Anniversary Edition

1966-96

CIMMYT

International Maize and Wheat Improvement Center

CIMMYT in 1995-96

The Next 30 Years

COPY

Sustainable Maize and Wheat Systems for the Poor

CIMMYT An international, non-profit, agricultural research and training center dedicated to helping the poor in low-income countries

Focus Increasing the productivity and sustainability of maize and wheat farming in low-income countries, protecting the natural resources upon which agriculture is based Work concentrates on maize and wheat, two crops vitally important to reducing poverty and to ensuring food security for the poor. These crops provide about one-quarter of the food (total calories) consumed in low-income countries, are critical to the diets of the poor and, for poor farmers, are an important source of income.

Activities

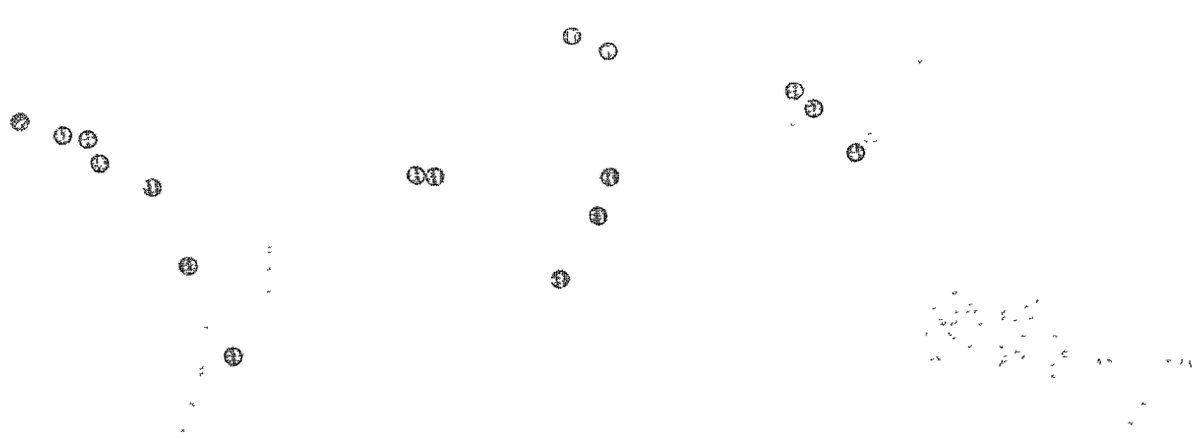
- Development and worldwide distribution of higher yielding maize and wheat with built-in genetic resistance to diseases, insects, and other yield-reducing stresses.
- Conservation and distribution of maize and wheat genetic resources
- Strategic research on natural resource management in maize- and wheat-based cropping systems.
- Creation and documentation of new knowledge about maize and wheat
- Development of more effective research methods
- Training of various types
- Consulting on technical issues

Partners Staff work with colleagues in national agricultural research programs, universities, and other centers of excellence around the world, in the donor community, and in non-governmental organizations

Impact

- 50 million hectares in low-income countries are now planted to CIMMYT-related wheat varieties (about 70% of the total wheat area in those countries, not counting China)
- CIMMYT-related wheats were sown on an additional 16 million hectares of farmland in low-income countries during the 1980s alone.
- 13 million hectares in low-income countries are now planted to CIMMYT-related maize varieties (about 50% of the total nontemperate area devoted to improved varieties in those countries).
- Nearly US$ 4 billion in extra grain production each year can be traced to the higher genetic yield potential and built-in pest resistance of CIMMYT-related varieties
- More than 4,500 researchers are alumni of the Center's training programs

Location Headquarters are in Mexico, but activities and impact extend to over 100 countries via 16 regional offices (see contact information, back cover)



CIMMYT: The *Next* 30 Years

Prof. Timothy G. Reeves
Director General

During the week of September 24-27, 1996, CIMMYT formally commemorated three full decades of operation We did so with just a touch of fanfare and a great deal of consultation with key research partners and investors In honor of the occasion, we devoted the first day to an inauguration of CIMMYT's new Plant Genetic Resources Center and our expanded Applied Biotechnology Center, as well as some crystal ball gazing by a number of developing country partners and financial supporters concerning the future of maize and wheat research Those events were then followed by three days of intensive consultation with more than 35 national system leaders and financial backers, all focused on our draft Medium-Term Plan, 1998 - 2002 The results of that very productive consultation are being combined with input from CIMMYT staff obtained during a similar "in-house" set of meetings as we move toward a final draft plan

Several who spoke during the 30th Commemoration noted that CIMMYT has good cause to celebrate, for we have — together with our many research partners — accomplished much on behalf of the world's poor. And yet, even as each spokesperson reflected on past accomplishments, all urged us to maintain our focus squarely on the agricultural development challenges that confront the world as the next millennium approaches

Amid today's apparent plenty, tremendous inequalities exist The World Bank estimates that there are about a billion people — roughly one in every five — who must survive on less than one US dollar per day Equally alarming is the deteriorating condition of the natural resources that underpin our current agricultural production systems We are now witnessing a never-before-seen rate of increase in the world's population — nearly 200 new residents

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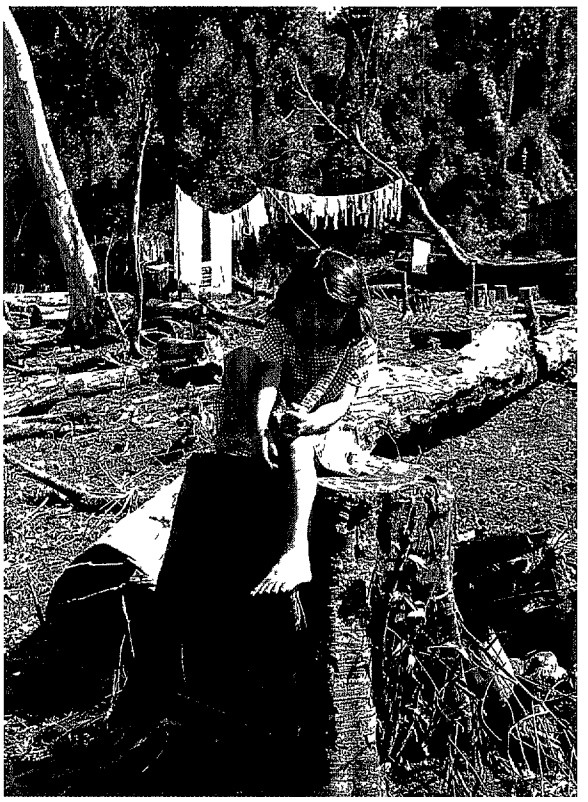


are added to this crowded planet *every minute*, a new Mexico City *every 12 weeks* a new Mexico *every year* Moreover, global food stocks, as a percent of utilization, are at their lowest level since we began keeping such records Clearly, we can claim only a tenuous hold on global food security

Agricultural research by CIMMYT and by many, many other institutions has provided the margin of survival for millions of the world's poor It remains our best hope for confronting the daunting challenges before us now reducing poverty, conserving the natural resources upon which our children's welfare will depend, and producing enough food for all

CIMMYT's maize and wheat technologies — more productive varieties combined with new, more efficient and environmentally friendly ways of growing them — provide hope in an uncertain future They promise more food from less land, better, more nutritious grain with fewer chemical inputs, and more stable yields under less predictable growing conditions

Our research is constantly evolving as advances in science open new opportunities for research We are moving from our traditional and more narrow focus on producing high-yielding, input-responsive cultivars to a more inclusive concern with enhancing not only the productivity but also the sustainability of maize and wheat production systems in developing countries Our research strategies increasingly transcend conventional plant breeding to achieve a creative blend of proven and new research methodologies

One tangible result of such changes is the new Wellhausen-Anderson Plant Genetic Resources Center that we dedicated in late September This center combines a state-of-the-art genebank complex, refurbished seed distribution facilities, and a revamped array of related research activities — some of which are highlighted later in this 30th Anniversary *Annual Report* The new facilities were made possible by generous donations from Japan and other core donors to CIMMYT, and will enable us to more effectively conserve and more efficiently use the maize and wheat genetic resources we hold in trust for humankind

In this *Report*, readers will find considerable evidence of change in CIMMYT, beyond that reflected in the bricks and mortar of our new Genetic Resources Center For example, we highlight several initiatives involving our recently created Natural Resources Group (NRG) The NRG was formed specifically to target natural resource issues The Group uses a variety of networking approaches to solve problems, and features a strong in-house capacity for geographic information systems research The NRG mission is to develop efficient research methods, conduct strategic research on processes and prototypes, and, most important, to backstop CIMMYT researchers and their partners in developing countries as they address productivity and sustainability issues In so doing, the NRG helps answer key questions having to do with increasing maize and wheat yields in environmentally safe ways, using maize and wheat technologies to help slow or reverse resource degradation, and measuring the long-term impacts of technical change

CIMMYT is devoting a growing share of its resources to research aimed at improving the resiliency of maize and wheat to a variety of stresses, especially those encountered in more marginal production environments In this *Report*, we feature our work on

maize drought tolerance, on heat tolerance in wheat, and on reducing widespread losses in maize production attributable to the parasitic flowering plant, *Striga* spp , known to sub-Saharan farmers by the charming and all too descriptive name "witchweed " Other important work involving our Maize and Wheat program staff is featured throughout this *Report*

The last six years have witnessed the development of an impressive applied biotechnology capability in CIMMYT, one closely linked to the work of our Maize and Wheat programs Special funds recently provided by DANIDA and others have enabled a modest — yet critical — expansion of this capability, such that our Applied Biotechnology Center is now well positioned to carry out its mission into the next century That mission is to do no less than make maize and wheat breeding even more effective through DNA marker techniques and the genetic transformation of these vital crops Our biotechnology staff continually evaluate and adapt new technologies for use at CIMMYT and in developing countries, transfer useful technologies to developing countries through training and consulting, and collaborate closely with other biotechnology groups worldwide In this *Report*, we look more closely at four aspects of the Biotechnology Center's work. the use of marker assisted selection in the development of drought tolerant maize, recent successes in the genetic transformation of maize and wheat for developing country production settings, our progress in transferring apomixis to maize from its wild relative, *Tripsacum*, and the results of CIMMYT's first-ever biotechnology course, held in late 1995

One of CIMMYT's greatest strengths is its close, long-standing relationships with research partners throughout the developing world These relationships are absolutely vital to addressing the agricultural

development challenges of the 21st century We have set about rededicating the Center — and ourselves as individuals — to research partnerships in service to the poor, to protecting the environment, and to increasing global food security Central to the progress we are making in this regard is our firm commitment to *listening to* and *understanding* the needs of our partners, as well as a growing openness to innovative organizational forms that facilitate meaningful collaboration This includes new arrangements with sister centers, as the recent agreement with ICARDA on joint research to improve and disseminate spring bread wheat, durum wheat, and facultative and winter bread wheat for West Asia/ North Africa, as well as to share conservation responsibilities for wheat genetic resources We highlight in this Annual Report several activities that embody the above-mentioned operating principles, giving special attention to work under way in Central America, southern Africa, and in tiny but densely populated Bangladesh

We are also moving in new directions in the area of economics research related to genetic diversity in maize and wheat, long-term supply and demand projections, technology assessment and forecasting, adoption and impact studies, and research priority setting — all are either new, or recently modified activities In this *Report*, we give special emphasis to our economics work relating to genetic diversity in wheat, and to a recently completed study of the maize seed industry in developing countries

CIMMYT is increasingly aware of the strategic importance of information and the potential benefits associated with managing it more effectively We are investing in this area now in anticipation of significant payoffs both for CIMMYT and for our research partners as we move into the next millennium We highlight in this *Report* some recent activities and a noteworthy internal reorganization that we think will strengthen our ability to capitalize on the information revolution going on around us all

Finally, a few words relating to the Center's financial situation Specifics are provided later in this *Report* Of more immediate interest here is the fact that, like all CGIAR centers, CIMMYT finds itself confronted with a dynamic set of circumstances funding for international agricultural research seems increasingly hard to come by, but important changes in the System's financing procedures resulting largely from the CGIAR's "renewal process" are providing incentives for fundraising by individual centers

Efforts to strengthen ties with current and potential investors have been expanded through the creation of an External Relations program, whose primary mission is to broaden the Center's funding base The new program combines the areas of donor relations, project development, public awareness, and other information areas that contribute to these operations

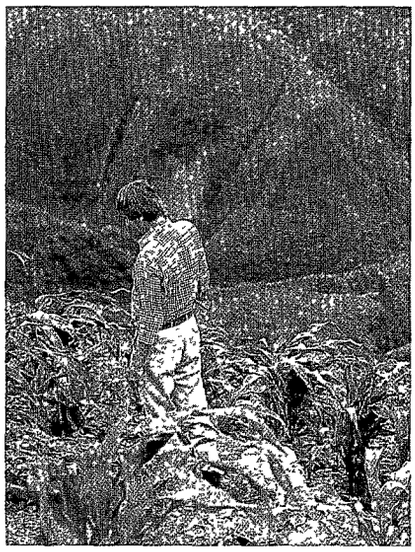
Perhaps more importantly, we are in the process of redefining CIMMYT's research agenda in terms of a number of "megaprojects," each of which addresses research challenges of major global or regional importance These megaprojects will form the heart of our new Medium-Term Plan, referred to at the very beginning of this introductory section. We are working hard to ensure input by key stakeholders into the formulation of these megaprojects and the Plan itself

So, on this, the occasion of CIMMYT's 30th anniversary, let us celebrate the climate of change in which we find ourselves Let us reiterate the fundamental operating principles of true research partnerships, mutual respect and understanding, and professionalism in the face of adversity, that will guide CIMMYT staff and their colleagues in developing countries into the next century And yes, let us take time to recognize all that has been accomplished during the past 30 years

But even more important, let us rededicate ourselves to meeting the challenges of the *next* 30 years easing the plight of the poor, protecting our children's natural resources, and increasing food security for all

Natural Resource Initiatives

The facts cannot be ignored They point toward hard conclusions with the cold logic of a schoolbook syllogism or a proposition out of Euclid



- World population is increasing at a rate of 100 million per year
- Food production must increase dramatically to cope with this growth
- Most of the world's arable land—and all of its best lands—are already being cultivated, often at a high level of efficiency

How then are we to continue feeding ourselves? Given that trade opportunities are limited and that much of the world derives its income from small-scale farming, only two answers are possible by *intensifying production* on currently cultivated lands and by *expanding production* onto marginal lands

Both options will require an unprecedented level of expertise in managing the natural resource base At present, however, we know relatively little about the long-term implications of intensified production, nor are we well equipped to deal with large-scale migrations into marginal and easily degraded environments

Unless we can develop strategies that produce adequate food supplies in the short term without compromising the long-term productive capacity of the resource base, the human and environmental costs are apt to be catastrophic Even at current population levels and production intensities, resource degradation in developing countries has often been swift, severe, and widespread

CIMMYT's newly formed Natural Resources Group (NRG) was established with these challenges in mind More specifically, the NRG helps CIMMYT and its collaborators answer these key questions

- What are the opportunities for environmentally safe increases in maize and wheat productivity?
- How can maize and wheat technologies help slow or reverse environmental degradation?
- How can the long-term consequences of technical change best be assessed?

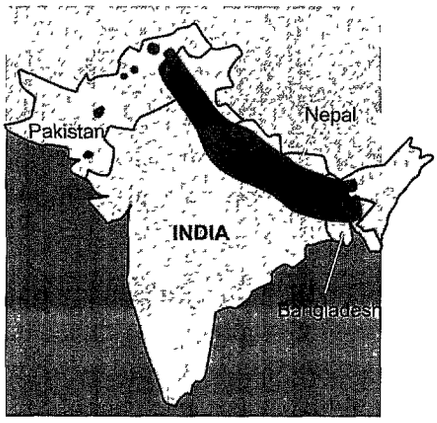
Because natural resource issues are inextricably connected to CIMMYT's ongoing work, the NRG has been designed not as a separate program but as a cross-cutting activity that supports and complements efforts in the Maize, Wheat, and Economics Programs The following projects are representative of the natural resource initiatives in which CIMMYT participates

Rice- and Wheat-based Cropping Systems in the Indo-Gangetic Plains

Recent evidence from some high-productivity sites suggests that resource degradation may be reducing productivity in South Asia's rice-wheat systems Such news has sobering implications for the more than 200 million farmers who depend for their livelihoods on this cropping sequence. Sobering too is the possibility that widespread degradation has been masked by the increased use of fertilizers and other inputs, thus raising the risk that irreversible damage may occur before the danger is fully realized

Rice and wheat dominate South Asia's food supply, accounting for about 90% of the region's total cereal production Because further expansion of the area planted to these crops is likely to be negligible, the production gains necessary to keep pace with population growth will have to come mainly from yield increases Although average rice and wheat yields rose at about 2% per year between 1960 and 1990, evidence suggests that these impressive rates are no longer being maintained Indeed, in some intensively cultivated areas, yields have already begun to decline

These indicators are especially alarming since the use of productivity-enhancing inputs seems to be approaching saturation levels in many areas Adoption



South Asia's rice-wheat area.

of modern varieties is virtually complete, and although farmers can realize further genetic gains by regularly replacing old varieties with new ones, many breeders now focus on maintaining yields through improved resistance and grain quality Fertilizer use on rice and wheat is now close to optimal in many zones With traditional sources of productivity growth showing signs of exhaustion, how will farmers keep pace with increases in demand?

"We aren't going to meet this challenge simply by conducting the same kind of research we've conducted in the past—or even by conducting the same research better," says NRG staff member Peter Hobbs "Although some low-production areas still have scope for yield gains from increased input use, high-productivity areas are going to require more and more sophisticated information about how to increase the *efficiency* of input use and how to arrest—or reverse—soil and water degradation "

The Rice-Wheat Consortium

Developing this kind of efficiency is one of the chief aims of the Rice-Wheat Consortium for the Indo-Gangetic Plains An outgrowth of collaborative work between CIMMYT and national partners in the 1980s, the Consortium now includes national programs from Bangladesh, India, Nepal, and Pakistan (China is an associate member), as well as a number of universities CGIAR partners include IRRI, ICRISAT, and IMMI CIMMYT leads work on land management, tillage, and crop establishment, we support work on system ecology and on nutrient and water management

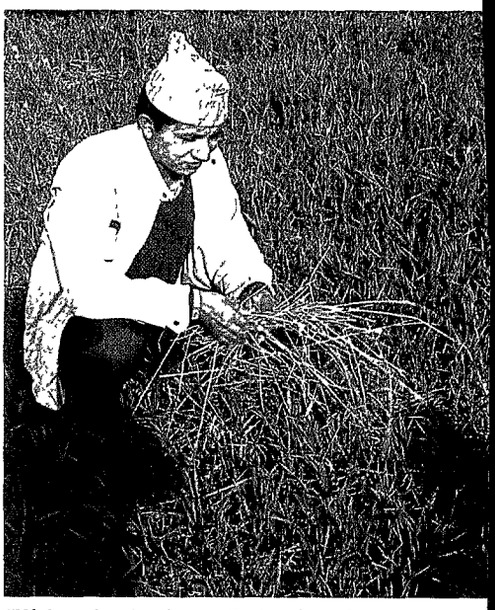
"The Consortium provides a good model for the development of an ecoregional initiative in line with national research priorities," says William D Darr, Chairperson of the Asia-Pacific Association of Agricultural Research Institutions

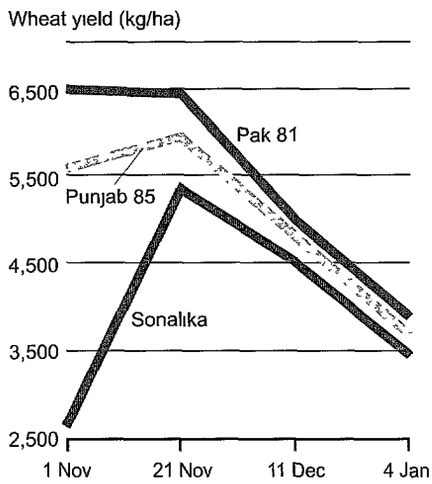
Hobbs concurs that this kind of responsiveness is crucial to the Consortium's success "We can't just develop prepackaged solutions, administer them across large regions, and expect to achieve uniformly beneficial results," he says "To cope with these increasingly complex problems, we must develop flexible technical options that farmers can adjust to their own circumstances "

A multidisciplinary, systems-oriented approach is clearly evident in CIMMYT-led work on reduced tillage and improved crop establishment Properly managed, a reduced tillage system offers a number of advantages farmers can plant earlier, avoid late-season heat stress, increase the efficiency of applied inputs, produce better stands, use less fuel, and reduce equipment wear To maximize these benefits, however, the Consortium must foster collaboration among a broad range of participants

"We work with plant breeders to develop varieties capable of flourishing under various new schemes," Hobbs says "We work with equipment designers and blacksmiths to ensure that the machinery is effective and available We work with crop protection specialists and specialists in water and fertilizer management to develop site-specific practices and to monitor the long-term impact of those practices We work with policy-makers to help catalyze change And we work with farmers since they must ultimately be convinced that the new packages are more effective "

The potential payoffs from this kind of collaboration are difficult to overstate "When wheat planting is delayed past the end of November, yield declines by 1 to 1.5% per day," Hobbs says "One of the chief causes of these delays is time-consuming—and often excessive—tillage operations In some regions, these delays can push back planting dates by four weeks or more. Reduced tillage


"We've clearly shown that reduced-tillage options can be more efficient and economical," says G.S. Giri of Nepal's National Wheat Program



Effect of planting date on wheat yield

systems often require more careful management, but by cutting the turnaround time between rice harvest and wheat planting, they can be a great boon to farmers "

Thus far, the Consortium is examining a range of reduced tillage systems—as well as some systems that rotate reduced and conventional tillage "In low lying, poorly drained areas with heavy soils, surface seeding may be the best option since it doesn't require any equipment," Hobbs says "In other areas, we are examining the effect of various tractor-drawn drills We are also testing a two-wheeled Chinese drill that looks promising and eliminates the need to keep a pair of bullocks just to plow the land And we have had some promising preliminary results with bed planting systems that have become popular in Mexico "

Reduced Tillage: Impact in Nepal

The surface-seeding option has proven so effective in parts of Nepal that farmers are now fine-tuning the practices in their own fields. "Wet soils that produced about 1 5 tons per hectare under conventional tillage are producing up to 3 0 tons per hectare under the zero-tillage system," says Hobbs "Moreover, when one considers that tillage operations account for about a third of all production costs, the advantages of this option become even more obvious "

NRG Manager Larry Harrington adds that, in evaluating these and other technologies, his staff are particularly mindful of sustainability issues "We don't just focus on near-term, on-site impacts," he says. "Our role is to clarify the consequences of various alternatives across a broad agricultural, environmental, and social canvas On-site assessments must be balanced against off-site assessments at various levels of system hierarchy Short-term impacts must be balanced against long-term impacts Productivity concerns must be evaluated alongside environmental and ecological considerations As we learn more about these complex interrelationships, farmers and policy-makers become better equipped to make informed choices about the kinds of systems they want "

Smallholder Maize Systems in Mesoamerica

In Mesoamerica, land degradation, primarily from erosion, now affects about 50% of the hillside farmland And the farmers who work these lands are among those least able to withstand production vagaries and implement costly remedies

The effects of land degradation, however, are not borne solely by farmers Runoff from farms and cattle operations has contributed to a broad range of environmental and economic problems: contaminated water, flash floods, the siltation of rivers, financial losses to fish-farming industries, and the compromised efficiency of hydroelectric power plants

Because the area devoted to hillside maize is three times the combined area devoted to other hillside crops, productivity-enhancing, resource-conserving maize systems tailored to the needs of marginal farmers are crucial to addressing Mesoamerica's food-security and environmental problems

The chief components of these systems are well-established Farmers and researchers have long known that both cover crops and conservation tillage strategies can stabilize the land, reduce runoff, improve water infiltration, and increase soil organic matter. What has often been underestimated, however, is the difficulty of tailoring these general strategies to the specific economic and environmental conditions of marginal farmers

CIMMYT works to overcome these problems with a wide range of partners These include the Mexican national

research program, the Programa Regional de Maíz, CIAT, IFPRI, the Instituto Interamericano de Cooperación para la Agricultura, CATIE, the Instituto Centroamericano de Administración de Empresas, the Escuela Agrícola Panamericana, and various NGOs

Farmer Adoption Studies

One collaborative venture is helping to clarify why farmers adopt (or fail to adopt) new maize technologies In Mexico, NRG staff member Olaf Erenstein has shown that indiscriminately promoting soil conservation measures developed in the industrialized world often proves misguided since measures such as conservation tillage can have substantially different implications in the tropics For unmechanized maize-based systems, conflicting demands for crop residues are a particularly important consideration

"When residues are used as fodder, the cost of leaving them on the field is painfully clear," Erenstein says "The land-stabilizing benefits tend to be less so. Before we try to transfer conservation tillage systems to these hillsides, we need to appreciate the constraints under which farmers labor"

Responding to that insight, maize agronomist and NRG staff member Eric Scopel has determined that farmers in Jalisco state, Mexico, generally have a small surplus of residues after they feed their animals—enough to provide about 2 tons of mulch per hectare Typically, these residues have been burned or incorporated "Very few studies in tropical regions have analyzed the impact of this minimal level of mulch on productivity and soil moisture," Scopel says

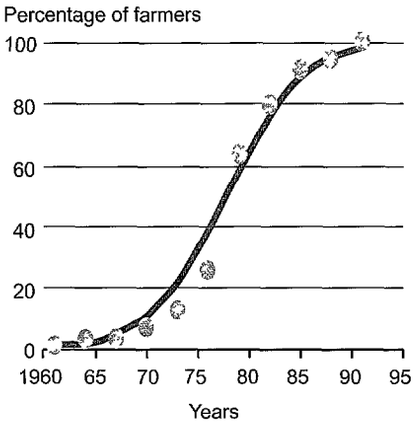
Scopel's preliminary studies are encouraging "In some dry areas at least, conservation tillage practices that employ just 2 tons of mulch per hectare can have a tremendous effect—in some cases enabling farmers to produce 50% more grain and 30% more biomass as compared to traditional practices," Scopel says He points out, however, that herbicides and specialized equipment will be required if farmers

are to plant through the residues and avoid weed problems To obtain and employ these materials, many farmers will require financial and technical support—issues that policy-makers need to consider carefully

Related work in El Salvador has clarified the confluence of technical, institutional, and economic factors related to the widespread adoption of conservation tillage practices in the Guaymango area "Unlike farmers in other parts of El Salvador, Guaymango farmers adopted these practices—and they did so for two basic reasons," says Gustavo Sain, a member of CIMMYT's Economics Program and an NRG associate "First, the recommended package combined soil conservation components and productivity-enhancing components, thus ensuring that long-term benefits were not overshadowed by short-term costs Second, economic and institutional incentives encouraged the adoption of *both* components—not just the one related to production"

The Guaymango case also offers an excellent example of how increased productivity can contribute to long-term sustainability In this case, the

introduction of high-yielding maize varieties tremendously increased stover production As a consequence, farmers had more than enough stover to feed their animals and so could apply the additional residues to their fields Far from depleting the resource base, the more productive technology is actually helping to protect it



The spread of conservation tillage in Guaymango, El Salvador

Targeted Policy Workshops

In El Salvador and the Sierra de Santa Marta Region of Mexico, CIMMYT has organized targeted policy workshops that bring together local-, regional-, and national-level stakeholders to develop a common vision with respect to crucial productivity and sustainability problems CIMMYT staff then build on this vision, encouraging coordinated action to ameliorate problems Targeted policy workshops will become an increasingly important component of the NRG approach

In the Sierra de Santa Marta, workshop participants devised a strategy that is also becoming an important part of the NRG approach farmer-to-farmer dissemination of improved practices. In this instance, designated contact farmers were trained and then encouraged to form regional groups interested in learning more about the new methods Improved practices were subsequently implemented on more than 1,500 hillside hectares

Although pleased by this outcome, Erenstein points out that researchers still have a lot to learn about farmer-to-farmer dissemination methods "Perhaps the most important result of this project was the opportunity it afforded us to refine those methods," he says. "We are now in a better position to employ this cost-effective strategy for reaching large groups of farmers "

Assessing Impact and Scaling Up

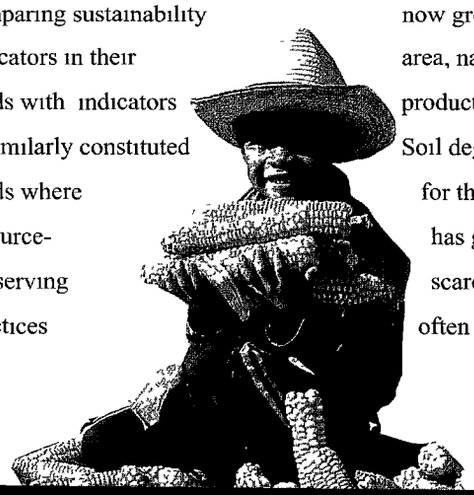
CIMMYT's emphasis on increasing and sustaining production requires an ability to monitor the long-term impact of technical change The problem with such monitoring, of course, is that (by definition) long periods are required to obtain results—and farmers and policy-makers often need answers now CIMMYT and its collaborators are employing an innovative approach that may help to circumvent this problem Recognizing that many farmers have already been growing green manure cover crops in maize rotations or employing conservation tillage practices, researchers are comparing sustainability indicators in their fields with indicators in similarly constituted fields where resource-conserving practices have not been employed These studies are helping researchers develop a time series (or *chronosequence)* for monitoring system productivity and resource quality

In work that will help to extend these kinds of findings across large regions, NRG staff member Hector Barreto has developed and digitized a soil database using information from studies conducted in Honduras over the last 25 years A soil scientist jointly sponsored by CIMMYT and CIAT, Barreto points out that the database contains over 600 soil profile descriptions, each of which can be georeferenced to various environmental and socioeconomic factors Such information provides essential baseline data for the chronosequence studies currently being conducted at two sites in Honduras

Smallholder Maize Systems in Southern Africa

Maize dominates the smallholder cropping systems of southern Africa Recent projections suggest that yields must increase from 1 1 to 2 5 tons per hectare to meet food needs into the first quarter of the next century At present, declining soil fertility prevents such increases in the wetter agroecologies and is also a major constraint in semi-arid regions

Although improved germplasm is now grown on 33-50% of Africa's maize area, national per hectare increases in productivity have been disappointing Soil degradation is largely responsible for that disappointment As population has grown, lands have become more scarce and shifting cultivation has often been replaced by continuous



maize cropping Fallows—which traditionally restored soil fertility and reduced the buildup of weeds, insects, and diseases—are disappearing Nutrient losses now generally exceed nutrient inputs Only about a third of the region's maize area receives any inorganic fertilizer The task of improving productivity without compromising sustainability has become so large that no single discipline can hope to address it

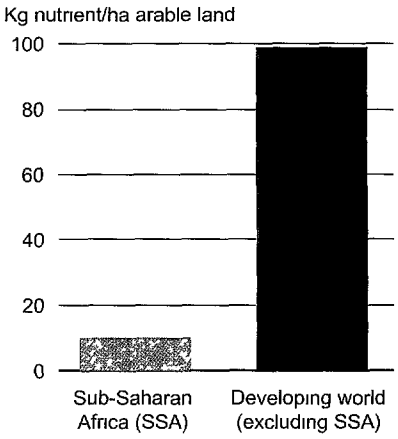
"Improved germplasm alone will not meet the challenge," says CIMMYT's Steve Waddington, an agronomist with the Maize Program and an NRG associate based in Zimbabwe "We must address the complex issues related to building-up and maintaining soil fertility under the income constraints faced by poor farmers "

Innovative Approaches

With the Rockefeller Foundation and national programs, CIMMYT has organized a Soil Fertility Research and Extension Network to address just such complexities The network links multidisciplinary groups in Malawi, Zimbabwe, and Kenya Members conduct basic, applied, and adaptive research, and they encourage technology adoption by working closely with farmers and NGOs Particular attention is devoted to combining organic and inorganic nutrient sources

At present, inorganic fertilizers are expensive and not very profitable for smallholders—especially since blanket applications are recommended even in semi-arid areas To change that reality, farmers need information about what types of inorganic fertilizers to apply, when to apply them, and what parts of the field are likely to be most responsive Because such information tends to be site specific, network members are developing a menu of options that users can adapt to their own circumstances

"To halt the downward spiral of soil fertility, farmers also need to increase the proportion of locally produced organic materials," says Waddington "Legumes offer a way to provide these materials and to capitalize on the freely available nitrogen in the atmosphere, but the potential of these technologies is rarely realized in farmers' fields "



Inorganic fertilizer application rates for 1993 dramatize the need for innovative approaches to solving sub-Saharan Africa's soil fertility problems.

How do we change that reality? "We need to do more with legumes that farmers can plant for food," Waddington says "And old technologies such as rotations with grain legumes need to be made more attractive to farmers "

Combining low rates of organic and inorganic inputs seems a promising way to increase maize productivity, but innovative mechanisms will be needed to help farmers obtain these inputs One such innovation, working well with an NGO in central Malawi, is to provide farmers with start-up grants paid into savings schemes from which farmers can obtain loans In the future, the network plans to explore more and more of these options

GIS and Modeling

The Network will benefit from CIMMYT's expanded potential for applying and extending research information "To simplify a bit, geographic information systems help us extrapolate across space and modeling tools help us extrapolate across time," says new NRG staff member Jeff White "With modeling, we're trying to reduce risk and improve research efficiency by making projections over long periods With GIS, we're trying to broaden the impact of what we learn at one site by extending it to other sites. One challenge, of course, is identifying the scale we need to employ for such transfers to be successful "

"It's not just a question of matching-up soil analyses," White adds "We need to consider a whole range of production variables That's complicated work—but the potential payoffs are enormous "

So too are the consequences of failure "Our technology-development process is becoming more attuned to farmers' needs," Waddington says "We must persist in those efforts if we are to prevent a continuing decline in rural living standards across southern Africa "

Fine-Tuning Fertilizer Applications to Raise Wheat Yields and Protect the Environment

In the Yaqui Valley of northwestern Mexico, a team of scientists from CIMMYT, Stanford University and the University of California Berkeley is investigating what may be a significant but hidden relationship between farmers' nitrogen fertilizer applications and stagnating wheat yields, the holes in the ozone layer, and other environmental phenomena

In an outstanding example of research collaboration, these scientists are studying farmers' fertilizer use from three different perspectives CIMMYT agronomists are focusing on ways to improve farmers' fertilizer practices and raise their yields, behavioral scientists from Stanford are studying the socioeconomic factors that influence farmers' decisions regarding fertilizers, while ecologists from UC Berkeley are concentrating on measuring gas emissions produced by fertilizer applications "This is a potential 'win-win' situation where the results we hope to get will benefit farmers and the environment alike," explains Ivan Ortiz-Monasterio, CIMMYT wheat agronomist coordinating the project in Mexico The project is being funded mostly by the US Department of Agriculture

Studies conducted in developed countries have shown that nitrogen fertilizer applications tend to increase atmospheric levels of two nitrogen-derived gases nitrous oxide, a greenhouse gas that also contributes to the destruction of the ozone layer, and nitric oxide, which adds to the unwanted ozone in heavily populated cities and is an ingredient in acid rain Similar information on nitrogen fertilization in developing country agriculture is lacking, although scientists suspect it may account for a significant amount of these gases present in the atmosphere Finding out just how much is one of the reasons this study was undertaken in the Yaqui Valley, a site representative of nearly half the wheat growing environments in developing countries

For the wheat crop to absorb more nitrogen, the timing of fertilizer applications and of irrigation is as important as the amounts applied With this in mind, researchers set up an experiment to compare the typical farmer's practice, in which most of the fertilizer and one irrigation are applied almost a month before planting, with an alternative that schedules nitrogen applications and irrigation in response to the wheat plants' needs — at planting and one month afterwards Their observations suggest that nitrogen is lost mainly during irrigation The water carries away part of the nitrogen and triggers gas emissions when it comes into contact with the nitrogen "If what we're finding is true, the farmers' practice causes a significant portion of the nitrogen to be lost before the wheat crop is even planted," says Ortiz-Monasterio

The experimental practice produced lower gas emissions and higher wheat yields, which makes CIMMYT agronomists feel they are on the right track for finding a combination of fertilizer applications, irrigation, and timing that will improve farmers' yields and reduce nitrogen loss Eventually the practice will be recommended to local farmers, who may or may not adopt it

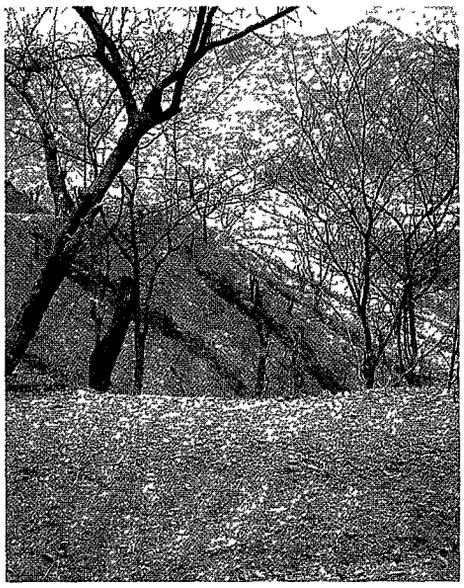
Ellie Rice, of the Stanford group and predoctoral fellow in Economics at CIMMYT, is reviewing CIMMYT interviews with farmers from the past 15 years to see if the new practice will prove attractive "To the extent that we understand what the farmers are doing and why, we can come up with fertilizer practices that are good for the environment and well suited to farmers' needs," says Rice Adds Beatriz Avalos, also of the Stanford group, "Our hope is that the practices that result in the highest yields and lowest nitrogen losses will also be economically profitable to farmers "

Research for Marginal Areas:

Feeding the Millions,

Shepherding Scarce Resources

They say you can't get water from a stone This well-known admonition against unrealistic expectations might color the thoughts of many a farmer in marginal production zones of Africa, Asia, and Latin America The extraordinary multiplication of humanity and its demands in developing countries have elbowed agriculture into ever more forbidding environments acid savannas, tropical forest margins, steep, erosion prone hillsides, drylands threatened by creeping desertification, areas where rainfall may come too little or too late, areas where infertile soils, like a starving mother, poorly nurture the crop Water from a stone.



Burgeoning populations are also overwhelming once abundant, traditional crop lands, in effect making them more marginal too. Partitioned and spread among members of expanding families, the land is stretched thinner with each successive generation To squeeze productivity out of their holdings, farmers practice intensive, multiple cropping year round Fertility drops and weeds, pathogens, and insect pests flourish.

There will be relatively few offerings from the private sector to meet the demands for agricultural technology in such regions, where the promise of large profits or impacts is scant Despite the hardship, though, few farmers choose to abandon their lot — agriculture is the only life they know and other sectors in their nations do not yet furnish viable alternatives

In keeping with its mission, CIMMYT is working with research partners to help address the needs of these half-forgotten farmers Outputs include hardy, resource efficient strains of maize and wheat suited to the rigors of marginal production settings, as well as cropping practices that boost yields while preserving scant natural resources With funding from such long-term supporters as the Inter-American Development Bank (maize for acid soils) and the United Nations Development Programme (maize stress breeding), we have made great strides and are now working with partners to get useful products to farmers' fields For many years, the Canadian International Development Agency has financed crop management research in sub-Saharan Africa that has brought, among other things, significant progress on methods for controlling the parasitic flowering plant, *Striga* spp In wheat, stable resistance to major fungal pathogens and tolerance to important stresses such as heat make the crop even more apt for developing country farming systems As is evident from the reports below, much of the work we do has strong relevance for sub-Saharan Africa, where farmers badly need more productive, resource saving technology

Helping Maize Farmers Through Dry Spells

Nothing is more obvious to people in eastern and southern Africa than the overriding influence of rain on the region's economic well-being Most dramatically, after the major drought of 1991-92 some US$800 million in food aid was needed to stave off starvation Export deficits soared from reduced agricultural production and many poor rural inhabitants were pushed to starvation

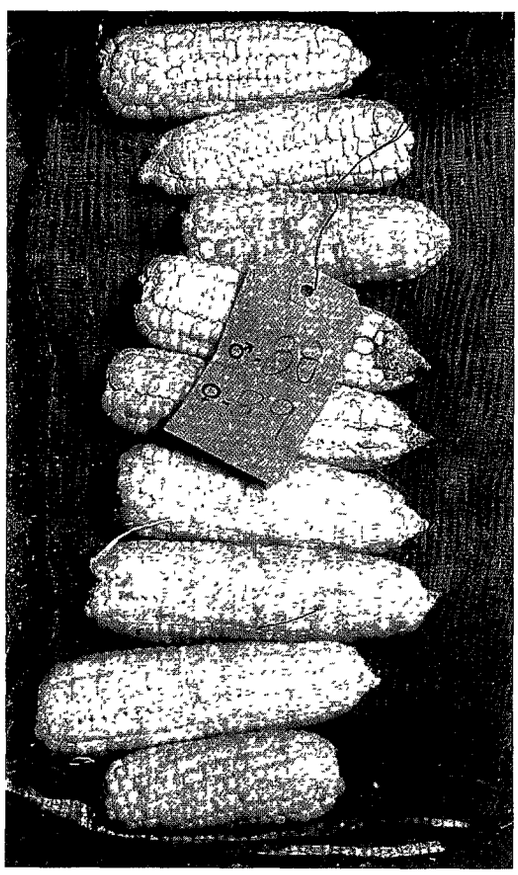
Eastern and southern Africa is not the only region, though, where maize farmers struggle on limited moisture "Throughout the developing world, drought is second only to soil infertility as a constraint to maize production, and probably reduces yields overall by more than 15% yearly," says CIMMYT maize physiologist Gregory Edmeades "This represents annual losses in excess of 20 million tons of grain "

To help farmers capture this foregone productivity, Edmeades and his colleagues found a simple yardstick for identifying and improving drought tolerance in maize In essence, they showed that mid-season drought tends to increase the number of days between

male and female flowering, known formally as anthesis-silking interval (ASI), and that this effect was tied to the dramatic loss in productivity under dry conditions during flowering Capitalizing on the correlation, they developed a methodology for improving the drought tolerance of maize by selecting under dry conditions for reduced ASI The technique can increase maize yields by half under severe, mid-to-late season drought. A valuable spin-off was the more recent discovery that selecting for reduced ASI also improves the performance of maize under low nitrogen conditions

The methodology is relatively easy and does not require special equipment "Breeders need only measure yield, ASI, and a few related secondary traits under uniform drought or low nitrogen conditions," Edmeades says "Nonetheless, establishing and maintaining controlled stress levels is difficult for many maize research programs in developing countries, given their resource constraints "

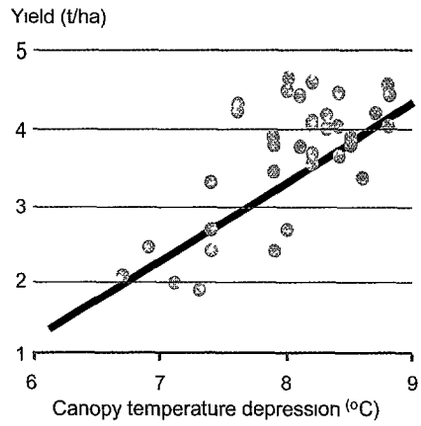
So, with funding from the United Nations Development Programme (UNDP) and Swiss Development Cooperation (SDC), CIMMYT is beginning joint research with national programs in sub-Saharan Africa to establish suitable selection sites and help local breeders improve leading maize cultivars from the region for drought and low-nitrogen tolerance To foster the best use of resources and speed progress, we are helping to set up a drought and low-nitrogen tolerance breeding network for eastern and southern Africa, and will work with IITA and existing networks in West and Central Africa Network scientists throughout each region will work collaboratively, sharing seed and information "There is no overstating the importance of this for subsistence maize farmers in Africa," Edmeades says "Their yields typically hover around one ton per hectare they and their families have absolutely no margin for crop failure " Added help for the above initiatives is forthcoming in the form of DNA marker-assisted selection techniques for drought and low-nitrogen tolerance in maize



The tag tells the story for these ears from a drought tolerant line of maize grown under dry conditions Male flowering (anthesis) occurred 88 days after planting, the female flowers (silks) appeared only one day later Such a brief anthesis-silking interval (ASI) is what breeders aim for when improving maize yields under drought

Wheat for the Subtropics: Cool Heads Prevail under Heat Stress

Keeping a cool head has big advantages, not only in humans, but in wheat as well In places where temperatures may reach 35-40° C, only wheats that manage to keep their 'heads' (canopies) cool produce good yields "After five years of observing



Association between CTD and yield of sister lines (Seri 82/Siete Cerros) in Tlaltizapan, Mexico (average for two cycles)

wheat's reaction to heat, we can confidently say that a cooler canopy leads to higher yield," says Matthew Reynolds, CIMMYT physiologist and leader of a project focusing on developing methods for selecting heat tolerant wheat Funds for the project were provided by the United Kingdom's Overseas Development Agency (ODA)

Wheat, normally a temperate crop, has been moving into hot, subtropical environments, where people's rising incomes and changing tastes have increased the demand for wheat products Today over 7 million ha of wheat in about 50 countries is grown under continual heat stress, often with low yields In an even larger expanse in South Asia, where wheat is often

planted late (after rice), damage inflicted by heat during critical phases of the crop's development notably reduces yields Recognizing the need for wheat varieties that yield reasonably well in those harsh environments, CIMMYT breeders have been focusing on improving heat tolerance since the 1980s

Selecting for heat tolerance in the field is difficult Up to now, breeders have had to rely on measuring final yield under stress But yield is not a good indicator of how well wheat tolerates heat, so a more reliable one was needed Reflecting the close collaboration between wheat breeding and physiology at CIMMYT, physiologists went to work on testing several traits that might be used to guide selection

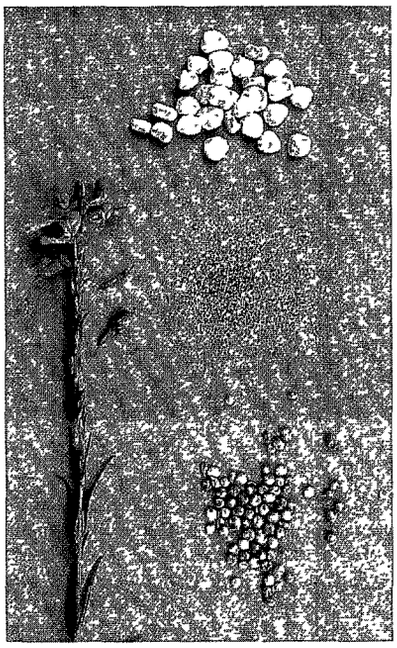
One likely candidate was the ability of some wheats to keep their canopies cooler than the surrounding air (a phenomenon called canopy temperature depression, or CTD) Initial studies revealed that CTD is closely associated with yield, the fact that it can be measured quickly and easily with an infra-red thermometer made it doubly attractive "Other physiological traits are measured on individual leaves, one by one," explains Reynolds "But the infra-red 'gun' reads the temperature of scores of leaves at once, in a matter of seconds, and gives more precise readings "

Researchers tested the CTD-yield connection under hot, irrigated conditions at CIMMYT's experiment station in Tlaltizapán, Mexico, and in such countries as Sudan, India, Brazil, Bangladesh, and Nigeria, where wheat is cropped under similar conditions Results confirmed that CTD is positively correlated to yield and could serve as a powerful breeding tool in heat stressed sites all over the world "Thanks to the cooperation of national research programs, our findings are truly representative of wheat growing environments worldwide," emphasizes Reynolds

Breeders hope the new technique will be useful in improving other traits besides heat tolerance—for example, to increase wheat's genetic yield potential "CTD is probably a good indicator of higher yield in all kinds of environments, not just hot ones," says Maarten van Ginkel, head of bread wheat breeding at CIMMYT "If so, it could help us breed varieties that yield even more than our current ones This would benefit farmers in developing countries whose yield increases aren't keeping pace with population growth "

Fighting Witchweed's Spell in Sub-Saharan Africa

To farmers in sub-Saharan Africa, the term "witchweed," used popularly for the parasitic flowering plant *Striga* spp , is certainly no misnomer The parasite is one of the foremost biological constraints to food production in the region, and sorcery might well be invoked as an explanation for the widespread damage it causes Witchweed infests an estimated grain growing area of 21 million hectares in Africa, resulting in annual yield losses calculated at 4 1 million tons In northern Ghana alone, witchweed attacked maize on more than 40% of the region's 134,000-ha maize area in 1988,



Seeds of *Striga* spp (center) appear dustlike in comparison with those of maize (above) and sorghum. A single stalk of this parasitic weed can produce tens of thousands of seeds, making containment of *Striga* difficult

reducing yields as much as 16% and the value of the crop by some US$4.5 million. Kenya has suffered similarly catastrophic crop losses to *Striga* in the current decade.

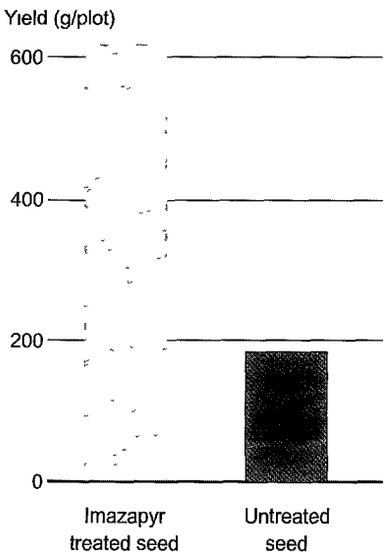
The modus operandi of this parasitic plant makes it notoriously difficult to control. Early in its life cycle, the seedling attaches to the roots of a potential host and siphons off water and nutrients Worst of all, it poisons its victim, often leaving a stunted and barren plant. "By the time *Striga* emerges above ground, considerable damage has already been wrought upon the crop," says Joel Ransom, CIMMYT maize agronomist in eastern Africa "This means that farmers can't really control it through the traditional approach of weeding "

Ransom and his colleagues in the region have been collaborating for several years to develop simple and inexpensive ways to break witchweed's spell. It turns out that there are no easy solutions, but they have discovered that *Striga* primarily affects small-scale farmers with limited resources, so integrated control strategies are required Ransom talks about three primary components for control containment, reducing seed banks, and maintaining or increasing farm productivity Containment simply means using clean seed and farm implements Reducing *Striga* seed banks, in contrast, may involve several steps. One is to prevent reproduction through hand-weeding and herbicides Another is essentially tricking *Striga* into suicide by planting "trap crops" — false hosts that trigger its germination but resist its attacks A particularly effective trap crop is the fast growing leguminous tree, *Sesbania sesban,* also known to enhance soil fertility when used as part of a managed fallow Finally, productivity can be improved by using resistant cultivars or non-host crops, by bathing herbicide-resistant seed in herbicides to delay attachment and kill the *Striga*, and by improving soil fertility "This pest occurs in varied agroecologies and farming systems in the region," Ransom says, "So our research partners need to test and adapt control measures locally "

Ransom has been promoting *Striga* control in various ways besides collaborative research For example, with funding from the Canadian International Development Agency and diverse supporters, he organized the 5th International Symposium of Parasitic Weeds in Nairobi, Kenya, and coordinated production of the related proceedings Ransom is also active in educating colleagues and decision makers about the seriousness of *Striga* "We are talking here about one of the most intractable pests of maize in sub-Saharan Africa," he says

To help small-scale maize farmers hold the line on *Striga* in the future, CIMMYT will begin work in a project involving the University of Hohenheim, Germany, the Kenya Agricultural Research Institute (KARI), the Rockefeller Foundation, and our sister

Lovely and lethal, the parasitic flowering plant Striga attaches to the roots of cereal crops, sapping nutrients and poisoning hosts with a potent phytotoxin This Kenyan maize field has been overrun by *Striga hermonthica.*



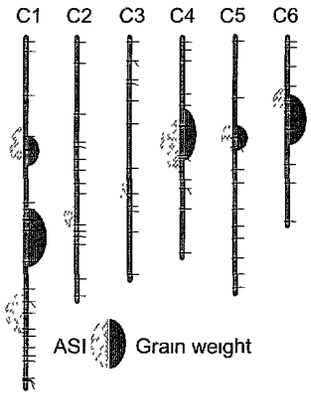
Using herbicides to coat herbicide-resistant maize seed before sowing helps control *Striga*

center, IITA, to develop and disseminate *Striga* resistant maize varieties and hybrids using conventional and DNA-based approaches Efforts will capitalize on the recent identification at IITA of resistant maize lines, the genomes of which the CIMMYT biotech staff will help map in hopes of applying DNA marker assisted selection to transfer resistance to a range of maize for sub-Saharan Africa Also, given the discovery of witchweed resistance in maize's grassy relatives, teosinte and *Tripsacum,* CIMMYT will provide seed of these wild species for screening and will develop mapping populations for any new resistance genes found within either species. Finally, Ransom and his research partners in eastern Africa will conduct field evaluations for *Striga* resistance in experimental products from the above activities "Controlling *Striga* will not only increase maize productivity in Africa," Ransom says, "but will improve the lot of poor farmers, who are the hardest hit by the pest."

Toward the Future

To develop resistance sources and breeding and crop management research methodologies for stress, work initially focused on individual traits But crop production constraints rarely occur in isolation, and interactions among them can multiply damaging effects Thus, in recent years CIMMYT has worked increasingly on combining two or more traits in elite experimental varieties for specific regions In sub-Saharan Africa, for example, this includes developing maize that possesses resistance to both streak virus and major insect pests The approach will be expanded in the future, with the help of new genetic resources and techniques supplied by the CIMMYT ABC. Finally, to ensure the relevance and profitability of new technology for crop and natural resource management in marginal environments, researchers will draw heavily on contributions from the areas of social science, crop modeling, and geographic information systems.

Since 1990, CIMMYT's Applied Biotechnology Center (ABC) has been working with breeders and others to develop and apply molecular selection techniques for improving maize and wheat and, more recently, to utilize desirable genes from organisms with which the crops cannot intermate A list of the CIMMYT research areas where marker-based techniques are being used reads like a description of key crop production concerns in wheat, there is work on vernalization and photoperiod, durable resistance to rust and barley yellow dwarf virus, and tolerance to aluminum, in maize, efforts cover drought, acid soil, and low-nitrogen tolerance, as well as resistance to insect pests and pathogens such as maize streak virus, maize mozaic complex, and *Fusarium* spp Markers are also being used to further our understanding of the origins and evolution of maize and to obtain and apply apomixis Finally, drawing on expertise in tissue culture, genetic engineering, and molecular biology, ABC staff have successfully transformed tropical maize and wheat with genes from other organisms



Selection for drought tolerance in maize using molecular markers will target genes associated with anthesis-silking interval (ASI) and yield. This will be easier in cases like the one shown here, where the same genome regions are linked to ASI and a yield-related secondary trait such as grain weight

Coming this far has not been as easy or as fast as some first imagined But, whatever the difficulties, leading research institutes worldwide continue to push the biotech frontier forward, plant breeding's future, as its past, is anchored in the genome

Marker Assisted Selection: Methodologies and Drought Tolerant Maize

Among the most promising tools of biotechnology are molecular markers, DNA signposts which allow near-direct selection for traits of interest In tandem with conventional field work, marker assisted selection (MAS) could considerably expedite breeding for certain genetically complex traits CIMMYT molecular geneticists and biometricians have been collaborating with breeders over the last year or so to develop a workable MAS scheme Their studies involve anthesis-silking interval (ASI) — the number of days between male and female flowering in maize As described in the section "Research for Marginal Areas," conventional selection for short ASI under drought significantly improves maize yields in droughted fields, and does not adversely affect yields in favorable settings. "The problem is that conventional breeding for drought takes about eight years and must be done under carefully controlled conditions," says molecular geneticist Jean Marcel Ribaut

This year, though, Ribaut and his colleagues tested an approach that should cut the development time for drought tolerant maize in half, as well as substituting laboratory selection for much of the fieldwork. The method alternates use of an older type of marker, restriction fragment length polymorphisms (RFLPs), with newer types known as sequence tagged sites (STSs) and simple sequence repeats (SSRs) To lay the groundwork, the researchers used RFLPs to map the maize genome and identify major genes associated with short ASI. They then developed experimental populations by crossing a short-ASI maize line of average agronomic characteristics with an elite line that has a long ASI

"This is a typical breeding scenario, and normally you would select in the field for progeny that show both short ASI under stress conditions and the superior traits of the elite parent," Ribaut says "In the lab, though, you don't have to wait till plants mature or place them under stress, you simply select for ASI and other yield-related markers, using DNA samples from plantlets." At one point midway through their work, the group needed to run marker tests on 2,200 plants "This would have been hard using RFLPs, which are relatively laborious," Ribaut explains. "So we did a preselection using the new markers In three weeks we identified 250 promising progeny " From this subset, a handful of plants that meet the requirements will be chosen using RFLPs once again. After one more molecular culling, breeders will be given the few choice plants that remain "These may require a cycle or two of work," Ribaut says, "but that's nothing compared to the labor of the conventional approach "

Genetic Transformation: From Biolistics to Agrobacterium

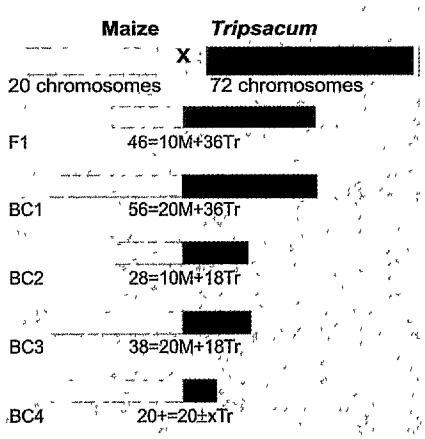
During 1995-96, ABC staff achieved their first successful genetic transformations of tropical maize and wheat In maize, they inserted and obtained expression of a gene from a common soil bacterium, *Bacillus thuringiensis* (*Bt*), that makes the plants resistant to maize borers. "Eventually, CIMMYT will be able to offer tropical maize cultivars which possess both *Bt*-based resistance and resistance developed through our conventional breeding efforts here," says Natasha Bohorova, head of the ABC's genetic engineering lab "Those materials will serve as a cornerstone for integrated pest management in developing countries, making maize farming more productive and sustainable " The work is far from finished, though Among other things, ABC and maize staff still need to study the inheritance of the transgene, its stability, and its expression in different maize plant tissues In wheat, Bohorova's group inserted transformation "tester" genes, in preparation for later transferring genes for fungal resistance and other useful traits

Insertion of the novel genes in both crops was accomplished using a "gene gun" — a device that propels DNA-coated dust into target cells on bursts of pressurized gas However, looking to the future, ABC staff are beginning experiments with a recently reported technique in which new DNA segments are carried into cells by Agrobacterium "The method seems to have several advantages over biolistics, both for us and for researchers in developing countries," explains David Hoisington, ABC head "First, it is more efficient at achieving stable insertions, second, it allows insertion of larger or multiple genes, and finally, the technology is much simpler "

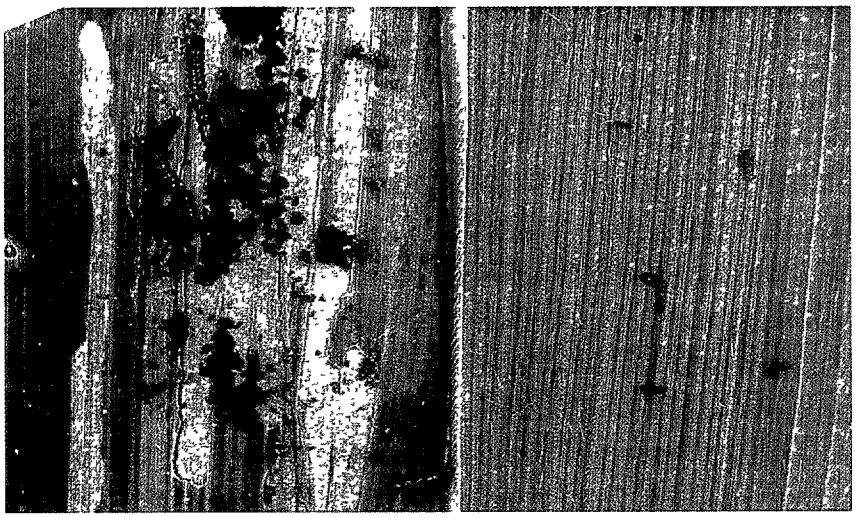
Progress in Research on Apomixis

Apomixis — asexual reproduction through the seed — results in plants that are exact clones of the mother plant Having apomictic versions of improved varieties and hybrids would mean that maize growers could replant seed from their own harvests each year and still maintain high yields, instead of having to purchase fresh seed The possible implications for farmers in developing countries — most of whom cannot afford or obtain commercial seed — are nothing short of revolutionary

Scientists from the French National Research Institute for Development Cooperation (ORSTOM) working at CIMMYT have been on the trail of apomixis since 1990, attempting to transfer it to maize from a grassy relative of that crop known as *Tripsacum* In 1995 the group achieved another milestone in that effort, generating several plants that closely resemble maize but reproduce apomictically (see figure) The researchers identified the apomicts using advanced cytogenetic and molecular techniques "Our methods



The ORSTOM-CIMMYT researchers' scheme for obtaining apomictic maize. First, maize and apomictic *Tripsacum* are crossed Selected hybrids (F1) are crossed back to maize Selected progeny from that step (BC1) are crossed back to maize again, and so on for successive backcross (BC) generations Each time the size of the *Tripsacum* genetic contribution is reduced Researchers use advanced techniques to ensure that the progeny selected at each step are those whose *Tripsacum* complements contain the apomixis gene The ORSTOM-CIMMYT team has reached BC4 — a largely maize-like plant — and estimate they are one or two steps from success



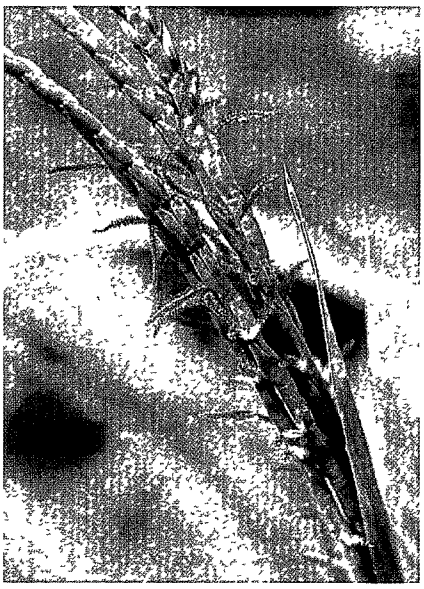
Leaves of maize endowed with *Bt*-based insect resistance (right) show the power of genetic transformation.

had to be efficient," says Yves Savidan, head of the ORSTOM-CIMMYT team, "because over five years we tested about 150,000 plants!" The new apomicts will be crossed with maize yet again, and Savidan and his group will comb the progeny for asexually reproducing maize, a process that should take two years

Since they began this crossing and sifting scheme, biotechnology has advanced rapidly and the resulting wealth of molecular tools also holds promise for apomixis transfer "We are exploring other avenues for analyzing and directly manipulating the genes involved, with the idea of eventually using apomixis in a range of crops," Savidan says "Right now we don't know how large the genome segment controlling apomixis is, but it tends to be transmitted as a cluster, rather than re-assorting itself as sometimes occurs from one generation to the next in reproduction, and this is an advantage "

Wrestling with thorny research issues is nothing new for Savidan and his team Since beginning the apomixis project, they have progressed through a seeming maze of challenges, bringing new answers to several old questions along the way One example was the puzzle of why apomixis exists in the wild only in polyploids — plants with chromosome sets in multiples greater than two — and never in diploids like maize. Their studies showed that the explanation lies in a natural barrier to apomixis transmission through haploid gametes, the reproductive cells of diploid organisms They then found a way around this stumbling block, making it conceivable to transfer apomixis to maize

"Past reports on apomixis have conveyed strong optimism, and the optimism remains," David Hoisington says "But we realize this is a long-term process that requires concerted effort and the use of both conventional and molecular methods Whatever it takes, we have the qualified scientists, the tools, and the resources — the potential payoff for poor farmers is too great not to pursue this work."

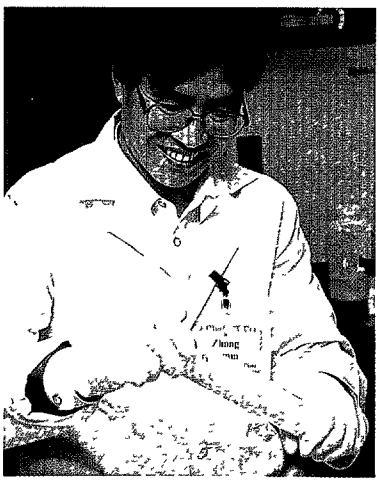


The flower of the *Tripsacum* plant.

CIMMYT Biotech Course: From Cutting-Edge Research to Applied Breeding

"We arrived with many questions We leave with many answers " Thus began a thank-you note signed by the 18 participants in the course "Molecular Marker Applications to Plant Breeding," held in December, 1995 The first-ever of its kind offered by CIMMYT, the course provided an introduction to plant genome analysis and its application to plant breeding problems in maize and wheat

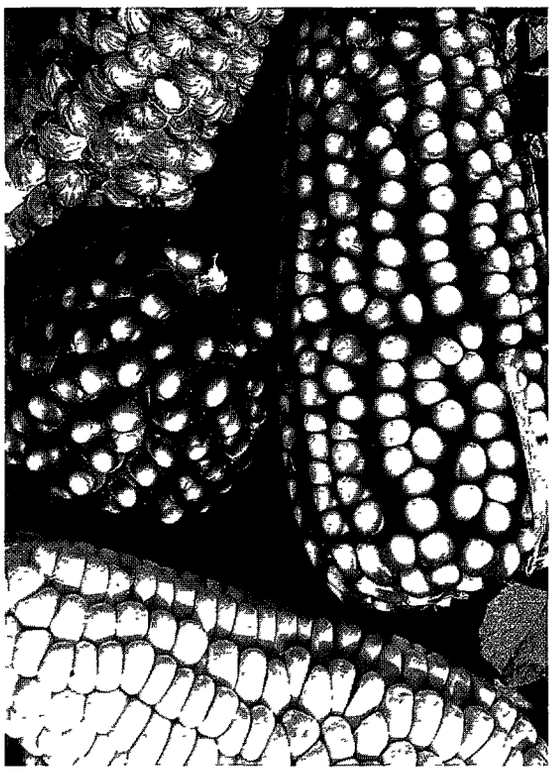
The professional background of participants ranged from conventional breeding, with no prior practice in molecular techniques, to extensive laboratory experience with DNA markers They came from 13 countries in Asia, Africa, Eastern Europe, Latin America, and North America All expressed admiration at the quality and organization of the course, which mixed classroom lectures, extensive lab practice, and long sessions of data analysis on the computer The fruits of their labors included directly applicable skills in the isolation, digestion, electrophoresis and transfer of DNA to blots, in the non-radioactive marker techniques used at CIMMYT, in the generation of PCR-based markers, in bacterial transformation, and in plasmid preparation Course members also learned how to enter and verify molecular genetic data in the computer, produce genetic maps, and perform quantitative trait loci analyses with different statistical tools As a detailed reference for all they studied, they received a 200-page manual documenting terminology, protocols, statistical techniques, and other areas of course content



"We plan to offer another course on marker applications in late 1996 and are looking to develop a similar course on maize and wheat transformation," says David Hoisington, head of CIMMYT's Applied Biotechnology Center (ABC) "A key function of the ABC is to help bridge the gap between cutting-edge research in the industrialized world and applied breeding in the countries we serve " The 1995 event was sponsored by the International Triticeae Mapping Initiative (ITMI) — a consortium which promotes collaboration among researchers — as well as by Pioneer Hi-Bred International, Inc , and CIMMYT

In September 1996 CIMMYT inaugurated the Wellhausen-Anderson Plant Genetic Resources Center, built to replace our outdated 24-year-old germplasm bank The state-of-the-art facility, funded in part by the Japanese Government, has a storage capacity of 450,000 seed samples — roughly three times our current collections — and signals CIMMYT's continued commitment to the preservation and use of maize and wheat genetic resources for the benefit of humanity

The facility is fittingly named in memory of two researchers who made gigantic contributions to both aims As a staff member of a Rockefeller Foundation-Mexico collaborative breeding program in the 1940-50s, Edwin J Wellhausen coordinated and took part in the systematic collection and preservation of native Mesoamerican maize germplasm against the day of its possible replacement or extinction He later served as CIMMYT's first director general Glenn Anderson, who died in 1981, is fondly remembered by many CIMMYT staff and researchers worldwide for his unique blend of talents as a wheat scientist, teacher, research administrator, and inspiring leader He was instrumental in the Green Revolution that changed world agriculture forever The following reports describe efforts which carry forward the torch lit by these two visionaries, who were well ahead of their time in comprehending and applying the power of crop genetic resources and helping ensure that future generations might do the same



Rescuing an Invaluable Seed Heritage

In mid-1996 the principal investigators of the Latin America Maize Project (LAMP) and the Maize Regeneration Project met at CIMMYT to review four years of collaborative work to regenerate maize landrace collections threatened by poor germination or low seed supplies Some 7,000 seed samples — nearly a quarter of the total collections in the region's genebanks — were renewed through the joint efforts of CIMMYT and genebanks of 14 Latin American nations The seed, much of which no longer exists in farmers' fields, is now available for use by scientists throughout the world Back-up samples are in long-term storage at CIMMYT and the USDA National Seed Storage Laboratory (NSSL) Datasets from the landrace regeneration plantings are being made available to all project cooperators The effort was funded by USAID through Project Noah and by NSSL

Participants in LAMP evaluated over 12,000 Latin American maize landrace collections, 270 of the best were selected for further testing and analysis In addition, 50 tropical and temperate elite LAMP accessions are being used to add diversity to US maize This work was funded by Pioneer Hi-Bred, with administrative support from the USDA Agricultural Research Service The American Seed Trade Association financed the meetings

In Situ Insights

CIMMYT post-doctoral fellow Dominique Louette is working to bring realistic perspectives to discussions on the *in situ* conservation of maize landraces Her PhD research, a three-year case study in the Cuzalapa watershed along Mexico's Pacific Coast, used agronomic and genetic tools to examine relationships between traditional farming systems and maize genetic diversity "Results suggest that indigenous systems may

be far more open and dynamic than is commonly imagined," she says More specifically, her work questions the relevance of models that would "freeze the genetic landscape" under the supposition that conservation and development are incompatible Louette's findings point to more hopeful — and considerably more challenging — realities

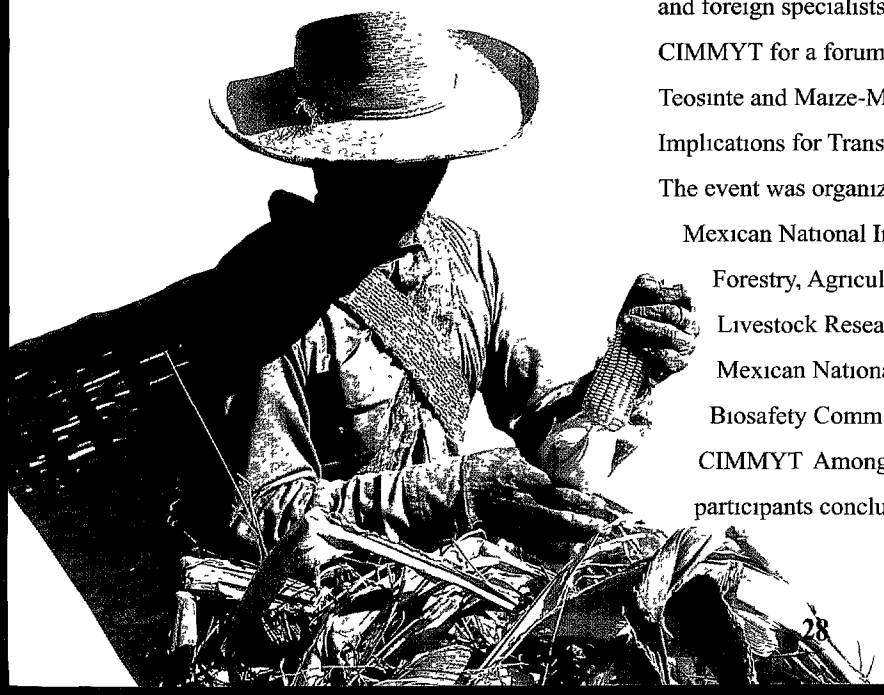
"Maize varieties in the Cuzalapa watershed change in composition over time," Louette says "A small group of local landraces dominates the area, but farmers also plant a succession of foreign varieties — sometimes from quite distant origins " These varieties tend not to replace local cultivars, Louette says, but to complement them, satisfying unmet needs or occupying a niche that has not yet been exploited What impact does this influx have on genetic diversity? "In Cuzalapa, about 15% of the maize area is planted to foreign varieties," Louette says. "At that level of introduction, foreign material tends to be a source of phenotypic diversity rather than a cause of genetic erosion "

In her current work, Louette is looking more closely at gene flows

between introduced and local varieties, as well as the impact of farmer seed-selection practices on those flows Identifying the critical values of factors that affect genetic erosion will be difficult, Louette points out, particularly if other indigenous systems are as dynamic as those in Cuzalapa What seems clear, however, is that there is no simple equivalence between the introduction of new varieties and the loss of genetic diversity

A related conclusion came in 1995 from a group of 20 Mexican scientists and foreign specialists who gathered at CIMMYT for a forum entitled "Maize-Teosinte and Maize-Maize Gene Flow Implications for Transgenic Maize " The event was organized jointly by the Mexican National Institute of Forestry, Agriculture and Livestock Research (INIFAP), the Mexican National Agricultural Biosafety Committee (CNBA), and CIMMYT Among other outcomes, participants concluded that farmers must have a central role in preserving and selecting their own materials, if the *in-situ* conservation of maize genetic resources is going to work

Finally, CIMMYT is developing a proposal for a project entitled "Conserving Maize Diversity in Mexico A Farmer-Scientist Collaborative Approach " Among other things, the project will test the hypothesis that selective breeding of landraces while preserving their distinctive local traits will increase the likelihood that farmers will maintain the diversity of the maize they grow

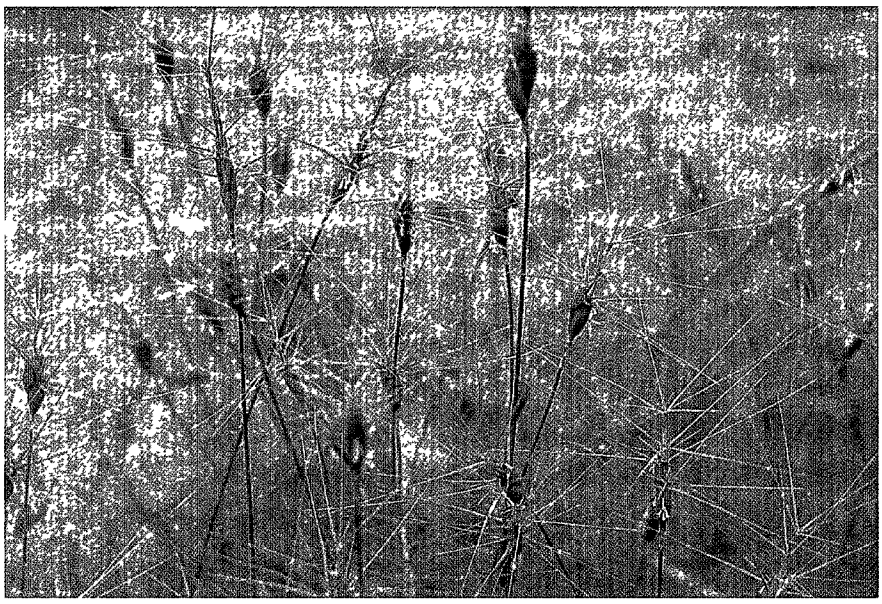


Wheat Information Systems: Bringing Sense to Seed Collections

Someone once said that germplasm without information is just a pile of seed Indeed, unless something is known about certain basic traits, germplasm bank seed collections cannot be used effectively to improve crops On occasion, useful collections may not even be known to plant breeders This can happen because breeders have followed different systems for naming wheat lines As a result, some wheats have several names, or several different wheats may share the same name To complicate matters even more, information on a given wheat may have accumulated in numerous venues scattered worldwide

Two closely linked CIMMYT initiatives have addressed the problem of making information on bread wheat, durum wheat, and triticale germplasm easy to access One is the International Wheat Identification System (IWIS), a database management tool that helps

link useful information from different sources By assigning each wheat a unique identifier, IWIS eliminates the traditional confusion associated with names With this identifier, breeders, genebank curators, physiologists, and cereal chemists can pinpoint a particular wheat, trace its family tree, and access relevant information IWIS runs on a PC and is available on CD-ROM Development of the tool was supported by Australia (GRDC), Canada (CIDA, Agriculture and Agri-Food Canada), Denmark (DANIDA), the Netherlands (the Ministry of Development Cooperation), and the USA (USDA)



***Aegilops neglecta*, a wild relative of wheat**

Another product that should bring wheat seed closer to interested users is the Genetic Resources Information Package (GRIP), a system for linking the identifiers used in IWIS to other classification systems Because it was developed by CIMMYT in collaboration with countries such as Australia, USA, Canada, India, Russia, and China, to name just a few, GRIP has achieved a degree of standardization in nomenclature unprecedented in other crops The GRIP I package was designed by staff managing the Australian Winter Cereals Collection and is available on diskette for PC It contains the names, pedigrees, abbreviations, and bibliographies of more than 100,000 wheats. Funds for its development were provided by the Australian Centre for International Agricultural Research and Australia's Department of Industry, Science, and Technology

IWIS gave rise to a collaborative project between CIMMYT and other CGIAR centers to develop the International Crop Information System (ICIS), a data management structure based on the IWIS model ICIS is expected to enhance data management for wheat and a wide range of crops

Global Arrangements Hail a New Era of Conservation

An agreement signed between the CGIAR centers and FAO in 1994 calls for the designation of specific accessions to be included in collections held "in trust " This means long-term conservation for the benefit of the international community and exemption from intellectual property protection

All CIMMYT maize germplasm bank accessions except those defined as varieties are stored under the auspices of FAO as "in trust" collections Maize bank accessions from other institutions will also be held in trust, as will elite CIMMYT-derived germplasm placed under long-term storage in our bank

With regard to wheat and related species, CIMMYT stores only bread wheat (*Triticum aestivum* L) and triticale (X *Triticosecale* Wittmack) in trust Of these, we aim to store all old and new cultivars, landraces, and genetic stocks, provided they are not under protection as intellectual property In addition, we will place in trust useful CIMMYT-derived advanced lines identified from international trials

"Rich country or poor, we all must — and we all do — contribute to global agricultural research and development," says R B Singh, Director of the Indian Agricultural Research Institute Singh's statement eloquently defines CIMMYT's view of its growing partnerships with national agricultural research systems in developing countries. The tremendous challenges presented by poverty, environmental degradation, and population growth are far too great for any one institution to overcome Nor can any one institute afford to duplicate the efforts of others CIMMYT is re-dedicating itself to partnerships aimed at helping the poor, conserving natural resources, and increasing global food security As part of its renewed commitment, the center is exploring alternative forms of cooperation

Networks: An Evolving Concept

Networks — arrangements through which researchers and others involved in agricultural development share knowledge and products — constitute one approach for linking national systems, non-government organizations (NGOs), advanced research institutes, and international centers to solve the complex problems facing farmers in developing countries Indeed, such cooperation has been central to CIMMYT achievements since the Center's inception An example? For three decades the Center has shipped its top experimental wheat and maize lines to hundreds of cooperators each year for testing in scores of countries worldwide The cooperators keep the best performers for their own breeding programs and CIMMYT receives crucial feedback for improving its products These distribution and testing networks have contributed significantly to the impact of CIMMYT germplasm, which in modified form covers fully seven-tenths of developing country wheat lands and is an important component in maize research programs throughout the developing world Yet these networks and the format they offer for participants' input are relatively simple and largely informal — few agreements have been signed or proposals written, only letters between CIMMYT and participants to announce or request seed and report results Participants have come almost exclusively from the disciplines of plant breeding and agronomy

This situation has changed dramatically over the years, as national systems and CIMMYT have matured and our awareness of the complexities of agricultural development has sharpened. Improved, resource efficient maize and wheat varieties are still seen as vital to improving productivity But concerns about biodiversity, the efficient use of natural resources in maize and wheat farming systems, and equity in gender and international relations are now included in our thinking on productivity Building on the foundations of its germplasm testing networks and in-service training alumni, CIMMYT has gradually entered into complex partnerships involving a range of organizations and disciplines and reflecting the above concerns

The Center still provides recognized leadership in technical areas, but we now regularly seek the expertise of national systems and others to set shared research directions Just such a consultation took place in mid-1996 as part of CIMMYT's efforts to develop a new medium-term plan The spirit of participatory decision-making also suffuses recent regional partnerships, fostering the commitment and efficacy of all involved The following highlights exemplify our interest in working effectively with a range of partners to help developing country farmers and consumers

The Regional Maize Program for Central America and the Caribbean

The PRM (after its Spanish name, *Programa Regional de Maíz*) is a network of maize researchers from nine countries in Central America and the

Caribbean and from CIMMYT The PRM develops and tests alternative technologies to sustainably increase productivity in the region's major maize production systems The network builds on a strong research capacity which can be traced to mid-century collaborative initiatives of the Rockefeller Foundation in Latin America. The PRM originally concentrated on breeding and training, but expanded its focus nearly a decade ago to include sustainable cropping systems research and socioeconomics. Its activities have had an enormous impact more than three-quarters of the area under improved maize in the region is sown to PRM-derived varieties and hybrids, a range of environmentally-friendly cropping practices disseminated by the network are used by farmers, and national systems have been strengthened through PRM training and other support, to name a few achievements The technical contributions of CIMMYT are one key to the PRM's success, but no less important has been the guidance of the network's long-term donor, Swiss Development Cooperation (SDC), on network organization and planning

"Beginning in the mid-1980s, SDC encouraged the PRM to form its own directive bodies, to implement participatory planning and budgeting, and to appoint a regionally recruited coordinator," says Jorge Bolaños, CIMMYT technical advisor to the PRM The suggestions were implemented in a careful, stepwise fashion over the course of several years, and now constitute central features of the network Participants meet each year to review progress toward objectives and allocate funding for subsequent activities based on proven

"Farmers Don't Climb Hillsides for the View..." A Network Coordinator's Perspective

During a recent visit to CIMMYT headquarters, PRM coordinator Elio Durón, an Honduran native, stressed the importance of finding germplasm, technologies, and collaborators capable of helping farmers in difficult environments

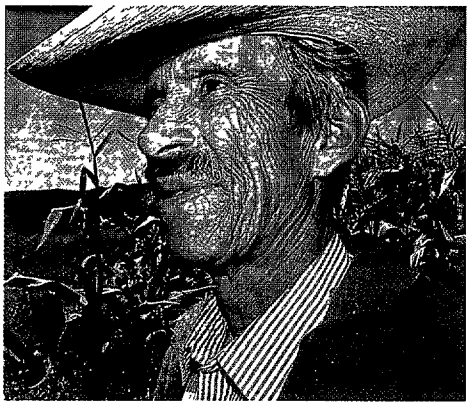
"About two million hectares of maize are grown in Central America," Duron says, "about 60% of it on small hillside farms that are extremely vulnerable to erosion At present, most farmers cannot sustain yields on these slopes From both a human and an environmental perspective, the costs of that inability can be catastrophic "

In working to improve the prospects of hillside maize farmers, Durón emphasizes the importance of CIMMYT's relationship with the nine Central American and Caribbean nations that participate in the PRM "One key to the PRM's effectiveness is CIMMYT's willingness to serve as a true partner rather than as a dictatorial big brother," says Durón "CIMMYT provides germplasm, technical expertise, and financial support, but all the participating countries have an equal voice in determining our research focus and directions That kind of approach keeps us focused on the real-world problems faced by national programs "

CIMMYT's support is essential, Duron says, because many countries in the network have neither the funds nor the human resources to address food production and natural resource management problems on their own "The network enables us to pool our efforts and attack problems systematically," Duron adds "That way participants don't waste time and money rediscovering what someone else has already learned "

Duron points out that the PRM has a particularly valuable ally in Jorge Bolaños, CIMMYT's technical advisor to the network and a member of CIMMYT's Maize Program "Without Jorge this network couldn't function at anywhere near the level of efficiency it does," says Durón "In addition to his invaluable work as a maize agronomist, he also serves an important role as a facilitator, helping network members to consider problems in their full complexity and encouraging researchers to work toward a consensus that best serves our common interests — one of which is improving the plight of hillside farmers "

"Farmers don't climb hillsides for the view," Durón says "They do it because they have nowhere else to go With CIMMYT's assistance, the PRM is helping these farmers establish a foothold so that they can increase and sustain productivity while avoiding on- and off-site damage to the natural resource base "



results The planning exercises are notably democratic, network members come away with a strong sense of having "bought into" the research agenda, which is laid out in a matrix comprising detailed objectives, verifiable progress indicators, and specific activities Activities are assigned to individual countries based on comparative advantage or overriding interest, so there is no duplication of effort Outputs — germplasm and information — are shared regionwide

More recently, SDC has encouraged the PRM to reach out to key NGOs and other networks in the region, and representatives of these organizations now share in PRM research and priority setting

In the words of Walter Fust, Director General, SDC "Quality partnerships with national programs, good collaboration with other regional programs, and strong linkages to development are evident characteristics of the PRM " These outstanding features and PRM impacts have led CIMMYT to enter into comparable arrangements in recent years in Asia (such as the rice-wheat consortium described in the section "Natural Resource Initiatives") and Africa, one example of which is outlined below

The CIMMYT-Zimbabwe Research Program

Without diminishing the significance of PRM accomplishments, it can be mentioned that its members hold a common language and culture, and that production environments in Central America and the Caribbean are relatively more alike than those of, say, Asia or Africa Can a similar networking approach function in places where none of the preceeding circumstances applies? An answer to that question from one region — southern Africa — may not be long in coming, based on the experiences of the CIMMYT-Zimbabwe Research Program

CIMMYT established a research station at Harare, Zimbabwe, in the mid-1980s to collaborate with national systems in developing and disseminating improved maize technology, including varieties and hybrids that resist several major cropping constraints of midaltitude maize areas in the region Among the impacts of that effort are the more than 150 varieties and hybrids based on CIMMYT maize that have been released by national programs and are sown on some 2 million hectares

As CIMMYT has brought greater resources to bear on the problems assailing maize and wheat farmers in sub-Saharan Africa, the Zimbabwe station seemed a logical base for several collaborative research networks the Center has helped establish in the last two years

The Maize and Wheat Improvement Research Network for the Southern African Development Community (SADC) — Initiated in 1994 and financed by the European Union, this network is promoting the free exchange of improved seed throughout the region, helping provide training opportunities and access to relevant information for maize and wheat professionals, and administering a small-grants program to support research by local maize and wheat scientists on regional priorities It operates under the auspices of SADC and the Southern African Centre for Cooperation in Agricultural Research and Training (SACCAR). Regional collaboration is particularly important for the small grants, which are allocated by a steering committee of national program commodity coordinators

Soil Fertility Research and Extension Network — Initiated in 1994 with funding from the Rockefeller Foundation, this project combines the talents of soil scientists, agronomists, on-farm researchers, extensionists,

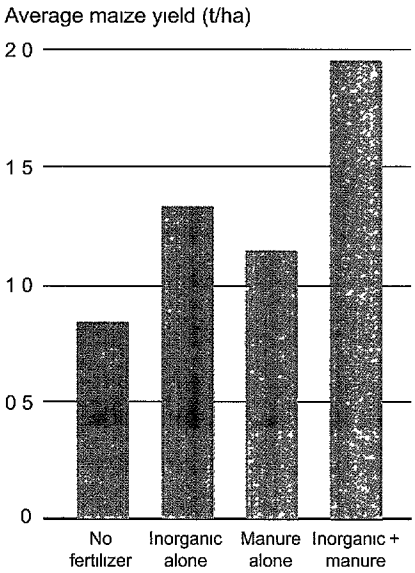
socioeconomists, and applied modelers from Malawi and Zimbabwe to define local soil fertility problems, map problem areas and improve the targeting of fertilizer recommendations, conduct long-term studies on regional fertility trends in maize-based cropping systems, and identify and document technical and socioeconomic constraints to improved soil management "We're also working to establish relationships among researchers, extension workers, NGOs, and policy-makers," says Stephen Waddington, CIMMYT agronomist posted to southern Africa and technical advisor to the network

The Southern African Drought and Low Fertility Project — Initiated in 1996 and funded by Swiss Development Cooperation (SDC), this network will apply new selection methodologies to increase the drought and low soil fertility tolerance of maize for SADC countries and help national systems to develop viable breeding programs for these traits Funds are available for national programs to upgrade existing facilities for use in selection and testing

All three networks involve a CIMMYT technical advisor, a steering commitee comprising specialists from national systems in the region, and serious efforts to interface with NGOs and other networks to reach goals more quickly and efficiently In addition, a portion of the budget administered by the steering committee is allocated to small grants for local research

Given the research potential represented by this array of networks, the challenge may be to see that, where feasible, they operate as a sort of "mega-network," according to Zimbabwe station team leader, David Jewell "We have a critical mass of people with a range of skills in maize and wheat breeding, cropping systems, and socioeconomics. Now we must build a team approach and integrate additional human resources through collaborative research " To help integrate the networks, he sees his role as one of facilitating relationships among national systems and regionwide organizations "Fortunately we are on excellent terms with national systems, NGOs, and SACCAR," Jewell says "If inter-network collaboration saves resources and gets better products to farmers faster, I am sure the idea will be received enthusiastically " He points out, for example, that agronomists in the region already have experience working with improved maize varieties in their trials "This complements our maize testing network," Jewell says Breeders as well routinely resort to on-farm evaluations as an acid test for experimental germplasm, a process that can involve cropping systems experts

Finally, Jewell expects that further opportunities for collaboration will be explored by a socioeconomist whom CIMMYT will post to the region in early 1997 "Among other things, we would like this person to study factors that influence technology adoption, help design and apply farm-level surveys, assess impacts, and assist in implementing matrix planning and management systems for the networks," Jewell says "We also hope the socioeconomist can help develop linkages with the seed industry and NGOs If the networks are to be judged on impacts, then we must be more pro-active about disseminating useful products "



Southern Africa soil fertility network studies show that combined organic-inorganic fertilizer treatments are the best option

Family Training in Bangladesh: An Innovative Approach

Six Bangladeshi farm families—men, women, and children—are gathered for a training session in a room at the local rural development office A woman in full burka raises her hand and begins to speak She hesitates, but with her husband's encouragement, shyly continues and asks how to keep insects away from the wheat seed she has selected

"Something as simple as a woman speaking in front of a mixed gender group tells us these sessions are totally different from how training is conducted in most developing countries, especially in this part of the world," points out Craig Meisner, CIMMYT agronomist stationed in Bangladesh He is acting as advisor to the Whole Family Training Project (WFTP), a pilot project funded by the Australian Agency for International Development (AusAID) that aims to teach farmers how to handle and store wheat seed after harvest in several wheat producing districts of Bangladesh

Typically, NGO and government programs in Bangladesh target either males or females and, in fact, this pilot project, implemented through the Bangladesh-Australia Wheat Improvement Project and Bangladesh's Wheat Research Centre, was originally conceived as a training program for women involved in wheat production "Before starting the project we did a survey and found that in Bangladesh wheat production is a family affair," relates Marla Smith O'Donoghue, a consultant hired to help find an effective means of reaching and training women "This gave us the idea that it was probably better to train the whole family, instead of just the women "

Although largely unrecognized, women's contribution to agricultural production at both the household and national levels is significant in the developing world However, for the most part women farmers have little access to the training and information that are so basic for improving crop production Furthermore, in countries where, for cultural reasons, women do not speak to men outside their families, reaching them through mostly male extension workers is virtually impossible The WFTP arose from the perceived need to address these issues and give women access to wheat production technologies

Wheat is currently the second most important staple cereal crop in Bangladesh, where production is projected to reach 1 4 million tons in 1996 As the country's population increases and land pressures intensify, farmers will have to learn new ways of increasing yields while protecting natural resources Marginal farmers, however, have remained largely beyond the reach of extension services "An additional payoff of this project is that, in seeking to benefit rural women, it will contribute to increasing wheat yields in the poorer districts of Bangladesh," says Meisner

Local women with previous experience in rural development work and training were hired to organize and conduct the training sessions They delivered to each family (defined for the purposes of the project as husband, wife, plus two other family members) a written invitation for the sessions This was particularly important in getting people to attend, though many of those invited cannot read, they considered it a great honor to receive a written invitation Instructors used demonstration techniques and visual aids to convey simple but essential seed storage procedures A total of 2,370 people belonging to 508 mostly marginal and small landholding families attended the training sessions, which recorded almost 100% attendance

"Some time after harvest, we visited the families and found that except in one district where it was too late in the season to apply what they learned, between 90 and 100% were using the technologies," observes O'Donoghue "All of them said they would gladly attend training sessions again "

In view of this success, the next phase of the project will also focus on whole families in sessions on wheat cultivation Although a departure from tradition, this innovative approach may prove useful for teaching modern technologies to farmers who grow wheat and other crops in similar cultures in developing countries

Habit Trial and Error Conjecture

Too often, these are the bases on which farmers, agricultural researchers, and policy-makers must make decisions How do we break that pattern? This is the challenge being met by the CIMMYT Economics Program (CEP)

The CEP doesn't generate germplasm and crop management practices It generates information about how germplasm and management practices are being used and about how they can be used more efficiently Consider the following applications of our work

- An Asian research director studies a shrinking budget *How do the potential payoffs from wheat research compare with other alternatives?*
- A subsistence farmer in the Andes worries that a new high-yielding maize variety will prove more vulnerable to diseases and stress than traditional varieties *How can breeding programs address that concern?*
- An African agricultural minister wonders why a new maize hybrid is not being adopted *How can policy changes break this bottleneck?*
- Donor agencies are apprehensive that scientific plant breeding is eroding crop genetic diversity *How do we measure that diversity? Do recent trends suggest that it is eroding? What impact has plant breeding had on those trends?*
- A development assistance agency wants to redirect research funding from irrigated to rainfed environments *How is this shift likely to affect farm-level incomes, employment, food prices, and the environment?*

CIMMYT's Economics Program helps to answer these kinds of questions It provides researchers and policy-makers with information and analytical tools to evaluate complex options and to assess difficult tradeoffs Carefully reasoned criteria thus replace habit, trial and error, and conjecture as the foundation for research and policy decisions

New Directions in Economics

Under the leadership of new Program Director Prabhu L Pingali, the CEP has recently outlined an exciting list of research initiatives

Genetic Diversity

Long-term food security requires that we safeguard genetic diversity CEP researchers are helping to clarify what we mean by diversity, where it comes from, and how we measure and value it One project is clarifying global trends in the use of wheat diversity and international flows of genetic resources (described below) Another project is exploring the prospects of on-farm improvement of maize landraces as a strategy to conserve maize diversity *in situ*

Long-Term Supply and Demand Projections

Effective agricultural policies and research strategies have a clear prerequisite reliable estimates of supply and demand CIMMYT helps establish such estimates by clarifying macroeconomic trends in world maize and wheat production, incorporating specific supply and demand information into established models, developing supply scenarios by region and crop, and evaluating and modifying global projection models developed by experts in advanced research institutions

Technology Assessment and Forecasting

What impact is a new technology likely to have in the years ahead? How will that impact vary across regions? How do projected payoffs from germplasm research compare to those for crop management research? The CEP is helping to answer these kinds of questions so that funds can be wisely allocated and problems efficiently addressed Future work will develop a world-wide technology inventory for maize and wheat, extending to the years 2000, 2010, and 2020 Researchers will also assess the potential

impact of those technologies across similar ecological, agricultural, and social environments

Adoption and Impact Studies

The CEP monitors the diffusion of improved germplasm and clarifies its impact with respect to the poor, the environment, and gender The CEP also analyzes factors that affect adoption, including policy and institutional constraints Case studies of maize seed industries are clarifying ways that the public and private sectors can complement one another (described below) In sub-Saharan Africa, researchers are identifying policy changes that will increase the use of mineral fertilizers, thus boosting food production and avoiding environmental degradation

Research Priority Setting

By integrating information from the research topics outlined above, the CEP develops procedures for efficiently allocating maize and wheat resources, both on a global and a regional basis Future efforts will develop models for setting research priorities at the institutional, program, and problem levels Exploratory efforts will be made in understanding priority setting for more difficult areas, such as social science, policy, and natural resources research

Ongoing Projects

Understanding Wheat Diversity and International Flows of Wheat Genetic Resources

Microsoft Word's spell-check doesn't recognize the word *genome,* but helpfully offers the following alternative—*genie* Such flights—from hard fact to airy fancy—occur all too often in discussions about plant genetic resources CIMMYT's *1995/96 World Wheat Facts and Trends* counteracts that tendency, providing detailed information about the use of wheat diversity and international flows of wheat genetic resources That report is part of an ongoing initiative between CIMMYT's Wheat and Economics Programs

CIMMYT research indicates that landraces from *all* the major wheat-producing regions have contributed germplasm to the bread wheat varieties now being grown by farmers in the developing world A study of bread wheat pedigrees reveals that all regions are indebted to varieties from other regions. Indeed, in almost all cases, the largest contributor of landraces to a given region is not the region itself For bread wheats, neither the distinction "North-South" nor "developing-developed" is useful for characterizing germplasm flows.

Yield stability of all wheats grown from 1955 to 1994 in regions of the developing world—lower numbers equal greater stability.

	Sub-Saharan Africa	North Africa	West Asia	South Asia	Mexico/ Guatemala	Andean Region	Southern Cone of S.A.
	Coefficient of yield variation adjusted for trend (%)						
1955-1964	10 8	13 4	8 7	6 5	12 3	9 8	12 9
1965-1974	4 3	10 3	8 0	9 1	7 9	2 4	8 1
1975-1984	7 1	12 1	4 0	3 0	5 6	5 6	12 2
1985-1994	8 8	11 0	7 5	4 0	5 5	4 8	5 0

Note China is excluded

Consider, for example, the pedigree for Sonalika, the bread wheat cultivar planted across the largest area in the world in 1990.

- Farmers in 17 countries contributed landraces or selections,
- Breeders in 14 countries contributed lines;
- Landraces and lines originated on 6 continents and in most of the major wheat-producing nations of the world

CIMMYT's findings also indicate that for every region in the developing world, variation in wheat yields was greater in the decade preceding 1965 (i e., the early years of the Green Revolution) than in the most recent decade Indeed, since the 1950s, the balance of evidence from farmers' fields suggests that wheat yields have become more stable even as mean yields have increased This holds true for the major wheat-producing nations of the developing world and for the world as a whole

Evidence on resistance to the rusts (which are among the major diseases of wheat) is similarly encouraging Of the six screening nurseries that CIMMYT annually distributes to cooperators in wheat-growing countries around the world, the one with the longest history is the International Bread Wheat Screening Nursery (IBWSN), initiated in 1967 The nursery contains 200-400 new advanced lines from CIMMYT's Bread Wheat Breeding Program As measured by average coefficients of infection, advanced lines have in general proven increasingly resistant to stem, leaf, and stripe rust

CIMMYT's findings also suggest that modern lines are *not* being drawn from a more and more restricted genetic base A sample of the pedigrees from the more than 800 wheats released in developing countries since the early 1960s reveals that the average number of *different* landraces per pedigree has increased over time Since the 1970s, the upward trend suggests an average of one new landrace per pedigree, per year. Today, landraces tend to enter the pedigrees through crosses of advanced lines with different genetic backgrounds Among the more widely grown CIMMYT bread wheats released since 1950, the number of *distinct* parental combinations and *different* landraces occurring in the pedigrees have both increased

Finally, many researchers and policy-makers assume that, since the early years of the Green Revolution, fewer and fewer varieties are being planted across larger and larger areas Recent evidence suggests that this assumption is invalid "In many major wheat-producing nations of the developing and industrialized world, the percentage of wheat area sown to any single cultivar is lower that it was earlier in this century," says CIMMYT economist Melinda Smale.

This is not to suggest that farmers have adequate access to the range of cultivars they want What limits that access, however, is more often related to economic policies and government regulations than to crop breeding strategies. "Breeders can improve the attractiveness of varieties and the rate of release of new varieties, but they cannot assure that all farmers have access to seed," says Smale "That kind of change will require careful attention to issues such as input and output prices, the proportion of released cultivars for which seed is actually multiplied and distributed, and the design and functioning of seed systems "

Ongoing efforts at CIMMYT will continue to illuminate issues related to wheat diversity "Our aim," says Economics Program Director Prabhu Pingali, "is to clarify how international agricultural research has affected wheat genetic diversity in the past and how it can enhance that diversity in the future "

A Study of the Maize Seed Industry

The terms *life cycle* and *evolution* may prove as relevant to the growth of maize seed industries as they are to the growth of the seeds those industries sell That insight has important implications, for if all seed industries pass through predictable stages of development, then nations can learn from each other's successes and failures

CIMMYT researchers and their collaborators in national programs have helped policy-makers in this regard by identifying key technical, economic, and institutional issues which must be resolved if maize seed industries are to function effectively Already, case studies are suggesting that—at various stages of industry development—certain institutional arrangements may be more efficient than others in fostering rapid and equitable growth

In developing countries, maize seed production and distribution have been weak rungs in the ladder of productivity "Investment in maize research has been extensive, and this investment has produced results," says CIMMYT economist Michael Morris "Plant breeders have developed many varieties and hybrids which clearly outperform the materials being grown by farmers Researchers have also identified improved management practices capable of significantly boosting productivity "

"Unfortunately," Morris adds, "many of these technologies have failed to spread beyond demonstration plots "

Why? Unlike rice and wheat, which are self-pollinating, maize is open-pollinating, meaning that individual maize plants readily mate with other nearby plants Farmers who grow maize thus have difficulty maintaining genetically pure seed stocks and must replace seed annually to avoid contamination through natural outcrossing For hybrid maize technologies to diffuse widely, farmers must have access to reliable sources of affordable, high-quality seed

Public-sector organizations have not been notably successful in meeting this need As a result, private companies and non-governmental organizations are often encouraged to play a greater role in disseminating improved varieties and hybrids. But not everyone is comfortable with the idea of a global maize seed industry that consists exclusively of private companies

"Thus far, moves to privatize national maize seed industries have had largely positive results," Morris says. "Still, it's legitimate to ask where such changes will ultimately lead If current trends continue, for example, will maize farmers in developing countries always

be able to obtain a wide range of germplasm and related production technologies at affordable prices? Must governments actively engage in maize research and seed production in order to protect the interests of poor producers and consumers? Or will it be sufficient if they merely establish and enforce the rules of the game?"

Recognizing that organizational and institutional change are necessary features of seed industry development, Morris has outlined some practical lessons about the shifting roles of public, private, and participatory organizations

During the emergence and growth stages of the industry life cycle, for example, national public organizations must assume a leading role in research, seed production, and seed distribution activities Early on, these activities provide few opportunities for cost recovery Public organizations are better suited to carrying out inherently unprofitable activities because they are able to pursue non-economic objectives

As demand for seed increases, private companies begin to appear Initially, they are unlikely to recover research costs and so tend to produce and sell the seed of public open-pollinated varieties and hybrids—research costs for which have been borne by public breeding programs "Because private companies respond rapidly and efficiently to market signals, they almost always outperform government seed organizations by offering better products and better customer service at equal or lower prices," Morris says

As the industry develops, public and private responsibilities gradually shift "When competition intensifies, companies find that they can remain in business only by offering proprietary products," Morris says "At this point, they are compelled to launch their own research programs "

Many companies soon find that they can compete successfully with public organizations in this sphere as well "Although examples can be cited of instances in which private companies have performed poorly, on balance, the record is extremely positive," Morris adds

Does this mean that public organizations can then disappear? "No," says Morris "It is important to realize that private seed industries are unlikely to provide all things to all people For the system to work most efficiently, public organizations must gradually assume new roles involving the production of goods and services that do not provide attractive profit opportunities " Such activities include basic research, research targeted at marginal environments, and the production of seed for subsistence farmers

Where does CIMMYT fit in? "In accordance with its global mandate, CIMMYT focuses on research activities that national public organizations are unable or unwilling to perform," Morris says He points out, however, that these activities are not static either

"As the adoption of hybrids has increased in many developing countries, CIMMYT has reduced its work on open-pollinated varieties and placed greater emphasis on hybrid development And as private companies have become more visible in global germplasm improvement efforts, CIMMYT has formed new links with the private sector "

Morris speculates that CIMMYT's role will change further as the global seed industry continues to evolve "As a public organization, CIMMYT will be most effective concentrating on the production of goods and services that do not offer clear profit opportunities and therefore are unlikely to attract the attention of private companies," he says

He also notes that because national seed companies operate in limited markets, they are often unable to mount breeding programs of sufficient size to compete effectively with large transnational companies that have access to global networks of research and testing facilities As a result, national seed companies are turning to CIMMYT as a source of the materials and technologies they need to compete with the transnationals

"Large numbers of maize farmers are well served by the systems presently in place, but in some countries many rural households still do not have regular access to reliable sources of high-quality, affordable seed," Morris says "Innovative strategies will have to be introduced if these households are to be reached "

By clarifying the comparative advantages of various public and private organizations at various stages of industry development, CIMMYT and its national program collaborators are providing a foundation upon which such strategies can be built

The International Wheat Information System

opens the door to a wealth of information for wheat scientists

What Is IWIS?

IWIS is a system that manages and integrates diverse information pertaining to bread wheat, durum wheat and triticale. The body of data on these crops is large and intricate. By providing a common language to identify individual wheat and triticale germplasm, including IWIS successfully promotes conservation, utilization and exchange of genetic material. IWIS [illegible] information to

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Background

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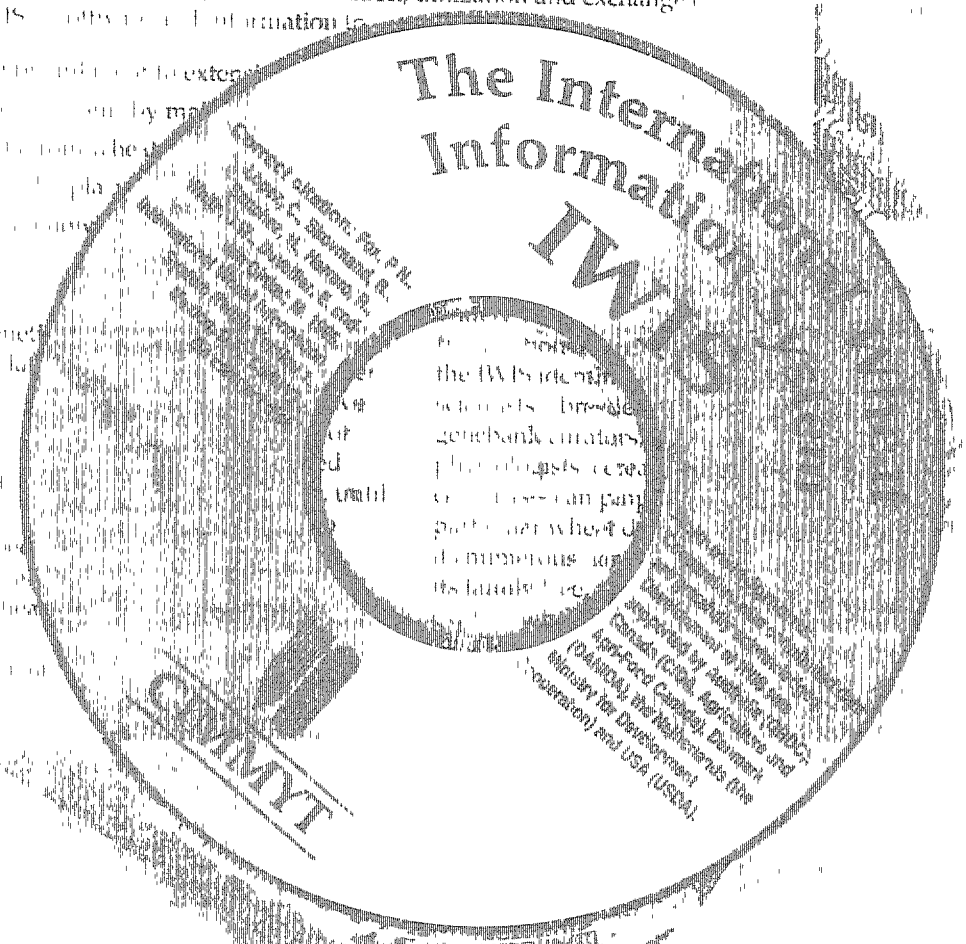
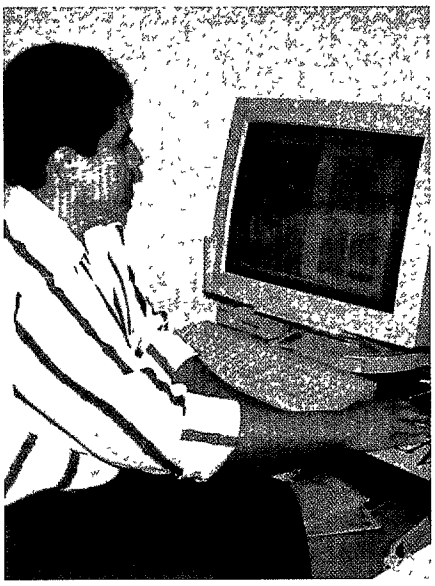


The complexity and urgency of the agricultural development challenges facing the world today demand a strong interdisciplinary approach to research — the full participation of plant breeders, biotechnologists, agronomists, social scientists, and professionals from many other disciplines Improvements in how research information is managed are strengthening this essential collaboration, leading to a new information-intensive approach to research that, in the end, is greatly benefiting poor farmers and consumers alike throughout the developing world



How is this new approach changing the way agricultural researchers — and in particular, those working at CIMMYT — do their jobs? As only one example, our breeders are increasingly deciding which parent plants they should cross based not only on physical appearance and field performance, but also on firmer knowledge about the genetic makeup of individual plants, lines, and populations

Crossing programs based on greater knowledge of genetic backgrounds are enabling breeders to more closely tailor the pedigrees of their new varieties to specific environmental conditions, thus enabling the broadest possible adaptation and producing end products that are preferred both by producers and by consumers

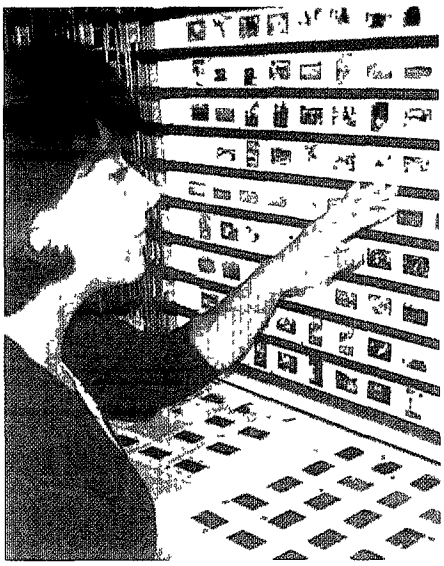
In addition, performance and evaluation data from sources as diverse as international nurseries and molecular marker laboratories are increasingly made available globally via the Internet and in CD-ROMs, with minimal delay after being recorded

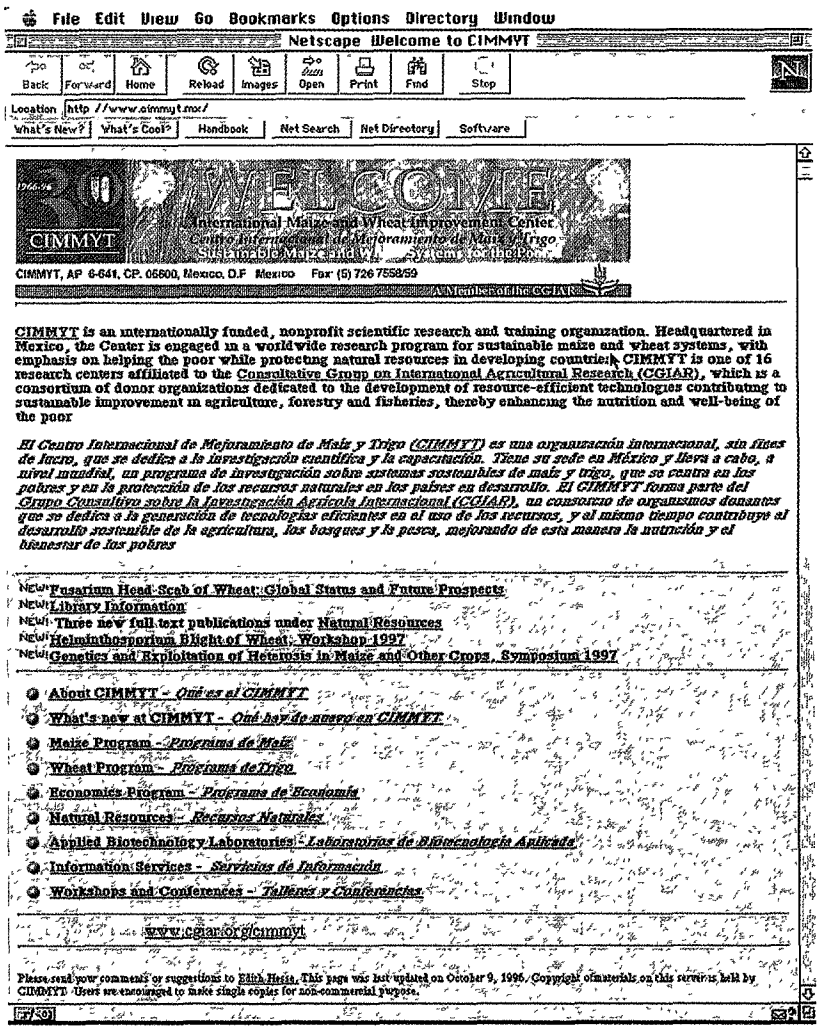
Complementing these efforts is the application of new geographic information systems (GIS) technologies to more clearly identify important strategic targets for CIMMYT's agronomic and natural resource research The Center has established a strong, in-house GIS capacity that is closely linked to related efforts under way elsewhere, both in developed and developing countries

Our library has evolved into much more than a repository of publications and information available to interested researchers and trainees It has become instead an electronic information center designed for the timely and comprehensive provision of worldwide scientific information, and it does so on a pro-active basis, according to the needs and desires of individual researchers and other users, whether located at CIMMYT headquarters in Mexico or in any of more than 100 countries around the world

We continue to produce and distribute thousands of copies of a wide range of CIMMYT-imprimatur publications, of course, including field and laboratory manuals, special reports, working papers, information bulletins, fact sheets, and annual reports like this one. We have added a new working paper series on natural resource management research issues, as well as a reprint series for journal articles on those same topics published elsewhere by our staff And through a variety of public awareness materials and activities, we have redoubled our efforts to foster support — both political and financial — for CIMMYT's work and for international agricultural research in general

In order to facilitate the adoption of a more information-intensive approach to research by our partners in developing countries, we make sure that all trainees and visiting scientists learn how to operate our systems, so that when they return home they can confidently access global information databases about maize, wheat, and other crops, as well as support the development of appropriate information infrastructures in their own institutions. With respect





to the latter, we also provide consultancies in the information area to our research partners in developing countries

Finally, in October 1995 we initiated the CIMMYT home page on the Internet's World Wide Web (www cimmyt mx) This new tool allows easy access to a wealth of information about our work, both in straight text format and in Adobe Acrobat, which allows viewing of fully formatted text and photographs Our library catalog is available on-line, as are the email addresses and other contact information for all current staff In its first year of operation, we have experienced a three-fold increase in the number of files transmitted via this medium each day (to an average daily delivery of over 300 files, or about 10,000 files per month) Importantly, a growing number of developing countries are now routinely accessing our home page

Closely linked databases for cultivars and breeding records, cropping systems, biophysical data, and socioeconomic data are providing the foundation of a new research style in CIMMYT Decision support tools, including simulation models, GIS, expert systems, and genetic analysis software are increasingly enabling our scientists to focus on central issues and navigate through oceans of data, synthesizing critical information as they go Electronic distribution is further ensuring that the benefits of this new research modality will spread rapidly beyond CIMMYT's immediate realm, and add to the impact we seek — impact on science and, even more important, impact in farmers' fields

Coping with the Information Revolution

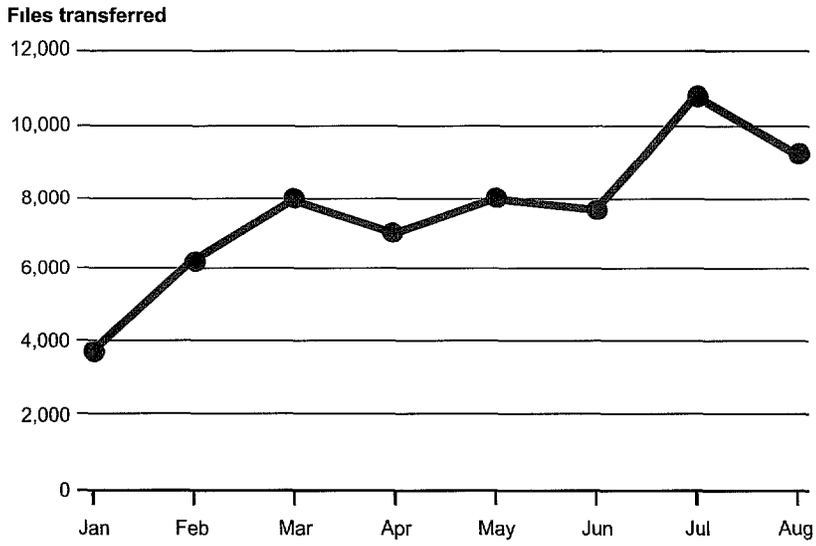
Information technology is now indispensable to CIMMYT researchers and those who work in support of their efforts A variety of new and not so new information tools are enabling staff to work both faster and smarter than ever before But the field of information technology is evolving at an unprecedented rate, and staying on top of new developments and adapting them to CIMMYT's particular needs presents the Center with a difficult challenge In response, CIMMYT created in late 1995 a new unit — the *Information Technology Unit* — dedicated to the evaluation and creative application of new information technologies

Initially, the Unit's efforts were focused on establishing and refining a CIMMYT web site on the Internet's World Wide Web That task is now well along, though as is the case with such web sites, they are never truly "finished", rather, they are continually being refined as new information needs and opportunities are identified

The Unit has also helped bring about adoption of a standard database management package for a number of CIMMYT's internal information management needs Working first with the Library to identify and implement a flexible, cost-effective package to replace our 10-year old library system, the Unit experimented with DB Textworks, a generalized text (as opposed to "data") base designed with libraries in mind but suited for a range of uses Our positive experience with this inexpensive and user-friendly package led us to seek other applications in CIMMYT, and so far we have used it to develop management systems for information on our financial backers, project proposals, and approved special projects Other recent applications include the implementation of strategic databases for the Visitors Services and Human Resources departments

Currently, the Unit is researching cost effective optical storage systems, with an eye toward eliminating our current and laborious microfiche system for archiving CIMMYT's management records, and is exploring the development of an "intra-net" that will enable Center staff and management to more easily access a wide array of internal databases

Operationally, the general idea behind the formation of this new Unit was to bring more leadership, coordination, and expertise (in the form of interdepartmental teams of specialists and users) to address significant information-related challenges We seek to ensure both a clear delineation and prioritization of those challenges and the mobilization of sufficient resources to resolve them in a timely manner To further capitalize on the benefits of enhanced coordination and communication in this arena, CIMMYT is now folding its Systems and Computing Services and its Software Development Group into an expanded Information Technology Unit



Heavy traffic is not always bad, especially if it indicates widespread interest in your home page on World Wide Web Access to CIMMYT's home page was truly "worldwide," users from Argentina, Bolivia, Brazil, Chile, China, Colombia, Costa Rica, Ecuador, Egypt, Indonesia, Mexico, Malaysia, Nepal, South Korea, Turkey, Uruguay, Venezuela, and Zambia, as well as many industrialized nations, logged on and extracted information

Financial Highlights

Of the many developments that have affected CIMMYT finances in the last year and a half, several promise to exercise a strong, continued influence First of all, domestic budget debates in key donor countries have brought considerable uncertainty to funding prospects Offsetting this somewhat, renewal in the CGIAR has led to increased funding from several donors Finally, sweeping changes in the System's financing procedures and funding classifications should provide incentives for fundraising by individual centers As detailed below, CIMMYT is intensifying fundraising efforts in response to these changing and challenging circumstances Among the measures being taken are the integration of the information and donor relations functions and the reorganization of research by megaprojects

Shifting Perspectives in the CGIAR

As part of the CGIAR renewal process, starting in 1997 centers will no longer have an "approved" budget, rather, the level of funding of each will be based directly on donor commitments to the center. In addition, CIMMYT has increased its funding base by gradually consolidating all of its activities into its agreed agenda (to be completed in 1997) Finally, as of 1998 the World Bank will provide centers with an additional 12% of the funds they obtain from other sources, rather than filling gaps in approved funding as previously These changes essentially remove past disincentives to fundraising

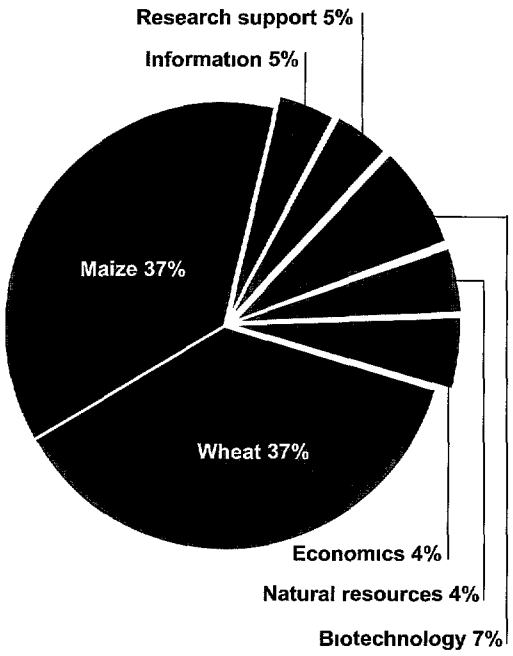
In general, there is a growing tendency for donors to restrict their contributions for use in specific research activities, that is, the money is assigned to special projects or to individual cells in the CGIAR agreed agenda matrix, rather than being left for free allocation by centers Although this has improved transparency and accountability for funding agencies and their constituencies, a step that CIMMYT welcomes, it also entails the gradual loss of budgeting flexibility for the Center Moreover, given the growing influence that funding agencies can exercise on Center research priorities because of this shift, CIMMYT is actively promoting congruence between basic aims of donors and research partners, all within the context of our mission

Reorganizing Research, Focusing on External Relations

Intensive fundraising efforts begun in 1994 have continued About 18 new projects began operation in 1995, representing US$7 7 million in additional funds over the next five years On the other hand, 16 projects, worth US$3 3 million, ended in 1995 These, along with projects that end in 1996, will have to be replaced.

The efforts of the Director General to strengthen ties with donors have been expanded through the creation of an External Relations program The move is intended to consolidate and intensify fundraising, responsibility for which was formerly spread across several areas The new program integrates the offices of donor relations, public awareness, project proposal development, and other information areas which contribute to these operations

Finally, as part of the new Medium-Term Plan under development, the center is redefining its research agenda under a dozen or so "megaprojects " Each megaproject addresses a major global or regional challenge, among them food



1995 research budget allocations by area

security, poverty alleviation, and developing and disseminating sustainable production systems The issue- and output-oriented (rather than activity-oriented) terms of the megaprojects should allow policy-makers and funding agency representatives to readily identify areas of CIMMYT's work that coincide with their own key priorities

1995-96 Highlights

Total funding for 1995 was US$33 million (31 6 from donors and 1 4 from other sources), expenditures totaled US$27 6 million The combined effect of reduced operational costs, primarily through reductions in staff, and a devaluation of the Mexican peso (60% in 1994 and an additional 50% in 1995, partially offsetting the previous five years of significant local inflation) allowed CIMMYT to add US$5 4 million to operating funds in 1995 This improved the Center's financial condition and enlarged the cushion against potential shortfalls in 1996 and the uncertainty foreseen for 1997 In addition, it is helping to maintain a positive cash flow in the face of late payments by members In 1996 unrestricted core funding was US$1 8 million less than anticipated, and US$9 0 million had not been received by late September (52% of the unrestricted funds anticipated) For 1996, anticipated funding and expenditures are slightly over US$28 million

CIMMYT also took advantage of special funding to make capital improvements in areas of strategic importance For example, the government of Japan helped fund the construction of a modern Crop Genetic Resources Center, including new maize and wheat germplasm storage, seed preparation, and shipping facilities In addition, the Danish government provided crucial additional support to construct needed space for CIMMYT's Applied Biotechnology Center, and UNDP paid for the renovation of special greenhouses for work on genetically transformed maize

Sources of income from grants (US$000), 1995.

Donors	Core unrestricted	Core restricted and special projects	Complementary	Total
Asian Development Bank			81	81
Australia	671	33	510	1,214
Austria	150		2	152
Belgium	176	128	4	308
Canadian International Development Agency	928	236	1,211	2,375
China, People's Republic of	80			80
CIRAD			6	6
Colombia		127		127
Danish International Development Agency	870	195		1,065
European Union	2,583		1,180	3,763
Ford Foundation	400	46	16	462
France		485		485
Germany	627	50	370	1,047
Global Environment Facility			6	6
ICRAF			36	36
IFPRI			29	29
India	75			75
Inter-American Development Bank	750	214	84	1,048
International Fund for Agricultural Development			235	235
International Tropical Agriculture Center			175	175
Islamic Republic of Iran			33	33
Italy	100		6	106
Japan		3,104	153	3,257
South Korea	60			60
Leverhulme Trust			16	16
Mexico,Government of	120			120
NAFINSA		5		5
National Association of Oilseed and Wheat Producers, Bolivia (USAID PL480)			188	188
National Institute of Agricultural Research-Uruguay			76	76
Netherlands		295	7	302
Norwegian Ministry of Foreign Affairs	154		7	161
OPEC Fund for International Development		60		60
Overseas Development Administration,UK	879	81	43	1,003
Philippines	24			24
Rockefeller Foundation		37	286	323
Stanford University			16	16
Spain	50	50		100
Switzerland		370	294	664
Tropical Agriculture Research Center, Japan			19	19
United Nations Development Programme		1,984	70	2,054
United States Agency for International Development	4,230	68	16	4,314
United States Department of Agriculture		103	79	182
World Bank	5,705			5,705
Other grants			42	42
Totals	**18,632**	**7,671**	**5,296**	**31,599**

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(as of October 1996)

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[1] Ex officio position

Norman Borlaug, Francisco Labastida Ochoa, and Timothy Reeves during the 30th Anniversary Celebration

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Claudio Cafati, Chile, Deputy Director General of Administration and Finance
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[1] Appointed in 1995
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[3] Appointed in 1996
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Rafael Herrera M , Mexico, Software Development
Carlos López, Mexico, Software Systems
Héctor Sánchez V , Mexico, Project Leader, Wheat Systems

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Fernando García P , Mexico, Electronic Information Specialist
John Woolston, Canada, Visiting Scientist

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David Bergvinson, Canada, Entomologist[1]
Hugo Córdova, El Salvador, Breeder
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Daniel Jeffers, USA, Pathologist
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Javier Eddy Flores, Bolivia, Breeder
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Ricardo Mora, Mexico, Breeder
Lawrence Mshana, Tanzania, Breeder
Stephen Mugo Ngure, Kenya, Breeder
George Ombhako, Kenya, Breeder
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Zhang Shukuan, China, Breeder
Satish K Sudan, India, Breeder
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Paul Fox, Australia, Head, International Nurseries
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Reynaldo L Villareal, Philippines, Head, Germplasm Improvement Training
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Janny van Beem, Colombia, Physiologist[3]

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1 Appointed in 1995
2 Left CIMMYT in 1995
3 Appointed in 1996
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1 Appointed in 1995
2 Left CIMMYT in 1995
3 Appointed in 1996
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