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Invest in the Future

TODAY'S SCIENCE FOR TOMORROW'S IMPACT

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Our work demands creative scientific insight into an uncertain future. We know that the research we conduct today, if conducted with foresight and a concern for equity, will improve economic and environmental conditions for many poor people.

This sense of responsibility to the future is reflected in the articles presented here. Each article describes a new scientific endeavor, approach to research partnerships, or research tool that should contribute to future food security, poverty alleviation, and environmental well being.

THIS IS PROACTIVE SCIENCE ON BEHALF OF POOR PEOPLE.

FOREWORD

At a time of great change and uncertainty in the scientific world—particularly in the CGIAR—we thought it important to let our development partners and investors know that every day CIMMYT conducts research that is meeting the challenges of the future.

In uncertain times there is a tendency to stand back and wonder. We believe at CIMMYT that the realities and challenges of life for the resource-poor in developing countries cannot be put "on hold." Therefore we are not standing back but moving forward in a positive way on the issues that we think are vital to future food security, poverty alleviation, and natural resource protection.

This publication provides an insight into new science for development that has the potential to have huge impacts on the livelihoods of the rural and urban poor. New science at CIMMYT encompasses a full range of development activities, from harnessing the power of functional genomics and computer modeling, to the development of exciting new technologies such as high nutrient maize, to innovative delivery of technologies into farmers' fields.

CIMMYT is developing and harnessing cutting-edge science (see the stories on genomics; on software to answer breeding questions; insect resistant maize for Africa). We are engaging with advanced research institutes (ARIs) and the private sector in "win-win" alliances to lever the resources of the North onto the problems and opportunities of the South (see "Public/Private Sector Alliances") in ways that strengthen our partnerships with national research systems. At the same time, we are forming new and innovative partnerships with farmers, non-governmental organizations, seed companies, rural communities, and extension agents to deliver technologies where they are needed (see "Farmers' Voices Are Heard Here" and "New Tillage Practices for South South Asia").

CIMMYT's work is already largely focused on sub-Saharan Africa and South Asia (around 70% of expenditure), but we are not forgetting the resource-poor of Central America. We believe investment in CIMMYT now is an investment in the future livelihoods of the resource-poor. We thank our development partners for their support and seek an ongoing partnership as we move forward into the new millennium.

Timothy Reeves

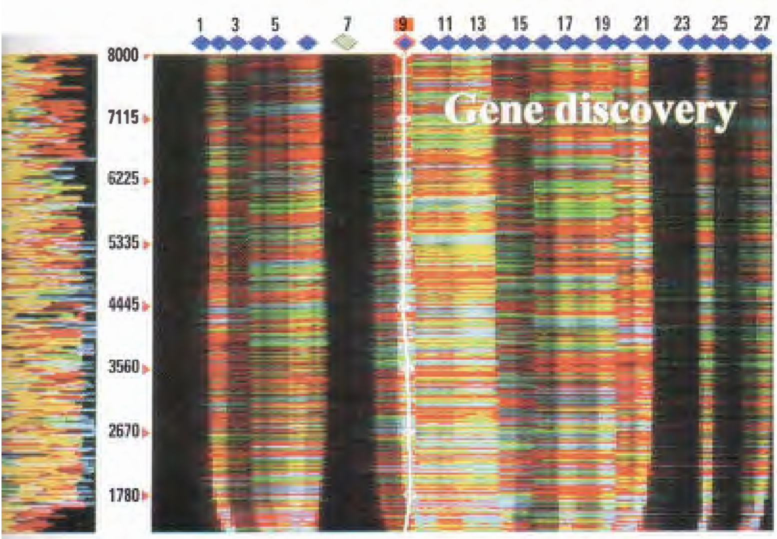
Prof. T.G. Reeves
Director General

FUNCTIONAL GENOMICS: The Force Behind the Future of Plant Breeding

The world is undergoing a revolution in efficiency fueled by advances in information and computer technology. One manifestation of this is a shift in all types of products and services from "one size fits all" to "custom fitting." This change is most visible in the retail world. Go to a company's website, select the features you want from drop-down menus, and in a matter of a week or more you are wearing your custom-made clothes or driving a car manufactured just for you. This type of production is not only more efficient and profitable for producers, but better meets consumer needs as well. Impossible just a few years ago, today it is a dividend of technology.

The flashy world of e-commerce may seem eons away from the patient and methodical world of plant breeding, but designer crop plants—plants that carry specifically selected genes with traits that allow them to thrive in particular environments or produce valued consumer characteristics—are now only earth years, not light years, in the future. The impact of such an advance on CIMMYT's clients could be immense. Crop varieties could be "ordered" to meet both local consumer preferences and the demands of the niche environments where the crop is being grown.

Below: **The output of a high-throughput gene sequencer at CIMMYT's new facility.** Eight hundred base pairs of 27 genes (lanes indicated by the blue diamonds at top) are depicted. DNA sequences are indicated by color, with red indicating T; blue, C, yellow, G; and green, A. Sophisticated bioinformatic tools are used to derive useful information from such data.



IDENTIFYING GENES AND GENE FUNCTIONS

Functional genomics is a major force behind this imminent revolution. Defined simplistically, functional genomics is a scientific approach that seeks to identify and define the function of genes, and uncover when and how genes work together to produce traits. Current structural genomic approaches (i.e., mapping) generally focus on traits controlled by one or only a few genes, and often they only provide information regarding the location of a gene or genes in the genome.

Although location information is a critical first step, functional genomics goes further to examine the interrelationships and interactions between thousands of genes to determine when and why certain traits are expressed, which sets of genes are specifically responsible for that expression, and under what conditions. Armed with this information, scientists will be well equipped for efficiently creating varieties with exact combinations of traits. Globally, if varieties are produced that can optimize the yield potential under any given set of conditions, a large step would be taken towards meeting our growing demand for food.

Global Advances

Recent developments, both within and outside of CIMMYT, have brought functional genomics to the fore. In the global arena, the public release of the gene sequences of wild mustard (*Arabidopsis thaliana*) and rice has made a wealth of information available to scientists. Because the genes that code for scores of plant traits and processes are similar across many species, this knowledge can be applied to genetic research on wheat, maize, and other crops. Furthermore, rapid improvements in innovations, such as microarray technology, make it possible for scientists to generate data on thousands of genes and expressed sequences (so-called "Expressed Sequence Tags" or ESTs) in their search for a trait, as opposed to looking at just a few specific "candidate genes."

Analyzing the mountains of data generated by such technologies falls into the realm of bioinformatics and requires powerful computational capabilities and highly sophisticated software, networking, and database packages—and the human resources to run them. Such resources, although expensive, are now available.

CIMMYT Advances

Developments within CIMMYT in many ways mirror those in the outside world. During the past year, a unit devoted to bioinformatics was created and incorporated into the Applied Biotechnology Center (ABC). On another front, the International Crop Information System (developed through the work of NARSs, seven CGIAR centers, and other advanced agricultural research centers) was released on CD in early 2000. This new product will be the foundation for more comprehensive crop data systems in the future. A gene sequencing facility was established at CIMMYT as well. It has enabled the Center to contribute more than 1,000 ESTs to the International Triticeae EST Consortium (ITEC, a group of 20 private and public labs, including CIMMYT), which will publicly release at least 20,000 wheat gene sequences by July 2000. Whereas a few years ago public institutes had only a handful of sequences to work with, they will now have an abundance. Such sequences are the raw materials for predicting the possible function of a gene, which can then be substantiated in DNA microarrays. These arrays, in turn, can provide data on when and under what conditions ESTs (or genes) express themselves. Mutagenesis and genetic engineering technology also employ ESTs to further define the function of a particular gene.

CIMMYT has also gained access to the data, expertise, and technologies to pursue functional genomics by forging partnerships and other arrangements with public and private sector research groups. The task of tackling a genome is too large for any single institution, but by leveraging CIMMYT's germplasm, research capabilities, and international stature, we aim to produce win-win situations for all the partners and ultimately for our clients in the developing world. There are several recent examples of such efforts.

In 1999, CIMMYT and the International Rice Research Institute (IRRI) launched the "Maize-Rice Functional Genomics Project," with some initial financial support from the CGIAR's Technical Advisory Committee. The ambitious aim of the project is to discover the key genes responsible for drought tolerance and to produce molecular tools that will enhance breeding for the requisite trait(s).

Another step in this critical area was the Strategic Planning Workshop on Molecular Approaches for the Genetic Improvement of Cereals in Water Limited Environments. Hosted and coordinated by CIMMYT, and funded by the Rockefeller Foundation, this international workshop assembled scientists to explore and propose molecular strategies for producing more drought resistant plants for developing countries.

Whether the ultimate goal is improved drought resistance, enhanced nutritive composition, or higher yield potential, functional genomics will undoubtedly play an increasingly importantly role in helping scientists achieve their aims. CIMMYT is committed to harnessing this powerful new approach to provide the world's resource-poor farmers the means to produce not just more food, but better food.

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FARMERS' VOICES

Are Heard Here

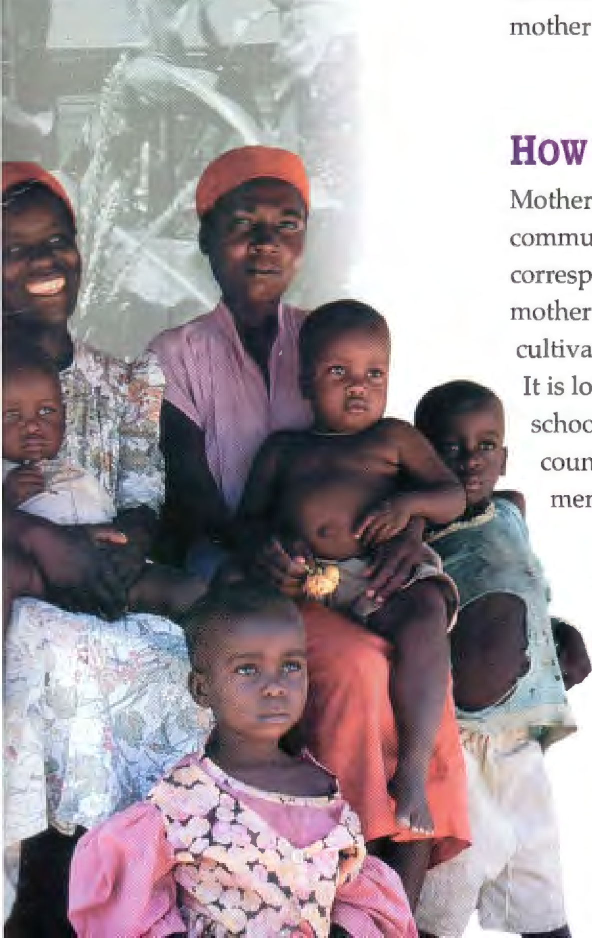
In one of the largest sets of farmer-participatory trials ever established in southern Africa, CIMMYT and its partners have found a powerful forum for resource-poor farmers to make their wishes known to the people and organizations that can give them the kind of- maize cultivars they want.

In rural communities across Zimbabwe, a new kind of research trial engages smallholder farmers in decisions that will help them obtain the kinds of maize cultivars they want to grow.

Ensuring that resource-poor farmers have access to maize cultivars that are suited to their specific farming conditions and preferences is a goal that CIMMYT researchers Marianne Bänziger and Julien de Meyer take very seriously. Through their innovative "mother-baby" trials, they are coming closer to this goal.

Over the past few years, Bänziger and her colleagues in southern Africa have focused on developing maize cultivars that produce more grain under severe drought and low soil fertility, two of the most common and challenging conditions of subsistence agriculture in the region. Through the Southern Africa Drought and Low Soil Fertility (SADLF) project, supported by the Swiss Agency for Development and Cooperation (SDC), they have developed experimental cultivars that yield 25-50% more under drought stress than popular local cultivars.

Now, a second set of challenges arises: to verify the performance and acceptance of stress-tolerant cultivars under resource-poor farmers' conditions and to ensure that the seed becomes available. That is where the mother/baby trials, established through SADLF, come into the picture.



HOW THE TRIALS WORK

Mother/baby trials are sets of experiments grown in and by farming communities. For each "mother" trial, there are as many as 6-12 corresponding "baby" trials within walking or bicycling distance. The mother trial, designed by researchers, evaluates a set of promising maize cultivars under optimal and farmer-representative management conditions. It is located in the center of a farming community, often at a secondary school, or with a progressive farmer, or at a research station. A local counterpart (a teacher of agriculture, an extension officer, or a staff member of a non-governmental organization) manages the mother trial.

All baby trials contain a subset of the cultivars in the mother trial (no more than four) and are planted and managed exclusively by the farmers that host them. Because farmers want to use the information from mother/baby trials for purchasing seed of a good cultivar in the following year, only half of the cultivars in the trial are experimental. The other half are open-pollinated varieties or hybrids already available on the market.

What's In A Name?

"These trials are like a mother with her babies." This is how a Malawian farmer described his perception of trials that ICRISAT researcher Sieglinde Snapp had established to test new practices for improving soil fertility. The trials featured one larger, researcher-managed trial with a complete set of treatments and several smaller, farmer-managed trials each having a selected set of treatments. They were all situated relatively close to each other, like a small family. This model has been adapted by CIMMYT and its partners to test new maize varieties and hybrids from the public and private sector under the real conditions of resource-poor farmers. The farmer found the perfect words to describe these kinds of trials to other farmers.

In 2000, 37 mother trials and more than 280 baby trials were planted all over Zimbabwe. Partners in implementing the trials included non-governmental organizations (NGOs) such as CARE International, SALRED (Southern African Unit for Local Resource Development), and ITDG (International Technology Development Group). They also included community development associations, such as the Horseshoe Farmer Association in northern Zimbabwe, in which commercial farmers link with smallholders to improve agriculture. Other partners were AGRITEX, the national extension service; secondary schools; and national research stations.

The demand by collaborating research and extension staff, and particularly NGOs, for mother/baby trials was so great that researchers ran out of seed. For 2001, Bänziger and de Meyer hope that similar testing systems are established by other countries in southern Africa.

Mother/baby trials address several problems encountered with traditional on-farm variety testing, in which one organization tries to manage many trials all over the countryside. These problems include high transport costs, delayed planting, poor supervision of trials, and poor contact with farmers. In the approach used with the mother/baby trials, the local partner provides established links to the community and intrinsic knowledge of the problems faced by farmers in the area. Because the trials are located nearby, it is easy for the partner to visit and monitor them and provide feedback to the coordinating unit (in this case CIMMYT). A partner enters the mother/baby trial program only if the farming community has identified improved knowledge of maize varieties as a priority topic. This is an important reason for the success of the trials.

The farming community usually selects the farmers who plant the baby trials. Each farmer receives seed of four cultivars to be tested at no charge. The seed comes in a 250 g bag labeled with the name of the cultivar and color-coded (blue, red, yellow, or green). Stones painted with the same four colors come with the seed to enable farmers to plant the baby trials himselves; farmers place each stone in the field when they start to plant the seed that comes in the bag with the corresponding color.

Farmers might be unable to recall or read the name of the cultivar on the seed bag, but they are always aware of the "color" of a certain cultivar and its location. In this way, researchers, partners, and farmers keep track of individual cultivars in a farmer's field. De Meyer believes that this color-coding system has been the key to timely and decentralized planting of baby trials by virtually hundreds of smallholder farmers.

Valuable Information from the Trials

What kinds of data are produced by the trials? Both the mother trial and baby trials yield quantitative data on the performance of new cultivars under optimal, farmer-representative, and farmer-managed conditions. Farmers supply qualitative information about the varieties and hybrids they are testing in the baby trials through a questionnaire in the local language that is filled out with the local partner. Data are also gathered on soils, rainfall, the geographical location of the mother/baby sites, and socioeconomic factors.

Results from all mother/baby trial sets in a country are distributed to all partners and farmers involved. This information is valuable, because in an environment like Zimbabwe's, where conditions can vary so greatly from one year to the next, it is risky to depend on data from just one year or just one site when making reliable recommendations to farmers. In addition, the results are distributed through the usual information channels such as the extension system or the press.

Something for Everyone

Why do these trials capture the imagination and excitement of just about everyone who plays a role in delivering good seed to farmers—the farmers themselves, NGOs, seed companies, extension workers, and researchers?

According to Bänziger and de Meyer, the trials offer unique and considerable benefits to all of these groups.

Farmers observe commercial and experimental varieties and hybrids in their own fields and in the mother trials, and they tell researchers, extension, seed companies, and others what they think about the cultivars being tested.

The mother/baby trial concept has proven to involve whole communities, not just individual farmers, as neighbors come and compare the varieties in the baby trials and as community members attend field days held at the mother trial.

The involvement of secondary schools has been particularly valuable for conducting the mother trial. Students plant and care for the mother trial, compare results under different levels of fertilizer and under conditions that prevail in most farmers' fields, and involve their parents and the wider community in what they are learning.

Farmers' opinions of commercial seed systematically flow back to researchers and to seed companies, increasing the chance that seed companies may provide the kind of seed that farmers want. If farmers identify an experimental variety or hybrid they like, and if seed companies realize that there will be demand for the seed, the company may be more likely to produce and market the seed of new cultivars.

In the past, if seed of a particular variety or hybrid was not available in the market, farmers often lacked information to choose among the other varieties or hybrids on offer. Farmers can now make more informed choices about which kind of commercial seed to buy, because the trials give them first-hand information about a wider number of commercial varieties and hybrids. Stan Tapererwa, District Officer of AGRITEX, has seen smallholder farmers asking for and purchasing seed of the best cultivar released after the previous year's trials. Because half of the trial entries are experimental and the other half are recent releases, this means that farmers are adopting new cultivars even as research is being conducted and decisions are being made on future releases.

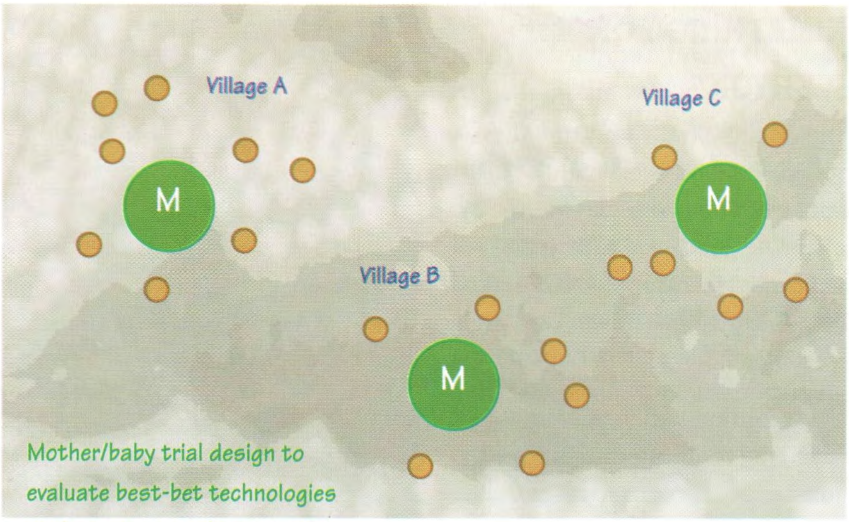
Voices from Partners in CIMMYT's Mother/Baby Pilot Project:

Mr. S. Tapererwa, District Agricultural Extension Officer, AGRITEX: **"These on-farm trials have served research, observation, adoption, and implementation simultaneously. Extension officers feel highly honored to be involved with these trials, and they are taking it as a part of their core business—unlike in the past when they were just on-lookers and only got involved when new varieties had been released. I therefore think that such collaboration between researchers, extension, and farmers could accelerate the information flow between research and reality, and accelerate the release and adoption of more suitable varieties."**

Mr. Dodoh, Agricultural Teacher at Mananure Secondary School: **"The students and the community have had the chance of evaluating cultivars with different fertilizer inputs, but under our own conditions. This is very different to just growing a maize crop and not learning what choices can be taken to influence the performance of a crop. We have seen pupils interacting with their parents on the results of these trials. They are recommending the best varieties to their parents and tell them, 'If you find this variety in the shops, buy the seed because we have seen it doing very well in the trial at our school.' But most importantly, we have experienced as a school and as a community that we can have an active involvement in research and development. This is how it should be happening."**

Mr. V. Zvarevashe, CARE International: **"A partnership between research, NGOs, and farmers has several benefits. As an NGO, we benefit from results of cutting-edge research, knowledge of new varieties, and very practically the seed of relevant varieties already packed as a trial. Our field officers receive training in field experimentation. The farmers have an immediate benefit because they can make a more informed decision about what varieties to grow next year. In addition, the entire farming community benefits in the medium-to-long term because they can influence breeding priorities and marketing decisions."**

The public extension service and NGOs work closely with rural communities and possess the dedication and farmer contacts that make the mother/baby trials work well. The NGOs are particularly keen to link community-based seed production schemes to a mother/baby testing scheme. A community may choose an open-pollinated variety that has been doing well in their trials and in trials of farmers with similar growing conditions. The research/NGO partnership that has been established through the mother/baby trials has made it easy for researchers to provide base seed and simple instructions for the NGO to increase and maintain the seed. In addition, NGOs appreciate the technical support they receive from researchers—even the simple fact that they do not have to be concerned with the task of collecting seed of the most recent cultivars and assembling trials to plant in a meaningful manner.



Mother/baby trial design to evaluate best-bet technologies such as stress-tolerant maize cultivars by researchers and farmers. "M" indicates a mother trial.

The Message: Loud and Clear

Because interest in the trials is so high, Bänziger, de Meyer, and their partners in the mother/baby trials are exploring ways of making the trials available more widely in southern Africa. Representatives from national agricultural research programs, extension, and NGOs from neighboring countries recently visited and discussed mother/baby trials during a travelling workshop. The feedback from the group was clear: "The concept of mother/baby trials is logical, desirable, and exciting. Its great advantage is that farmers start adoption while new technologies are verified. This greatly reduces the lag-phase between research and impact, the adoption rate is likely to increase, and smallholder farmers and extension are bound into a natural flow of new research products. The approach guarantees a high return to investment due to cost-sharing and synergy among partners."

When transferring the approach to other countries, the crucial issue will be to preserve the elements of the trials that make them so valuable for community development, especially the links between farmers' needs, research, and seed production.

As Bänziger notes, the trials allow smallholder farmers to communicate their likes and dislikes very explicitly, and the voices of hundreds of farmers in favor of a particular variety or hybrid will be forceful and hard to ignore. By bringing together so many groups that are interested in what farmers have to say, the chances that everyone benefits are very high.

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New Tillage Practices for South Asia: *Plowing Less to Save Water and Slow Global Warming*

For decades the continuous rotation of rice and wheat—two crops or more per year—has provided food and livelihoods for hundreds of millions of rural and urban poor in South Asia. Now a crisis looms. The population is growing at more than 2% (nearly 24 million additional mouths to feed) each year. Yet agricultural land area dwindles and yield increases are leveling off. In the next two decades, fresh water will become increasingly scarce in South Asia, and water tables in some areas are already dropping as much as one meter per year. Finally, heavy diesel use and crop residue burning pose local health hazards and add significantly to global warming.

Simple Changes, Astonishing Benefits

Alternative tillage practices that reduce costs and raise productivity are being tested and promoted by the Rice-Wheat Consortium for the Indo-Gangetic Plains (RWC).[1] It turns out that widespread adoption of one or several of these reduced tillage methods will also bring significant environmental benefits.

1 The RWC is an alliance of national organizations, CIMMYT, the International Rice Research Institute (IRRI), other international centers, and advanced research institutes that fosters sustainable productivity in rice-wheat farming systems of South Asia. The RWC is an ecoregional initiative of the CGIAR, with CIMMYT as the convening center.

For example, current land preparation practices for wheat after rice involve as many as 12 tractor passes. Changing to a zero-till system on one hectare of land would save 98 liters of diesel and approximately 1 million liters of irrigation water.[2] Using a conversion factor of 2.6 kg of carbon dioxide per liter of diesel burned, this represents about a quarter ton less emissions per hectare of carbon dioxide, a principal contributor to global warming.

These benefits increase dramatically if extended across even a portion of the rice-wheat region's 12 million hectares. Adoption of zero-till on, say, 5 million hectares would represent a savings of *5 billion cubic meters of water* each year. That would fill a lake 10 km long, 5 km wide, and 100 m deep. In addition, annual diesel fuel savings would come to *0.5 billion liters*—equivalent to a *reduction of nearly 1.3 million tons in CO_2 emissions* each year.

Scientists in the RWC are also working with farmers to cut down on the burning of crop residues, which amount to as much as 10 t/ha, producing some 13 t of carbon dioxide. Eliminating burning on just 2 million hectares would reduce the huge flux of yearly CO_2 emissions by *17 million tons*.[3] Leaving stubble on the field, rather than burning it or incorporating it, also leaves a better habitat for beneficial insects to proliferate—a benefit that has not yet been quantified.

How Likely Are These Scenarios?

Alternatives to burning residues are still in the exploratory stage, but reduced tillage practices are catching on quickly, simply because they are so attractive to farmers. For example, two methods promoted by the RWC—direct drilling and surface seeding—allow farmers to prepare soils and sow wheat in a single tractor operation after the rice harvest. How can one argue with a practice that saves 75% or more fuel, obtains better yields, uses about half the herbicide, and requires at least 10% less water? Farmers save at least US$ 65/ha in production costs, which makes a big difference to their profit margin.

This year, farmers used direct drilling with locally manufactured drills to plant 8,000 ha in Haryana, India, and 5,000 ha in the Pakistan Punjab. The area of adoption has increased ten-fold each year for several years. The main constraint on more rapid expansion has been a lack of good quality, fairly priced seed drills. Small private shops are beginning to produce more drills in response to rising demand.

Small-scale mechanization is also spreading in the form of the two-wheel tractor and a range of new implements. Used widely by smallholders in China and Bangladesh, two-wheel tractors are being tested as a one-pass, reduced-tillage system and adapted by farmers in Nepal and eastern India for more timely sowing and reduced labor and land preparation costs. Here the need is for more tractors, repair shops, mechanics, and credit support to purchase equipment.

Another recently promoted technique—planting wheat on raised beds—improves yields, increases fertilizer efficiency, reduces herbicide use, saves seed, saves an average 30% water, and can reduce production costs by 25-35% when permanent beds are used. Bed planting is gaining acceptance in Pakistan and is being tested by researchers in India and Nepal.

To help make seed drills, hand tractors, and tractor implements more widely available, RWC staff are linking and advising farmer groups, local machine shops, and agricultural engineering specialists. CIMMYT and the RWC are also developing appropriate planters and bed-shaping equipment so that farmers can maintain permanent beds and retain crop residues. This adds the advantages of conservation tillage to bed planting, reducing costs another 20-25%.

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2 Because zero-till takes immediate advantage of residual moisture from the previous rice crop, as well as cutting down on subsequent irrigation requirements, water use is reduced by about 10 cm-hectares.

3 Normal decomposition of straw would still produce nearly 9 million tons of CO_2 per year.

Public/Private Sector Alliances in Agricultural Research: *Towards Equitable Partnerships for Developing Countries*

How can organizations from the private and public sector join forces to bridge the gap between cutting-edge research and development (R&D) in industrialized countries and publicly sponsored research in most developing countries?

This is the central question addressed in the Tlaxcala Statement, which reflects the consensus of an international forum convened by CIMMYT in Tlaxcala, Mexico, in late 1999 to initiate a dialogue on key issues related to public/private alliances in agricultural research. The participants were all highly respected, experienced individuals active with the private sector, major public research institutes in the developing world, multilateral donor agencies, academia, and the Consultative Group on International Agricultural Research (CGIAR).

Progress through Dialogue

The need for creative approaches to private and public sector alliances that benefit developing countries is an urgent one. By engaging in continued dialogue, we can find new ways of working towards basic human rights for poor people—the right to food, to employment, to everything that constitutes a better life. The dialogue initiated in Tlaxcala, which explored the interests, strength, investment, and future roles of the public and private sectors in agricultural research, was an important step towards this goal.

Participants recommended that further progress could be made by developing a strategic framework for mutually beneficial alliances. To do this, several steps are needed:

- In-depth discussions with groups of national agricultural research programs with similar levels of capacity are needed to define the mechanisms for alliances, including guidelines for negotiations between public and private organizations (based on the relative strengths of each type of organization) and desirable rules to govern such alliances.
- The roles of the public and private sectors within individual nations, and possibly with respect to research conducted by CGIAR centers, should be defined with greater specificity.
- Such discussions should also define, with greater precision, what national research organizations, international research organizations, and private companies need/want to achieve their goals. They should also assess the needs for developing the capacity to establish effective alliances (e.g., intellectual property rights).

Main Points of the Tlaxcala Statement

The Tlaxcala Statement focuses on research related to the three most widely produced food crops—maize, wheat, and rice—although the issues it highlights are likely to be similar for other plant and animal species. The Statement outlines:

- Strategies and objectives of public and private organizations that might lead to mutually advantageous ("win-win") alliances to achieve all partners' objectives without working to the detriment of any partner, its mission, or its constituency.
- Prospects for public and private organizations to direct their efforts toward (for example) separate geographical areas, groups of clients, or types of products.
- Implications of dividing public and private efforts in this way.

Participants in the Tlaxcala Forum agreed that in the coming five to ten years, maize, wheat, and rice R&D by the public and private sectors are likely to focus on different activities/areas. The private sector is likely to focus on investments in developing technology and information resources in genomics and biotechnology. Private organizations will also develop new crop varieties (particularly hybrids) in areas where profits can be anticipated; this activity will be a function of the public sector in other areas. Genetic resource conservation will remain a major public sector activity, as will pre-breeding (i.e., research to produce elite breeding materials that researchers can use to develop varieties adapted to local farmers' conditions). The public sector will also probably have a major role in the application of agricultural biotechnology in developing countries, in conducting basic research, and in developing human resources.

Given that the public and private sectors are likely to specialize as outlined above, their probable/desirable relationships will take several forms. By developing products, training researchers, and undertaking other activities, the public sector will help private firms to become involved in agricultural R&D at a lower cost. Local private seed companies have a role to play in enhancing competition, and the public sector has a role to play in supporting such companies.

Where conditions permit competitive seed markets to exist, the public sector should encourage and support rather than compete with the private sector in providing improved seed and related technology to farmers. Where conditions discourage the private sector from investing in providing a range of appropriate, affordable technologies to farmers, the public sector (and/or public sector funding) should take responsibility for meeting farmers' needs. Conditions that discourage private investment include a preponderance of non-commercial farmers, small markets, and low-productivity growing environments.

Even where both private sector and international public researchers are active, strong national public research programs are needed to adapt privately and internationally developed research products to local conditions. National governments should allocate additional resources to enable national programs to accomplish this task. If this is not fully possible in the short term, other institutional arrangements should be devised to accomplish this task.

Future Steps to Equitable Alliances

Public/private sector alliances are critical to ensure that biological and information technologies are adapted in ways that enable resource-poor farmers to benefit from improved agricultural productivity, profitability, and sustainability. What conditions will foster such alliances? The relative strengths of the private sector in genomic information and the public sector in germplasm (especially information and expertise related to the characteristics and improvement of germplasm for developing countries) should provide a strong basis and considerable impetus for forming alliances. Public/private sector alliances will vary by the type and size of market, (which could be determined, for example, by the level of economic growth), the productivity of the region, product (e.g., hybrid versus open-pollinated maize), crop, and/or type of farmer (e.g., commercial, subsistence).

Finally, as public/private sector alliances develop, key public awareness issues emerge. Members of an alliance should provide information about their collaboration and address concerns in an open, frank manner. Although they may be members of an alliance, it is important that partners retain their own identities and credibility based on their particular missions and constituencies. Organizations, especially in the public sector, will need policy statements that specify the conditions under which they engage in alliances.

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INSECT RESISTANT MAIZE FOR AFRICA: New Project Seeks to Eliminate Production Losses of US$ 90 Million

Maize is a major food crop in Africa, especially in the eastern and southern regions of the continent. For many, it is the main dietary staple, as evidenced by annual consumption levels of 79 kg per capita in the region and 125 kg per capita in Kenya. Threats to this food source endanger food security, and stem borers pose just such a threat in much of Africa. In Kenya alone, farmers report losing 15% of their maize harvest to stem borers, equivalent to 400,000 t of maize valued at US$ 90 million. Farmers in some areas have reported losses as high as 45%.

These losses are considerable in a country where maize must be imported to meet domestic demand. For individual farmers, many of whom live on less than US$ 1 per day, this destruction is significant. Insect pest infestations can decimate entire fields of maize and deprive families of a vital source of food and income.

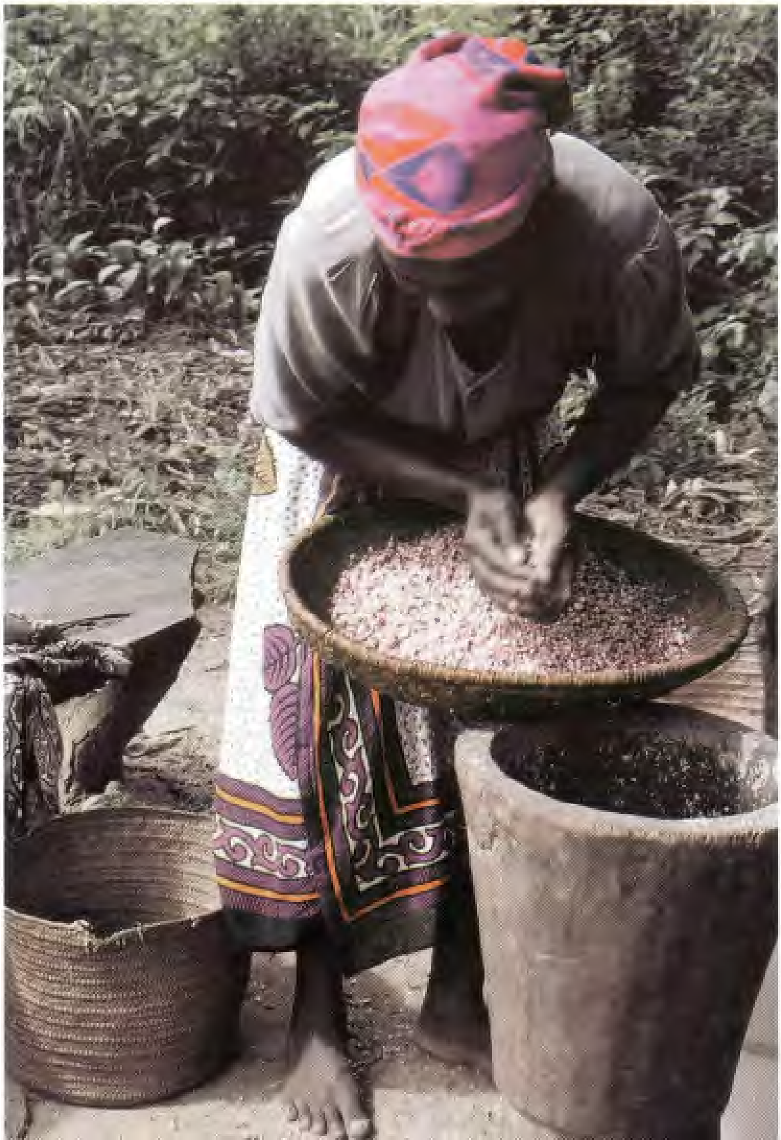
To tackle this problem, the Insect Resistant Maize for Africa (IRMA) project was launched in 1999 by the International Maize and Wheat Improvement Center (CIMMYT) and the Kenya Agricultural Research Institute (KARI), with financial support from the Novartis Foundation for Sustainable Development.

The project is aimed at producing maize that is adapted to various Kenyan agroecological zones and is also resistant to key insect pests, primarily stem borers. Both conventional and biotechnology-based sources of resistance will be examined for their effectiveness against the borers. The project emphasizes public involvement and awareness through events such as the Stakeholders Meeting, described later. Furthermore, major project objectives include environmental and socioeconomic impact studies, resistance management strategies, and project documentation. Based on the experiences and results generated in Kenya, appropriate technologies and varieties will be extended to other African nations.

Objectives of the IRMA Project

The general objectives are to:

- develop insect resistant maize varieties for the major Kenyan production systems and insect pests;
- establish procedures to provide insect resistant maize to resource-poor farmers in Kenya;
- assess the impact of insect resistant maize varieties in Kenyan agricultural systems;
- transfer technologies to KARI and Kenya to develop, evaluate, disseminate, and monitor insect resistant maize varieties; and
- plan, monitor, and document project processes and achievements for dissemination to other developing countries.



Project Activities

The project engages in three groups of activities: 1) development of insect resistant maize,
2) development of effective dissemination strategies, and
3) impacts assessment.

Development of insect resistant maize will entail:

- development of infrastructure in Kenya to screen maize plants for insect resistance;
- identification of genes that are active against Kenyan stem borers;
- identification of target maize germplasm for transformation and for backcrossing to source germplasm;
- development of transgenic-based insect resistant maize germplasm;
- backcrossing of maize adapted to Kenya with transformed germplasm; and
- development of high-yielding, improved, and adapted insect resistant maize germplasm.

Development of effective dissemination strategies for insect resistant maize in Kenya will entail:

- development of insect resistance management (IRM) strategies;
- acquisition of the required licenses and agreements to enable the technology to be used in farmers' fields;
- full application of biosafety and bioethical standards and protocols;
- agronomic studies of insect resistant maize; and
- dissemination of insect resistant maize to farmers.

Impact assessment and socioeconomic analysis will entail:

- assessment of the demand for insect resistant maize varieties through studies of the different maize-based farming systems, a survey of farmers' perceptions and preferences, and a survey of consumers' preferences;
- assurance that the technology fits within the country's institutional framework and an assessment of the implications and costs of intellectual property rights (IPR);
- assurance of the safety of the technology to the public through continuous dialogue with environmental groups, local research institutes, and private or public companies involved with seed production;
- assurance that the technology is acceptable to farmers (through farmer participatory research);
- comparisons of the costs of the new technology to its benefits at various levels, including the maize producer, the seed company, the consumer, and society as a whole; and
- impact assessment and cost-benefit analyses of the research.

The Insect Resistant Maize for Africa (IRMA) project uses conventional breeding and biotechnology to develop maize adapted to Kenyan production environments and resistant to key insect pests, including stem borers. Resistant maize will help Kenya avoid maize grain losses estimated at US$ 90 million.

EXPECTED OUTPUTS

Expected outputs of the project include:

- maize inbreds, hybrids, and open-pollinated varieties that combine conventional and biotechnology-based insect resistance;
- protocols developed and KARI scientists trained in the development, evaluation, dissemination, and monitoring of insect resistant maize;
- economic analyses to determine farm-level profitability, farmers' willingness to pay for the technology, and the overall private and public benefits of the technology;
- insect resistance management strategies;
- practical experience for KARI staff in biosafety and intellectual property rights procedures in Kenya; and
- documentation of experiences on development, dissemination, and impacts of gene-based resistant maize germplasm.

Successful Stakeholders Meeting Marks Opening of Project

The IRMA project convened a Stakeholders Meeting in Nairobi, Kenya, in March 2000. Approximately 100 people representing different stakeholder groups—including farmers' associations, women's groups, religious organizations, seed producers, regulatory agencies, NGOs, the media, and others—were in attendance. Representatives of CIMMYT, KARI, and the Novartis Foundation for Sustainable Development also attended.

The Stakeholders Meeting introduced the IRMA project to stakeholders; created awareness of the economic importance of stem borers in Kenyan agriculture; created awareness of the control options for stem borers, including conventional and novel approaches like the Bt-gene technology; and solicited responses from stakeholders on the need for insect resistant maize in Kenya and the process that will be used to develop such maize.

The session was chaired by the Permanent Deputy Secretary and Director of Agriculture Wilfred Mwangi, currently on leave from CIMMYT's Economics Program, and was officially opened by the Minister of Agriculture, the Hon. Christopher M. Obure. Cyrus Ndiritu, Director of KARI and an outspoken proponent for biotechnology and genetic engineering for developing countries, provided some general remarks on the project, while CIMMYT-IRMA project coordinator Stephen Mugo gave a more detailed account. A letter on CIMMYT's role in the project from Director General Timothy Reeves was read by David Hoisington, Director of CIMMYT's Applied Biotechnology Center, and Klaus Leisinger, Executive Director of the Novartis Foundation, gave a short speech on the Foundation's role in the project.

Following the opening, the stakeholders readily engaged the expert panel in the question-and-answer period. Because of the stakeholders' intense involvement, the session ran well over its allotted time and was extended. Importantly, Bt maize was viewed as having high potential for closing the wide and increasing food deficit in Kenya. The stakeholders expressed the need to incorporate sound management strategies and to follow the national regulations strictly during introduction and testing of Bt genes, but nearly all present agreed that this technology must be evaluated in-country. Media coverage of both the Stakeholders Meeting and the preceding Africa Biotechnology Stakeholders Forum workshop (sponsored by CIMMYT and the Rockefeller Foundation) was extensive and generally positive.

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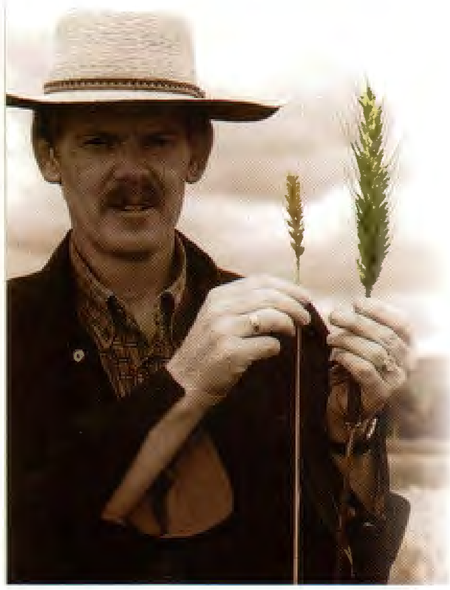
"SOFT" ware to help answer "HARD" breeding questions

In the works at CIMMYT and at the University of Queensland, in Brisbane, Australia, is a computer tool so sophisticated that it will help wheat breeders make some of the toughest decisions they face when developing a variety. QU-GENE, a genetic simulation software package, can be programmed to integrate enormous amounts of data from widely different sources, process them in many ways, and produce alternative theoretical but realistic scenarios that the breeder can draw on to make a decision.



Forward-looking breeders are always on the lookout for new technologies that could help them do their work better, faster, or more economically, and the wheat breeding simulation module being developed using QU-GENE certainly looks promising.

A trained geneticist can picture the potential effect of four or five genes at the most, but this simulation module will go much further than that, according to Maarten van Ginkel, bread wheat breeder for optimum environments at CIMMYT who is collaborating on this effort. It will take the information needed to, for example, create the superior wheat variety envisioned by a breeder and come up with alternative selection scenarios and the specific crosses that would produce it. It may even indicate when and where to employ physiological and biotechnological tools to enhance the efficiency of the breeding process.

Simulation Software for Superior Wheats

QU-GENE was developed by Mark Cooper and Dean Podlich, researchers at the University of Queensland. A four-year project to create a breeding simulation module based on CIMMYT's bread wheat breeding program is being funded by Australia's Grains Research and Development Corporation (GRDC).

CIMMYT's bread wheat breeding program was chosen for this project because, according to Ian De Lacy, a biometrician and expert on database management, the program has 53 years of accumulated breeding data, and it is one of the most important, largest, and most successful plant breeding programs in the world. De Lacy is part of the team of Australian and CIMMYT researchers who will be working to fine-tune the simulator to respond to real-life breeding situations.

The laws of genetics put forth by Mendel more than 130 years ago underpin the simulation module, which also contains genetic equations developed by scientists over the past century. For the simulator to work, it must draw upon data from other systems such as the wheat section of the International Crop Information System (ICIS) and the Geographic Information System (GIS) at CIMMYT. It will also link to the Agricultural Production System Simulator (APSIM), a collection of biological, physical, system control, and other modules that interact to simulate the operation of a farming system. Currently researchers are working to set up these links, which would effectively endow the simulation module with knowledge of genetic and other types of relationships among wheats, plus their performance in real farming situations.

One of the most important applications of the module will be to figure out the combined effects of several genes. Breeders know that the effect of putting genes together is not as simple as $1 + 1 = 2$. There is a synergy at work that sometimes causes $1 + 1$ to equal much more than 2, and sometimes less. Positive synergy can produce huge genetic gains, but until now, except for their experience and intuition, breeders have had no means of predicting how and when this synergy would happen. With the simulation module they would gain a good idea of how to achieve the synergistic effects they seek.

Another significant contribution of the module would be to indicate when it is cost-effective and/or efficient to use a specific technology, such as molecular markers, in improving a particular trait of wheat. Applying molecular markers at an early stage of the breeding process might seem the thing to do, but at that stage the number of plants to be tested is still very great, as is the cost of testing. It might make more sense to apply the technology later in the breeding process, when the population of experimental wheats has been pared down to a more manageable and economical number. But by that time the gene of interest may have been bred out of the population, or nearly so, which is also undesirable. What is a breeder to do? Apply the module to get a better idea of how the two scenarios would play out, and then make a more informed decision.

Simulating Environments and Environmental Variability

The QU-GENE wheat simulation module would give breeders not just one possible scenario in which to run tests, but would generate different versions of an artificial environment to simulate conditions in different years and run, say, 100 breeding cycles to see what the outcome would be. Why is this useful?

In North Africa, for example, four out of five years are dry. Farmers sow their wheat, and if they see the year will be very dry, they will not let the crop grow to harvest, but allow their livestock to graze on it. For that they need a wheat variety that produces lots of stems and leaves. The variety has to produce a lot of grain, too, since farmers expect to reap an abundant harvest one year out of five, when rainfall is adequate. In this case, the simulation module would aid in setting breeding priorities by running many breeding cycles while weighing the importance of different traits depending on the specific needs (feed vs. food) in the environment where the variety will be grown.

Reducing Breeding Costs and Increasing Impact

The simulator could help bring down breeding costs by reducing the number of needed crosses, identifying the best method for a particular step in the breeding process, or determining the best time to use a certain method in terms of efficiency and cost effectiveness. It could also compare the cost of an input to the cost of the corresponding output to determine whether applying a given technology makes sense.

The QU-GENE simulation module is being developed at a time when it is more urgent than ever to speed up the breeding of wheat. As the world population rises, so does the challenge of producing enough wheat to satisfy the growing demand. With the QU-GENE wheat breeding simulator, breeders will more easily and economically develop wheats that meet specific needs of farmers in developing countries.

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NUTRIENT ENRICHED MAIZE: An Inexpensive, Accessible Protein, Vitamin, and Mineral Supply for the Poor

CIMMYT is developing a new product that could contribute significantly to the well-being of millions of resource-poor farmers and consumers in Asia, Africa, and Latin America. What do people from such diverse regions have in common, besides a harsh, daily struggle to survive? For one thing, maize is frequently their chief source of energy. Moreover, their diets often comprise mostly carbohydrates and lack protein, vitamins, and important minerals. This can cause chronic poor health, stunted growth, and conditions such as anemia, blindness, kwashiorkor, or pellagra.

ENDING NUTRITIONAL DEFICITS

To help improve maize-based diets, CIMMYT plans to generate and promote a new, nutrient-enriched maize that will provide more of the above dietary components.

Efforts will build on three decades of successful research on quality protein maize (QPM) by CIMMYT, in concert with partner countries, to overcome undesirable side-effects of the quality protein gene. Now QPM looks and tastes like normal maize, yields as much or more, and contains nearly twice the lysine and tryptophan—two essential amino acids. The nutritive value of protein in QPM approaches that of protein from skim milk. Children can meet 90% of their protein needs by eating 175 g of QPM. Pigs raised on QPM gain weight at roughly twice the rate of animals fed on normal maize; a boon for smallholder farmers, who often cannot afford balanced feeds.

The superior yields of new QPM hybrids—10% more than leading commercial hybrids of normal maize type—together with their protein quality, have generated tremendous interest in developing countries. China, El Salvador, Guatemala, and Mexico have released new QPM varieties based on

CIMMYT will take quality protein maize (QPM), which is being sampled in this photo, several steps further to develop much more nutritions maize that is widely accessible to farmers and consumers.

CIMMYT germplasm and launched programs to promote QPM production and use in diverse food and feed products. Several other maize-consuming nations are preparing QPM varieties for release to farmers.

NEXT STEPS FOR BETTER NUTRITION

As a next step, CIMMYT will work with global partners to generalize the use of QPM in maize consuming countries. Among other things, the quality protein trait will be incorporated into most elite maize lines of CIMMYT and national maize research systems. Support will be provided to promote QPM, produce genetic and basic seed, conduct mass on-farm testing at different stages of promotion, and strengthen nascent markets for this product. Provisions will be made to monitor seed quality and, in collaboration with advanced research institutes and the milling industry, to assess processing quality.

Building on access to farmers gained through QPM, CIMMYT will also work with its applied biotechnology specialists and advanced research institutes to enhance other nutritional components of maize—including zinc, iron, and vitamin A—and combine them with protein quality to develop much more nutritious maize that is widely accessible to farmers and consumers. The initiative will draw on germplasm bank sources of these traits, molecular marker and genetic transformation technologies, and partnerships with other groups involved in research on maize nutrition. It will benefit the estimated two billion persons worldwide who suffer from iron-deficiency anemia, the many developing country children at risk of blindness from lack of Vitamin A, and the approximately 600 million people whose health is affected by zinc deficiency.

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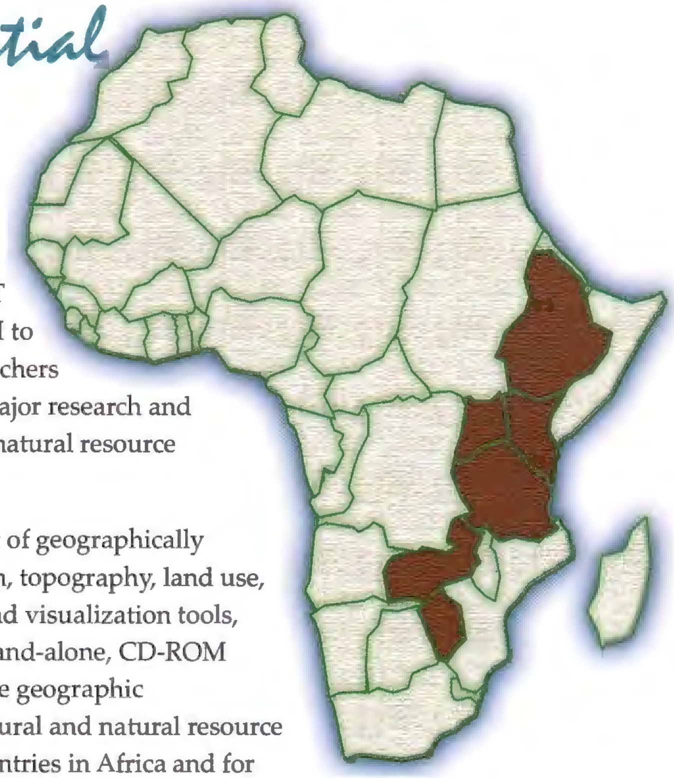
COUNTRY ALMANACS: GIS to Address Major Issues of Climate Change, Potential Impact of Research

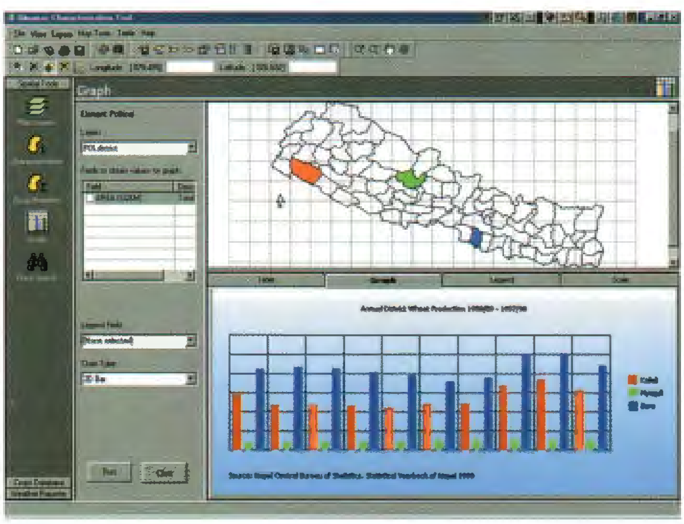


The Country Almanacs offered by CIMMYT and its partners provide access on CD-ROM to an entire knowledge base that allows researchers and policy makers to answer some of the major research and policy questions related to agriculture and natural resource management.

The Almanacs contain an integrated set of geographically referenced data on soils, climate, population, topography, land use, and other variables, along with querying and visualization tools, documents, and key references. They are stand-alone, CD-ROM software that incorporates powerful, flexible geographic information systems (GIS) tools for agricultural and natural resource workers. Almanacs are available for six countries in Africa and for Nepal. Several other Country Almanacs are under development.

ADDRESSING MAJOR ISSUES

Almanacs can help researchers answer questions that have a bearing on some of the most important agricultural issues of the day. For example, researchers can assess how global warming might affect wheat production in a given country. If the temperature increases by 2°C, how much wheat area will be lost? How will this affect future food security? How can research programs prepare for this possibility?



The Almanacs can also help researchers and decision makers project the potential impact of a plant variety with a special trait. For example, the Country Almanacs can help researchers understand the potential for expanding wheat area in a given country, if farmers have access to wheat with better heat tolerance. Information on the distribution of important diseases and pests can help breeders determine which pest and disease problems should be given priority for research.

People who fund or plan research can also evaluate whether national research sites are effective for developing plant varieties suited to the areas where farmers actually grow the crop.

Through the Almanacs, researchers—in either the public or private sector—can also use GIS to gain a better idea of where new crop and resource management practices or new plant varieties should be tested, distributed, or marketed. This kind of information can be extremely useful for developing and providing practices or products that farmers need.

Ending the Limits to Site-Specific Research

Such information may be even more crucial in natural resource management research than in research to develop new plant varieties. With GIS, researchers can increasingly overcome one of the greatest challenges in research on practices directed at conserving natural resources: site-specificity.

Natural resource management research is often described as site-specific, because the success of the practices that are developed can depend greatly on the particular combination of factors at a given site. In the past, researchers lacked the information to identify many sites that shared similar characteristics, where a new management practice could make a larger impact.

For example, a soil fertility management practice, such as rotating a food crop with a green manure, may considerably enhance soil fertility and appeal to farmers under certain conditions: suitable temperature and rainfall for the green manure to grow, low population density, and distance from roads and markets. By identifying the areas within a country or region that share those conditions, the Almanacs give researchers a powerful means of successfully "scaling up"—of extending the new soil fertility practice to many more farmers.

GIS for Everyone

These sorts of questions could not be examined previously without costly hardware and software, access to good data, and specialized training in GIS. By removing barriers to the effective use of GIS, the Almanacs enable users to manipulate and combine datasets and search results to create customized maps and tables that are easily exported to spreadsheet, word processing, graphics, or other computer packages. They also offer a wide array of textual information, such as Internet sites, major articles and journals relating to the country (and especially to its agriculture), CIMMYT technical publications such as field manuals and socioeconomic analyses; and a collection of ready-made maps.

The Almanacs were developed with funding from the US Agency for International Development (USAID) by CIMMYT and Texas A&M University's Characterization and Assessment Applications Group at Blackland Research Center. Potential users include national agricultural research systems, non-governmental organizations, international agricultural research centers, and the private sector.

Training in use of the Almanacs has resulted in an enthusiastic and growing number of users, especially in Africa, and has also contributed to improvements in the Almanacs, including on-line tutorials that walk users through Almanac functions using real-life scenarios. In many countries, Almanacs are already guiding the selection of research sites, the construction of spatial sampling frames for surveys, decisions about where new crop varieties are likely to perform the best, and decisions about where new research efforts should be concentrated. Because research can be targeted more effectively, research resources can be used more efficiently.

By providing a framework and a location for research data based on geographical regions, the Almanacs can also serve as a kind of "institutional memory." They can store research results and other valuable information that might otherwise never have been exploited by a larger group of researchers and decision makers.

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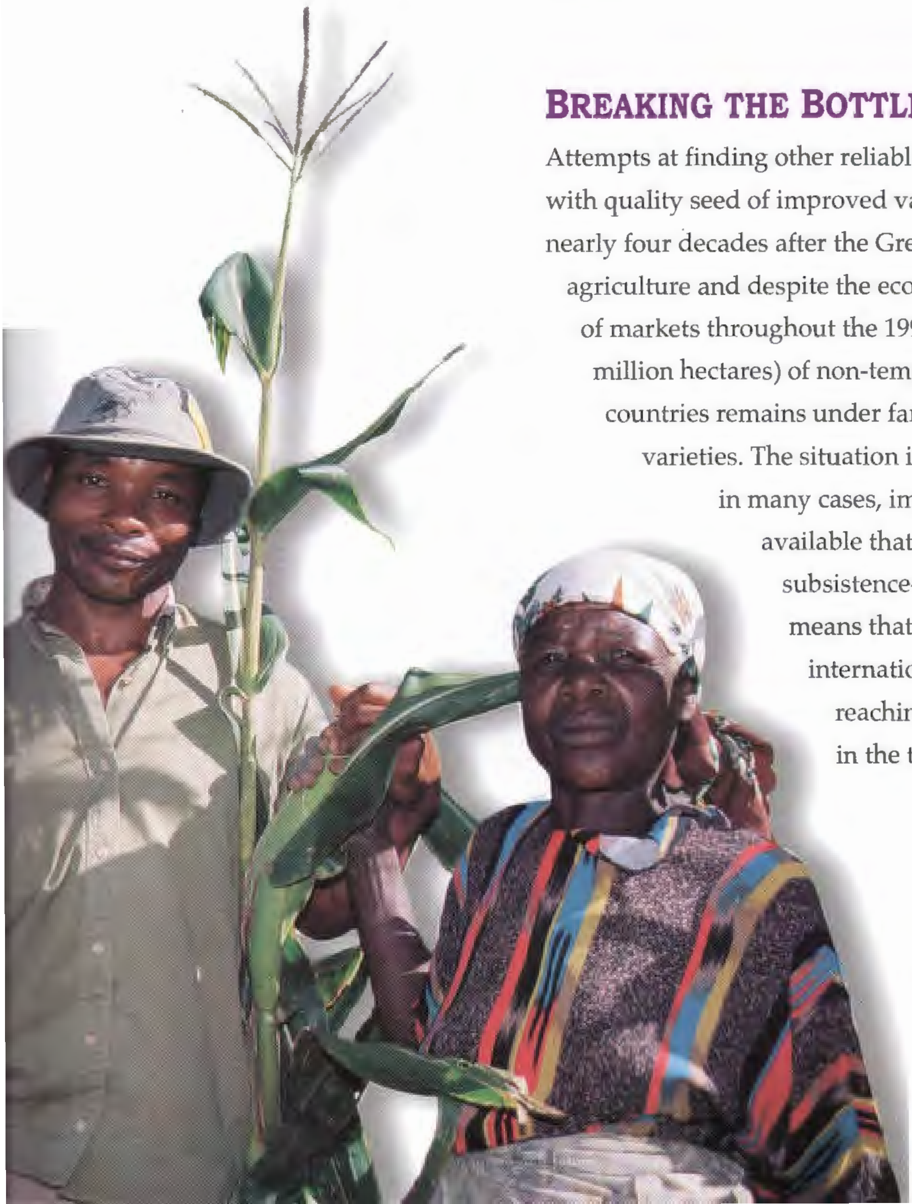
FROM PIPELINE TO PRODUCTION: *Delivering Improved Maize to Subsistence Farmers*

Distinct from the cases of rice and wheat, seed production in maize is costly. For subsistence maize farmers—many of whom practice low-yield, low-input agriculture in difficult environments where crop failures are frequent—the modest expected returns to investment in improved seed from commercial suppliers frequently do not justify the relatively high price of the seed. Private seed companies then have little reason to target such settings.

BREAKING THE BOTTLENECK

Attempts at finding other reliable means to provide those farmers with quality seed of improved varieties have largely failed. So, nearly four decades after the Green Revolutions in rice and wheat agriculture and despite the economic restructuring and opening of markets throughout the 1990s, more than 50% (fully 30 million hectares) of non-temperate maize area in developing countries remains under farmer-saved seed of low-yielding varieties. The situation is particularly frustrating because, in many cases, improved varieties and hybrids are available that perform extremely well in subsistence-farming environments. This means that the fruits of a very successful international breeding effort are not reaching farmers because of a bottleneck in the technology delivery system.



Cheap, Dependable Seed Sources

The challenge now is to explore innovative ways to create low-cost, sustainable sources of quality seed for smallholder maize farmers in difficult, often remote locations.

The seed must be of locally adapted varieties and hybrids of farmers' preferred grain types, but which are higher yielding, tolerant of prevalent stresses, and improved for other traits that farmers value. In attempting to address this challenge, CIMMYT efforts will feature the following strategies:

- A focus on target locations for which demonstrably superior varieties and crop management practices exist but have not been adopted, because low yield conditions do not yet provide a payback on seed costs.
- Collaboration with agencies experienced in setting up small, sustainable businesses, as well as other relevant, community-based organizations.
- Innovative marketing schemes (e.g., packaging of seed, timing and targeting of delivery, mobile distribution units, publicity campaigns, etc.).
- Documentation of and linkages with informal seed exchange networks (one scenario would be a network of informal distribution systems supported by formal outlets).
- High quality technical training in seed production, as well as support for key infrastructure.

Work will capitalize on current CIMMYT efforts to develop maize that tolerates production constraints typically faced by subsistence farmers: low fertility, drought, insect pests, diseases, and weeds. (For example, see the second story in this publication, "Farmers' Voices," which describes an innovative series of trials designed to link farmers and sources of improved seed.) Novel arrangements with seed certification agencies may be needed.

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NEW CHALLENGES for Asian Maize Production Translate into New Hope for Disadvantaged Upland Areas

In Asia, a critical question is how the projected unprecedented growth in demand for maize, and the resulting commercialization and intensification of maize production systems, will affect agriculturally disadvantaged upland areas.

These areas are populated by poor rural communities, many of them ethnic minorities, for whom maize is a primary staple. The food security implications of the rise in maize demand need to be understood and addressed for these poor households.

A new three-year project will identify the constraints to sustainable and equitable growth in maize productivity in upland areas; evaluate the potential environmental and equity impacts of intensified maize production; identify key policy options for encouraging sustainable, equitable growth in maize productivity; formulate plans for developing and testing promising maize technologies; and foster policy dialogues with influential decision makers to increase awareness and understanding of the problems in upland farming systems.

Can poor rural communities in agriculturally disadvantaged upland areas benefit from Asia's exploding demand for maize?

The project is supported by the International Fund for Agricultural Development (IFAD) and brings together researchers from China, India, Indonesia, Nepal, the Philippines, Thailand, Vietnam, CIMMYT, the International Food Policy Research Institute (IFPRI), and Stanford University.

EXPANDING CHALLENGES TO FOOD SECURITY AND SUSTAINABLE AGRICULTURE IN ASIA'S UPLANDS

Across Asia, the expansion in maize production that has occurred during the last decade has been concentrated in the marginal uplands. In all probability, future expansion in

Asian maize production will take place in these same areas.

Recent IFPRI projections (IFPRI IMPACT model, 2000) indicate that:

- by 2020, demand for maize in all developing countries will overtake demand for wheat and rice, with Asia accounting for 60% of the global increase in maize consumption;
- demand for maize will rise from 138 million tons in 1993 to 243 million tons in 2020; and
- China alone will witness a 94% increase in demand for maize over this period.

In some Asian countries, rising domestic demand for maize could also be complemented by rising export demand, which will place additional strain on domestic production capacity.

The projected increases in demand for maize in Asia will have significant implications not only for the sustainability of agriculture in the marginal upland environments of Asia, but also for household food security.

Importance of Rainfed Uplands for Maize Production

Throughout large parts of Asia, maize is grown in the rainfed uplands, primarily to meet the subsistence needs of the poorest households. Future rapid growth in maize demand will lead to intensification on lands already planted to maize and to expansion of maize cultivation into lands that are not currently farmed.

To date, these upland rainfed cropping systems have received relatively little attention from research. Research and development efforts have understandably focused on the lowland irrigated zones where most surplus food is produced. As the capacity of these high-potential zones is exhausted, and as diets diversify out of cereals, the rainfed uplands will play an increasingly important role in feeding the region's rapidly growing populations. Given the ecological fragility of many of these rainfed upland systems, intensification must be guided in a way that will not only be sustainable, but that will also improve the incomes and welfare of local populations while protecting the natural resource base.

Information for Appropriate Planning

Careful planning and appropriate policies can ease the adjustment to the new maize supply and demand situation. To plan wisely, decision makers require comprehensive, accurate information on upland maize farming systems and options for promoting sustainable growth in maize productivity.

The new project will strengthen the capacity of research managers and policy makers to understand and respond to the intensification of maize-based farming systems in the rainfed uplands of the seven participating Asian countries.

Expected Impacts

A stronger local capacity to promote the sustainable intensification of maize-based farming systems in the rainfed uplands will increase and stabilize the supply of maize for home consumption as well as increase the amount of surplus maize available for sale. In this way, the project will foster improved food security in the many low-income households that subsist partially or totally on maize production. At the end of the three-year project period, the following impacts will have been achieved:

- **Improved knowledge** of upland maize-based farming systems, constraints to future productivity growth, and potential environmental and equity consequences likely to result from the intensification of maize production.
- **Increased awareness** among research managers of technological options for promoting sustainable, equitable intensification of maize systems in rainfed uplands.
- **Increased awareness** among decision makers of policy options for promoting sustainable, equitable intensification of maize systems in rainfed uplands.
- **Country-specific plans** to generate and diffuse technologies for sustainable growth in maize productivity in rainfed uplands.
- **An international network** of researchers and stakeholders working towards the sustainable, equitable intensification of maize systems in rainfed uplands.

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CIMMYT® (www.cimmyt.cgiar.org) is an internationally funded, nonprofit scientific research and training organization. Headquartered in Mexico, the Center 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 similar centers supported by the Consultative Group on International Agricultural Research (CGIAR, www.cgiar.org). The CGIAR comprises about 60 partner countries, international and regional organizations, and private foundations. It is co-sponsored by the Food and Agriculture Organization (FAO) of the United Nations, the International Bank for Reconstruction and Development (World Bank), the United Nations Development Programme (UNDP), and the United Nations Environment Programme (UNEP). Financial support for CIMMYT's research agenda also comes from many other sources, including foundations, development banks, and public and private agencies.

CIMMYT supports Future Harvest,® a public awareness campaign that builds understanding about the importance of agricultural issues and international agricultural research. Future Harvest links respected research institutions, influential public figures, and leading agricultural scientists to underscore the wider social benefits of improved agriculture—peace, prosperity, environmental renewal, health, and the alleviation of human suffering (www.futureharvest.org).

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