors limiting maize production in the region.

The effects of drought on maize production and food supplies are severe in eastern and southern Africa. Although the effects are greater in the dry midaltitude ecology, water deficits are frequent in the other major maize producing ecologies. Annual losses due to drought in the region are around 17% of total production, equivalent to about US$280 million of lost production each year (Edmeades et al. 1992).

Lost productivity due to the low-N status of soils in SSA is estimated at around US$500 million annually. Fertilizer use is less than 10 kg/ha with increased usage constrained by high prices, poor infrastructure, risk associated with climatic uncertainty, and lack of access to credit for smallholders (Heisey and Mwangi 1996). While N derived from legumes in various sysems with maize is possible, land pressure for subsistence food (maize) production limits the adoption of systems that compete for space on the farm.

CIMMYT's programs in eastern and southern Africa have used a two-pronged approach to address the constraints of abiotic stress on maize productivity. The primary approach concerns the development of maize germplasm tolerant of the stresses, that is, materials that are able to yield more than currently available cultivars under suboptimal conditions of limiting moisture and soil N fertility while yielding as well or better under optimal conditions. The second prong of the strategy involves the development, adaptation, and use of crop management practices that reduce or overcome moisture and soil fertility constraints.

Germplasm

Introducing new stress breeding methods to southern and eastern Africa

In the late 1980s and early 1990s, CIMMYT developed breeding methods that enabled the improvement of maize for tolerance to individual abiotic stresses such as drought, low-N, and soil acidity (Bänziger and Cooper 2001). These methods were introduced by CIMMYT to southern[1] and eastern[2] Africa in 1996 and 1998, respectively, through collaborative projects with NARS implemented through maize research networks. Through these projects, 30 managed abiotic stress screening sites were established at NARS stations throughout the eastern and southern Africa region: 10 for drought, 15 for low-N and 5 for low pH (Fig 1). Concurrently, NARS breeders were trained in stress breeding methodologies (Bänziger et al. 2000). NARS and

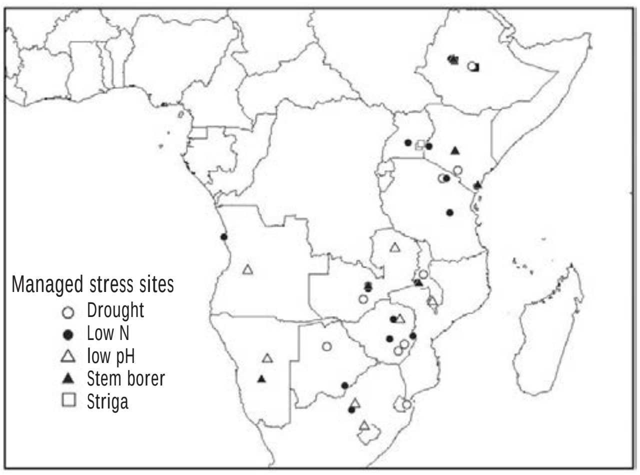

Figure 1. Managed-stress screening sites established in southern and eastern Africa for improving maize for priority stresses.

[1] The Southern Africa Drought and Low Soil Fertility Project, funded by SDC and the Rockfeller Foundation
[2] The Africa Maize Stress Project, previously funded by UNDP, Sida, IFAD; currently funded by BMZ.

CIMMYT breeders have been using these screening sites together with biotic stress screening sites (leaf and ear diseases, stem borers, storage pests, *Striga*) and hot spots for developing and evaluating maize genotypes with a trait combination appropriate to their respective target environment.

To aid in setting appropriate breeding goals, maize growing environments were characterized and incorporated into a CD-ROM based GIS tool, thus allowing site similarity comparisons and targeting of adapted germplasm to appropriate agroecological environments (Hodson et al. 1999, 2002). More than 250 scientists from the public, private, and NGO sectors were trained in using the tool, and its impact goes far beyond maize research. Relevant to maize breeding, the GIS information together with regional trial results has recently led to a redefinition of regional agroecologies for maize ("maize mega-environments"), i.e., environments within which common constraints can be assumed and cross-country collaboration will be the most effective (Fig 2).

The establishment of managed abiotic stress screening sites on-station revolutionized maize breeding in Africa. Previously, breeders did not select maize varieties under drought or low fertility conditions, instead focusing on increasing yields under agronomically well-managed conditions. The eastern and southern Africa stress breeding projects changed that, and even more. Maize varieties that performed well under managed abiotic stress conditions on-station were taken to farmers' fields and exposed to farmers' own management practices in a system that has become known as "Mother-Baby Trials."

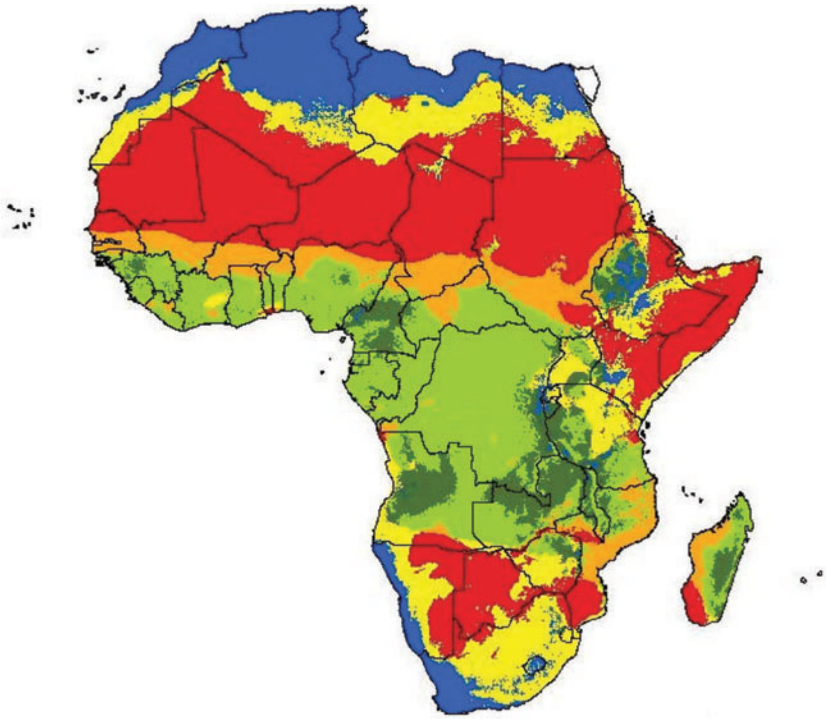

Figure 2. Maize mega-environments (Hodson, 2004, unpublished). Similar colors indicate similar growing environments for maize.

Initiated by CIMMYT in 1999 in Zimbabwe, mother-baby trials are sets of experiments grown *with* farming communities. They evaluate the performance and acceptance of new crop varieties under farmers' real conditions. A partner organization (extension, NGOs, schools) grows the mother trials, containing all varieties under evaluation, in the center of a farming community using both recommended and farmer-representative crop management practices. Several farmers in the community grow the baby trials, sub-sets of four varieties per farmer, under farmer-managed practices. Both performance and farmers' assessment are recorded. Being collaborative in nature, mother-baby trials allow all stakeholders—farmers, international and national research programs, extension, NGOs, agricultural teachers—to play their respective roles, thus bringing to the table the comparative advantage of each partner in the context of the farmers' needs. An additional merit of the scheme is that it provides feedback to seed companies and other relevant organizations so that decisions on release and seed multiplication of best varieties can be taken. Breeders also receive feedback from farmers on their preferences and priorities. In this way, the bottom-up approach to technology generation is actualized.

To analyze the impact of this new selection approach, a recent study compared 41 hybrids from CIMMYT's stress breeding program with 42 released and pre-released hybrids produced by private seed companies in 36-65 trials across eastern and southern Africa. Hybrids from CIMMYT's stress breeding program showed a consistent advantage over private company check hybrids at all yield levels (Fig. 3).

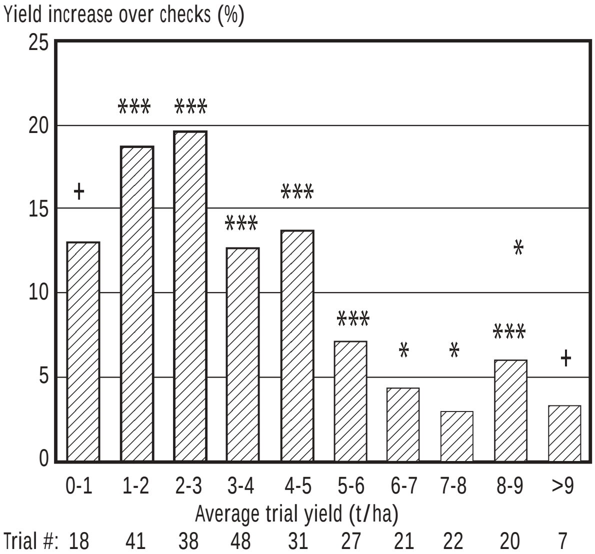

Figure 3. Percentage yield increase of stress tolerant experimental hybrids from CIMMYT (n=42) over check hybrids from the private seed sector (n=41) when evaluated in regional trials across eastern and southern Africa between 200 and 2002.

Selection differentials were largest for yields between 2 to 5 t/ha and became less significant at higher yield levels. These results provide strong evidence that the new breeding approach significantly increases maize yields in a highly variable stress-prone environment and particularly at yield levels most relevant to resource-poor farmers.

Collaboration on germplasm development

Both in eastern and southern Africa, collaboration was effectively utilized to jointly develop and evaluate germplasm under controlled and rainfed abiotic stress conditions, as well as under various biotic stresses (*Striga*, MSV), and farmers' conditions, and thereby accelerate breeding progress for materials with high value to resource-poor farmers.

The southern African network simply opened the opportunity to all breeders—private and public, national and international—to evaluate their newest germplasm products through regional trials at various stress screening sites. Within one year, a breeder could obtain a characterization of its germplasm in various agroecologies and under stresses important to resource-poor farmers. This fostered the recognition of good varieties from any germplasm developer, which then naturally progressed to mother-baby trials and release. Project funds were used to support both CIMMYT and NARS with operational funds for stress breeding, based on annual work plans.

A rather unique germplasm development strategy was adopted in eastern Africa, involving exchange of breeding materials among NARS breeders in the network and with CIMMYT's breeding program in Kenya, and evaluation at NARS' screening and testing sites in the region. CIMMYT-Kenya's breeding program focused on the development of stress tolerant (i) early and extra populations adapted to the lowland and midaltitude dry ecologies, (ii) conventional and nonconventional hybrids using midaltitude CIMMYT Maize Lines (CMLs) and streak resistant tropical lines from CIMMYT's former Ivory Coast program, and (iii) F2 populations and S2-S3 bulks. The purpose of the program was to develop semi-finished and finished products for direct release or use as breeding materials by NARS collaborators. At the NARS level, breeding programs with long-, medium-, and short-term objectives for each member country having screening sites were initiated.

Releases

In 1999, the first drought and low-N stress tolerant OPVs were released in southern Africa, demonstrating significant yield increases under conditions typically found in resource-poor farmers' fields. This was followed by releases of stress tolerant OPVs and hybrids in most eastern and southern Africa countries. They included early and extra-early varieties that farmers prefer to Katumani, the single most popular "drought-avoiding" maize variety in eastern Africa, and two QPM hybrids (Fig. 4 and 5).

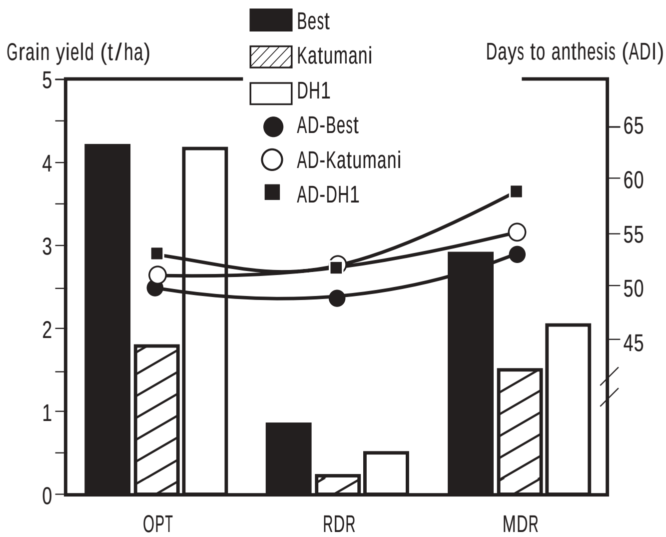

Figure 4. Yield of best stress tolerant population, a commercial hybrid (DH1) and Katumani composite across 7 environments in 1999.

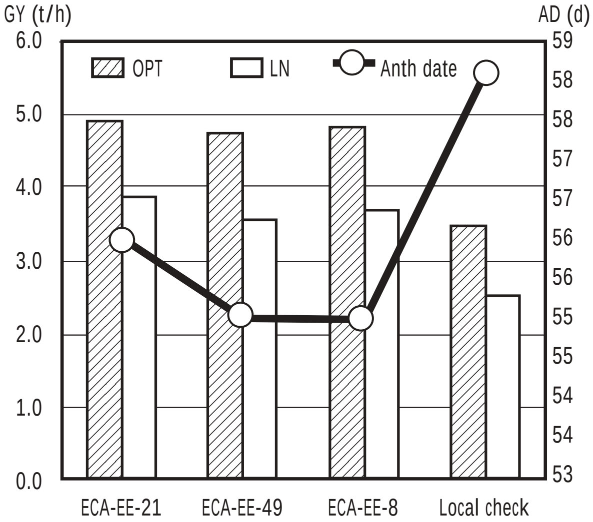

Figure 5. Yield and days to anthesis (AD) of the three best stress tolerant extra-early OPVs and local checks across 26 sites in eastern and southern Africa and Fiji (2000-2001).

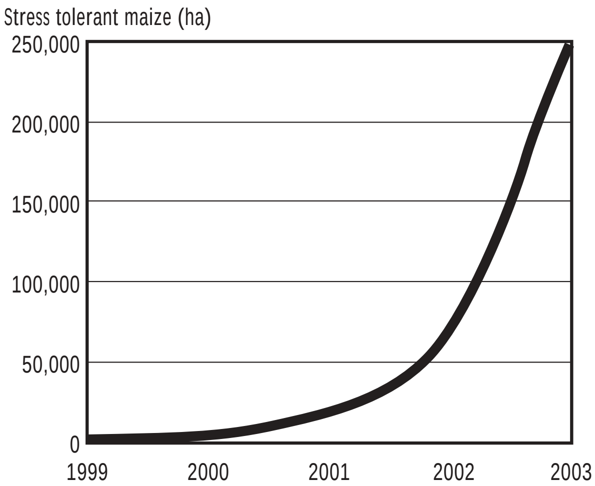

Figure 6. Area in southern Africa grown to abiotic stress tolerant OPVs, estimated based on seed production by the private seed sector.

Private seed companies in eastern Africa have reported sales of 93 t of CIMMYT hybrid seed and 11 t of OPVs. More than 100,000 farmers in Western Kenya have been exposed to the new stress tolerant hybrids/OPVs either through demonstrations or promotion packets (250 grams of seed distributed per farmer). Estimated seed production for the 2004 season is 630 t of hybrid and 175 t of OPV seed. During 2004, more than 32,000 ha will be planted with stress tolerant germplasm in Kenya.

In southern Africa, each of the past four years has seen a four-fold increase in the seed production of new stress tolerant CIMMYT OPVs (ZM421, ZM423, ZM521, ZM523, ZM611, ZM621, ZM623). Today, several small- to medium- sized seed companies are producing seed of the new varieties and current deployment exceeds 250,000 ha (Fig. 6).

Research for the future: understanding the response of tropical maize to drought

Investigations into the mechanisms of drought tolerance in tropical maize have been undertaken at the molecular level at CIMMYT-Mexico for ten years. The research focus has been tolerance mechanisms at flowering since it is at this developmental stage that drought has the greatest impact on grain yield. Initial work concentrated on the morphological characterization of segregating germplasm with the aim of identifying quantitative trait loci (QTL) for yield components, secondary morphological traits, and physiological parameters. Research has been conducted in four crosses, at different inbreeding levels, under different water regimes and in several locations. This has generated considerable phenotypic data and, independent of the cross and location, approximately 400 QTL profiles have been produced for morphological traits across 30 stressed field trials, generating more than 3000 QTL data points. The last two segregating populations have been developed with contrasting parental lines adapted to SSA and, during the last four years, this material has been extensively evaluated under different water conditions in Zimbabwe and, to a lesser extent, Kenya.

To provide a suitable biological framework for the interpretation of changes in gene expression, a set of physiological measurements were made over the last three years. Quantification of abscisic acid, sucrose, glucose, proline, relative water content, and osmotic adjustment were made in ear, silk, and ear leaf tissues at different times in a recombinant inbred line population. This work is now being complemented with functional genomic technologies to identify significant differences in gene expression belonging to target pathways. Similar tissues, harvested on the same timescales as the physiological measurements, are being used in microarray experiments conducted in collaboration with the private sector and in in-house expression studies of genes using semi-quantitative RT-PCR. A number of genes that have biological significance have been selected from the target metabolic pathways (abscisic acid, starch and sucrose, and polyamines) and are now being studied in detail through RT-PCR in different tissues at different stress levels and over different time periods. Many candidate genes are also being mapped in our drought crosses, and alleles from these genes are being characterized in different contrasting maize lines.

To effectively utilize data generated from these activities, a unique linkage map has been created from a set of anchor markers common to the different segregating populations. QTL information for each cross and validated genes have been integrated to create a drought consensus map, from which target genomic regions (those that accumulate the most QTL/genes across crosses and environments) have been identified. These regions represent about 10% of the maize genome and account for approximately 50% of the phenotypic variance. To validate these regions, a marker-assisted selection (MAS) experiment solely based on these regions is being conducted on four new crosses (elite drought tolerant lines with different genetic backgrounds). Selected lines for the MAS experiment have been identified and are well-adapted to SSA. Contrasting F3 families identified through MAS for the four crosses were evaluated during the last summer drought cycle in Zimbabwe and are under evaluation spring 2004 in Tlaltizapan, Mexico.

It is clear that only a multidisciplinary approach combining breeding, physiology, and biotechnology will provide a clearer understanding of a plant's response to drought stress. QTL information provides a bridge between data emerging from functional genomics and from phenotypic evaluation. This strategy will permit us to identify and characterize the major pathways responsible for the response to drought and tolerance in tropical maize, and will lead to the development of MAS strategies to improve yield in maize and other crops under water-limited conditions.

Crop, Soil, and Water Management Strategies

The potential gains in maize productivity possible from improved crop management, especially soil fertility management, arguably far exceed those possible with improved germplasm tolerant of the abiotic constraints of low soil fertility and moisture stress. Yet the impact of technological options to overcome these constraints remains below the impact of improved germplasm despite many diverse efforts. This limited impact has as much to do with structural, policy and socioeconomic issues as it does with biophysical limitations, although the added risks of uncertain and unfavorable weather to farmers' adoption of new technologies is also a major factor. Added to this uncertainty is the highly site specific nature of many crop management options, which mitigate against magic bullet solutions to issues of soil fertility improvement and increased crop water productivity under conditions of water deficit. CIMMYT in eastern and southern Africa has used a highly collaborative approach to confront the challenges of soil fertility and water deficit in maize-based systems by engaging in crop and resource management research through two regional networks: SoilFertNet[3] in southern Africa and the ECAMAW[4] in eastern and central Africa (see the Capacity Building chapter of this briefing book for more information).

SoilFertNet has worked for nine years to help smallholder farmers in southern Africa maintain and improve soil fertility of their dominant maize-based cropping systems through the development and promotion of farmer-use of improved soil fertility technologies; and the economics and policy support to help farmers access the technologies. Within the ECAMAW Network, drought and low soil fertility were identified as the two most important abiotic constraints to maize production in the region and much of the focus of crop management research within the network has focused on strategies to enhance soil fertility in maize-based systems.

Soil fertility constraints

In both southern and eastern Africa, networking has helped to focus a critical mass of research resources on high priority themes addressing soil fertility constraints, e.g., organic x inorganic input mixes, green manures, and participatory technology testing. Through peer review of proposals, joint planning/priority setting, and information exchange and collective learning (publications, workshops, field tours), research on priority constraints has become more coordinated, allowing better understanding of soil fertility problems and the wider testing of technologies under a broader range of conditions. In southern Africa, farming systems diagnostics has helped us learn about current smallholder maize systems, their problems and opportunities related to soil fertility improvement. Long-term studies on productivity

[3] The Soil Fertility Management and Policy Network for Maize-Based Farming Systems in Southern Africa.
[4] Eastern and Central Africa Maize and Wheat Research Network, comprising ten countries (Ethiopia, Eritrea, Sudan, Kenya, Tanzania, Uganda, Rwanda, Burundi, D.R. Congo and Madagascar).

trends of current cropping systems has given us a better understanding of soil degradation and the urgency for solutions. Process research, e.g., on plant rooting systems and nutrient capture for major crop associations, N losses and fixation under farm biophysical conditions, has helped to identify technologies that optimize nutrient use efficiency.

Network collaborators in ESA have conducted extensive on-farm research on productivity and resource efficiency of many soil fertility options, including inorganic (mineral) fertilizers, lime, animal manures, green manure and grain legumes, agroforestry and trees in cropland, and biomass transfer systems, as well as evaluation of stress tolerant crop germplasm (e.g., N-use efficient maize). Through a system of small grants, scientists in the ECAMAW Network have carried out numerous multi-year, multi-site projects since the network's launch in 1997 on issues related to soil fertility improvement in maize-based systems. The majority of them were implemented on-farm with farmer participation. Because farmers in general have poor access to purchased inputs, soil fertility management research has put much emphasis on organic sources (especially legumes) of N. Through regional screening trials, adapted legumes for intercropping and rotations have been identified and characterized, and their contribution to soil N supply and maize production has been evaluated in systems in different ecologies. Benefits of legumes in systems are highly site specific and variable. For example, legumes in rotations increased maize yields between 37% and 134% while intercropping and relay cropping of legumes with maize were less effective (Table 1).

ECAMAW projects have also evaluated maize yield response to animal manures applied alone or in combination with inorganic fertilizers with mixed results, more frequently recording no effects of manure due to its poor quality. Despite this, most of the studies were consistent in finding that manures combined with inorganic fertilizer reduced the rate of fertilizer required for optimal maize growth. For example, in Ethiopia, manure enriched (through composting) with 25% of the recommended N-P fertilizer rates produced maize yields as great as those produced using the recommended N-P rates alone. In the central highlands of Kenya, manure applied in combination with N-P fertilizer reduced the fertilizer requirement by 50%.

Similar extensive work within SoilFertNet has led to the identification of soil fertility technologies for maize-based systems in southern Africa that offer farmers the "Best Bets" for improved productivity, sustainability, useful products and income (Table 2). SoilFertNet has undertaken widespread testing, feedback on, and integration of these "Best Soil Fertility Bet" technologies through farmer participation to ensure farmer compatibility and their effectiveness within available farmer resources (cash, labor, and land). The use of "best bet" soil fertility technologies has been promoted through

- Pilot Activities—on provision of inputs such as best bet legume seed to farmers, farmer groups, and NGOs in Zimbabwe and Malawi;
- Participatory Extension and Farmer Training of Technologies—involving widespread testing, modification based on farmer feedback, and promotion through partnerships with extension services, farmer groups, and NGOs;

Table 1. Effects of legume intercrops and rotations on maize yields in the subsequent season at four locations in Eastern Africa (summary of ECAMAW regional trials, 2000-2001)

	Grain yield of maize in subsequent season (t/ha)			
System	Jimma, Ethiopia	Tanga, E. Tanzania	Hai, N. Tanzania[d]	Namulonge, Uganda
Sole maize w/o N fertilizer	1.95 ef	1.48 c	2.2 b	3.93 c
Sole maize with N fertilizer[a]	3.15 bc	2.78 ab	-	6.94 a
Maize/mucuna intercrop[b]	2.36 de	2.40 b	-	-
Maize–mucuna rotation	2.92 ef	3.22 a	4.1 a	5.66 b
Maize/canavalia intercrop	1.88 ef	2.31 b	-	-
Maize–canavalia rotation	3.85 ab	3.25 a	4.3 a	6.47 ab
Maize/crotolaria[c] intercrop	1.96 ef	-	-	-
Maize–crotolaria[c] rotation	4.56 a	-	4.6 a	5.32 b

[a] N rate = 69 kg/ha (Jimma), 50 kg/ha (Tanga) or 120 kg/ha (Namulonge).
[b] intercrop was either planted simultaneously with maize or relayed planted at tasseling.
[c] crotolaria at Jimma; Dolicos lablab at Hai; soybeans at Namulonge.
[d] on-farm trials at Hai; on-station elsewhere.

- Commodity Task Forces and Expanded Partnerships (on maize in Malawi and soybean in Zimbabwe)—to focus awareness, resources, and partnerships into large-scale efforts to address soil fertility issues and to disseminate some of the "best bets";.
- Information Dissemination—production of information brochures on "best bets";
- Economics and Policy Support—including financial analysis of options, and economics and policy support for external inputs such as fertilizer, lime, and seed;
- Advocacy—bringing soil fertility issues to the agricultural development policy debate at the national and regional levels; and
- Promotion and Training of Agro Dealers—to provide the right soil fertility inputs (seed, fertilizer, lime) and advice on use to smallholder farmers in the right areas.

Table 2. "Best Bet" soil fertility input and cropping system technologies for smallholder maize-based farming systems in Malawi and Zimbabwe

Technology	Target: Agro-ecology	Target: Farm type	Ease of Adoption[1]
Malawi			
Soil-fertility technology			
Area-specific NP fertilizer recommendations for hybrid maize	All areas by soil type and market or home use	Richer and middle income farmers	++
Optimum combinations of organic and mineral fertilizers	Most of Malawi		++
'Magoye' promiscuous soyabean	All mid-elevation areas	Richer cash croppers	++
Tihonia spp. biomass transfer to maize	Zones with *Tihonia* spp.	*Tihonia* spp growing on farm and labour available	+++
Fertility-enhancing cropping system			
Groundnut in rotation with maize, and pigeonpea intercropped with other grain legumes	All mid elevation areas	Medium to large holdings	+++
Tephrosia undersowing of maize	Mid elevation and Lakeshore areas	Medium to large holdings	++
Mucuna + maize rotations	Most of Malawi, poorer soils.	Medium to larger holdings	+
Faidherbia albida trees in cropland	Adaptation range (500-1000 masl)		++
Sesbania undersowing	Mid elevation areas	Larger holdings	+
Pigeonpea + maize intercropping	South and central Malawi	Smaller holdings	++++
Off-season "Dimba" maize to exploit fertile wetlands	Dambo areas throughout Malawi	Access to dambo	++
Soil fertility x *Striga* interactions	*Striga* affected areas		+++
Zimbabwe			
Soil-fertility technology			
Fertilizer management package for maize (conditional on rainfall) and grain legumes	Subhumid and semiarid areas	All except poorest farms in driest areas	+++
Liming on acidic sandy soils	Acidic soils in subhumid areas	Higher-input farms	++
Phospho-compost	Subhumid zones	Farmers near Dorowa rock P mine and with cattle kraal	++
Optimum combinations of organic and mineral fertilizers	Subhumid and wetter semiarid areas		++
Other grain legume rotations	Subhumid and wetter semiarid areas		+++
Improved cattle manure management, including anaerobic composting	All except driest areas where farmers reluctant to use manure	Farmers with cattle	+
Fertility-enhancing cropping system			
Pigeonpea rotations and intercropping	Subhumid areas		++
Soyabean (inoculated and promiscuous) in rotation with maize	Subhumid areas on better soils	Cash crop farmers	+++
Mucuna + maize rotations	Subhumid areas		+
Other grain-legume rotations	Subhumid and wetter semi-arid areas		+++
Cowpea/maize intercrop	Subhumid and wetter semi-arid areas	Most farmers	++++

[1] + = low ++ = moderate +++ = high ++++ = extremely high

SoilFertNet is a very good example of active support and long-term commitment from an enlightened donor and CGIAR center. The network effectively joins diverse perspectives (global/local, multidisciplinary, micro- and macroeconomic) in the service of a common goal. It has improved the effectiveness of soil fertility research and technology dissemination by the more efficient allocation and use of limited resources and minimized duplication of effort.

Drought stress and soil moisture constraints

A fundamental aspect for technology development and policy support in drought-prone environments is reducing the risk associated with low, unreliable, and poorly distributed rainfall. Improved drought stress tolerant varieties alone cannot reduce food insecurity. To reduce the risk of crop failure due to drought and to improve the productivity of drought tolerant varieties, crop management practices that improve soil water conservation and increase crop water productivity as well as build soil fertility must go hand-in-hand with the introduction of new varieties. The keys to improved crop water productivity (CWP) and mitigating intra-season dry spells in rainfed agriculture are maximizing the amount of plant available water and the plant water uptake capacity. This implies systems that partition more incident rainfall to soil storage and less to run-off, deep percolation and evaporative loss, and crops and systems that provide more soil cover and root more deeply. Improved soil fertility would also improve CWP by increasing root growth and development. We hypothesized that the combination of moisture conserving technologies and drought tolerant germplasm would reduce risk and increased yield stability when rainfall was less than normal, produce higher yields when rainfall normal or above average, and extend the season for drought-tolerant, later-maturing varieties with greater yield potential.

During the past five years, the ECAMAW Network has been evaluating alternative technologies for increasing water capture and reducing evaporative losses in maize systems in the dry midaltitude ecology in eastern and central Africa. Activities initially focused on evaluation of alternative water harvesting techniques combined with drought tolerant germplasm of different maturity classes (extra early and early).

Tied ridges and pot-holing were evaluated on-station and on-farm in northern Tanzania, eastern Kenya, and the Rift Valley of central Ethiopia over several seasons. The results demonstrate that ridging has the potential to increase maize yields during years of inadequate moisture (Fig. 7). In general, positive benefits of tied-ridges appear to be related to severity of water deficit. In seasons with well-distributed and adequate rainfall and in seasons with particularly severe drought conditions, tied-ridges produced no benefits. In seasons where moisture deficit was not so severe as to cause complete crop failure, tied-ridges substantially increased maize yields: more than 100% near Arusha, Tanzania, and by 75% at Jijiga, Ethiopia. Earlier-maturing varieties such as Katumani performed better than later-maturing varieties during seasons where moisture was limiting (Fig. 7, in 2000). During seasons where moisture was sufficient, ridging (tied or open) gave added advantage to later-maturing cultivars, such as TMV-1 (Fig. 7, in 2001).

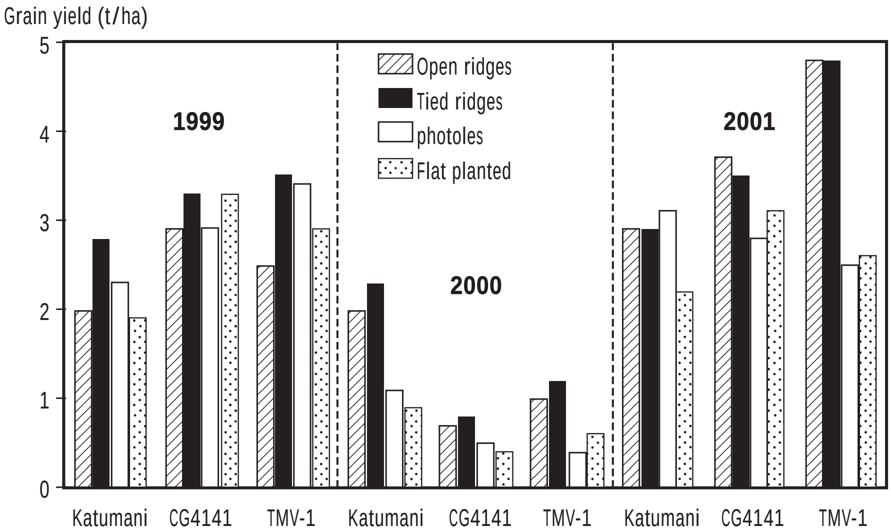

Figure 7. Effect of soil moisture conservation methods on yields of 3 extra-early and early cultivars in 3 contrasting seasons in Tanzania (source: TE Mmbaga, SARI)

Unfortunately, the beneficial effects of tied-ridges have generally not been consistent nor substantial enough to interest farmers where they have been tested on-farm with their participation. There are added costs in labor and time involved in forming ridges, which, if they do not provide a consistent benefit, are not economically attractive. Consequently, the Network has recently begun testing conservation agriculture (CA) methodologies in combination with drought tolerant germplasm in partnership with other projects in the region. A new initiative funded by BMZ/GTZ will be launched in southern and eastern Africa this year to test and disseminate with smallholder farmers various CA methods that bring together soil and water management, soil fertility, and abiotic stress tolerant maize.

Risk management strategies

Rainfall in southern Africa varies greatly over distance, over seasons, and within seasons, with the consequence that a technology that does well in one year at one location may not do well in a different season or at a different location, even on adjacent fields of the same farm. The risk associated with highly variable rainfall is a major constraint to adoption of improved technologies related to soil fertility improvement, especially those requiring purchased inputs.

The Risk Management Project has been working with farmers in Zimbabwe and Malawi in promoting and testing a range of soil fertility technologies. The project combines a range of farmer participatory technology development and promotion mechanisms with crop simulation modeling of risk prone environments to help farmers in the Zimuto area of Zimbabwe and Chisepo in Malawi, to access and use risk coping agricultural technologies, with emphasis on soil fertility management. The main objective of the project is to accelerate the widespread adoption of improved soil fertility management practices that (i) are targeted to clearly defined niches within the farm, (ii) are attractive to farmers in the near term, and (iii) do not lead to large losses during bad seasons.

The project has developed and refined tools for examining spatial variability in technology performance (through GIS defined climate similarity zones, combined with farmer-defined land type and farmer wealth categories), and temporal variability in technology performance (through simulation modeling that allows the quantification of the probability of unacceptable loss in bad seasons). Tools have also been developed for communicating with farmers about land type characterization, identification of existing whole farm nutrient management scenarios, development of alternative scenarios of interest to farmers or based on research and extension advice, and assessment of the performance and riskiness of each alternative scenario.

Current work includes farmer assessment and experimentation with several legumes including mucuna and pigeonpea, assessment of several area specific and high input fertilizer packages for maize, N x P interactions for maize, maize response to low amounts of N fertilizer, P for legumes, assessments of farmer interest in and use of such technologies, and studies on farmer participatory methodologies for such work.

The capability of the APSIM crop simulation model has been expanded to successfully simulate the growth and production of maize and the most common legume species being tested by the project, both as sole crops and as intercrops, under conditions representative of farmers' situations in the project pilot areas. Using long-term weather data, the model is able to assess the productivity benefits and risk associated with the various technology configurations on different land types under different levels of farmer management.

The outcomes of the field research and the simulation modeling are being incorporated into 'rules-of-thumb' and simple decision guides aimed, principally, at extension agents of the various partners in the project. Rules-of-thumb and decision trees are useful for the scaling out of the technologies pursued by the project. They can be used to relate the benefits of each technology to farmer wealth categories, crop management and land types, and, most importantly, assess the risk associated with the technology under local conditions. An example of the utility of combining these methodologies in assessing the benefits of different technologies is provided by a comparison of the mucuna-maize rotation and pigeonpea/maize intercropping on topland fields in the Zimuto pilot area. The mucuna-maize rotation is extremely risky, due to the possibilities of drought during either the mucuna crop cycle or the succeeding maize crop cycle, which would then be unable to benefit from the increased soil fertility produced by incorporating the mucuna. In contrast, there is very low risk associated with the pigeonpea/maize intercrop system, which produces increases in total land productivity, with maize yield benefits and additional production from the pigeon peas.

The scaling-out of technologies is underway, especially in Malawi where several NGOs have been exposing farmers in other areas to the "best bet" technologies extended by the project. These activities include distribution of legume seed to farmers with recommendations on the conditions where they are likely to give the greatest benefits, encouragement of farmer experimentation with the legumes, and farmer exchange visits to observe the technologies in the production system and talk to local farmers about their experiences. Spontaneous adoption of the technologies championed by the project is also occurring in areas surrounding the pilot areas in both Malawi and Zimbabwe. Farmers from nearby villages who have observed, or heard of, the improved legume technologies, are visiting farmers in the pilot areas and requesting seed of the most favored legumes.

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5. Overcoming Biotic Constraints through Breeding, Biotechnology, and Agronomy

Diseases

The warm climate and high rainfall common to many maize production zones of eastern Africa permits two crops a year or even continuous cropping, whereas the climate in southern Africa generally allows only one maize crop per year, but conditions are often warm with extended periods of moisture. Cool seasons (winters) throughout eastern and almost all of southern Africa are mild, such that disease inoculum and insect pests readily survive on crop debris or alternate hosts from one season to the next. These conditions generally result in frequent disease epidemics and insect pest outbreaks that reduce maize yields. Endemic maize diseases can significantly affect the maize crop, particularly northern leaf blight (NLB) caused by *Exserohilum turcicum*, common rust (CR) caused by *Puccinia sorghi*, maize streak virus (MSV), gray leaf spot (GLS) caused by *Cercospora zeae maydis*, ear rots (ER) caused by *Fusarium* and *Diplodia spp*., downy mildews (DM) caused by *Sclerospora* and *Sclerophthora spp.*, head smut (HS) caused by *Sphacelotheca reiliana* and increasingly Phaeosphaeria leaf spot (PLS) caused by *Phaeosphaeria maydis.* Selection for resistance to these diseases is an integral part of germplasm improvement at CIMMYT offices in SSA (Table 3).

Maize diseases are also addressed through the East and Southern African Regional Maize Nursery (REGNUR) project, in which breeders and pathologists across the region work together to improve germplasm for resistance to the major diseases. REGNUR Phase I (1997–2001) covered eastern Africa alone, while Phase II (2002–2004) was expanded to include southern Africa (Table 4).

Table 3. Regional diseases used for screening maize germplasm at CIMMYT locations in Africa

Common Name	Species	Method and location of testing
Fusarium moniliforme ear and stalk rot	*Fusarium moniliforme*	Natural inoculation at all locations
Fusarium graminearum ear rot	*Fusarium graminearum*	Natural inoculation in Ethiopia
Stenocarpella ear rot	*Stenocarpella maydis*	Not established
Northern leaf blight	*Exserohilum turcicum*	Artificial inoculation (spray) in Zimbabwe (Harare), natural inoculation in Kenya (Embu and Kakamega)
Common rust	*Puccinia sorghi*	Natural inoculation in Zimbabwe (Harare), Kenya (Embu and Kakamega)
Gray leaf spot	*Cercospora zeae-maydis*	Natural inoculation in Zimbabwe (Harare), Kenya (Embu and Kakamega)
Phaeosphaeria leaf spot	*Phaeosphaeria maydis*	Natural inoculation in Kenya, Zimbabwe
Maize streak virus		Infestation with leaf hopper in Kenya (Embu) and Zimbabwe (Harare)

Table 4. Regional diseases addressed through collaborative projects with NARS in Africa

Disease	Collaborating National Programs
Northern leaf blight	Kenya, Malawi, Tanzania, Zimbabwe
Common rust	Kenya, Zimbabwe
Gray leaf spot	Ethiopia, Kenya, Malawi, Tanzania, Zimbabwe
Ear rots	Ethiopia, Kenya, Malawi, Tanzania, Zimbabwe
Phaeosphaeria leaf spot	Kenya, Zimbabwe
Head smut	Kenya
Downy mildew	Mozambique
Maize streak virus	Kenya, Tanzania, Zimbabwe

REGNUR was initiated to (i) address the limited regional dissemination of information about available germplasm, (ii) enhance public access to information about maize diseases, (iii) extend information about the agronomic characteristics of breeding materials. Prior to REGNUR's arrival, the reality on the ground had severely limited the selection of breeding materials from CIMMYT, as well as sharing of germplasm and information among regional NARS maize breeding programs. Lack of funds among these programs had reduced their ability to evaluate new germplasm and drastically curtailed opportunities for pathologists, entomologists, and breeders to work together.

Through REGNURI the following goals were accomplished:

- National Programs were provided with access to a wide range of improved germplasm.
- Systematic evaluation of disease resistance evaluation as an integral component of breeding programs.
- Exchange of information, and exchange, evaluation, selection, and use of promising but unfinished materials.
- Understanding of regional variation of maize pests.
- NARS were provided with integrated information and results from the evaluations.
- A basis for regional breeding programs to verify the utility of their present screening techniques for identification of germplasm with satisfactory disease and insect reactions for inclusion in development of new germplasm for the region was provided.

A team of maize scientists from Ethiopia, Kenya, Uganda, Tanzania, Malawi, and Zimbabwe was formed to work together to evaluate the disease and insect resistance of experimental germplasm. Each collaborator identified promising and potentially useful germplasm (Ngwira and Pixley 1999). Several collaborators proceeded to use REGNUR lines in their breeding programs, and two identified and advanced hybrids to pre-release evaluation stages (Tanzania and Malawi).

REGNUR II was started in 2002 with a changed emphasis—"collaborative maize breeding" rather than "collaborative germplasm evaluation"—that enabled NARS scientists to be fully involved at all stages of the maize breeding process. While collaborators were extremely successful in identifying good source germplasm in Phase I, the next logical step was for each collaborator to use such germplasm in a sustained breeding effort that would ensure a continuous supply of new germplasm in the long term. Involving the collaborators at the early stages of the breeding process created a sense of ownership among them of the germplasm developed. This provides motivation for the scientists to see the process through to its conclusion: moving germplasm through variety release and dissemination to farmers. Thus, products will be developed by NARS for constraints of greatest importance in each respective country, while still maintaining regional adaptation.

During its first two years, REGNUR II has enabled its partners in Ethiopia, Kenya, Malawi, Tanzania, Zambia, and Zimbabwe to incorporate elite germplasm from REGNUR I and CIMMYT into the existing germplasm base of each national program. Three-way and double-cross hybrids have been made and are being evaluated. Pedigree projects using elite single crosses have been started. Training to computerize germplasm records has been done with several collaborators.

Many REGNUR collaborators are also members of other regional germplasm development and evaluation networks. To develop useful end-products, therefore, REGNUR II activities emphasize complementarity with other projects. Examples include

- Use of maize lines with superior drought and low-N tolerance from the SADLF and AMS projects.
- Use of maize lines from the AMS project with superior *Striga* tolerance.
- Use of maize lines from the Insect Resistant Maize for Africa (IRMA) project with superior stem borer resistance.
- Use of promising lines identified by the highland maize project to increase the genetic diversity of highland germplasm.

Future directions in pathology include the quantification of the interaction between crop management and diseases, and establishing a capacity to produce ear rot (*F. monilliforme*) inoculum to facilitate large-scale screening of maize lines, hybrids, and OPVs to reduce the incidence of mycotoxins in maize produced by both commercial and subsistence farmers in Africa.

Insect Pests

Insect pests are among the most important constraints to African maize production. Participatory rural appraisals in different agroecological zones in Kenya revealed that farmers systematically list stem borers and storage pests among the most important pests. Stem borers account for 13% annual loss of maize yields in Kenya, equal to over US$76 million (De Groote 2002). However, losses due to insect pests do not stop in the field. Farmers participating in mother-baby trials routinely list storage pest resistance among the four most desirable traits for maize varieties (together with high yield, drought tolerance, and earliness). Storage pests, specifically, the maize weevil (*Sitophilus zeamais*) and larger grain borer (LGB) (*Prostephanus truncatus*), cause tremendous losses (>15%) in maize cropping systems and are a major impediment to the strategic marketing of maize by smallholders. This pest complex interacts, often in a synergistic manner, with abiotic stresses to further reduce the limited grain production achieved by small-scale farmers.

Stem borers and armyworm

There are many species of stem borers worldwide; the African complex include the sugarcane borer (*Eldana sacharina* Walker), spotted stem borer (*Chilo partellus* Swinhoe), African maize stalk borer (*Busseola fusca* Fuller), and the pink stem borer (*Sesamia calamistis* Hampson). Various control practices for stem borers exist that vary in efficacy, cost, farmer acceptance and management, potential environmental and health impacts, and applicability in diverse agroecological zones. The main control practices are chemical, biological, cultural, and host plant resistance. Host plant resistance is developed through conventional breeding or using biotechnology, such as the *Bacillus thuringiensis* (Bt) technology. Developing insect resistant maize using conventional means has been elusive due to limited genetic variation, difficulty in maintaining the quantitatively controlled trait, and the fact that the procedure deals with two organisms: pests and the hosts. Bt maize offers farmers an effective and practical option for controlling stem borers as novel genes from the soil dwelling bacterium *Bacillus thuringiensis* are genetically engineered into maize to control lepidopteran stem borers.

Stem borer and armyworm (*Spodoptera exigua* Hubner) control by host plant resistance produced through conventional breeding and transformation technology has been the focal point of the Insect Resistant Maize for Africa (IRMA) project , a collaboration between KARI and CIMMYT. Suitable *Bt* genes have been acquired or synthesized and backcrossed into elite maize germplasm at CIMMYT-Mexico, and "clean" *Bt* gene events, containing only the gene of interest and no antibiotic or herbicide resistance markers, have been developed. During IRMA I (1999–2003), maize source lines of the key *Bt* genes *cry1Ab* and *cry1Ba* were produced. Insect bioassays were conducted on Bt maize leaves introduced from CIMMYT-Mexico and the effective Cry proteins against the major maize stem borers in Kenya were identified to better target pests. These proteins were effective against *C. partellus*, *C. orichalcocillielus*, and moderately effective against *S. calamistis*, and *E. saccharina*. However, constructs effective against *B. fusca* have yet to be developed.

An approval has already been obtained to introduce Bt maize seed into Kenya, for growing sequentially in a biosafety greenhouse, open quarantine site, and in the field. The biosafety greenhouse being constructed at the KARI National Agricultural Research Laboratories in Nariobi, Kenya will be used to backcross the donor line (CML216) to various lines and varieties identified by KARI as priority for stem borer resistance.

The project has not only developed Bt maize, but has also allocated resources to the development of conventional sources of resistance for Kenyan farmers. This started with screening insect resistant germplasm from CIMMYT-Mexico and has advanced to where insect resistant synthetics have been tested on-farm and are now in the process of being tested by government agencies in the Kenya maize National Performance Trials, the first step towards release to Kenyan farmers.

The IRMA project takes a broad view of the biotechnologies it is developing to ensure that it will be accepted by farmers and consumers alike, and that possible environmental issues are thoroughly studied. Protocols for biosafety, and molecular transformation were developed and training carried out to increase KARI's capacity to work with GM materials. Facilities, such as insect mass rearing facilities to efficiently produce insects for screening purposes, biosafety laboratories, biosafety greenhouses, and open quarantine facilities were also developed. Protocols for risk assessment uniquely adapted to Africa were established and documented so that neighboring countries can learn from the experience gained through this project.

For safe and effective deployment of Bt maize, studies on its impacts on target and nontarget arthropods, mainly through their characterization and quantification, were conducted. Digital and physical databases and reference collections have been made for use in monitoring the technology. Insect resistance management strategies are being developed by quantifying the oviposition preference and survival of stem borers in various alternative hosts and the economic viability of the putative species to serve as *refugia*. Through field surveys, the distribution and adequacy of putative refugia from alternative crops and wild species have been determined for Kenya's major maize growing regions over the short and long rains growing seasons.

Given the complexity of deploying Bt maize, the project undertook extensive farmer surveys (PRAs) and socioeconomic impact studies to establish the need for insect resistant maize and to identify societal factors that may influence its adoption. Baseline data, essential for monitoring and evaluating the impact of the Bt maize, was collected. An impact assessment conducted by the project shows that if a *Bt* gene that is effective against *B. fusca* can be obtained and transferred into a well-adapted variety, adoption rates are likely to be high, and therefore, so will the returns. Under standard assumptions, the economic surplus of the project is calculated at US$208 million over 25 years (66% of which is consumer surplus) as compared to a cost of US$5.7 million (De Groote et al. 2003). Geographically, the project should focus on the high production moist-transitional zone. If such a gene cannot be found, benefits would still exceed costs, but impacts would be confined to the low potential areas, and adoption rates would be fairly low.

Given the controversy and novelty of the Bt technology in SSA, the IRMA project has devoted extra attention and resources to its communication efforts. A joint workshop of scientists and journalists was held to train scientists on how to work better with the media, and to train journalists on how to better cover high science. Stakeholders meetings have been held annually. A traveling seminar on GM crops and Bt maize sensitized about 120 key extension officers in Kenya's five maize growing ecologies to the technology and solicited their input for effective communication about it to farmers. Educational materials in the form of fact sheets and posters are under development, together with a package of media for use at regional agriculture shows.

Postharvest pests

The major storage pests are the maize weevil, *Sitophilus zeamais*, and the larger grain borer (LGB), *Prostephanus truncatus*. The LGB was introduced into East Africa in the early 1980s and has since spread to most countries in southern and eastern Africa. In the absence of its natural enemies, it has caused severe damage to grain stores due to its efficient feeding behavior and high rate of reproduction.

CIMMYT has focused on genetic approaches to reducing storage pest losses through the use of local varieties that have been reported to have moderate levels of resistance. Kilima, a white flint variety from Tanzania, has a noticeable level of resistance to the maize weevil, but is less effective against the LGB. Through support by the Rockefeller Foundation, four MSc students have explored various approaches to incorporating weevil resistance into improved maize varieties and have studied the genetics of maize weevil resistance. This work has resulted in the development of eight synthetics with weevil resistance combined with good levels of foliar disease resistance, especially GLS. Divergent selection studies have shown that population improvement is possible for maize weevil resistance, a quantitative trait that has a strong maternal component. Lines developed by this project have been shared with CIMMYT-Kenya, CIMMYT-Mexico, and IRMA project collaborators to incorporate weevil resistance into germplasm adapted to different agroecologies.

Since the LGB has not been officially reported in Zimbabwe or Ethiopia, CIMMYT's efforts to develop resistant sources have been concentrated at CIMMYT-Mexico and, for the past two years, in Kenya. CIMMYT-Mexico has been able to screen a number of germplasm bank accessions that were collected in areas known to be hot spots for LGB in the Americas. This enabled the identification of a Caribbean accession with moderate levels of resistance, but poor agronomic characteristics, to be improved for resistance and yield under a structured breeding program that routinely screens for LGB resistance after each harvest. Lines developed from this effort are now being crossed into lines from Kenya and Zimbabwe to elevate the level of LGB resistance in African germplasm.

Our understanding of storage pest resistance has increased in the past five years, particularly for the genetic and the biochemical bases for resistance, important factors when it comes to food safety and grain processing issues. A molecular mapping population has been developed for the maize weevil and a second map is being constructed for the LGB. We now know that QTL exist on chromosomes 1 and 6 that account for 25% of the phenotypic variation for the resistance trait. These overlap with QTL for pericarp cell wall phenolics and kernel hardness. The pericarp is a critical tissue in kernel resistance, as is good husk cover. Both of these traits are being improved as they do not appear to adversely affect the nutritional or processing quality of the maize. In fact, the resistant source contains a higher level of protein than susceptible checks, in part due to a higher test weight.

Products coming our of storage pest resistance research include new OPVs targeted at eastern and southern Africa. As an example, CIMMYT-Kenya is developing an early maturing QPM variety (our of Pool 15 QPM) that has have been selected under drought, low-N, and screened for storage pest resistance. The intermediate- to late-maturing variety Weevil A/B, from CIMMYT-Zimbabwe, has generated wide interest from NARS in southern Africa.

There is a clear need to increase CIMMYT's efforts in postharvest research and support NARS in using routine screening for storage pests, an integral part of an effective breeding program. To this end, CIMMYT will provide two training workshops in eastern Africa in June 2004 and one in southern Africa in November 2004 to increase the capacity of NARS and to encourage the development of a postharvest research network for Africa.

CIMMYT has developed a simple screening protocol that evaluates germplasm in the same way a farmer would store their maize. The protocol is called the "weevil warehouse," and it stores replicated maize samples under ambient conditions for three months using a design that encourages a uniform infestation. A rapid visual scale is used to evaluate ears (with and without the husk), with the results analyzed in time to be of use to breeders in selecting for the following planting. This system has enabled the evaluation of over 1500 genotypes per season. The protocol does not require a large capital investment and does not require extensive training for technical staff to become proficient in screening varieties.

Soil pests

As a group, termites and soil pests are often overlooked due to their cryptic behavior. Nevertheless, they are a noticeable constraint to maize production in Africa. Some of these soil dwellers have broader beneficial functions aside from their destructive aspects. For instance, termites are very important for biomass decomposition and C cycling in African agroecosystems, and products such as termitaria soil provide islands of soil fertility for cropping. CIMMYT has invested little time or resources into better understanding the soil pest complex in Africa. Control interventions by farmers have been largely limited to the use of insecticides to control termite colonies and soil pests.

Protocols are now being developed to characterize germplasm for soil pests such as white grubs, wire worms, and root worms. Given the aggressive feeding behavior of termites, genetic approaches are not likely to provide solutions. For termite control, cultural practices, including novel rotations may reduce termite damage. The use of entomopathogens, botanicals, and other indigenous technologies should also be explored. Although CIMMYT does not have the human resources to develop these technologies, it can test and promote technologies that have demonstrated some level of control against pernicious soil pests.

Plant Pests

The parasitic weed, Striga, continues to devastate millions of hectares of arable land in Africa, causing considerable losses in maize production. Estimates of grain loss due to the impact of *Striga* on infested fields typically range from 15 to 50%, however, total crop failure has been observed under conditions of heavy infestation. This weed results in at least US$1 billion in lost yield and has deleterious impacts on the welfare and livelihoods of more than 100 million peoplein SSA. CIMMYT has been involved in integrated *Striga* control practices for around 15 years, specifically, crop rotation, tolerant maize varieties, soil fertility management, and herbicide use. These have shown value in reducing losses. However adoption by small-scale farmers has been poor, so these measures have failed to slow the spread of this weed.

As an alternative to agronomic and conventional breeding approaches to *Striga* control and tolerance, respectively, CIMMYT has developed a novel approach: seed coating herbicide-resistant maize with low doses of imazapyr (30 g/ha), prior to planting. Extensive on-farm testing in several African countries has demonstrated that this technology has tremendous potential for high and immediate impact in controlling this destructive maize pest. The treatment leaves a field virtually clear of emerging *Striga* stalks up to harvest, allows intercropping with legumes, and increases yields up to three-fold (Table 5).

In Kenya, Striga occurs mainly in the Lake Victoria region, from the shore (at 1100 masl) up to 1600–1700 meters. This area, home to six million people, produces 500,000 t of maize on 212,000 ha. Farmers estimate that *Striga* reduces maize yields by 30–50%.Meanwhile, farmer participatory trials show that the herbicide seed coating is very efficient in suppressing *Striga*, with highly increased yield at a cost of US$4/ha (8% of the cost of production). Since the maize seed is treated, there is no added cost for spray equipment and no possibility of off-target application, so the technology is highly profitable and environmentally friendly. Farmer interviews indicate that, at current prices, 67% of the farmers would purchase the seed, 3.8 kg on average. Extrapolation indicates that the potential market of IR maize would cover 44% of the area, with an expected demand of IR seed at 3,500 to 4,000 t, in Kenya alone.

Breeding efforts have resulted in the development of 60 late maturing and 22 early maturing OPVs for midaltitude areas, 10 OPVs for lowlands, 30 new inbreds, and 12 CMLs fully converted to herbicide resistance. These CMLs are sufficient to cover all *Striga* endemic areas in Africa. Most of these products will be extensively tested this year in eastern, southern, and western Africa. Last year, five hybrids were nominated in Kenya's National Performance Trials, from which three were pre-released. One of these hybrids was given to three seed companies to produce 12 t of seed for use in demonstrations with 21000 farmers next year. This technology can provide African farmers with an affordable, cost-effective solution for *Striga* control while improving the potential for returns on other inputs such as fertilizers and pest control products. The development and deployment of herbicide resistant varieties holds increasing promise while breeders identify sources of resistance for the long term.

Table 5. Effect of imazapyr on Striga emergence and grain yield in 78 on-farm trials in Kenya

Entry	Imazapyr rate (g ha^{-1})	*Striga* emergence (m^{-2})[a] Weeks after planting				Grain yield[a] (t/ha)
		6	8	10	12	
H513 (local hybrid)	0	1.45 a	8.6 a	25.3 a	50.4 a	1.49 a
NYAMULA (landrace)	0	1.1 a	5.4 b	16.5 b	36.7 b	1.91 b
IR-HYBRID-1	30	0.0 b	0.3 c	2.0 c	4.1 c	325 c
IR-HYBRID-2	30	0.0 b	0.3 c	2.8 c	5.1 c	3.57 c
	LSD	0.4	2.0	5.5	9.5	0.35
		N=78	N=78	N=78	N=78	N=68

[a]Means followed by a same letter do not differ significantly.

CIMMYT in collaboration with the Silsoe Research Institute, ICIPE, KARI, NARO, and Tanzania's Ministry of Agriculture and Food Security are attempting to integrate new technologies with pest and soil management to combat *Striga*, stem borers, and declining soil fertility in Kenya, Uganda and Tanzania. This best-bet approach for these multiple constraints includes "push-pull" (a technology that combines napier grass and *Desmodium uncinatum* intercropped with maize in a particular lay-out to control both stem borers and *Striga*). Herbicide-resistant and stress-resistant maize varieties will be identified, adapted, and tested in farmer-participatory trials taking into account the overall biophysical and socioeconomic factors driving farmers' decision making processes. In these trials, CIMMYT emphasizes full community participation and ownership.

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6. Overcoming Constraints to Highland Maize Production

Background

Much of CIMMYT's germplasm improvement in SSA has focused on the midaltitude and lowland areas, and most of the information in this briefing booklet implicitly refers to maize germplasm targeted at those areas. However, CIMMYT has a vested interest, by virtue of our mission statement, in highland maize production. The highland zone in eastern and central Africa (Fig. 8) is characterized by high human population density and high levels of poverty. Although maize production potential is high, yields are low, partly due to the predominance of unimproved varieties. The major biotic constraints are Turcicum leaf blight (*Exserohilum turcicum*) rust (*Puccinia sorghi*), stalk lodging, and stem borers. Grey leaf spot (GLS) is a looming potential threat to maize production in the highland zone. The abiotic stresses in the highland zone are frost, hail, and waterlogging (on vertisols). Undulating terrain, low soil fertility, and wide variation in climatic and other environmental conditions compound these problems.

For the past 10 years, few improved varieties have been released in the African highlands. For example, in Ethiopia, only two improved OPVs (Kuleni and Rare-1) have been targeted for the highland zone (up to 2000 masl). Farmers wishing to grow hybrids, plant those released for the midaltitude zones (e.g., BH660), which tend to be very late maturing and prone to frost damage when planted in the highlands. Maize varieties grown above 2000 masl are generally local, late-maturing cultivars that are vulnerable to frost, have extremely tall plant/ear heights, and poor stalk quality, which together contribute to low yield potential. In the Eastern Highlands of Ethiopia, for example, only 3.2% of total maize area was planted to improved maize in a recent CSA (1995).

Perhaps *the* major constraint to improving maize productivity in the highlands is the low yield potential of the commonly used varieties, the result of a narrow genetic base of eastern African highland maize. Thus, improving the yield potential of local highland maize is an important priority in ECAMAW's five-year research plan.

Highland Maize Improvement Project

In 1997, CIMMYT launched a collaborative project with East African NARS to address the germplasm development needs of the African highlands. The objectives were (i) to better define highland environments in eastern and central Africa; (ii) to improve the targeting of improved maize germplasm; (iii) to introduce and improve maize well adapted to highland ecologies; (iv) to facilitate the collection, evaluation, and documentation of regionally important highland maize germplasm; (v) to develop heterotic gene pools; and (vi) to enhance and facilitate collaboration among the region's NARS. In entering into the collaboration, one major constraint was quickly recognized. In the long, cold highland rainy season, maize takes 5-7 months to mature. This limits breeders to only a single improvement cycle per year. Nevertheless significant achievements were made.

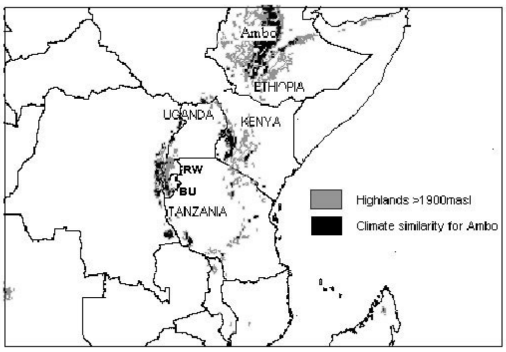

Figure 8. Highland zone in eastern Africa with climate similarity to Ambo, the project's main germplasm screening site in Ethiopia.

Characterization of the highland zones

In collaboration with NARS scientists, GIS data was collected from key highland testing sites in the zone. CIMMYT's GIS lab incorporated the information into the Africa Maize Research Atlas, a CD-ROM based tool, developed site-similarity maps (Hodson et al. 1999, 2002), and assisted in training 25 highland maize scientists in effective use of the information. Fig. 1 shows the highland zone for East Africa, indicating sites with climate similarity to Ambo, the project's main germplasm screening site in Ethiopia.

Germplasm introduction and evaluation

About 1200 local maize landraces were collected in 1998 and were evaluated at key regional locations for categorization and use in formation of germplasm pools. Following the evaluation, heterotic groups were formed for distinctive local germplasm types and used in the development of heterotic maize gene pools, from which NARS and other regional scientists could derive varieties for highland farmers. However, due to lack of funding, this activity has yet to be completed.

Data from the evaluation of the landraces showed that highland farmers plant a wide range of unimproved maize. The landraces identified varied widely in grain color, and genotypes were highly mixed. The general distinctive characteristics of the local germplasm were very tall plant and ear heights (up to 4 m), very late maturity (8–9 months duration), and very diverse plant and grain characteristics (Fig. 9). Although some landraces had high yield potential (Fig. 10), the plant stature made them prone to lodging, especially when fertilizers were applied..

Figure 9. Plant architecture and lodging experienced in highland maize landraces is evaluated at Kulumsa.

Some midaltitude and transitional zone materials from CIMMYT-Zimbabwe and CIMMYT-Mexico were evaluated to identify materials of value to the African highlands. Five years of maize germplasm evaluation in the African highlands has shown that

- The transitional zone materials from CIMMYT-Mexico are well-adapted to the highlands up to 2200masl, but they are susceptible to MSV and GLS, two diseases of economic importance. These materials are early for the highland zones and are well-suited to escaping frost. However, the length of the rainy season means, at best, they can be used as green maize because grain yields are low compared with long-season local maize and harvest would coincide with the heavy rains in the middle of the season.
- The true highland materials from CIMMYT-Mexico are susceptible to GLS and MSV, but have the advantage of being early and better adapted to high altitude zones greater than 2200 masl. They are poorly adapted to highland zones up to 2200 masl. At lower elevations, the true highland materials succumb to Turcicum leaf blight.
- The midaltitude materials from CIMMYT-Zimbabwe have good levels of resistance to both GLS and MSV, but they are ill-adapted to the highland environments and require genetic adaptation or crossing with the more adapted materials. These materials are also relatively early compared with the released hybrids in the zone and are thus lower yielding compared with popular hybrids such as BH660 and H614, which are grown in the highlands of Ethiopia and Kenya.

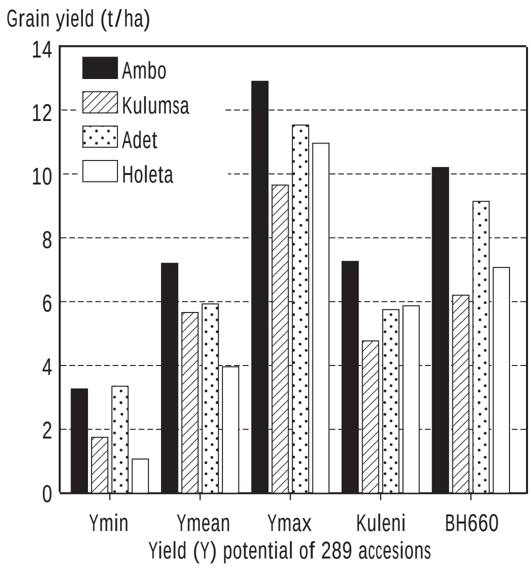

Figure 10. Variation in grain yield potential of highland landraces evaluated in Ethiopia in 1999.

Germplasm enhancement, heterotic classification, and product development

A regional highland nursery was established at Ambo, Ethiopia for maize germplasm enhancement, specifically to improve maize with adaptation to highland ecologies. About 4000 midaltitude lines from CIMMYT-Zimbabwe and highland transitional zone maize lines from CIMMYT-Mexico were pre-screened. Emphasis was placed on selection for tolerance against diseases (especially Turcicum leaf blight and rust), vigor, and general adaptation to the highland environment. The materials were improved further through inbreeding, and selected lines were topcrossed to three testers, Kitale Syn II, Ecuador, and Pool 9A. Performance rating of the various nurseries showed that the transitional zone materials derived from Pool 9A had the best adaptation to the zone. Midaltitude materials derived from Ecuador and Kitale, with previous improvements for MSV and GLS, had mixed adaptation and performance. These materials need further screening for better adaptation to the highlands, although several midaltitude lines were identified that would add value to the highland germplasm.

A major objective of the project was to classify the maize germplasm into heterotic groups. A number of selected early generation lines were topcrossed to three local testers (Kitale Syn 2, Ecuador 573, and Kuleni (Pool 9A). The topcrosses were evaluated at sites in Ethiopia, Kenya, Tanzania, Uganda, Burundi, and Rwanda.

Topcross evaluation identified several lines that had high positive general combining ability. The CIMMYT-Zimbabwe midaltitude version of Pool 9A, with improved MSV and GLS resistance, had high general combining ability and also high specific combining ability with Kuleni, an Ethiopian OPV based on the original source material for CIMMYT Pool 9A (Fig. 11). From this, four synthetics and several hybrids were formed for further testing and release in the region, and several lines were distributed to NARS and seed companies. The data on specific combining ability was used to group the CIMMYT transitional zone and midaltitude lines into three distinct heterotic groups based on the Ecuador-Kitale pattern and on Kuleni (Pool 9A). Hybrids generated from these lines have performed well in six countries and some are under consideration for release in Ethiopia in 2004.

With regional NARS, several hybrids were developed from the three heterotic groups and evaluated. We have now obtained hybrids with shorter stature, more resistant to lodging and prevalent diseases, earlier maturing, and competitive in grain yield to the old hybrids released in the highland zone. About 78 inbred lines in three heterotic groups are currently at the BC_2 level of conversion to QPM. In addition, the parental lines of BH660, the most popular hybrid in Ethiopia, have also reached the BC_2 level of conversion to QPM. One topcross hybrid is being released in Ethiopia.

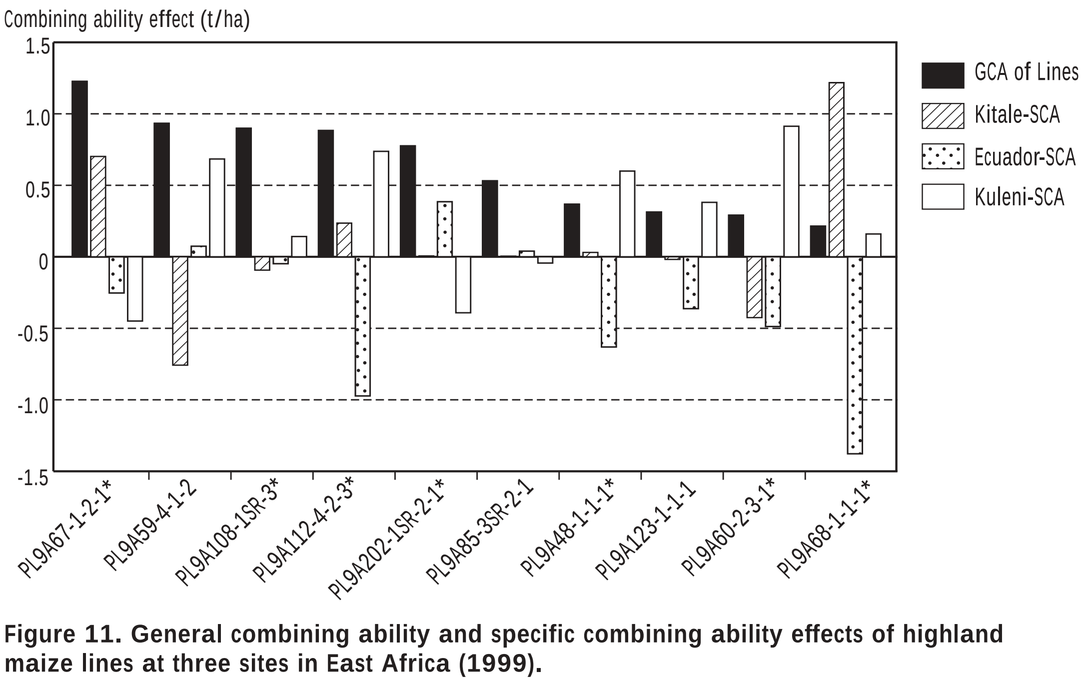

Figure 11. General combining ability and specific combining ability effects of highland maize lines at three sites in East Africa (1999).

7. Nutrient-Enhanced Maize to Reduce Malnutrition in Sub-Saharan Africa

Maize is the major food source for many poor. It is the preferred staple of hundreds of thousands of consumers in sub-Saharan Africa, where 30 to 50% of the populationparticularly the poor and women and childrenare malnourished. The maize-based diets of inhabitants in extremely poor areas center on carbohydrates and lack proteins, vitamins, and important minerals, often leaving them disease-prone and unable to work, care for children, or take part in normal activities of their communities. Maize cultivars that offer enhanced protein quality and/or increased available iron, zinc and - and ß-carotene could greatly improve the nutrition, health, and quality of life of these people.

CIMMYT's maize work essentially has two basic thrusts in the area of improved nutrition:

- Quality Protein Maize (QPM), with deep roots in CIMMYT's maize program;
- Biofortification for micronutrients (iron, zinc, and pro-vitamin A carotenoids), which received a more recent focus with the initiation of the Harvest Plus (formerly Biofortification) Challenge Program.

Quality Protein Maize

Quality protein maize is the result of more than three decades of scientific discovery. In 1963, scientists at Purdue University discovered the gene called *opaque-2,* which improves the nutritional quality of the maize by increasing its lysine and tryptophan content. Farmers initially showed little interest in opaque-2 maize because of its low yields, chalky-looking grain, and susceptibility to pests and diseases. Starting in 1970 and with funding from the United Nations Development Programme (UNDP), CIMMYT converted *opaque-2* maize into Quality Protein Maize (QPM), which is effectively indistinguishable from normal maize. Work on QPM has intensified dramatically over the past six years due to a renewed interest in nutritional aspects. Ian Johnson, chair of the CGIAR and vice president for environment and sustainable development at the World Bank, said, "The development of quality protein maize is people-centered science at its very best, providing better nutrition while fostering economic growth for the world's poor."

Three complementary projects are especially crucial to the success of the current QPM work, which in West Africa are being done largely by IITA:

- The Nippon Foundation has been a strong supporter of QPM germplasm development, dissemination, and training focused on Africa but with activities both in Mexico and Africa-based programs. Through Steering Committees three networks, WECAMAN (West and Central Africa Maize Network), ECAMAW (East and Central Africa Maize Network) and the SADC maize breeding network (coordinated by the Southern Africa Drought and Low Soil Fertility, SADLF) ensure transparency and regional ownership of QPM research activities and grant allocation to NARS in various sub-regions.
- The QPM-D project for eastern Africa, funded CIDA (Canadian International Development Agency), has provided strong support to socioeconomic, nutrition, and QPM dissemination activities.
- The QPM project funded by the Rockefeller Foundation enables eastern and southern African National Program scientists to convert their preferred OPVs to QPM. 19 widely-grown elite maize cultivars are in this program.

In addition, considerable opportunities for synergies exist between QPM and Harvest Plus activities, particularly related to nutritional advocacy and dissemination of nutritionally enhanced varieties.

QPM germplasm development

The primary objective of the CIMMYT QPM breeding program for East and Southern Africa is to develop stress tolerant QPM hybrids and OPVs, well-suited to the needs of resource-poor farmers in the region. QPM research by CIMMYT in sub-Saharan Africa has focused on two broad approaches:

(1) Testing inbred lines, hybrids, and OPVs developed elsewhere, primarily from CIMMYT-Mexico (which has a wealth of QPM germplasm), as well as other breeding programs in Mexico, Ghana and South Africa; to identify the most adapted cultivars for direct release, and
(2) Converting existing adapted varieties to QPM. Considerable effort has also been dedicated to the formation of more streak resistant varieties. Experience has taught us that adequate resistance to MSV can often be achieved in hybrids by including one susceptible and one resistant parent. For this reason, improved versions of MSV-susceptible hybrids may be relatively quick to emerge. This also gives us reason to hope that new QPM lines emerging from research at CIMMYT-Mexico, may be quickly useful in Africa.

For the medium- and long-term objectives, each region focuses on different germplasm development activities.

CIMMYT-Kenya. Work in Kenya aims to (i) convert to QPM stress tolerant extra-early populations developed during the African Maize Stress (AMS) project, phase 1; (ii) improve streak resistant QPM populations from CIMMYT-Mexico; (iii) develop stress tolerant QPM lines using pedigree breeding in collaboration with NARS partners; and (iv) introgress the Imidazolinone Resistant (IR) gene to QPM cultivars for *Striga* prone ecologies. The QPM conversion activities are being accelerated through the use of marker-assisted selection. In recent trials, some of the new QPM hybrids yielded higher than the local checks under both stressed and non-stressed conditions, and showed more resistance to gray leaf spot (GLS), but more susceptibility to Turcicum leaf blight (Fig. 12).

CIMMYT-Ethiopia. QPM variety development focuses mainly on the highland zone, which has lagged behind other maize mega-ecologies. In collaboration with CIMMYT-Mexico, (i) normal maize inbred lines with tolerance to Turcicum/MSV/GLS, are undergoing conversion to QPM and are currently at BC2F1 stage, (ii) elite OPVs are being converted to QPM, including four highland synthetics, and the popular OPVs Kuleni, Awassa-511, and Melkassa-1. (iii) a rust and leaf blight tolerant Susuma (Obatampa) version is developed. For the non-highland areas, CIMMYT is converting parental lines of released hybrids, including the parental lines of BH660, the most popular maize hybrid in Ethiopia, constituting nearly 95% of the nearly 10,000 t of hybrid seed produced annually in the country. Two of the lines are at BC2F2 stage of conversion, while the third line is at BC2F1 stage. The parental lines of two other released hybrids; BH670 and BH540, are also being converted to QPM.

CIMMYT-Zimbabwe. Activities here aim to (i) convert the best Mexican QPM materials to MSV resistant, and (ii) develop new QPM germplasm by partially converting the best southern African materials to QPM. So far, about 1300 new MSV-resistant lines, based on best Mexico QPMs and nearly 2000 experimental maize lines, developed from crosses between elite African germplasm (from CIMMYT and IITA) and Mexican QPM lines, were selected for MSV resistance and advanced to further evaluation. Some exciting results include two MSV-resistant versions of CML144/CML159//CML176, a hybrid

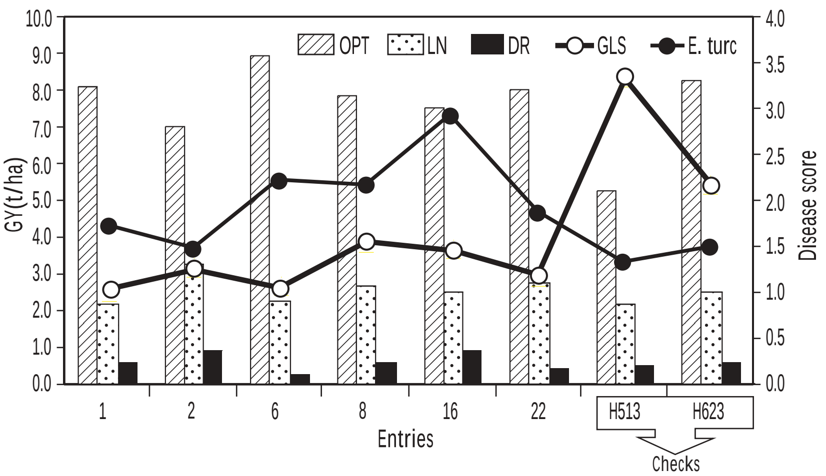

Figure 12. Yield (t/ha), and disease (GLS & E.Turc) reaction of 6 QPM hybrids and 2 commercial checks tested across 4 sites in Kenya, 2002A.

released in several countries, including Ethiopia and Tanzania. They yielded 22% more grain than the original hybrid across four locations, have acceptable MSV resistance under artificial, severely infected conditions (Table 6), and have been included in trials distributed throughout SSA during 2004. During 2004, testcrosses of 243 experimental MSV-resistant QPM lines will be evaluated in multi-location yield trials to identify the next generation of African, MSV-resistant, QPM lines. In addition three students from Zimbabwe and Mozambique are conducting their Master's degree projects on two QPM diallel designs. The results will be crucial to identifying a important new QPM lines for extensive use in southern Africa during coming years.

CIMMYT-Mexico. QPM activities at CIMMYT-Mexico continue to be highly relevant for Africa. Elite germplasm from CIMMYT Mexico is routinely screened at Africa-based CIMMYT locations and interested NARS. Traits of particular interest are further improved protein quality, yield potential, ear rot resistance, drought tolerance, and improved standability. New lines such as CML491 have shown excellent combining ability with Africa-based inbreds. There are many other benefits from collaboration with the long-standing QPM breeding efforts at CIMMYT-Mexico. As protein analysis facilities are only just being developed in Africa, most breeding materials germplasm is sent for quality assessment to CIMMYT-Mexico. Also, staff and technical information from CIMMYT-Mexico have been crucial for training of scientists and technicians in Africa.

QPM networking and status in various countries

Moving QPM from trials to farmers' fields entails utilization of partnerships, collaborations, and networks. Positive examples of this are regional meetings of QPM partners and stakeholders, such as for example the one conducted in Harare in March 2003. Representatives of private seed companies, non-governmental organizations, nutritionists, and economists presented the perspective of their institution or discipline to the group. This provided a foundation of mutual understanding of interests, expectations and potential contributions to the regional QPM effort by each type of partner. Maize scientists also briefed the group about the status and outlook for QPM activities in each of their countries. In spite of many constraints, QPM varieties are moving to the field as the following summary proves:

Ethiopia. One 3-way hybrid (BHQP-542) was officially released in 2002: This hybrid is referred to locally as "Gabissa"—which translates roughly to "something which makes one strong."

Table 6. Grain yield (across four locations) and maize streak virus disease (MSV) symptom score (one site with artificial infestation) for selected QPM and normal check hybrids

Pedigree	Across locations: Grain yield	Rel GY	Rank	MSV
		%	Avg	1-5
CML444/CML443//CZL00003 (normal)	7.7	134	3	2.6
GQL5/CML176//CML181	7.4	126	17	3.5
CML395/CML444//CML442 (normal)	7.3	126	10	1.7
GQL5/CML176//CML181	7.1	121	17	3.1
CML144/CML159//[CML389/CML176]-B-29-2	6.9	120	23	3.1
CML144/CML159//[CML176/CML395]-B-2-2	6.9	118	16	3.1
Normal Commercial Check:	6.6	115	15	2.3
CML144/CML159//[CML176/CML395]-B-1-1	6.6	115	16	3.1
CML144/CML159//[CML205/CML176]-B-2-1	6.5	113	22	3.1
CML144/[CML159/CML395]-B-17-2	6.2	108	27	1.2
CML144/CML159//[CML442/CML176]-B-8-1	6.2	107	30	3.3
CML144/CML159//[CML176/CML395]-B-6sx-1	6.1	106	29	2.8
CML144/CML159	6.1	105	31	4.4
CML144/CML159	5.8	102	37	4.4
CML144/CML159//CML176	5.7	100	38	4.5
CML144/CML159//CML176	5.6	97	47	4.6
Mean	**5.8**	**100**	**41**	**2.5**

Rel GY is the grain yield relative to the mean of the trial (100%, by definition)

Kenya. Two hybrids were fully released in 2004, while one hybrid and one OPV were pre-released, and another hybrid is being tested in the National Performance Trials. Popular varieties are being converted to QPM.

Malawi. Have been testing QPM for four years and conducted extensive farmer-participatory variety evaluations in partnership with SG2000; have released a three-way QPM hybrid in 2002, but it has some production problems and disease susceptibility (MSV); will likely release Obatanpa and/or an Obatanpa topcross hybrid in 2003; have formed a QPM country working group; have established two "QPM villages"; have a very limited QPM breeding effort; are constrained by the lack of protein quality laboratory facilities and lack of training for technicians.

Mozambique. Have a very substantial QPM breeding effort, focused on early maturing, white flint OPVs with resistance to MSV and downy mildew; have released 'Sussuma' (improved Obatanpa); are working on developing a QPM version of 'Matuba'; significant amounts of Sussuma seed have been produced; have formed a QPM country working group, but it is not working smoothly; are constrained by the lack of protein quality laboratory facilities, lack of seed storage facilities, and lack of foundation seed processing equipment.

South Africa. There are three QPM projects in South Africa, which due to large distance between them, operate largely independently of each other. (1) Eco Link (in Mpumalanga) is producing seed of Obatanpa and is working with small-holder farmers to disseminate QPM. (2) Quality Seeds is developing QPM hybrids in Natal area; have released about 20 QPM hybrids; are now partnering with another company interested in QPM OPVs; have had good success using yellow QPM germplasm from Brazil and white QPM from Ghana; their goal is to see QPM meal on supermarket shelves, soon; constraints are lack of interest in QPM by most private companies and government, although it is a good sign that ARC has revived QPM work. (3) ARC was not represented at our meeting, but they have initiated a very small effort in QPM breeding; they are also evaluating QPM trials from CIMMYT.

Swaziland. QPM activities in Swaziland to date are nil. We recommended that they should evaluate small trials available from CIMMYT, and they should explore opportunities to form alliances with Mozambique and Eco Link to benefit from the success of those nearby QPM projects. We recommended against forming a QPM country working group until there are products ready for extensive testing and promotion.

Tanzania. Three QPM varieties were officially released in December 2001: a top cross hybrid (Lishe H2), a 3-way cross hybrid (Lishe H1), and an OPV (Protini-1).

Uganda. An open-pollinated QPM variety was released in November 2000 under the official name *Longe 5*, but is locally promoted as *Nalongo*. The United Nations High Commission for Refugees and the World Food Program in Uganda are interested in procuring QPM grain locally for use as emergency food rations, and are encouraging local farmers to produce Nalongo for that purpose. In response, during 2001, the Sasagawa 2000 program in Uganda facilitated the production of 150 tons of Nalongo seed.

Zambia. Started QPM activities in 2002; are evaluating CIMMYT regional trials at 2 sites; plan to link QPM testing to the existing Mother-Baby Trial scheme; the National Council for Scientific Research has a program to fortify maize meal (could link with QPM activities); constraints are lack of resources, very few staff, and need for training in quality assessment.

Zimbabwe. AREX (government research and extension) and/or Midlands University are testing QPM under low-N and drought stress; selfing in early generation bulks provided by CIMMYT; would like to convert local yellow varieties to QPM; would like to conduct feeding demonstrations with dairy, chickens, and pigs; will link QPM testing to ongoing mother/baby trial scheme. Seed Co has a substantial QPM breeding research program and expects to have commercial QPM hybrids on the market soon. A University of Zimbabwe nutritionist is experimenting with protein quality analyses; is interested in working with nutrition studies. It was agreed to convene a first meeting of a QPM country working group for Zimbabwe.

Socioeconomic analysis of QPM and nutritionally enhanced maize varieties

The potential of QPM for the feed industry was analyzed for the poultry sector in Kenya, where maize constitutes 50% of commercial feed. Calculations showed that QPM can reduce feed costs by 5%. Optimal ratios based on QPM and on regular maize were calculated and formulated, and trials showed that broilers raised with either mixture had the same food intake, mortality, and growth. Moreover, there was no difference in taste between the meats. This cost reduction could translate into a gain for the feed industry of about US$300,000.

Nutritionally enhanced maize is likely to have an impact on human nutrition where maize is the main staple food, and where protein and micronutrient deficiencies are widespread. Studies to determine the areas with high potential impact and quantify that impact are underway in Kenya, Tanzania, Ethiopia, and Uganda. The analysis in Kenya, based on secondary data and Participatory Rural Appraisals (PRA), showed that nutritional deficiencies are less severe in the central highlands, but increase rapidly with lower altitudes. Self-sufficiency in maize also reduces with decreasing altitude, so the zone with highest potential impact is located in the dry midaltitudes and the dryer areas of the transitional zones.

Micronutrient Enriched Maize (Harvest Plus Challenge Program)

CIMMYT is the lead Center for both wheat and maize activities of the Harvest Plus Program. The global maize work has been led from CIMMYT, Zimbabwe. The objectives of the maize project are to develop and disseminate maize varieties with meaningfully enhanced concentrations of pro-vitamin A carotenoids, iron, and/or zinc. Harvest Plus was officially initiated in 2004 and the Biofortification Strategy for Maize may be found at www.harvestplus.org. CIMMYT, however, had initiated screening activities for Fe (1994), Zn (1994) and specific carotenoids (2002) already at an earlier data. Current activities fall within three categories: (1) vitamin A work, (2) development of germplasm with multiple aleurone layers, and (3) development of germplasm with decreased phytic acid content.

Vitamin A

Analysis (by HPLC) of beta-carotene, beta-cryptoxanthin and alpha-carotene concentrations of nearly 500 yellow maize genotypes is in progress at the University of Zimbabwe, in collaboration with CIMMYT. Results to date indicate average beta-carotene concentration of 3 g/g, but two inbred lines have been identified with greater than 10 g/g. These two lines together with several lines from Dr. Torbert Rocheford, University of Illinois, were planted at Harare in November 2003 for seed increase and for use as donor lines in several breeding projects. One of the recipient materials is a yellow OPV from Angola, noteworthy because Angola is the region’s only country where yellow maize is consumed by a large percent of the population. - One of CIMMYT’s strategies is to combine vitamin A fortification with QPM, resulting in a nutritionally “doubly” superior product. About 200 experimental and elite yellow QPM varieties were grown at CIMMYT, Mexico, to produce grain for evaluation of their carotenoid concentrations. The carotenoid concentration of these QPM grain samples will be evaluated at Iowa State University during first half of 2004.

Multiple aleurone layer (MAL)

Research between 1994 and 2000 at CIMMYT-Mexico and Zimbabwe showed that genetic variance and heritability for iron and zinc are relatively low in maize. Iron and zinc in maize grain are concentrated in the aleurone layer. CIMMYT is investigating whether a mutation that results in multiple aleurone layers will produce increased levels of iron and zinc. Backcrosses (BC3 and BC4) of several CIMMYT elite inbred lines have been used to form hybrids among multiple aleurone versions of elite lines. Their performance is currently being compared with “iso-hybrids,” using the original (single aleurone layer) versions of the same lines so to test the hypothesis that multiple aleurone layers may be a route to increasing iron and zinc concentration of maize grain.

Low phytic acid (LPA)

Following a decision within the Harvest Plus CP, CIMMYT is no longer actively pursuing this approach to enhancing bioavailability of iron and zinc. However, because several projects reached third backcross generation during 2003, CIMMYT decided to continue this project at a very reduced level, until we are able to assess progress (if any) achieved to date.

8. Stimulating Seed Markets

Background

Seed is an essential, strategic, and relatively inexpensive input with a high rate of return on investment that often sets the upper limit for maize production. Progress achieved through breeding may increase and stabilize maize production and improve the livelihood of maize farmers. Over the past decade, several new maize seed-based technologies have become available in southern and eastern Africa, many of them through CIMMYT-collaborative projects. However, most maize farmers in southern and eastern Africa are resource-poor and live and farm in marginal areas characterized by high biophysical, socioeconomic, and political risk. The resultant low agricultural productivity translates into a limited cash resource base for the farm household and extremely challenging and underdeveloped seed markets. This chapter outlines the various attempts by CIMMYT to better understand seed availability constraints, and solutions that are being tried to address them. Donors and projects contributing to this effort include:

- DFID: core-restricted funding.
- The Rockefeller Foundation: The Southern African Drought and Low Soil Fertility Project – Phase II.
- The Rockefeller Foundation: Strengthening Maize Seed Production and Distribution Systems for Small-Scale Farmers in Kenya and Uganda
- The Rockefeller Foundation: Strengthening marketing incentives for farmers in southern Africa.
- USAID-TARGET: Providing smallholder farmers in southern Africa with seed and information about robust, stress tolerant maize varieties
- USAID-OFDA: Establishing more effective and sustainable community-based seed production schemes, and giving communities access to foundation seed of robust, stress tolerant maize varieties.

Understanding Seed Availability Constraints

Understanding farmers' challenges to access improved seed is of renewed interest to all stakeholders in the grain sector, as trade liberalization has changed the institutional environment in many African countries. After initial work in the 1980s and 1990s (as summarized in Byerlee and Eicher [1997]; and Morris [1998]), CIMMYT has recently been involved with several studies aimed at better understanding current challenges faced by smallholder farmers and the seed sector in eastern and southern Africa. In collaboration with several economists in southern Africa, six studies were conducted in Malawi, Tanzania, Zambia, and Zimbabwe to assess the marketing and utilization of improved maize seed and to understand the factors that determine the procurement and use of improved seed (Phiri et al. 2004). Studies in eastern Africa analyzed the effects of trade liberalization on the seed sector (De Groote et al. 2002; KARI and CIMMYT 2003). These studies complement information provided in an impact assessment of past investments made in the maize breeding sector (Hassan et al. 2001).

The results of the marketing and utilization studies showed that although farmers understand the yield advantage of improved maize varieties, use of improved seed continues to be low (ranging in selected study areas from 4% in Tanzania, 30% in Malawi, 45% in Zambia, to 82% in Zimbabwe) and may not be much different from those reported in 1996, when adoption of improved maize seed was estimated to average 25-35% (Hassan et al. 2001).

High costs of seed and fertilizer, low grain prices, long distances to seed outlets, and lack of credit opportunities were among the main reasons mentioned for low levels of improved maize seed use. On average, 76% of the respondents reported buying improved maize seed for some part of their cropped area. Hybrid seed was most commonly purchased because it was more readily available than improved OPVs. Male-headed households and households with large land holdings had a significantly higher frequency of purchasing improved maize seed, and farmers who had access to credit or were older tended to buy more seed than their counterparts. Farmers indicated that they preferred early-maturing, high yielding varieties with good drought tolerance, storability, poundability, and taste. Most widely grown improved varieties, however, were those farmers knew for a long time, possibly because transparent and simple variety information on new varieties is lacking. Variety names were usually considered too complicated, thus not easily remembered (Phiri et al. 2004).

In southern Africa, trade liberalization of the seed industry has led to a number of new seed companies entering the market (Phiri et al. 2004). However, because of the small number of companies per country, as determined by small and insecure national markets, no real competition has emerged. Seed outlets are found mostly in larger trading centers, requiring most farmers to travel long distances to buy maize seed. As input price subsidies have been removed and major credit and input distribution programs have collapsed, farmer-to-farmer seed exchange and free seed provision through NGO or government relief programs have become important sources of seed. These free seed distribution schemes often do not consider farmers' preferences, hence inappropriate crops and varieties are frequently disseminated at inappropriate times. This development also inhibits the development of more sustainable seed systems as seed companies focus their attention on the large buyers (NGOs or government) instead of the ultimate client (smallholder farmers).

A seed sector study in Kenya revealed that following the 1996 liberalization of the seed sector, new companies were permitted to enter the market, thus allowing for the natural privatization of the seed sector in the life cycle model (Morris et al. 1998). Plant breeders' rights were recognized and a plant breeders' rights office was established (KARI and CIMMYT 2003). The number of seed producers has increased from 5 to 41 since 1996, including national and multinational companies. However, liberalization had little impact on seed prices and the adoption of seed (De Groote et al. 2002). Prices dropped in the early 1990s, but real prices have been constant since. The ratio maize/seed price fluctuates between 6 and 8. One major factor is the domination of the market by the government-owned Kenya Seed Company (KSC). In particular, new companies have not been able to penetrate the lucrative highlands market (Nambiro et al. 2004) whereas two foreign companies were successful in marketing varieties for the moist transitional zones. Newly released maize varieties are still dominated by two institutions (one of them public), but private sector company releases have increased. The main constraints to the expansion of the seed business by private sector participants were identified as capital shortage, difficulties in accessing improved varieties from public sector institutions for production and distribution, lack of appropriate varieties, low farmer demand for certified seed, and the complexity of the variety release procedures. There has been little success in regional integration, and the variety release system considers only yield potential in approval for release.

In Ethiopia, the maize sector is still largely under government control. A strong extension with credit program increased the use of improved maize seed and fertilizer in the late 1990s. Maize production increased during this period, which was also a result of an increase in area. However, maize prices collapsed in 2001, leading to a decrease in adoption in 2002 (De Groote et al., 2002).

Realizing that problems limiting seed availability are many and dynamic, and partly based on the reported study results, CIMMYT has launched several new initiatives (discussed below) aimed at improving farmer's accessibility to improved maize varieties.

Giving Smallholder Farmers a Voice: Mother-Baby Trials

The primary objective of mother-baby trials (see section on abiotic stress) is to evaluate maize varieties in the actual target environments, taking into consideration climatic, edaphic, management, and socioeconomic factors. Mother-baby trials, however, also serve as a demonstration tool because they include new and upcoming maize varieties. Apart from providing feedback to the region- or country-wide evaluation scheme, most farmers and partner organizations use the trials to select varieties for their own purposes. NGOs in particular tend to follow-up with bulk purchases or community-based seed production of selected varieties, and typically they do not limit these follow-up actions to the participating farming communities, but rather extend them to *all* beneficiaries of their program. A few examples:

- In 2002/03, World Vision Malawi distributed seed loans to 2000 farming families based on mother-baby trials conducted together with Malawi's Ministry of Agriculture. Lessons learned were shared with World Vision programs in other countries and led to more focused seed purchases.
- The Department of Agriculture in the Limpopo Province, South Africa, conducted mother-baby trials together with the country's Agricultural Research Council (ARC). Whereas ARC used trial results from all mother-baby trials to decide on the release of ZM521, the Department of Agriculture in Limpopo Province together with Madzivhandila College for Agriculture started community-based seed production and today produces several hundred tons of certified seed in and for surrounding farming communities.
- To address farmers' lack of access to quality seed of improved maize varieties, CIMMYT, KARI, NARO in Uganda, and several NGOs and farmer groups initiated the "Strengthening Maize Seed Production and Distribution Systems for Small-Scale Farmers in Kenya and Uganda Seed Project" in 2000 (Mugo et al. 2004). The project intentionally used mother-baby trials to allow farmers to evaluate and select suitable varieties for their conditions, which was then followed up with the development of seed production and distribution systems among farming communities. Farmers' feedback, and that of researchers, has been widely shared to promote and facilitate the release and production of suitable varieties.
- Collaboration with Catholic Relief Services (CRS) and Western Seed Co. led to 200 on-farm demonstrations and 3000 farmer-promo packets (0.5 kg per packet), respectively, of CIMMYT derived OPVs in Kenya.

Whereas only 15-30 communities in one country may be involved in mother-baby trials, the impact of the trial system goes much further. It has become apparent that the involvement of partner organizations in mother-baby trials strongly increases the demand for seed of appropriate varieties, to the extent that they influence the type of seed that becomes available on the market. Indeed, the accelerated demand for varieties such as ZM521 is likely the first time that smallholder farmers have started to significantly influence maize seed markets in eastern and southern Africa. Given that region-wide close to 100 partner organizations (Annex B, Tables 1 and 2) and 200-250 farming communities (Annex B, Table 3) are involved in mother-baby trials, the potential impact of follow-up actions by partner organizations is enormous.

Community-Based Seed Production

Lack of access to improved seed is attributed to insufficiently developed and ineffective seed production and distribution systems. Seed can often only be purchased in larger trading centers and resource-poor farmers often consider the return to investment as high and insecure. The informal sector, including NGOs, NARS, and community-based seed efforts, has great potential for supplying seed to resource poor farmers, but is underdeveloped for various reasons. Two projects in eastern and southern Africa, under USAID[1] and RF[2] funding, try to address some of the constraints by

- Identifying appropriate varieties through mother-baby trials.
- Increasing the capacity of NARS to produce breeder and foundation seed of improved OPVs.
- Training research, NGO, and extension staff in more effective seed production and distribution systems.
- Developing training materials targeted at NGO and extension staff.
- Establishing more effective seed production and distribution systems among farming communities through existing NGO- and donor-supported community-based seed production systems.
- Linking small seed companies with seed growers in community-based seed production schemes.

Both projects have increased the capacity of institutions in NARS in southern Africa, Kenya, and Uganda to produce breeder and foundation seed through investments in capital, operational funds, and training. In several countries, farmers and farmer groups are now participating in on-farm seed production of varieties of their choice, and with quality control authorities of their respective country. Sustainability of community seed production, scale-up issues, quality control, and marketing, however, remain an ongoing concern and require further research into appropriate solutions.

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1 Establishing more effective and more sustainable community-based seed production schemes and giving them access to foundation seed of stress tolerant robust maize varieties.

2 Strengthening Maize Seed Production and Distribution Systems for Small-Scale Farmers in Kenya and Uganda.

Improving Variety Information

CIMMYT's regional trial system, implemented in collaboration with NARS and the private seed sector, develops transparent maize variety information on new varieties developed and submitted by the public and private seed sector. The information contained in the annual publication "Characterization of maize germplasm grown in eastern and southern Africa: Results of the ….. regional trials coordinated by CIMMYT," however, is not easily digested by non-breeders. Based on the regional trial scheme, CIMMYT more recently developed a simpler extension brochure on OPV characteristics and their recommendation domains, targeted particularly at NGO and extension staff. In addition, relevant information on the appropriateness of hybrids versus OPVs has been produced.

We would like to also provide the wider farming community with more transparent variety information to increase farmers' access to breeding progress and stimulate a more competitive maize breeding sector. Currently, few farmers know the characteristics of new varieties available on the market and therefore fail to benefit from recent breeding progress. Moreover, their tendency to request seed of old (and known) varieties works against the benefits offered by a competitive breeding sector. Two social scientists from the University of Zambia and Bunda College in Malawi were contracted to analyze farmers' communication on variety attributes. We expect that the study will help us to gain insight into more effective communication strategies that may use information developed in mother-baby trials to strengthen the demand for appropriate maize varieties through the wider farming community.

Seed Policies

While harmonization of regional policies in variety release and certification in eastern Africa have progressed through the ASARECA/ECAPAPA networks, less progress has been made in southern Africa. In partnership with SADC Seed Security Network, CIMMYT therefore supports the harmonization of regional policies on variety release, exchange, and certification in southern Africa, with technical advice and funding for meetings that draft policies. It is expected that during 2004, draft policies will be forwarded to the SADC directorate for consideration by the council of ministers. If trade barriers between SADC countries were removed, the number of seed companies that could sell seed in individual countries would drastically increase. Currently, the SADC seed market is estimated at 60,000–80,000 t of maize seed (without South Africa), which could potentially support 10 to 20 viable seed companies, sufficient for a competitive seed sector that could provide more affordable seed and variety options for farmers.

Material Transfer Agreement with Seed Producers

Given the disappearance of public sector seed companies and changes in the Intellectual Property Rights arena, the core values for disseminating CGIAR germplasm have been challenged, particularly for a highly commercialized commodity such as maize seed. During the past few years, as maize germplasm with unique value to resource-poor farmers in Africa has been developed (such as drought tolerant or QPM varieties), southern Africa has become a pilot area for CIMMYT in probing for a more effective transfer of elite maize germplasm to seed producers and farmers. We have arrived at a system in which breeding institutions and seed producers (public or private) are able to apply in a competitive and transparent manner for the right to commercialize CIMMYT hybrids in specified countries without gaining intellectual property rights to the parental lines. Rights to register CIMMYT OPVs (but not to gain IPR), on the other hand, are given under agreements that require the registering institution to provide other seed producers with breeder and foundation seed. This approach keeps all CIMMYT germplasm in the public domain, while permitting a fast and effective transfer of breeding progress to farmers. The system seems to have the strongest benefit for small and medium-sized seed companies, which are interested in markets that are less attractive to the multinationals, but that cannot afford their own breeding programs.

Strengthening Seed Marketing Incentives to Increase the Adoption of Improved Maize Varieties

A new project aimed at strengthening the marketing incentives for farmers in southern Africa, thereby increasing the adoption of improved maize germplasm in the SADC region, is being implemented by CIMMYT in collaboration with NARS in Malawi, Mozambique, Zambia, and Zimbabwe. This study hopes to consolidate previous studies by providing detailed information on the adoption and diffusion of improved maize cultivars, and the relative spatial impacts of various factors conditioning adoption. It is hoped that the study will also provide information on the organization and performance of maize seed markets and a critical review of the effectiveness of the innovative germplasm distribution policies being implemented by CIMMYT. If it can be shown that our germplasm distribution policy succeeds in increasing the adoption and diffusion of improved cultivars in the marginal environments of southern Africa, then lessons learned could help improve seed distribution policies in other parts of the developing world. Furthermore, the study would attempt to estimate maize seed demand in the region, which is vital for planning seed production and distribution in the region.

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9. Addressing Institutional and Human Capacity Constraints

Background

With an average gross national income (GNI) of US$500 per capita (US$300 without South Africa), sub-Saharan Africa is one of the poorest regions in the world. Consequently, public spending (based on tax income and donor support) barely reaches 1% of public spending in OECD countries, and less than 4% of a certain age-group have the chance to enroll in tertiary education (more than 50% have this privilege in high income countries). Even though agriculture forms the mainstay of more than 75% of the poor in SSA, investment in agricultural research is necessarily much less(60-100 times less) than in high-income countries. Overcoming such severe human and financial constraints is undoubtedly a daunting task.

Regional and inter-institutional collaboration that provides support to research and training activities in priority areas is widely recognized as an important tool for addressing resource constraints and capacity building. Research networks have therefore played an important role in CIMMYT's research and training agenda. Research networks promote cooperation and integration, allow priorities to be established, and scarce resources to be allocated according to comparative advantage and complementarity. They foster the exchange of products, experiences and resources, and contribute to institutional memory. CIMMYT also uses other strategies to overcome institutional and human capacity constraints. They include

- the implementation of short training courses, workshops, stakeholder consultations, monitoring, and field tours on a range of topics;
- visiting scientist schemes;
- active pursuit of opportunities for higher degree training of NARS scientists;
- supervision of BSc., MSc. and PhD. research studies by center staff;
- support of NARS in research project development and implementation, within CIMMYT-managed and other projects;
- provision of financial assistance for establishing new or improved research infrastructure and conducting research projects;
- provision of information, publications, and research tools (computers, software, field supplies, and equipment); and
- augmentation of service conditions of NARS scientists by involving them in regional research leadership.

This chapter reports on CIMMYT's work in institutional management and human capacity building by describing a series of networks and training initiatives we have managed in eastern and southern Africa during the last five to ten years. Annex C (Tables 1-3) provide a complete listing of training activities conducted during the past five years and also a 2003 spotlight on flow-through funds provided to NARS.

The Maize Breeding Network in Southern Africa

In the late 1980s, the Southern Africa Development Community (SADC) identified crop breeding as an area where synergies could be exploited through regional approaches and collaboration. As a result, in 1994 the Southern African Center for Cooperation in Agricultural and Natural Resources Research and Training (SACCAR) and CIMMYT initiated the European Union-funded Maize and Wheat Improvement Research Network (MWIRNET) for SADC. A transitional project to integrate the South African NARS to MWIRNET was jointly initiated in 1999 (through 2001) by CIMMYT and the National Department of Agriculture of South Africa and was financially supported by the European Union's EPRD fund. The project activities received technical backstopping from CIMMYT scientists with a major focus on capacity building for previously disadvantaged South African scientists. .

One of the highest research priorities for SADC, CIMMYT, and SACCAR was empowering NARS to develop and promote drought tolerant and nutrient-use efficient maize varieties. To pursue this priority, the organizations initiated the Southern Africa Drought and Low Soil Fertility Project in 1996, which has proven highly successful. The Steering Committee established under MWIRNET was adopted by SADLF and continued to administer annual work plans and resources allocation to NARS. In recent years, CIMMYT has put more maize breeding projects under the SADC Steering Committee (SADLF Phase II, USAID-Seeds, QPM) and involved members in the development of new proposals and work plans, thereby strengthening NARS capabilities in research management, peer review, accountability, networking, and collaboration. The SADC Steering Committee annually allocates about US$320,000 of direct support to NARS and supervises regional training activities equivalent to US$160,000. The network has make a considerable contribution to a more streamlined regional research agenda, greater institutional memory as new scientists are appointed and join, and has managed to involve an increasing number of institutional partners from the public, private, and NGO sector in network activities.

Significant achievements include

- training and active involvement of more than 100 scientists and technicians in stress breeding and variety dissemination approaches;
- development and identification of robust ,stress tolerant maize varieties with 50% or more higher yields under conditions typical for resource-poor farmers in the SADC region;
- establishment of regional trials among CIMMYT, NARS, private seed companies, and NGOs that evaluate elite pre-release maize varieties from <u>all</u> collaborators for growing conditions and characteristics important to resource-poor farmers in SADC;
- collaborative, cost-effective, NARS-led on-farm testing schemes that seek farmers' feedback to new maize varieties, and which have influenced variety release and seed availability;
- systematic links with agencies involved in seed dissemination (seed companies and NGOs) resulting in new stress tolerant maize varieties being grown on more than 250,000 ha;
- characterization of maize growing environments in SADC and use of those results in justifying a regional maize variety release approach in SADC;
- an increased awareness among NGOs and extension about maize varieties suitable to smallholder farmers conditions and the requirements for effective seed production and dissemination strategies;
- improved facilities for NARS, including stress screening facilities, cold rooms, computers, vehicles, and significantly increased research budgets for a wide range of NARS scientists;
- socioeconomic studies that characterize constraints limiting farmers access to improved seed and farmers' communication strategies on maize varieties; and
- leadership of relevant regional research areas by scientists jointly employed by CIMMYT and local universities.

Although the maize breeding network in southern Africa has exceeded many expectations, it also experiences continued challenges, foremost among them is the very sobering situation of human resources for public maize breeding in southern Africa. Table 7 indicates that

- on average, 50% of all scientists stay for less than three years in a NARS' maize breeding programs. This falls far short ot the time required to test and release a variety;
- newly appointed scientists rarely overlap with previous position holders as hiring procedures are overly lengthy. This together with inadequate educational background (new scientists typically join as BSc. holders) minimizes institutional memory and severely hampers the continuity of research activities;
- few NARS scientists in maize breeding have recent post-graduate training, because donors have greatly reduced their support to post-graduate training. Many PhD holders are close to retirement or absorbed in much needed research management.
- CIMMYT-related projects have become the main contributor to recent or current post-graduate training—due to lack of alternative options.

Table 7. NARS scientists involved in maize breeding in southern Africa

	Staff changes 1997-2004					Current staff		
Country	Joined program	Left program	In PhD training	In MSc training	Balance	PhD	MSc	BSc
Angola	5	1	0	1	3	0.5	1	2
Botswana	2	1	0	1	0	0	0	0.5
Lesotho	2	1	0	1	0	0	0.5	0
Malawi	4	3	1	0	0	2	0	1
Mozambique	3	1	0	1	1	0	1	2
Namibia	0	0	0	0	0	0	0	0
South Africa	5	3	0	0	2	2	0	2
Swaziland	2	3	0	0	-1	0	0	0
Tanzania	2	2	1	0	-1	2	1	0
Zambia	1	3	0	1	-3	0.5	0	0
Zimbabwe	5	4	0	0	1	0	0	2
Total	**31**	**22**	**2**	**5**	**2**	**7**	**3.5**	**9.5**
Graduated < 5 years	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**0**	**3**	**n/a**
Training in CIMMYT-related projects	**n/a**	**n/a**	**1**	**3**	**n/a**	**1**	**3**	**n/a**

Soil Fertility Management and Policy Network for Maize-Based Farming Systems in Southern Africa (SoilFertNet)

SoilFertNet began in late 1994, out of a collective realization by the Rockefeller Foundation (RF) Agricultural Sciences Program and its grantees that there was a need for better coordination of a large body of essential soil fertility research work in Malawi and Zimbabwe. CIMMYT became involved in the coordination of this network because of its longstanding expertise in farming systems research, training, and networking in the region. It has subsequently expanded to Zambia and Mozambique, developed far more socioeconomic work, and moved to promote the technology products from research. SoilFertNet, which officially ended in December 2003, is being transformed with continued support from the RF into a broader consortium, with a wider range of partners and a wider mandate across more agroecologies in southern Africa.

The network Coordination Unit was located at CIMMYT-Zimbabwe, with 1.5 international staff covering soil fertility agronomy and agricultural economics. CIMMYT managed a network grant from the RF of US$320,000–400,000 per year. A dedicated SoilFertNet Economics and Policy Working Group (EPWG) was set up in 1999. The EPWG was instrumental in initiating socioeconomics, adoption, and policy-related studies on soil fertility management. Beginning in 2001, regional theme leaders were appointed from member organizations (including the Universities of Malawi and Zimbabwe, DARTS in Malawi, and DR&SS in Zimbabwe) to cover

- integrated cropping systems, soil nutrient and water management;
- technology dissemination and promotion;
- economics and policy; and
- capacity building.

These institutions work with country groups and facilitators, established by the membership to address particular priority tasks and opportunities. Work with Zambia began in 2000 and with Mozambique in 2002.

One special feature of SoilFertNet was the way that members have been funded. The grant from RF to CIMMYT covered networking and coordination unit management. The Coordination Unit managed a small start-up/top-up grant program for members. However, the vast majority of funds for member organizations flowed directly to member organizations from RF, based on proposals reviewed and recommended by the network to RF for funding.

Members of the EPWG were able to access grants from RF during 2001–2003. The beneficiaries of these grants were graduate students at the University of Zimbabwe and Malawi Bunda College of Agriculture. More than 25 students have received their MSc degrees and two are completing their PhD training programs at the universities of Pretoria and Bonn. The thesis research projects were on economics, adoption of soil fertility technologies, and marketing problems of grain legumes.

Network activities

Networking to focus a critical mass of research resources on high priority themes (e.g., organic x inorganic input mixes, green manure network trials, participatory technology testing) involved peer review of proposals, sourcing funds, planning/priority setting, start-up/top-up funding, and information exchange and collective learning (publications, workshops, field tours). Through farming systems diagnostics, we learned about current smallholder maize systems, their problems, and opportunities related to soil fertility. Long-term studies on productivity trends and sustainability of current cropping systems to better understand soil degradation, and the urgency for solutions, were undertaken. Relevant process research was conducted, e.g., on plant rooting systems and nutrient capture for major crop associations, N losses and fixation under farm biophysical conditions.

On farm research developed and tested a wide range of soil fertility technology options, including inorganic (mineral) fertilizers, lime, animal manures, green manure legumes, grain legumes, agroforestry/trees in cropland, biomass transfer systems, crop germplasm (e.g., NUE maize). This work led to the identification of "Best Bet" soil fertility technologies.

Field tours and workshops have been regular features of SoilFertNet. Co-learning, by members, in the field conditions under which farmers and their technologies operate has been considered by many to be especially valuable over the years. Workshops have covered planning and reporting of work on priority topics, and building specific skills among the membership. See Annex D for a list of recent events.

SoilFertNet benefits and legacy

In terms of institutional impact, SoilFertNet has made immense contributions by strengthening research in network member institutions, building human capacity, and enhancing the exchange of information and technology. Undoubtedly, research networking is an important for more effective national, regional, and international natural resource management research collaboration, which directly contributes to more productive synergies. However, the actual impact on our work programs, approaches and methods, technology and management outputs, and on farmer well-being and livelihoods is difficult to assess.

Figure 13 graphs the annual trends from 1995 through 2003 in membership, numbers of participants at our workshops and conferences, those that traveled on our field tours, and the number of publications produced by SoilFertNet. More than 200 individuals and organizations were members, 650 persons have attended our workshops on a range of themes, almost 400 have traveled on the many field tours in the region, and there are around 110 publications, including working papers, technology brochures, special publications, and issues of the Target newsletter (see Annex E).

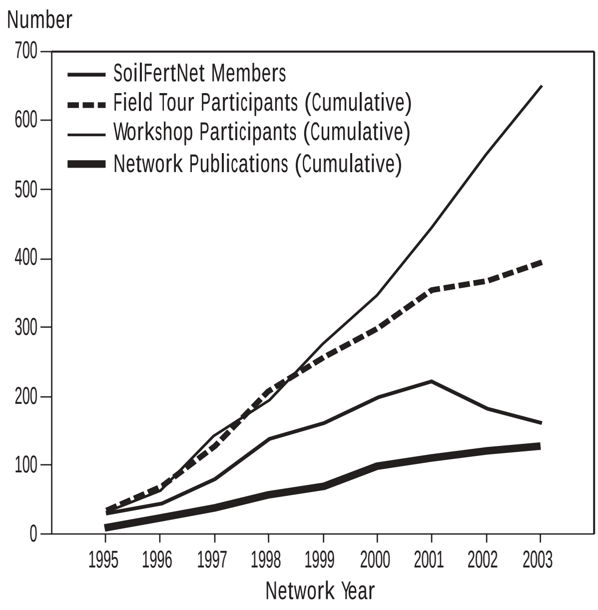

Figure 13. SoilFertNet membership trends, field tour and workshop participation, and publications from 1995 to 2003

The Eastern and Central Africa Maize and Wheat Network (ECAMAW)

The Eastern and Central Africa Maize and Wheat Network (ECAMAW) was initiated and facilitated by CIMMYT under the CIDA-funded Eastern Africa Cereals Program (EACP-Phase IV), with approval in 1996 by the ASARECA Committee of Directors (CD). ECAMAW is one of 19 networks, programs and projects (NPPs) that operate under the auspices of ASARECA. The participating countries are Burundi, the DRC, Eritrea, Ethiopia, Kenya, Madagascar, Rwanda, Sudan, Tanzania, and Uganda.

The EU EDF8 has funded the Network Coordination Unit at CIMMYT-Ethiopia since September 2003. In November 2003, the stakeholders guided the write-up of the Five Year Strategic Plan (2004-2009) based on the ASARECA Consolidated Conceptual Framework, and reviewed the composition and terms of reference for the steering committee members.

CIMMYT is the implementing agency for the ECAMAW Network and carries out most of its research activities in the region within the network's framework. Technologies and recommendations are developed in close collaboration with our partners in the NARS. CIMMYT-ECA maize scientists undertake strategic research in the development of improved maize germplasm, agronomic practices for enhanced productivity of maize-based production systems, and methodologies for technology development and transfer. In partnership with NARS scientists in the ECAMAW Network, they also conduct adaptive research to fine-tune these technologies to regional conditions.

Members of the Network include maize and wheat researchers in East and Central Africa and their collective administrative organizations. A database based on a survey of national research programs in the region in 1997 lists nearly 250 individuals involved in maize and wheat research at least part-time. Major achievements and impacts in capacity building include

- ***Development of research infrastructure:*** A total of 13 screening sites and 60 testing sites for drought, low nitrogen, *Striga,* and stem borers have been developed and are fully functional under the direction of NARSs scientists. This is enabling African maize researchers for the first time to conduct stress-breeding research. NARSs researchers have been trained in new breeding methodologies and all screening sites are fully computerized.
- ***Farmer participatory approaches:*** Participatory rural appraisals (PRA) have been used to elicit farmers' problems and understand their constraints. Participatory breeding and on-farm and mother-baby trials are being used to develop and test new technologies with farmers, and obtain information on the suitability of new cultivars for different agroecologies and their acceptability to farmers. Hands-on training for farmers involved occurs throughout the season.
- ***The involvement of women:*** Gender sensitivity training has been provided to many Network scientists directly or through "Training of Trainers" workshops. Gender analysis is a required component of every small grant proposal.
- ***Strengthening national research systems:*** Courses and workshops have been organized annually on selection methodologies, for increasing farmer participation in breeding and on-farm testing, and in computing to manage and evaluate large germplasm collections. Through AMS, 102 scientists/ technicians were trained in the region; the EACP provided training to a total of 343 maize and wheat researchers through visiting scientist grants, regional courses, and workshops in areas considered a priority by the steering committee.
- ***Building regional maize teams:*** The Network is promoting interactions between international and NARS scientists of different training and backgrounds, and between scientists and extension workers, non-government organizations (NGOs), and farmers' communities. The methodologies used by the projects have improved the efficiency of breeding and agronomic work conducted by NARS scientists, and made possible a quicker transfer of technologies from experiment stations to farmers. Training events have also allowed researchers from different countries to establish friendships and professional ties, thereby fostering trust and the free exchange of information and germplasm.
- ***Small grant projects:*** The progress and status of small grant projects for each year are presented in depth to the Maize Working Group by principal investigators in February. Table 8 shows funds disbursed to NARS by country and project in 2003.A total of 66 small grant projects were approved for funding during 2001; this increased to 78 in 2003. During February 2004, a total of US$446,094 was approved for small grant projects. From these funds, US$128,604 will be spent on capacity building, including dissemination of improved technologies.

Table 8. ECAMAW small grant projects funded in 2003 and funding sources

COUNTRY	No. of projects	BUDGET	Project-Donor	Amount ($)
Burundi	2	8,786	BMZ—AMS	89,250
DRCongo	1	1,000	RF—AMS	98,000
Ethiopia	20	64,850	NF-QPM	35,170
Kenya	23	106,467	CIDA-QPMD	103,874
Madagascar	1	1,000		
Rwanda	2	5,326		
Sudan	0	0		
Tanzania	20	64,171		
Uganda	9	35,273		
Funds for surveys & dissemination		16,000		
General supplies (bulk purchase)		25,700		
Contingency		7,421		
TOTAL	**78**	**326,294**	**TOTAL**	**326,294**

Crop Management Research Training (CMRT)

The Crop Management Research Training (CMRT) facility at Egerton University, Kenya, was established through CIMMYT efforts with funding from USAID and CIDA to provide practical hands-on training to researchers in the conceptualization, design, and execution of field trials in crop management. Its focus has been on maize, wheat, and beans with scientists from the eastern and southern Africa being nominated and funded largely through the MWIRNET, ECAMAW, and ECABREN networks. The CMRT facility provides an excellent venue for a wide variety of regional activities and training, and should be considered for further support as a regional training center for ASARECA networks. It is recommended that the ASARECA CDs and Secretariat consider what would be required to make the facility a truly regional entity as originally intended by the donor agencies that supported its development.

Training on Quality Seed Production and Distribution in Eastern and Southern Africa

Proper training in seed production management is critical for the production of high quality maize seed. Training has therefore been a major emphasis of two seed projects funded by RF ("Strengthening Maize Seed Production and Distribution Systems for Small-Scale Farmers in Kenya and Uganda") and USAID ("Establishing More Effective and More Sustainable Community-based Seed Production Schemes").

In eastern Africa, training was offered to nearly 125 individuals, including national program scientists, government extension staff, private seed company staff, and NGO members. In southern Africa, a series of in-country training courses has been conducted, targeting NGO and extension staff, and executed in collaboration with NARS, the SADC Seed Security Network, ICRISAT, CIAT, and IITA/SARNET. More than 200 individuals have attended trainings to date. An inter-center training manual was developed and is being distributed together with CD-ROMs that contain Powerpoint presentations of the lectures to foster the dissemination of training lessons.

One exciting training opportunity provided by the eastern Africa project was a visit made by four Ugandan farmers from Lira and Iganga districts and two technicians to Kenya. The group attended field days, visited farmers engaged in variety testing, key seed production sites, seed company operations, and some KARI research centers working on maize improvement. The farmers referred to the visit as an "educative and a historical one," adding that they "…learnt a lot of knowledge and skills that they were going to implement for the benefit of their fellow farmers." As a result of this trip, the participants were invigorated and determined to (i) re-organize their farmer association, (ii) train extension staff, (iii) establish stockist shops for farm inputs, (iv) mount campaigns for planting improved seeds and for fertilizers use, (v) increase the number of farmers multiplying seed, (vi) seek out markets for seed, and

(vii) improve seed storage system facilities at individual farmers' homes and at the group facility. Kenyan farmers subsequently visited Uganda to benefit from their knowledge about community production of maize seed. The project also had hands-on training for farmers already involved in seed production.

Training and Development of Facilities for Biotechnology and Biosafety within the IRMA Project (Kenya)

Decision-makers, scientists, and the public in many African countries have had little opportunity to be involved in projects that deal with transgenic crops. The Insect Resistant Maize for Africa (IRMA) project, a collaboration between KARI and CIMMYT, and funded by the Syngenta Foundation for Sustainable Agriculture, enhances the development, evaluation, dissemination, and monitoring of insect resistant maize varieties, but also exposes scientists, technicians, research managers and other stakeholders to a wide range of issues related to transgenic crops. More than 250 people have benefited from these training opportunities on topics such as

- the science of biotechnology and biosafety;
- laboratory, greenhouse, and field testing operations and procedures;
- biotechnology and biosafety policies, legislation, and enforcement;
- practical applications in biotechnology;
- conducting participatory rural appraisals and impact assessment studies;
- field and open days to visit trials; and
- communication and media relations.

Among the facilities developed are a level-2 biosafety greenhouse complex and a level-2 biosafety laboratory, and a comprehensive plan for laboratories at the KARI Biotechnology Center at KARI NARL. Other infrastructure developments are an open quarantine site, a seed store with air conditioning facilities at KARI Kiboko, computing and communication equipment, vehicles, laboratory equipment, and significant upgrading of an insectary at Katumani and entomology laboratories at KARI centers.

Contribution to Formal Training

CIMMYT's support to formal training (BSc, MSc. and PhD) of African scientists is an ongoing and many times overlooked investment in the future of agricultural research in SSA. In many instances, such training is only happening due to the dedication of individual scientists who spend additional work-hours on supervising thesis research projects under non-CIMMYT funding. As an example, the maize breeding team at CIMMYT-Zimbabwe alone is currently supervising 19 thesis projects of African students. A similar commitment comes from the other disciplines at CIMMYT-Zimbabwe and the team in eastern Africa. In terms of financial support over the past ten years, 66 students from SSA acknowledged CIMMYT's financial contribution to their thesis (Annex F).

Annex A: List of CIMMYT donor-funded projects active in sub-Saharan Africa during 2003

DESCRIPTION	DONOR	PROJECT LEADER
5214M1N SADLF PHASE II	SWITZERLAND	Banzinger M.
5210M1R SDFL PHASE II	ROCKEFELLER	Banzinger M.
5241M56 ENHANCING MICRONUTRIENTS IN MAIZE GRAIN PH. II	IFPRI	Banzinger M.
5210M2L RF-TAMU PHDS	ROCKEFELLER	Banzinger M.
5210M2Q CAPITAL ZIM	ROCKEFELLER	Banzinger M.
5204M3W USAID TARGET/TAF	USAID	Banzinger M.
5204M3X USAID OFDA	USAID	Banzinger M.
5263M3D QPM DEVELOPMENT CIMMYT-KENYA	NIPPON FOUND	Diallo A.
5201M3N QPM IN THE HORN OF AFRICA CIMMYT-KENYA	CIDA	Diallo A.
5217M87 STREAK VIRUS OF EARLY MATURING OF MAIZE	OPEC	Diallo A.
5210M4H STRESS TOLERANT MAIZE VARIETIES	ROCKEFELLER	Diallo A.
5289M1K SOUTHERN AFRICA HIGHVELD ECOREGION	REP OF SOUTH AFRICA	Friesen D.
5216M2Z STRESS TOLERANT MAIZE	GERMANY	Friesen D.
521WM4I ICIPE-STRIGA	DFID	Kanampiu F.
5231M4J SOIL MANAGEMENT LOWLAND MAIZE	SRI/DFID	Kanampiu F.
5210M4S IR MAIZE STEWARDSHIP	ROCKEFELLER	Kanampiu F.
5210M3Y QUALITY PROTEIN MAIZE	ROCKEFELLER	Kirubi D.
5283M1I DEPLOYMENT OF INSECT RESISTANT MAIZE-AFRICA	NOVARTIS FUND	Mugo S.
5210M5H MAIZE SEED SUPPLY SYSTEMS IN KENYA AND UGANDA	ROCKEFELLER	Mugo S.
5210M2B MAIZE SEED SUPPLYS SYSTEMS IN WEST KENYA & TANZANIA	ROCKEFELLER	Mugo S.
5131M77 MID ALTITUDE	DFID (ODA)	Pixley K.
5168M82 MAIZE SYSTEMS IN S.AFRICA	REP. S. AFRICA	Pixley K.
5263M3E QPM DEVELOPMENT CIMMYT-HARARE	NIPPON FOUND	Pixley K.
5263M3I QPM DEVELOPMENT-NARS	NIPPON FOUND	Pixley K.
5263M3K QPM DEVELOPMENT IITA WECAMEN	NIPPON FOUND	Pixley K.
5219M4X BIOFORTIFICATION CP MAIZE CROP LEADERSHIP	WORLD BANK	Pixley K.
5241M5E MAIZE HARVEST PLUS	HAVERST PLUS CP	Pixley K.
5263M3J QPM DEVELOPMENT-NARS	NIPPON FOUND	Pixley K.
5220M2C SEEDS OF LIFE-EAST TIMOR	ACIAR	Srinivasan G.
5201M3M QPM IN THE HORN OF AFRICA CIMMYT-ETHIOPIA	CIDA	Tanner D.
5201M3P QPM IN THE HORN OF AFRICA CIMMYT-NARS	CIDA	Tanner D.
5223M4Q ECAMAW COORDINATION UNIT	EU	Tanner D.
5204M4Z USAID-SEED ETHIOPIA	USAID	Tanner D.
5201M67 EAST AFRICA CEREALS - MAIZE PHASE IV	CIDA	Tanner D.
5263M3H QPM DEVELOPMENT ETHIOPIA	NIPPON FOUND	Twumasi A
5214M4K MAIZE IN NEPAL	SWITZERLAND	Urrea C.
5214M4L MAIZE IN NEPAL-NARC COMPONENT	SWITZERLAND	Urrea C.
5210M95 EAST AFRICA REGIONAL MAIZE NURSERY	ROCKEFELLER	Vivek V.

Annex B: Mother-baby trials in southern and eastern Africa

Table B-1. Collaborating partner organizations of NARS-led mother-baby trials in southern Africa

	Partner organizations involved in Mother-Baby Trials in SADC			
Country	**2001**	**2002**	**2003**	**2004**
Angola	0	3	3	7
Botswana	0	3	4	3
Lesotho	0	2	4	3
Malawi	4	4	4	3
Mozambique	6	3	12	19
RSA	10	10	10	10
Swaziland[$]	0	0	0	3
Tanzania	7	10	10	5
Zambia	0	7	7	9
Zimbabwe	14	14	14	13
Total	**34**	**56**	**64**	**75**

Table B-3 Mother-baby trials grown in southern and eastern Africa

	Number of Mother-Baby Trials			
Country	**2001**	**2002**	**2003**	**2004**
Angola	10	12	21	14
Botswana	0	5	7	7
Lesotho	0	6	6	10
Malawi	7	10	18	8
Mozambique	8	8	13	34
RSA	6	18	20	23
Swaziland	0	0	0	10
Tanzania	5	9	15	22
Zambia	0	17	17	15
Zimbabwe	26	26	26	28
Southern Africa	62	111	146	137
Ethiopia				
Kenya	82 (sum or three years)			
Uganda	41 (sum or three years)			
Eastern Africa	123 (sum or three years)			**106**

Table B-2. Partner organizations involved in mother-baby trials in eastern Africa

Country	Partner	Role
Kenya	CRS	Handle trials (plant & manage)
	Schools	Handle trials (plant & manage)
	Faida Seeds	Provide seed for testing
	Lagrotech	Provide seed for testing
	Western Seed Company	Provide seed for testing
	Kenya Seed Company	Provide seed for testing
	STP	Provide seed for testing
	Monsanto	Provide seed for testing
	National Program	Provide seed and management
	Farmers	Host trials and views
	CIMMYT	Expertise and seed
	Extension	Management
Uganda	IDEA	Handle trials (plant and manage)
	UNFA	Handle trials (plant and manage)
	Pannar	Provide seed
	Seed Co.	Provide seed
	Faida	Provide seed
	Western Seed	Provide seed
	National Program	Provide seed and management
	Farmers	Host trials and views
	CIMMYT	Expertise and seed
	Extension	Management

Annex C: Small grants funding by country and project (2001 and 2002)

Table C-1. Approved ECAMAW on-going small grant projects by country for 2001

Country	Maize		Wheat		Total	
	#	USD	#	USD	#	USD
Burundi	3	2,000	0	0	3	2,000
Eritrea	0	0	2	3,466	2	3,466
DR Congo	0	0	0	0	0	0
Ethiopia	11	21,100	5	7,789	16	28,889
Kenya	23	56,300	5	6,742	28	63,042
Madagascar	0	0	0	0	0	0
Rwanda	1	0	0	0	1	0
Sudan	1	1,000	0	0	1	1,000
Tanzania	9	21,100	2	2,516	11	23,616
Uganda	4	8,800	0	0	4	8,800
TOTAL	**52**	**110,300**	**14**	**20,513**	**66**	**130,813**

Table C-2. Funding allocation by country

Country	No. projects	Total US$
DR Congo =	1	1,341
Ethiopia =	12	30,720
Kenya =	18	55,928
Tanzania =	10	29,258
Uganda =	4	6,766
TOTAL =	**45**	**124,013**

Table C-3. Funding allocation by project and source

Project and/or source of funds	Total US$
EACP/ CIDA =	16,000
AMS/ BMZ =	63,941
AMS/ IFAD =	35,472
REGNUR/ RF =	8,000
MSV/ OPEC =	600
TOTAL =	**124,013**

Annex D: Africa-based training activities of selected projects 1998 – 2004

#	Title	Project	Type	Location	Dates	Duration	Participants
1	Ph.D degrees	AMS	Ph.D.	Zimbabwe, Kenya, Mexico	2002-2004	3 years	1
2	Management of Drought, Nitrogen, and Striga in Maize	AMS	Training	Ethiopia	2000	15	8
3	Breeding for Drought and Low N Tolerance in Maize, Fieldbook/Alpha software, GIS	AMS	Training	Kenya	2000	17	37
4	Fieldbook/Alpha software	AMS	Training	Kenya	1999	3	20
5	Use of Africa Maize Research Atlas	AMS	Training	Kenya	1999	2	80
6	Breeding for Drought and Low N Tolerance in Maize, Fieldbook/Alpha software, GIS	AMS	Training	Tanzania	1998	13	17
7	Breeding for Drought and Low N Tolerance in Maize	AMS	V.Sc.	Kenya	2000	6 months	2
8	Breeding for Drought and Low N Tolerance in Maize	AMS	V.Sc.	Kenya	1999	18 months	2
9	Breeding for Drought and Low N Tolerance in Maize, Fieldbook/Alpha software, GIS	AMS/SADLF	Training	Kenya	1999	13	36
10	Maize Crop Management Research	CMRT	Training	Kenya	2000	180	20
11	Maize Crop Management Research	CMRT	Training	Kenya	1999	180	20
12	Maize Crop Management Research	CMRT	Training	Kenya	1998	180	15
13	Fieldbook/Alpha software	Core	Training	Mozambique	2003	2	8
14	Maize Seed Production	Core	Training	Zimbabwe	2002	3	30
15	Maize Seed Production	Core	Training	Zimbabwe	1999	10	40
16	Genetic dissection, QTL identification, and marker-assisted selection to improve insect resistance and drought tolerance in maize	DGIS	Training	Zimbabwe	2000	7	6
17	Scientific Writing and Proposal Development	ECAMAW	Training	Ethiopia	2000	10	15
18	Scientific Writing and Proposal Development	ECAMAW	Training	Kenya	2000	10	15
19	Scientific Writing and Proposal Development	ECAMAW	Training	Uganda	2000	10	15
20	Analysis of Nutrient Response Trials	ECAMAW	Training	Kenya	1999	11	19
21	Training of Trainers in Gender Analysis	ECAMAW	Training	Kenya	1999	10	18
22	Scientific Writing and Gender Analysis	ECAMAW	Training	Tanzania	1998	6	23
23	Fieldbook/Alpha software	Highland	Training	Ethiopia	2000	5	25
24	Use of Africa Maize Research Atlas	Highland	Training	Ethiopia	1999	2	25
25	Field day at the open quarantine site	IRMA	Field day	Kenya		1	18
26	Field day at the open quarantine site	IRMA	Field day	Kenya		1	50
27	Visit of biosafety greenhouse complex	IRMA	Field day	Kenya		1	12
28	Masters degrees	IRMA	M.Sc.	Kenya		1-2 years	8
29	Training for parliamentarians	IRMA	Training	Kenya		2	50
30	Training for parliamentarians	IRMA	Training	Kenya		2	50
31	Management of open quarantine facilities	IRMA	Training	Kenya		3	10
32	Training on biosaferty greenhouse operations	IRMA	Training	Kenya		5	30
33	Development of biosafety laboratory and greenhouse facilities	IRMA	Training	Kenya		30	5
34	Development of biosafety laboratory and greenhouse facilities	IRMA	V.Sc.	Mexico		6	1
35	Visit to CIMMYT Mexico and Department of Agriculture, Mexico	IRMA	V.Sc.	Mexico		11	4
36	Bioassays and insectary operations	IRMA	V.Sc.	Mexico		14	2
37	Management of biosafety facilities	IRMA	V.Sc.	Mexico		14	3
38	Maize entomology lab and ABC, CIMMYT, Mexico	IRMA	V.Sc.	Mexico		15	2
39	Transformation and molecular analysis	IRMA	V.Sc.	Mexico		180	2
40	Assessment of Maize Stress Technologies Management	IRMA	V.Sc.	Nigeria		14	1
41	Tour of biosafety facilities in the USA & Mexico by senior management officials	IRMA	V.Sc.	USA & Mexico		14	6
42	Visit post harvest research at CIMMYT Harare	IRMA	V.Sc.	Zimbabwe		14	1
43	Maize Research Technician Training	MWIRNET	Training	Zimbabwe	1999	11	21
44	Maize Research Technician Training	MWIRNET	Training	Swaziland	1998	11	18
45	Training in socio-economics	MWIRNET	Training	Zimbabwe	1998	3	5
46	Field Visits to Zimbabwe and Mozambique	MWIRNET-RSA	Field Tour	Zimbabwe and Mozambique	2000	5 days	9

#	Title	Project	Type	Location	Dates	Duration	Participants
47	On Farm Research Tools and Methods	MWIRNET-RSA	Training	South Africa/ Drakensville	2000	5 days	36
48	On Farm Experimentaion Planning	MWIRNET-RSA	Training	South Africa/ Izongoweni	2000	5 days	40
49	Training Workshop on dignostics techniques	MWIRNET-RSA	Training	South Africa/ Begville	2000	5 days	25
50	On Farm Research Training of Trainers	MWIRNET-RSA/FAO	Training	Zimbabwe	1999	3 weeks	14
51	Kenyan V.Sc. at CIMMYT-Zimbabwe	REGNUR	V.Sc.	Kenya	2003	10	1
52	Kenyan V.Sc. at CIMMYT-Zimbabwe	REGNUR	V.Sc.	Kenya	2003	5	2
53	Mozambiquean V.Sc. at CIMMYT-Zimbabwe	REGNUR	V.Sc.	Mozambique	2003	5	1
54	Participatory Research Methodologies	Risk Management	Training	Zimbabwe	2000	6	20
55	M.Sc. degrees	RF	M.Sc.	Zimbabwe, Zambia, Mozambique	2004	2 years	3
56	Ph.D degrees	RF	Ph.D.	Zimbabwe	2002-2006	4 years	4
57	On Farm Verification of Maize Cultivars	SADLF	Field Tour	South Africa	2001	7	43
58	On Farm Verification of Maize Cultivars	SADLF	Field Tour	Zimbabwe and Mozambique	2000	8	45
59	Low N screnning of maize germplasm	SADLF	Field Tour	Malawi and Zambia	1999	4	17
60	Field Tour, drought screening of maize germplasm	SADLF	Field Tour	Zimbabwe	1998	2	100
61	Data Analysis of Mother-Baby Trials	SADLF	Training	Botswana	2003	2	15
62	Implementation of Mother-Baby Trials	SADLF	Training	Malawi	2003	1	30
63	Implementation of Mother-Baby Trials	SADLF	Training	Mozambique	2003	2	38
64	Data Analysis of Mother-Baby Trials	SADLF	Training	Mozambique	2003	3	15
65	Implementation of Mother-Baby Trials	SADLF	Training	RSA	2003	1	28
66	Implementation of Mother-Baby Trials	SADLF	Training	Swaziland	2003	2	13
67	Implementation of Mother-Baby Trials	SADLF	Training	Tanzania	2003	1	35
68	Implementation of Mother-Baby Trials	SADLF	Training	Tanzania	2002	2	20
69	Implementation of Mother-Baby Trials	SADLF	Training	Zambia	2002	2	20
70	Implementation of Mother-Baby Trials	SADLF	Training	Malawi	2002	2	20
71	Implementation of Mother-Baby Trials	SADLF	Training	Zimbabwe	2002	2	60
72	Breeding for Drought and Low N Tolerance in Maize	SADLF	Training	Zimbabwe	2002	6	37
73	Data Analysis of Mother-Baby Trials	SADLF	Training	Zimbabwe	2002	5	8
74	Data Analysis of Mother-Baby Trials	SADLF	Training	Zimbabwe	2001	5	23
75	Use of Africa Maize Research Atlas	SADLF	Training	Zimbabwe	1999	2	80
76	Data Analysis	SADLF	Training	Lesotho	1998	3	25
77	Breeding for Drought and Low N Tolerance in Maize	SADLF	Training	Zimbabwe, RSA	1998	9	15
78	Lesothan V.Sc. at CIMMYT-Zimbabwe	SADLF	V.Sc.	Zimbabwe	2003	5	1
79	Malawian V.Sc. at CIMMYT-Zimbabwe	SADLF	V.Sc.	Zimbabwe	2003	120	1
80	Tanzanian V.Sc. at CIMMYT-Zimbabwe	SADLF	V.Sc.	Zimbabwe	2003	60	1
81	Malawian V.Sc. at CIMMYT-Zimbabwe	SADLF	V.Sc.	Zimbabwe	2002	7	2
82	Angolan V.Sc. at CIMMYT-Zimbabwe	SADLF	V.Sc.	Zimbabwe	2002	7	2
83	Mozambiquean V.Sc. at CIMMYT-Zimbabwe	SADLF	V.Sc.	Zimbabwe	2002	14	1
84	Tanzanian V.Sc. at CIMMYT-Zimbabwe	SADLF	V.Sc.	Zimbabwe	2002	14	1
85	Malawian V.Sc. at CIMMYT-Zimbabwe	SADLF	V.Sc.	Zimbabwe	2002	14	2
86	Zambian V.Sc. at CIMMYT-Zimbabwe	SADLF	V.Sc.	Zimbabwe	2002	14	1
87	South African V.Sc. at CIMMYT-Zimbabwe	SADLF	V.Sc.	Zimbabwe	2002	4	1
88	Angolan V.Sc. at CIMMYT-Zimbabwe	SADLF	V.Sc.	Zimbabwe	2002	14	1
89	GxE analysis of Regional Trials	SADLF	V.Sc.	Zimbabwe	2002	30	4
90	Tanzanian V.Sc. at CIMMYT-Zimbabwe	SADLF	V.Sc.	Zimbabwe	2001	45	2
91	South African V.Sc. at CIMMYT-Zimbabwe	SADLF	V.Sc.	Zimbabwe	2001	14	1
92	Angolan V.Sc. at CIMMYT-Zimbabwe	SADLF	V.Sc.	Zimbabwe	2001	14	3
93	Zimbabwaen V.Sc. at CIMMYT-Zimbabwe	SADLF	V.Sc.	Zimbabwe	2001	25	2
94	Malawian V.Sc. at CIMMYT-Zimbabwe	SADLF	V.Sc.	Zimbabwe	2001	11	3
95	Zambian V.Sc. at CIMMYT-Zimbabwe	SADLF	V.Sc.	Zimbabwe	2001	64	1
96	Angolan V.Sc. at CIMMYT-Zimbabwe	SADLF	V.Sc.	Zimbabwe	2000	5	3
97	South African V.Sc. at CIMMYT-Zimbabwe	SADLF	V.Sc.	Zimbabwe	2000	7	1
98	Mozambiquean V.Sc. at CIMMYT-Zimbabwe	SADLF	V.Sc.	Zimbabwe	2000	3	2
99	Malawian V.Sc. To Zambia	SADLF	V.Sc.	Zimbabwe	2000	6	1
100	South African V.Sc. at CIMMYT-Zimbabwe	SADLF	V.Sc.	Zimbabwe	2000	5	2
101	Tanzanian V.Sc. at CIMMYT-Zimbabwe	SADLF	V.Sc.	Zimbabwe	2000	27	2
102	Lesothan V.Sc. at CIMMYT-Zimbabwe	SADLF	V.Sc.	Zimbabwe	1999	4	1

#	Title	Project	Type	Location	Dates	Duration	Participants
103	Zimbabwaen V.Sc. at CIMMYT-Zimbabwe	SADLF	V.Sc.	Zimbabwe	1999	2	1
104	Zimbabwean V.Sc. to South Africa	SADLF	V.Sc.	South Africa	1999	2	3
105	South Africa V.Sc. to Zambia, Zimbabwe	SADLF	V.Sc.	Zambia, Zimbabwe	1998	7	2
106	Malawian V.Sc. To Zambia	SADLF	V.Sc.	Zambia	1998	3	2
107	Mozambiquean V.Sc. at CIMMYT-Zimbabwe	SADLF	V.Sc.	Zimbabwe	1998	10	2
108	SADLF Collaborator's Workshop	SADLF	Workshop	South Africa	2003	4	48
109	SADLF Collaborator's Workshop	SADLF	Workshop	Zambia	2002	5	43
110	SADLF Collaborator's Workshop	SADLF	Workshop	Botswana	2001	3	30
111	Low soil pH workshop	SADLF	Workshop	South Africa	2001	4	16
112	SADLF Collaborator's Workshop	SADLF	Workshop	Zimbabwe	2000	5	32
113	Low soil pH workshop	SADLF	Workshop	South Africa	2000	3	28
114	SADLF Collaborator's Workshop	SADLF	Workshop	Zimbabwe	1999	5	26
115	SADLF Collaborator's Workshop	SADLF	Workshop	Zimbabwe	1998	4	22
116	Regional Variety Release	SADLF/SSSN	Workshop	Botswana	2003	3	35
117	Seed Production Course	Seed EA	Training	Uganda	2003	3	34
118	Seed Production Course	Seed EA	Training	Kenya	2002	4	30
119	Maize Seed Production	Seed EA	Training	Kenya	2001	3	31
120	Management of Mother-Baby Trials	Seed EA	Training	Kenya	2001	3	16
121	Seed Production Course	Seed EA	Training	Kenya	2001	4	30
122	Seed Production Course	Seed EA	Training	Uganda	2001	3	27
123	Seed Production Course	Seed EA	Training	Kenya	1998	5	34
124	CIMMYT Seed Week & Mexico Visit	Seed EA	V.Sc.	Mexico	2002	13	2
125	Management of Mother-Baby Trials	Seed EA	V.Sc.	Zimbabwe	2001	5	2
126	Field Survey Design and Implementation	Seeds & Impacts	Training	Mozambique	2004	3 days	9
127	Field Survey Design and Implementation	Seeds & Impacts	Training	Zambia	2004	3 days	9
128	Field Survey Design and Implementation	Seeds & Impacts	Training	Malalwiy	2004	3 days	9
129	Available Soil Fertility Practices	Soil Fert Net	Field Tour	Malawi	2003	5	18
130	Integrated Soil Fertility Research	Soil Fert Net	Field Tour	Malawi	2001	3	28
131	Soil fertility technologies on problem soils	Soil Fert Net	Field Tour	Zambia	2001	9	28
132	Sustainable Livelihoods and Social Analysis for Soil Fertility	Soil Fert Net	Field Tour	Zimbabwe	2000	4	33
133	Soil fertility research and extension in Zambia	Soil Fert Net	Field Tour	Malawi	1999	6	26
134	Soil pH and liming	Soil Fert Net	Field Tour	Zambia	1999	8	23
135	Masters degrees	Soil Fert Net	M.Sc.	Pretoria/Zambia	2003-2004	2 years	1
136	Masters degrees	Soil Fert Net	M.Sc.	Zimbabwe	2001-2003	2years	11
137	Masters degrees	Soil Fert Net	M.Sc.	Malawi	2001-2003	2years	15
138	Ph.D degrees	Soil Fert Net	Ph.D.	Malalwi/Germany	2003-	3 years	1
139	Ph.D degrees	Soil Fert Net	Ph.D.	Pretoria/Malalwi	2001-	4years	1
140	Soil Fertility and Food Security for the Poor in Southern Africa: Technical, Policy and Institutional Challenges	Soil Fert Net	Training	South Africa	2003	6	25
141	Economic Evaluation of Natural Resources and Soil Fertility	Soil Fert Net	Training	Zimbabwe	2002	5	29
142	Enhancing the Adoption of Soil Fertility Management Technologies for Sustainable Food Security in Southern Africa: The Role of Policy Instruments and Advocacy	Soil Fert Net	Workshop	Zambia	2003	5	37
143	Looking to the Future of Soil Fert Net	Soil Fert Net	Workshop	Zambia	2003	3	19
144	Agroforestry Impacts on Livelihoods in Southern Africa: Putting Research into Practice	Soil Fert Net	Workshop	SouthAfrica	2002	3	11
145	Grain Legumes and Green Manures for Soil Fertility in Southern Africa: Taking Stock of Progress	Soil Fert Net	Workshop	Zimbabwe	2002	5	56
146	East Meets South - Strengthening Ties and Synergies	Soil Fert Net	Workshop	Tanzania	2001	2001	10
147	Soil Fert Net Management Planning	Soil Fert Net	Workshop	Zimbabwe	2001	2	16
148	Understanding the Adoption and Impact of Soil Fertility Technologies	Soil Fert Net	Workshop	Zimbabwe	2001	4	45
149	First regional meeting of the Economics and Policy Working Group (EPWG)	Soil Fert Net	Workshop	Malawi	2000	3	33
150	Best bet soil fertility technologies, revisited	Soil Fert Net	Workshop	Malawi	1999	3	42
151	Policy and economics working session	Soil Fert Net	Workshop	Zimbabwe	1999	3	25
152	Combined use of organic and inorganic sources	Soil Fert Net	Workshop	Zimbabwe	1998	3	25

Annex E: Publications

This Annex provides a listing of two types of publications:

A. Selected CIMMYT staff-authored publications with relevance to research in SSA, 1999 – 2003

B. Publications developed in the frame of the Soil Fert Net, as an example for the kind of scientific interaction promoted by one of CIMMYT's SSA-based networks

A. Selected CIMMYT staff -authored publications (1999 – 2003) with relevance to research in SSA

Journal articles

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Velvet bean for soil fertility management in the smallholder farming sector of Zimbabwe. (2002). Lucia Muza, Agronomy Institute, DR&SS, Zimbabwe.

Cowpea: A traditional multipurpose grain legume for smallholders in Zimbabwe. (2002). Stephen Waddington, Ishmael Pompi and Shephard Siziba. CIMMYT-Soil Fert Net and Agronomy Institute, DR&SS, Zimbabwe.

Experimental Protocols:

Combined inorganic-organic nutrient sources: Experimental protocols for TSBF-AfNet, SoilFertNet and SWNM. (1999). Patrick Mutuo and Cheryl Palm. TSBF, Kenya.

Information Brochures:

Economics and policy initiative for southern Africa (1999). Soil Fert Net.

Soil fertility network for maize-based cropping systems in Malawi and Zimbabwe 1999 Soil Fert Net coordinator.

Annual Reports:

Soil Fert Net annual reports for 1995 to 2002. Soil Fert Net coordinators.

Annex F: Sub-Saharan African students acknowledging CIMMYT support to their academic research work (1993 – 2002)

The following is a listing of students from SSA which record CIMMYT and its support - either financial or through the use of its research resources - in the thesis itself or in a journal article based on the thesis. An acknowledgement to CIMMYT for the use of its seeds or its library is not sufficient to make a thesis eligible; nor is an acknowledgment to a member of CIMMYT's staff, whether for scientific counseling, for moral support, or for serving on the thesis committee. In practice, the eligibility rule has permitted us to make clear yes/no decisions in almost all cases; this, unfortunately, has been at the cost of omitting a number of theses for which individual members of CIMMYT staff had invested considerable personal effort.

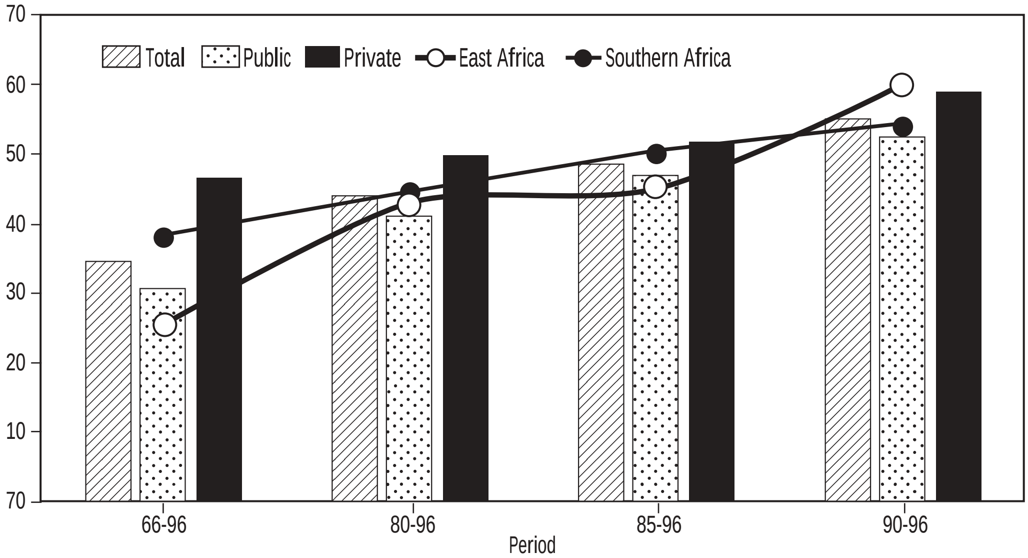
Student	Country of Origin	University	Year
Adriano Muiocoto Andre	Angola	ZA-UFS	2001
Ebrottie Kouacou	Cote d'Ivore	CI-ENSA	1995
Kabran Koffi Alain	Cote d'Ivore	CI-ENSA	1995
Kouassi Kan Jérémie	Cote d'Ivore	CI-ENSA	1995
Belay Derza Gaga	Ethiopia	MX-CP	2002
Amsal Tarekegne Tesfaye	Ethiopia	ZA-UFS	2001
Asefa Taa Weyesa	Ethiopia	ZA-UFS	2001
Amanuel Gorfu	Ethiopia	DE-GAU	1998
Asmare Yalew	Ethiopia	NL-LUW	1998
Getachew Boru	Ethiopia	US-OreSU	1996
Ayele Badebo Huluka	Ethiopia	NL-LUW	1994
Mulugetta Mekuria	Ethiopia	US-MichSU	1994
Tilahum Geleto	Ethiopia	ET-AUA	1994
Legesse Dadi	Ethiopia	ET-AUA	1993
Peter Adusei-Akowuah	Ghana	US-IowaSU	1997
Stella A Ennin	Ghana	US-UNeb	1997
Joseph Nketiah Berchie	Ghana	GB-UNott	1996
Joyce Haleegoah	Ghana	CA-UGuelph	1996
Albert Siaw Akyeampong	Ghana	GB-URead	1995
Angson Henry Dakurah	Ghana	US-ColSU	1995
Julius Q Ametefe	Ghana	GB-UEA	1994
Francis Boa-Amponsem	Ghana	US-UNeb	1993
Grace Esi-Kyirem Bolfrey	Ghana	US-MissSU	1993
Isaac Osei Owusu Ansah	Ghana	GB-URead	1993
George Owuor	Kenya	KE-Egerton	2002
Francis M Kirigwi	Kenya	US-KanSU	2001
Stephen Ngure Mugo	Kenya	US-Cornell	1999
Miriam Gaceri Kinyua	Kenya	KE-UNairobi	1997
Kelly Jean Nightingale	Kenya	US-MichSU	1996
Anne Wanjiru Wangai	Kenya	GB-URead	1994
Willie Gresham Nhlane	Malawi	GB-URead	1995
Pedro Fato	Mozambique	ZA-UFS	2000
Elfadl Yousif Elmogtaba	Sudan	DE-UHo	2002
Amani Ahmed Mohamed Idris	Sudan	SD-UG	1994
Amir Mohamed Hussein Ibrahim	Sudan	LB-AUB	1994
Komi Egle	Togo	DE-GAU	1998
Ephraim M Nkonya	Tanzania	US-KanSU	1999
George Bigirwa	Uganda	UG-Mak	1997
Denis Tumwesigye Kyetere	Uganda	US-OhioSU	1995

Student	Country of Origin	University	Year
Sabastian Mawere	Zimbabwe	ZW-ZOU	2001
Shorai Munjoma	Zimbabwe	ZW-UZ	2001
Philip Tichafa Mushayi	Zimbabwe	ZW-UZ	2001
Elliot Tembo	Zimbabwe	ZW-ZOU	2001
Thanda Dhliwayo	Zimbabwe	ZW-UZ	2000
Vivian Kazembe	Zimbabwe	ZW-UZ	2000
Ereck Chakauya	Zimbabwe	ZW-UZ	1999
John Derera	Zimbabwe	ZW-UZ	1999
Nelson Nhamo Gororo	Zimbabwe	AU-UMelb	1999
Rose Machiridza	Zimbabwe	ZW-UZ	1999
Rudo D Mazvodza	Zimbabwe	ZW-UZ	1999
Loretta T Rukobo	Zimbabwe	ZW-UZ	1999
Peter Jeranyama	Zimbabwe	US-MichSU	1998
Cosmos Magorokosho	Zimbabwe	ZW-UZ	1998
Sakile Nsingo	Zimbabwe	ZW-UZ	1997
Tsungai Bwerazuva	Zimbabwe	ZW-UZ	1996
Nelson Munyaka	Zimbabwe	ZW-UZ	1996
Berita Musara	Zimbabwe	ZW-UZ	1996
Charity Chikwati	Zimbabwe	ZW-UZ	1995
Sikhulile Moyo	Zimbabwe	ZW-UZ	1995
Maxmilian Mugabe	Zimbabwe	ZW-UZ	1995
Clappaton Chiwera	Zimbabwe	ZW-UZ	1994
Xavier Mhike	Zimbabwe	ZW-UZ	1994
Passmore Mukando	Zimbabwe	ZW-UZ	1994

Annex G: Constraints to maize production as listed by NARS in eastern and southern Africa

Country	Constraints
ANGOLA	Drought, low soil fertility, high soil pH, disease, acidity; Lack of inputs, market organizations; poor seed quality; political instability.
BOTSWANA	Environment (rain fall); sandy soils; technical, socioeconomic and policy constraints.
LESOTHO	Lack of trained personnel to conduct research; poor soils and low rainfall; high fertilizer and seed prices; drought, pests and diseases
MALAWI	Low productivity; declining soil fertility; low profitability drought; pests and diseases
MOZAMBIQUE	Soil fertility; drought; pests; diseases; weeds
NAMIBIA	Rainfall; no short season cultivars or OPVs available; high input costs; imported maize cheaper.
SOUTH AFRICA	Drought, poor soils, pests, diseases, weeds, inadequate equipment/infrastructure, poor seed and grain quality
SWAZILAND	Erratic rainfall; pests and diseases; lack of appropriate germplasm
TANZANIA	Drought; soil fertility; MSV; Striga; stalk borer; post harvest loss; unavailability of inputs
ZAMBIA	Weather; Low product prices; unavailable credits; high input prices
ZIMBABWE	Drought, low soil fertility, stalk borer, leaf blight, grey leaf spot, storage pests
EAST AFRICA	Low yield potential (especially in the highlands); foliar disease; drought; stalk borers; maize streak virus; poor soil fertility (particularly low N); storage pests; weeds; termites; Striga

Annex H: Use of CIMMYT maize germplasm in eastern and southern Africa: percent of new maize cultivars (1966-96)

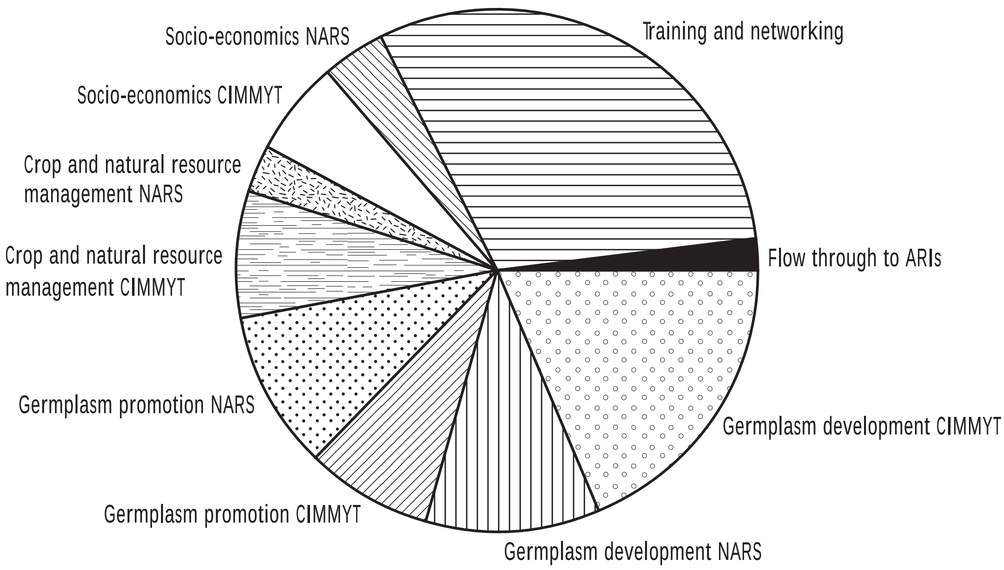


Annex I: Use of CIMMYT budget in 2003

The figure below provides a glimpse of how CIMMYT used its maize-related resources (approximately US$6.1 million) in SSA in 2003. The chart does not include funds that were given by donors directly to NARS within the framework of CIMMYT-collaborative projects (e.g., SoilFertNet, MSc and PhD training grants). Furthermore, there is considerable work and spillovers for SSA from CIMMYT projects in Latin America and Asia that are not included in the calculations below.

- Funds indicated with "CIMMYT" are resource used for CIMMYT-based research activities in SSA.
- Funds indicated with "NARS" are flow-through funds, which are transferred in cash and kind (supplies, capital) to NARS in SSA.
- "Training and networking" encompass all direct costs used for training courses, workshops, visiting scientists, network coordination including proportion of IRS time (IRS based in SSA).

Use of 2003 CIMMYT Budget



Annex J. CIMMYT international staff in SSA

Name	First Name	% Time	Location	Discipline
IRS in the SSA-Livelihood Program				
McLean	Scott	20	Mexico	Biotechnology
Ribaut	Jean-Marcel	30	Mexico	Biotechnology
Sawkins	Mark	30	Mexico	Biotechnology
Poland	David	50	Mexico	Communications
Tanner	Douglas	100	Ethiopia	Crop and resource management
Friesen	Dennis	100	Kenya	Crop and resource management
Kanampiu	Fred	100	Kenya	Crop and resource management
Wall	Pat	70	Mexico	Crop and resource management
Shamudzarira	Zondai	100	Zimbabwe	Crop and resource management
Waddington	Stephen	80	Zimbabwe	Crop and resource management
Mduruma	Zubeda	100	Ethiopia	Maize improvement
Twumasi	Strafford	100	Ethiopia	Maize improvement
Diallo	Alpha	100	Kenya	Maize improvement
Kirubi	Duncan	100	Kenya	Maize improvement
Mugo	Stephen	100	Kenya	Maize improvement
Bergvinson	David	40	Mexico	Maize improvement
Cordova	Hugo	20	Mexico	Maize improvement
Pandey	Shivaji	100	Mexico	Maize improvement
Banziger	Marianne	100	Zimbabwe	Maize improvement
Mwala	Mick	100	Zimbabwe	Maize improvement
Setimela	Peter	100	Zimbabwe	Maize improvement
Vivek	Bindi	100	Zimbabwe	Maize improvement
De Groote	Hugo	70	Kenya	Social sciences
Mwangi	Wilf	100	Kenya	Social sciences
Kamanga	Bernard	100	Zimbabwe	Social sciences
Langyintuo	Augustine	70	Zimbabwe	Social sciences
Mekuria	Mulugetta	80	Zimbabwe	Social sciences
IRS that were in RP1 and had maize-related activities				
Grimanelli	Daniel	10	Mexico	Biotechnology
Hearne	Sarah	20	Mexico	Biotechnology
Esilaba	Anthony	100	Ethiopia	Crop and resource management
Grace	Peter	25	Mexico	Crop and resource management
Hodson	David	50	Mexico	Crop and resource management
White	Jeff	15	Mexico	Crop and resource management
Vaughan	Kit	60	Zimbabwe	Crop and resource management
DeMeyer	Julien	50	Zimbabwe	Maize improvement
Jewell	David	75	Zimbabwe	Maize improvement
Pixley	Kevin	100	Zimbabwe	Maize improvement
Zambezi	Batson	65	Zimbabwe	Maize improvement
Verkuijl	Hugo	40	Ethiopia	Social sciences
Bellon	Mauricio	30	Mexico	Social sciences

Annex K. CIMMYT national staff in SSA

Name	First Name	Position	Location
Aklilewerk	Bekele	Secretary	Ethiopia
Antenyismu	Workalemahu	Liaison Assistant	Ethiopia
Gozguze	Mamo	Driver	Ethiopia
Worknesh	Gudetta	Office Cleaning	Ethiopia
Joseph	Kasango	Research Technician	Kenya
Peter	Mbogo	Field/Lab Technician	Kenya
Vincent	Eget	Field/Lab Technician	Kenya
Muthoka	Mailu	Field Technician	Kenya
Carolyne	Adhiambo	Skilled Labourer	Kenya
Ebby	Irungu	Administrative Assistant	Kenya
Linda	Alondo-Ackel	Administrative Secretary	Kenya
Alfred	Imbai	Principal Office Attendant - Accounts	Kenya
Isaac	Mutabai	Principal Driver	Kenya
Haron Ndiritu	Mwangi	Driver	Kenya
Siziba	Shephard	Research Associate	Zimbabwe
Nyamutowa	Evelot	Research Officer	Zimbabwe
Mawere	Sebastian	Research Officer	Zimbabwe
Damu	Nathan	Research Officer	Zimbabwe
Masukume	Morris	Research Officer	Zimbabwe
Chuma	Gesham	Research Assistant	Zimbabwe
Chisoro	Simbarashe	Research Assistant	Zimbabwe
Karigwindi	Johannes	Research Assistant	Zimbabwe
Dhliwayo	Thanda	Research Assistant (temp)	Zimbabwe
Munjoma	Shorai	Research Assistant (temp)	Zimbabwe
Phiri	Sign	Field Supervisor	Zimbabwe
Shoko	Martin	Senior Recorder	Zimbabwe
Chiputu	Moses	Senior Recorder	Zimbabwe
Maramba	Emma	Recorder 1	Zimbabwe
Chifamba	John	Recorder 1	Zimbabwe
Ndhlovu	Takesure	Recorder 1	Zimbabwe
Tambudzana	Dudu	Field Assistant 2	Zimbabwe
Chiunye	Ephias	Field Assistant 2	Zimbabwe
Viola	Semai	Field Assistant 2	Zimbabwe
Dzingisai	Bob	Field Assistant 1	Zimbabwe
Mupfawa	Batanai	Field Assistant 1	Zimbabwe
Gomo	Patience	Field Assistant 1	Zimbabwe
Chiunye	Everisto	Field Assistant 1	Zimbabwe
Makamba	Joseph	Field Assistant 1	Zimbabwe
Nyamande	Boniface	Field Assistant 1	Zimbabwe
Samudzimu	Christine	Human Resources & Administration Manager	Zimbabwe
Tofa	Esau	Senior Accountant/Administrator	Zimbabwe
Moyo	Nothando	Junior Administrator	Zimbabwe
Gumbo	Tsungayi	Secretary/Admin. Assistant	Zimbabwe
Gwabi	Irene	Secretary	Zimbabwe
Rabson	Alice	Receptionist	Zimbabwe
Sikirivawu	Freddy	Senior Driver	Zimbabwe
Wadi	Mafiyo	Driver	Zimbabwe
Wadi	Takemore	Caretaker	Zimbabwe
Johannes	Mary	Cook/Custodian	Zimbabwe
Kamphasi	Maria	Assistant Cook/Custodian	Zimbabwe
Chanza	Readman	General Hand	Zimbabwe

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