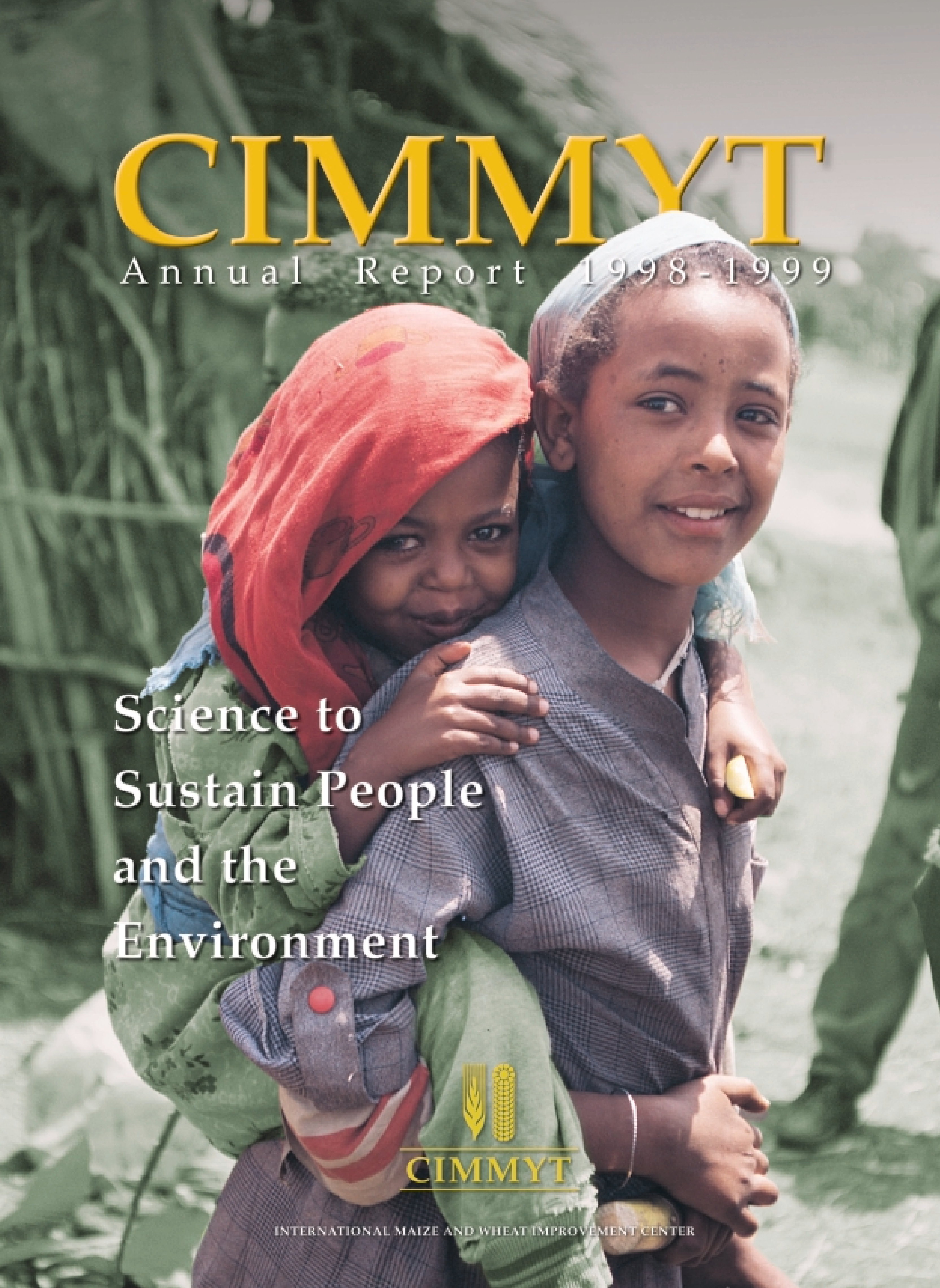


CIMMYT

Annual Report 1998-1999

Science to Sustain People and the Environment

CIMMYT

INTERNATIONAL MAIZE AND WHEAT IMPROVEMENT CENTER

CONTENTS

CIMM

In

OUR MISSION

CIMMYT is an international, non-profit, agricultural research and training center dedicated to helping the poor in low-income countries. We help alleviate poverty by increasing the profitability, productivity, and sustainability of maize and wheat farming systems.

FOCUS

Work concentrates on maize and wheat, two crops vitally important to food security. These crops provide about one-fourth of the total food calories consumed in low-income countries, are critical staples for poor people, and are an important source of income for poor farmers.

PARTNERS

Staff from our research programs in maize, wheat, economics, natural resources, and biotechnology 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.

Activities

- Development and worldwide distribution of higher yielding maize and wheat with built-in genetic resistance to important 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 many kinds.
- Consulting on technical issues.

Impact

- More than 60 million hectares in poor countries are planted to CIMMYT-related wheat varieties, accounting for just under two-thirds of total production. The additional grain from these varieties is estimated at more than 10 million tons each year.
- More than 21 million hectares in developing countries are planted to CIMMYT-related maize varieties (some 50% of the area devoted to improved varieties in those countries).
- CIMMYT-related maize and wheat varieties account for well over US$ 3 billion (in 1990 US$) in extra grain production each year in the developing world.
- More than 9,000 researchers from around the world are alumni of CIMMYT's training efforts.
- Our information products and research networks improve the efficiency of researchers in more than 100 countries.

Location

Headquarters are in Mexico, but activities and impact extend throughout the world via 17 regional offices (see contact information, p. 72).

A Message from the Director General

The message of this year's Annual Report is a simple one, but it bears repeating: at CIMMYT we conduct essential science to meet people's essential needs for food, for income, and for a healthy environment.

We and our partners conduct science not for its own sake, but for the sake of millions of people who cannot see beyond the struggle to stay alive. It is true that the nations of the world together produce enough food to feed everyone on earth, but global society is not equitable. Hundreds of millions of people cannot buy or grow enough food to sustain themselves. Until the complex equation that governs their access to food changes somehow, these people will continue to struggle for the right to survive.

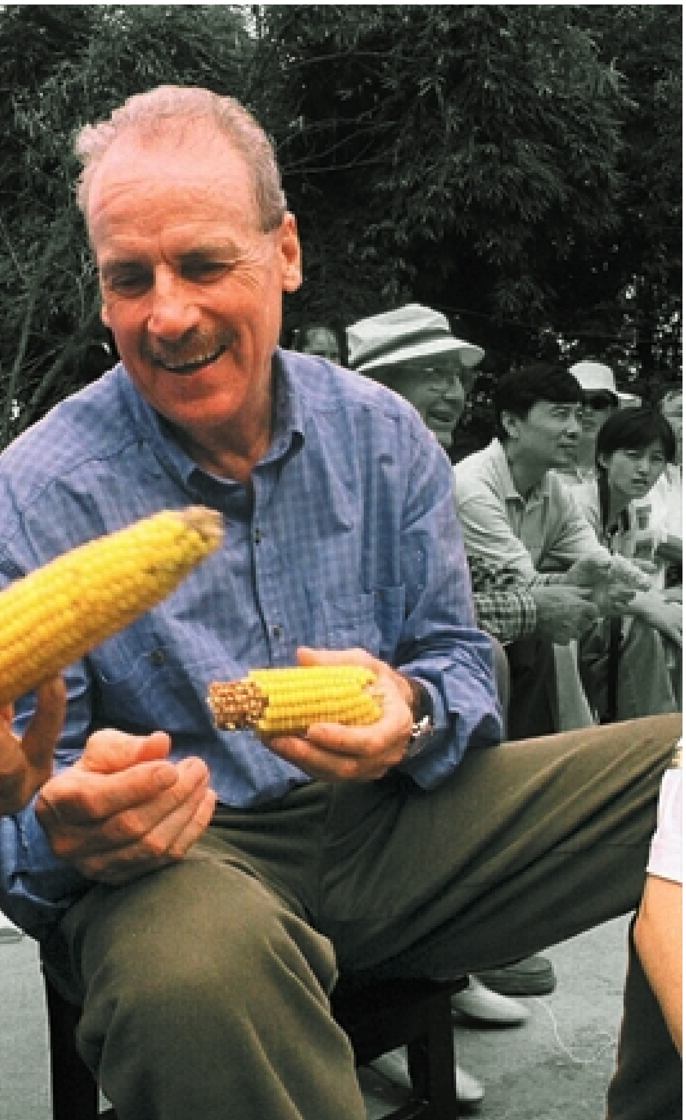
At CIMMYT we know that science can change the equation.

Science for Poor People: One Example

Anyone who doubts the impact of agricultural research on food security, poverty alleviation, and natural resource protection should visit rural areas of Guizhou, China's poorest province. I traveled there recently and witnessed an almost miraculous turnaround in the lives of poor people. The source of change was the introduction of quality protein maize (QPM) hybrids as part of a government effort to alleviate hunger. Quality protein maize is higher in two essential amino acids, lysine and tryptophane, that are vital to the growth of children and non-ruminant livestock. For example, 175 grams of QPM meet the daily protein needs of a child—equivalent to 250 grams of normal maize.

The QPM varieties used in Guizhou were developed through a longstanding partnership between the Chinese Academy of Agricultural Sciences (CAAS) and CIMMYT. The products of their research—used in farmers' fields today—are hybrids that generally have one CIMMYT parent line and one Chinese parent line. All of the Chinese scientists involved in the research have visited CIMMYT for training.

In Maoli Village, where a typical farm is about 0.7 hectares, annual incomes were below US$ 50 per capita until recently. For up to three months every year, families had virtually no food. The QPM hybrids have yielded around 10% higher than other hybrids, in addition to providing grain with enhanced nutritional quality. While some of this grain is consumed directly by farm families, its primary use has been to improve pig production. New animal production enterprises have enhanced household food security and increased disposable incomes for all of the families concerned.



One elderly woman farmer explained, "We have always worked hard, but this barely kept us alive until QPM arrived. Thank you for helping us. Now my family is happy, I have a good house, good clothes, and I can travel to the local town." She was 78 years old and had clearly endured much hardship. In addition to the families in Maoli, over 20,000 families in Guizhou Province have experienced similar impacts.

My day in Maoli Village was one of the great privileges of working for CIMMYT; I will remember it for all of my life. The skeptics may say, "But you have no baseline data. How can you measure the real impacts?" To them, I would say, "Go and listen. Once you have seen and spoken with the farmers involved, your belief in research for development will be further strengthened." Seeing is believing.

Highlights

of This Report

Our purpose in this annual report is to help people see and understand—through the experiences of scientists and farmers—how our research fosters food security, protects natural resources, and helps alleviate poverty all over the world. The stories in the following pages cover a range of topics, including: impending water shortages in agriculture; the restoration of seed for Central America's farmers after a devastating hurricane; the challenges for Central Asia's wheat researchers and farmers, who must work in a wholly new—and highly unpredictable—economy; the remarkable, sustained contribution of CIMMYT wheat and maize seed to plant breeding and food security worldwide; molecular breeding techniques that

ONE ELDERLY WOMAN FARMER EXPLAINED, "WE HAVE ALWAYS WORKED HARD, BUT THIS BARELY KEPT US ALIVE UNTIL QPM ARRIVED. **THANK YOU FOR HELPING US.** NOW MY FAMILY IS HAPPY, I HAVE A GOOD HOUSE, GOOD CLOTHES, AND I CAN TRAVEL TO THE LOCAL TOWN."

fortify wheat plants to overcome an aphid-borne virus; and many other research advances.

1998-99 IN REVIEW

Although space does not allow us to list every event that has marked this last year or so at CIMMYT, I would like to highlight a few.

During the India-CIMMYT Days in April 1998, we and our colleagues from the Subcontinent assembled in appreciation of one of the world's most enduring, productive research partnerships. One goal of the meeting was to examine prospects for further collaboration. The mood of the event was captured in a presentation by M.V. Rao, Ex-Wheat Project Director and Former Special Director-General, Indian Council for Agricultural Research (ICAR), "I feel that the biggest and only hope for the millions and millions of small farmers is the collaborative and most humane programmes like the India-CIMMYT collaboration."

CIMMYT's research is conducted by multidisciplinary project teams. In January 1999, our first Project Reporting Week brought all staff together at CIMMYT headquarters so that project leaders could report on progress and project teams could plan research for the upcoming year. Reporting Week was an excellent opportunity for staff to learn about each other's challenges and achievements and to appreciate the range of research that we conduct.

The year was also marked by awards and honors for CIMMYT staff. Most notably, the Friendship Award, the highest honor China awards to a foreigner, was presented to Sanjaya Rajaram, Wheat Program Director, in the Great Hall of the People in Beijing.

Similar professional honors, including awards for articles published in scientific journals and for participation in professional societies, were given to many other staff. We are extremely proud to belong to an institution whose members have achieved so much on behalf of others.

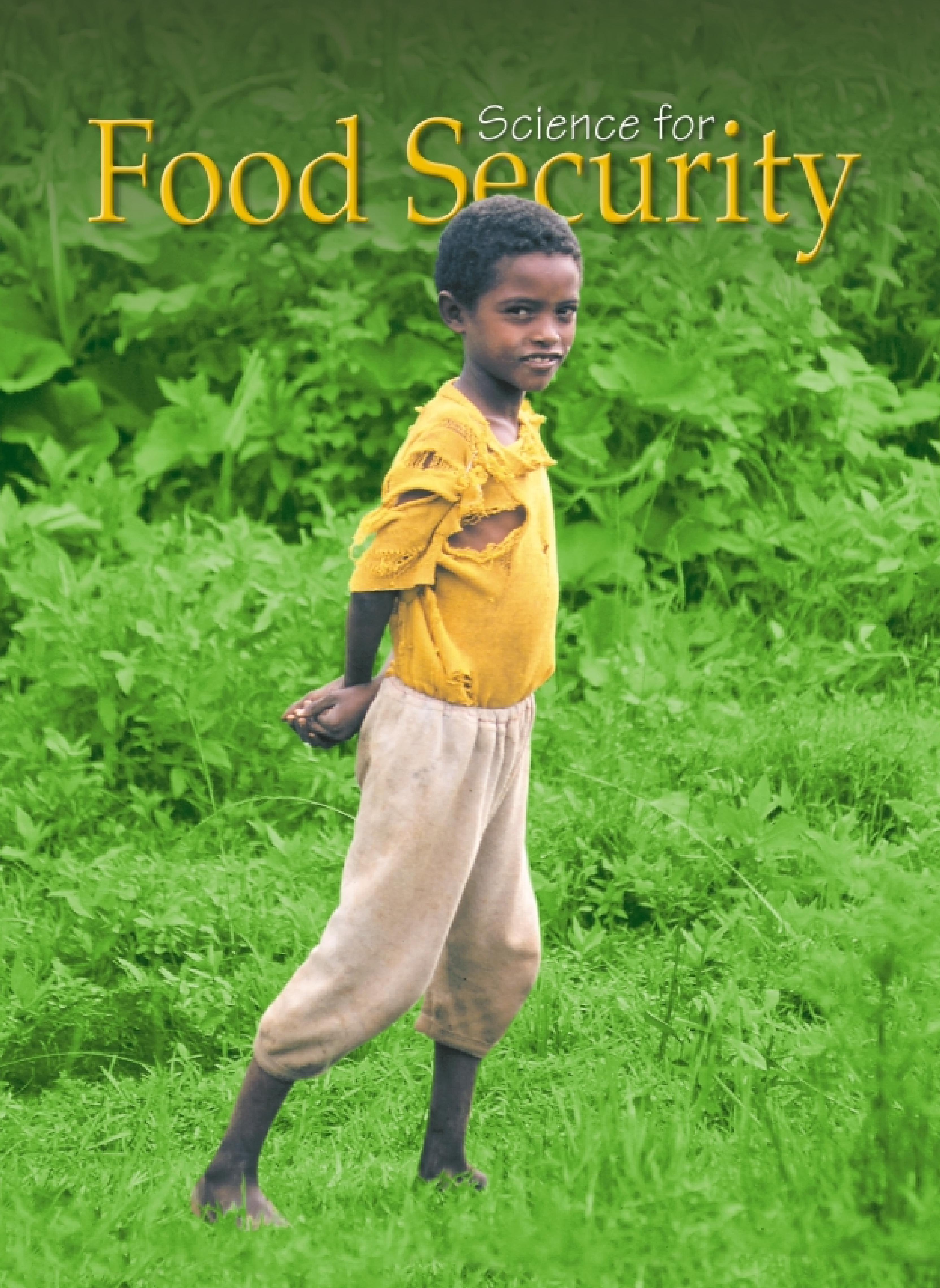
Two other occurrences in 1998-99 bear mentioning. First, following a review of the Center's information technology activities, we have incorporated all functions related to bioinformatics and biotechnology into the Applied Biotechnology and Bioinformatics Program. Second, in an effort to make staff evaluations more objective and useful, we continue to evaluate methods of multi-source assessment (an area of work initiated through the CGIAR Gender and Diversity Program).

Finally, it is important to add that this has been a banner year for documenting the impacts of our research. Once again, the numbers are in, and once again we see that CIMMYT, especially in wheat improvement research, is second to none in bringing about impacts in farmers' fields. The results of our studies are presented in greater detail in this report, but I would like to emphasize the human dimension of this achievement here. These impressive results are the product of much effort by our researchers and research partners, working long hours with limited budgets. All too often this work is not recognized by awards and ceremonies, but its importance must not be underestimated, because it enables millions of human beings to escape hunger and poverty.

Timothy Reeves

Prof. Timothy Reeves

Science for Food Security



Seed Security in Central America: From Disaster to Development

In the aftermath of Hurricane Mitch, many Honduran and Nicaraguan farm families found that they had escaped with their lives, only to lose their livelihoods. The storm destroyed crops and seed stores throughout these countries—including important government seed stores. Without seed to plant in the next growing season, how would these families survive?

"There were 23 landslides on my land alone. All was swept away—harvest, the road, fencing—everything!" Maize farmer Felix Lainez stood under blue skies on a balmy March afternoon. The sun warmed the hills and canyons. The peacefulness of this locale, just east of Choluteca in southern Honduras, made it hard to imagine the havoc wrought by Hurricane Mitch the previous October.

During its three-day rampage in the region, the storm dumped millions of cubic meters of rain on Honduras' and Nicaragua's mountainous terrain. Five months later the effects were still evident throughout the countryside: trails of hillslope erosion far and wide, like stretch marks on the landscape; rubble-strewn sand flats where riverside settlements once stood; small wooden crosses to mark the spots where flood victims were washed away. Of all Central America, Honduras was hardest hit by Mitch—agricultural losses were estimated to be as high as US$ 800 million—but damage was also considerable in the mountainous northern zones of Nicaragua, near the Honduran border. As seems typical in disasters, the hurricane's effects region-wide were most calamitous for the poor—many of them small-scale farmers, often living below the poverty line and possessing scant cash or food reserves.

Lainez was lucky: he and his family escaped with their lives, their modest homestead, a few hundred kilograms of maize grain, and savings that have allowed them to purchase more grain. But he and his peers in Honduras grew little maize during the winter season of 1999, devoting most of their efforts to relief or clean-up efforts.

A NATIONAL PROGRAM ARISES FROM RUIN

A potentially graver consequence for Honduran farmers over the long term was the devastation of the country's Dirección de Ciencia y Tecnología Agropecuaria (DICTA). The primary source of the foundation or basic seed that suppliers increase and distribute to farmers, DICTA lost major stores of seed, nearly all plantings of improved maize, and most machinery and infrastructure on several key experiment stations. Nicaragua's Instituto Nicaragüense de Tecnología Agropecuaria (INTA) came through the storm virtually intact but faced the challenge of intensifying basic grain production in winter farming zones to offset projected shortages of maize and beans. In both countries, visionaries dreamed of turning disaster to development by offering farmers high-quality seed of new, improved versions of traditional maize and bean varieties to replace older, less productive cultivars lost in the hurricane.

To bring that dream to fruition, CIMMYT has helped DICTA's maize seed and breeding program literally arise from ruin and has provided crucial support to INTA's development and seed production efforts. CIMMYT's activities, which formed part of its participation in "Seeds of Hope for Central America"—a relief initiative led by the Centro Internacional de Agricultura Tropical (CIAT)—and in the Regional Maize Program for Central America and the Caribbean (Programa Regional de Maíz, or PRM, a network funded by the Swiss Agency for Development and Cooperation), included the following:

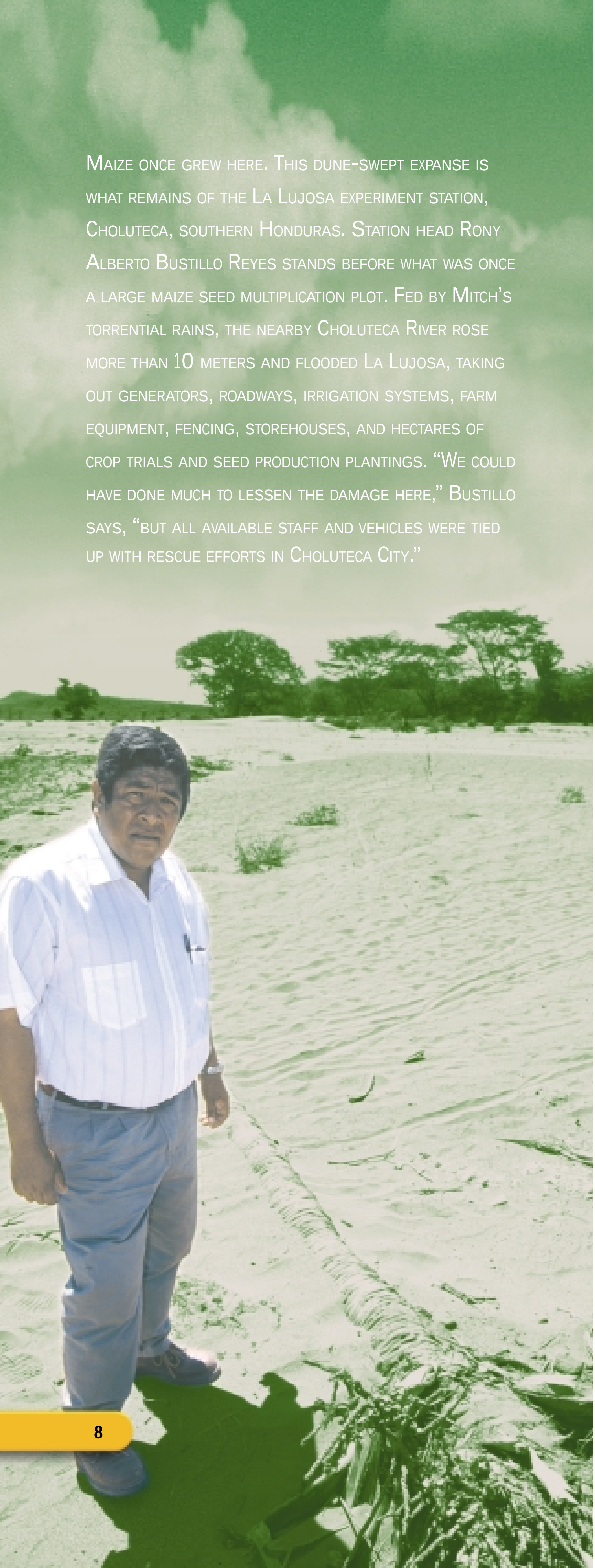
- In November 1998, CIMMYT sent DICTA nearly half a ton of seed of diverse improved varieties and inbred lines chosen for high yield, regional adaptation, and stress tolerance.
- Center and PRM staff worked directly with DICTA to plan and execute restoration of maize breeding stocks.
- CIMMYT and the PRM joined forces with representatives of funding agencies, research institutions at all levels, non-governmental organizations, and diverse other players to marshal and coordinate disaster and seed assistance in Honduras, Nicaragua, and storm-damaged areas elsewhere in Central America.

"We have been pleased and surprised at the speed of CIMMYT's response and support," says Norberto Urbina, Subdirector for Technology Generation, DICTA. "Maize is the number-one crop in Honduras—it is grown everywhere, mostly by smallholders on marginal lands and at low yield levels. Mitch destroyed the maize crop, but this disaster has actually given us a chance to purify seed stocks and extend the use of higher yielding, stress-tolerant varieties."

NEW SEEDS OF HOPE

To highlight Mitch-related seed activities and advances in crop breeding, DICTA held a field day at its Playitas research station near Comayagua on 25 March, 1999. Participants included political authorities and representatives of funding agencies, Seeds of Hope, CIMMYT, and the PRM. During a brief introductory ceremony, in which speakers described Honduras' agricultural research program and collaborative efforts to address the Mitch crisis, the Vice Minister of Agriculture, Miguel Angel Bonilla, formally thanked CIMMYT and the PRM: "Our program had been virtually

SOUTHERN HONDURAN MAIZE FARMER FELIX LAINEZ HAS CLEARED THE DEBRIS FROM HIS FIELDS AFTER MITCH AND IS READY TO BEGIN ANEW.



Maize once grew here. This dune-swept expanse is what remains of the La Lujosa experiment station, Choluteca, southern Honduras. Station head Rony Alberto Bustillo Reyes stands before what was once a large maize seed multiplication plot. Fed by Mitch's torrential rains, the nearby Choluteca River rose more than 10 meters and flooded La Lujosa, taking out generators, roadways, irrigation systems, farm equipment, fencing, storehouses, and hectares of crop trials and seed production plantings. "We could have done much to lessen the damage here," Bustillo says, "but all available staff and vehicles were tied up with rescue efforts in Choluteca City."

destroyed. Now we are rebuilding, testing selected varieties from CIMMYT that are higher-yielding and better-performing for farmers."

In the field, participants toured plots of maize, beans, rice, potatoes, and grapes under observation or seed increase. Much of the maize came from the seed shipment from CIMMYT, which comprised varieties and inbred lines similar to existing materials but superior in yield and agronomic performance. According to Jorge Bolaños, CIMMYT agronomist and PRM coordinator, this represents the near-total replacement of old Honduran varieties with newer, better genotypes. "All materials had already been tested extensively in PRM regional trials that included Honduran sites," Bolaños says. "They could have been used immediately by farmers, but they first must pass approval through the national seed certification system." In addition to high yield potential, the seed featured such valuable traits as drought tolerance, resistance to foliar diseases and ear rot, or enhanced protein quality. The PRM contributed US$ 20,000 for sowing and management expenses. "This foundation seed was sown during Christmas and New Year's Eve, under true duress, by dedicated DICTA agronomists, including Leopoldo Alvarado, Gustavo López, Oscar Cruz, and Elio Durón," Bolaños says.

One star in the field day was the replacement version of Guayape, the nationally renowned variety derived partly from CIMMYT Population 43. "This variety is so competitive that it gets yields similar to those of hybrids," says López, as he uncovered a large, white-grained ear from one of the plants in the Guayape trial plot. Selections from all materials will undergo widespread on-farm and on-station testing over the next year or so. The best will eventually reach farmers' hands through extension efforts assisted by nongovernment organizations and seed-for-grain programs. Barring other disasters or unforeseen circumstances, Bolaños expects a big jump in Honduran maize productivity in the coming years, as farmers begin to grow the new materials. "We'll achieve a significant advancement, particularly with farmers who never before used improved varieties and lost their seed to Mitch. Something good will come from this catastrophe!" he says.

Raising Sights in Nicaragua

In Nicaragua, seed relief efforts were so successful that maize production doubled and bean production tripled over previous levels—a credit to the vigorous and well-conceived response of government officials and timely assistance from CIMMYT, the PRM, CIAT, and PROFRIJOL (a Swiss-funded bean network), among many others.

"The immediate, opportune technical and economic support provided by CIMMYT and the PRM enabled us to develop and carry out a contingency seed production plan to replace seed lost because of the hurricane," comments Roger Urbina, director general of INTA.

"I've seen high-quality relief seed in very remote places—areas that can only be reached by combined air travel and several hours in a small boat," says Jerome Fournier, predoctoral fellow with the PRM. He is referring to the BOSAWAS natural reserve, home of the Miskito indigenous group, in northeastern Nicaragua near the border with Honduras. "Everyone is crying for impact assessment; with seed relief, for doing relatively little, you obtain large impacts," Fournier says. "We've done something significant in the wake of Mitch."

Importance of Public Access to Seed

Many CIMMYT staff have contributed to efforts in both Honduras and Nicaragua: Hugo Córdova, maize breeder; Gustavo Saín, economist in Central America; and Hector Barreto, former CIMMYT agronomist assigned to the CIAT Hillsides Project, to name a few.

In Bolaños' eyes, the Mitch crisis underlines the vital need to support collaborative efforts by public research institutes in basic grains, so governments have access to seed—a strategic resource—and can provide it to farmers. "CGIAR Centers like CIMMYT and CIAT, and crop research networks like the PRM, provide instant, free access to quality germplasm for developing countries where seed under intellectual property protection may not be available or even the right option for most farmers," he says.

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Maize agronomist Jorge Bolaños has spearheaded CIMMYT's seed relief efforts in Central America, in the wake of Mitch.

WORLDWIDE, WHEAT IMPACTS KEEP GROWING

A NEW STUDY DOCUMENTING THE GLOBAL IMPACTS OF INTERNATIONAL WHEAT BREEDING RESEARCH HAS ONCE AGAIN PUT CIMMYT'S ACHIEVEMENTS "ON THE RECORD." THE WHEAT IMPROVEMENT EFFORTS OF CIMMYT AND ITS PARTNERS CONTINUE TO REACH MILLIONS OF FARMERS, TO RAISE YIELDS IN FIELDS AROUND THE WORLD, AND TO LOWER FOOD PRICES FOR RURAL AND URBAN CONSUMERS ALIKE.

It is no exaggeration to state that CIMMYT's contribution to world wheat production is enormous. In their new global wheat impacts study, CIMMYT economists Paul Heisey and Mina Lantican, together with Wheat Program associate director Jesse Dubin, report that 62% of the total wheat area in developing countries is planted to CIMMYT-related varieties, and just under half the total area is sown to varieties that are either CIMMYT crosses or have at least one CIMMYT parent.

On closer examination, the figures become even more impressive. Spring bread wheat, the predominant wheat grown in the developing world, is sown on 68 million hectares of land in countries as geographically diverse as Ethiopia, China, and Brazil. In 1997, between 80% and 90% of the spring bread wheat area in the developing world outside China was planted to cultivars with CIMMYT breeding materials in their pedigrees (Figure 1). China alone planted approximately one-third of its spring bread wheat area to CIMMYT-related germplasm.

The news on spring durum wheat and winter/facultative wheat was also striking. Although in the past CIMMYT placed greater emphasis on spring bread wheat, significant adoption of CIMMYT spring durum germplasm was documented in this latest study. In West Asia/North Africa (WANA), where 80% of the developing world's spring durum wheat is grown, more than 50% of the of the area is sown to CIMMYT crosses. In Latin America, more than 90% of the area sown to spring durum wheat is planted with CIMMYT crosses.

Over the years, CIMMYT's contribution to winter wheat breeding in developing countries has been relatively much lower than its contributions to spring wheat breeding. "It's significant that this contribution increased substantially since 1990," says economist Heisey.

CIMMYT WHEATS REMAIN A VALUABLE RESOURCE FOR BREEDING PROGRAMS

Much of the data on wheat research impacts came from colleagues in national agricultural research systems (NARSs), who provided information on the release of new wheat varieties (see "Digging Out the Data on Wheat," p.12). Between 1991 and 1997:

- 56% of the spring bread wheats released by NARSs were CIMMYT crosses;
- an additional 28% had at least one CIMMYT parent; and
- another 5% had some CIMMYT ancestry.

"The percentage of spring wheat releases with CIMMYT crosses or at least one CIMMYT parent during that time was higher than in the earlier periods," observes Heisey, "which indicates that the use of CIMMYT germplasm has not declined in recent years" (Figure 2).

"Compared with spring bread wheats," says Lantican, co-author of the study, "an even greater proportion of spring durum and winter wheats released during 1991-97 by NARSs contained CIMMYT germplasm." Of 52 durum releases during that period, 77% were CIMMYT crosses, an additional 19% had one CIMMYT parent, and 2% were NARS crosses with known CIMMYT ancestry (Figure 3). Of 106 winter wheat releases, 19% were CIMMYT crosses and an additional 13% had one CIMMYT parent.

"Based on the data on varietal releases and on area planted," Heisey declares, "CIMMYT clearly continues to play a major role in wheat improvement research for developing countries."

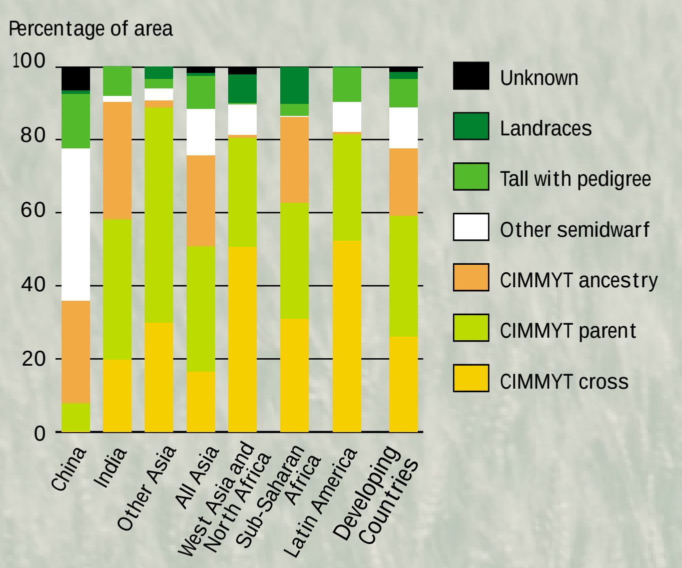

FIGURE 1. AREA PLANTED TO SPRING BREAD WHEAT IN DEVELOPING COUNTRIES, 1997.

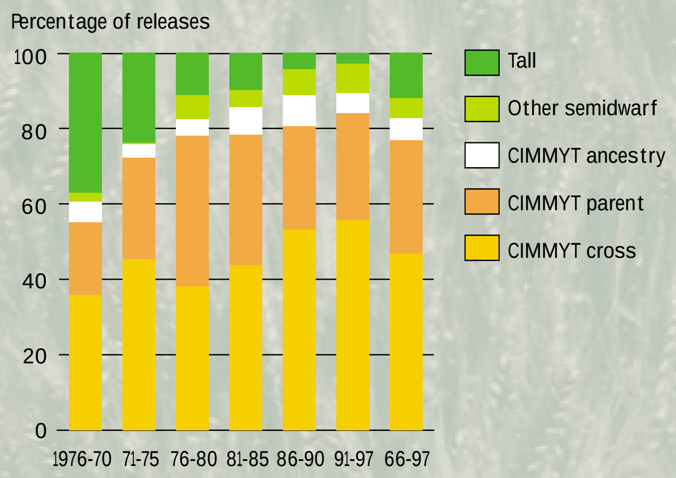

FIGURE 2. SPRING BREAD WHEAT RELEASES BY TIME PERIOD, DEVELOPING COUNTRIES.

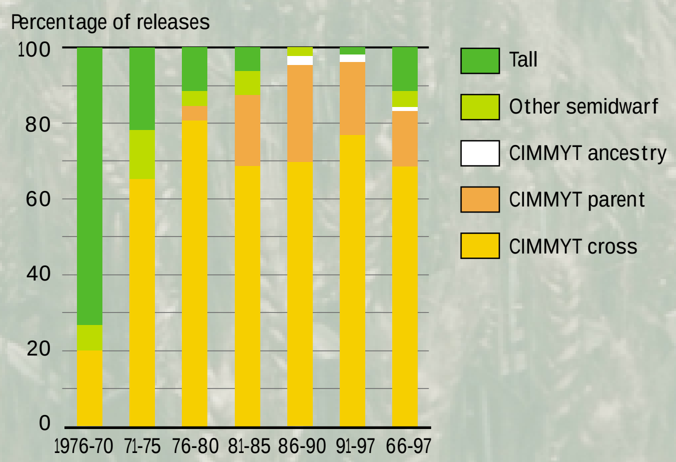

FIGURE 3. SPRING DURUM WHEAT RELEASES BY TIME PERIOD, DEVELOPING COUNTRIES.

Digging Out the Data on Wheat

Digging out the data on wheat impacts and putting them into a consistent form that is amenable to analysis required a concerted and extended effort by the CIMMYT research team and its associates. Questionnaires were sent to each of the 41 countries in the developing world that produces 20,000 tons of wheat or more annually (excluding the Central Asian and Caucasus states). Responses were received from 36 countries, representing just under 99% of all developing country wheat production. To obtain responses, it was often necessary to follow up personally in the country in question. The research team gratefully acknowledges the support from CIMMYT's Wheat Program, many colleagues in national research programs, and the International Center for Agricultural Research in the Dry Areas (ICARDA) in helping to gather this information.

Further obstacles were presented by the sheer scale of the endeavor in large countries like China and India, where no single person was likely to have all of the required information. Nevertheless, this latest wheat impacts study extended the scope of investigation beyond that of its predecessor. Most notably, considerably more data were gathered on this occasion from China, the world's largest wheat producer, which gives economists and policymakers a much more complete view of the world wheat situation.

Wheat harvest in China, 1999.

Trends in Wheat Research and Adoption

Several significant trends emerged during the period since that last wheat impacts study. "There has been a shift from planting direct CIMMYT crosses to crosses that use CIMMYT parents," notes the Wheat Program's Dubin, adding that "this could be largely explained by somewhat lower plantings of direct CIMMYT crosses in countries like India and Turkey, where the NARSs have stepped up their breeding efforts, most frequently using a CIMMYT variety as one of the parents." An unexpected trend was the upswing in the use of CIMMYT winter wheats, which went from a negligible level in 1990 to a respectable presence in 1997 in WANA, a major winter wheat growing area. In addition, some inroads were documented in China, where slightly less than three million hectares of winter wheat now have CIMMYT ancestry.

Two worrisome trends identified by the study team were the slow rate of varietal replacement in most countries and the slower rate of yield increases in farmers' fields. Regarding varietal replacement, Heisey points out that the average age of varieties used in farmers' fields increased between 1990 and 1997 in 19 of 31 of the countries where comparisons could be made. In other words, the lag between time of release and time of adoption may be growing, most likely because farmers simply lack access to improved seed. "If this trend continues," he warns, "depending on environmental conditions, rust or other disease outbreaks could pose a serious problem for some countries in the near future."

Meanwhile, Heisey says, the factors behind the slowing of yield increases in farmers' fields during the past 10-15 years in advanced developing country regions such as northwestern Mexico and the Punjab areas of India and Pakistan are many and complex, though crop management issues and environmental degradation are probably major contributors to this disturbing trend.

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CIMMYT MAIZE IN LATIN AMERICA: PRESERVING OPTIONS FOR SMALLHOLDERS

A NEW STUDY OF THE IMPACTS OF MAIZE RESEARCH IN LATIN AMERICA HIGHLIGHTS CHALLENGES FOR SMALLHOLDERS AND RESEARCHERS.

Compared to researchers working on wheat impacts, economists studying maize impacts face a different set of challenges, according to CIMMYT economist Michael Morris, who together with economist Miguel-Angel López-Pereira produced *Impacts of Maize Breeding Research in Latin America, 1966-1997.**

When it comes to evaluating impact, Morris explains, two kinds of issues set maize apart from wheat: technical measurement issues and data access issues. The technical measurement problems are rooted in the maize plant itself.

"Because maize is an open-pollinating plant, a lot of natural outcrossing goes on in farmers' fields, making it much more difficult to define 'improved germplasm,'" says Morris. "And when you have problems defining what qualifies as improved germplasm, that means it's also difficult to measure the area that's sown to improved germplasm. We don't have these problems with wheat."

Nor does wheat present as many challenges when it comes to obtaining data, which is clearly not the case with maize. Much, if not most, maize breeding research occurs in the private sector, which means that detailed information on what private companies are doing in their breeding programs is necessary to track how CIMMYT germplasm is being used.

"Naturally, the companies are often reluctant to give us that information because it's commercially valuable," says Morris, "and the problem is aggravated by growing concerns about intellectual property rights. This stands in contrast to wheat. The pedigrees of virtually all commercially grown wheats are publicly available, so it's easy to trace their genetic history." Nevertheless, by pointing out the ultimate benefit to the companies of such studies and by providing firm assurances of confidentiality, the CIMMYT researchers were able to obtain enough information to produce reliable figures and findings. (See "The Maize Impacts Study for Latin America: Logistics and Objectives," p.15).

* CIMMYT (1999). Individual maize impacts studies for sub-Saharan Africa and Asia are forthcoming, as is a global study synthesizing findings from all three regions.

Some Surprising Results

Perhaps the most important findings of the study are that (1) commercial seed production is almost entirely in the hands of the private sector and (2) three-quarters of the commercially produced seed in Latin America (and a similar proportion of area planted to improved materials) contain CIMMYT germplasm (Figures 1 and 2).

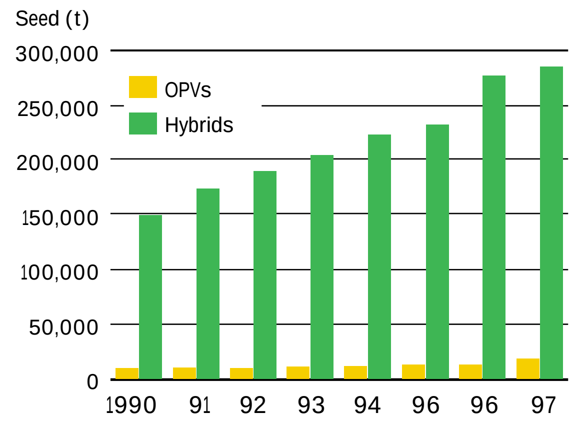

Figure 1. Sales of seed of improved open-pollinated maize varieties (OPVs) and hybrids, Latin America.

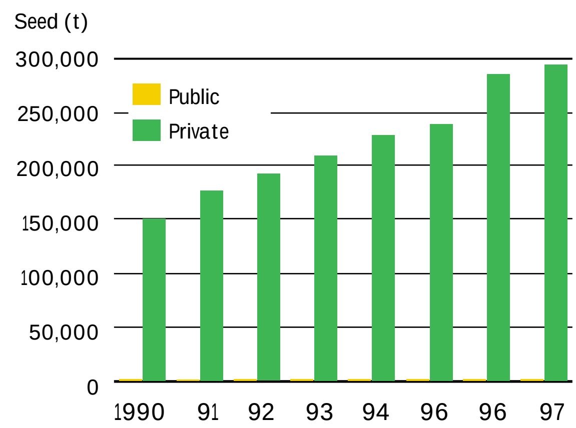

Figure 2. Public vs. private seed sales, Latin America.

Morris draws a strong message from these findings. "You often hear that the private sector can handle maize breeding and that a public institute isn't needed to perform that function. If that's true, then why do 75% of the materials sold by the private sector contain public germplasm? The public sector must be performing a useful function and the products that we're generating do have value—they are being used."

One particularly surprising finding of the impacts study was that improved varieties have not been adopted more widely in Mexico and Central America during the six years since the last survey was done. Roughly 80% of the maize area in those regions is still planted to landraces, often referred to as local varieties.

"Clearly, scientific breeding programs have not reached large, important areas of these regions," says Morris. Although the seed industry has grown tremendously in Latin America during the past few years, the industry is focusing on commercial production zones and is not trying to expand its coverage to the large number of farmers who continue to rely on local varieties.

Morris concludes that at this point the commercial seed producers are just not interested in the other 80% of the maize area. "They can't make money selling seed to those farmers," he says. "The demand is too dispersed over too large an area that has poor roads and distribution facilities. Also, the farmers there work on a very small scale, they lack the resources to pay for seed on a regular basis, and they don't know hybrid technologies very well yet. These companies are very good at identifying where they can make money, and they are even willing to lose money for a spell to develop a market. But our numbers show that at this time the companies don't even see a distant potential for profit in many of these areas."

Troubling Trends for Smallholders?

Given the near-total withdrawal of the public sector from seed production in Latin America since the early 1990s (another prominent finding of the study), serious questions arise about who will provide improved materials to the region's impoverished, small-scale farmers. Adding to this dilemma, the study also found a marked shift away from seed of open-pollinated varieties, which can be sown for several seasons without excessive yield losses, to seed of hybrids, which cannot be recycled as easily. This shift is yet another repercussion of the strong trend toward privatization of the seed industry.

Although the trend towards privatization can well be regarded as a maturation of the seed industry in the region, Morris and López-Pereira uncovered one potentially troubling fact. "An unexpected finding of this latest survey is the degree of concentration in the seed industry in many countries," says Morris. "We're finding, for example, that the top three seed companies in a given country typically control 80%, or even 90%, of the total market for commercial seed. Preliminary findings indicate that the same story is playing out in Africa and Asia. This raises the question of whether in the future farmers will have few choices and may have to accept whatever is offered at whatever price, although this unquestionably won't always be the case. It's certainly something we need to monitor quite carefully and think about in the future."

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The Maize Impacts Study for Latin America: Logistics and Objectives

Morris and López-Pereira in their Latin American impacts work conducted comprehensive interviews with representatives from 36 public maize seed organizations and 172 private seed companies in 18 Latin American countries. The intensive quest for data from the private sector far surpassed such efforts in the 1992 survey. Collectively, the organizations that participated in the survey accounted for 97% of the commercial maize seed sold in the region in 1996. The objectives of the research were straightforward:

- **to document the use of CIMMYT-related germplasm;**
- **to estimate adoption of modern varieties (MVs) at the farm level;**
- **to identify factors that affect adoption of MVs; and**
- **to generate information for research priority setting.**

Greater Than the Sum of Its Parts, Partnership Fuels Biotech Progress

The partnering of advanced Australian research institutes, whose ultimate mission is the betterment of that nation's highly evolved agriculture sector, with CIMMYT, whose clients are the poor farmers of the developing world, may at first seem a bit of a mismatch. In fact, it is a great fit.

"No Single Institute Has All the Resources"

When CIMMYT became a founding member* of the Australian Cooperative Research Centre for Molecular Plant Breeding (CRC-MPB) a scant two years ago, hopes ran high that the cooperative venture would prove productive, given the benefits to be reaped from the respective strengths of the CRC-MPB members. In reviewing the scientific partnerships and research progress made during 1998-99, it appears those aspirations were well founded.

"No single institute in the public or private sector has all the resources, technology, or scientific input we collectively need to do our work most effectively," says David Hoisington, director of CIMMYT's Applied Biotechnology Center (ABC). "This is particularly true with wheat, the focal point of our CRC-MPB activities, because of its large genome, its complexity, and the relatively low level of research investment it has attracted in the past.

"By working with the Australian institutes in the CRC-MPB," Hoisington continues, "we are involved with international leaders in wheat research and also some of the leading experts in molecular genetic analysis for wheat. Joining forces and tapping that knowledge and experience will enable us to use those resources to develop products that will benefit our clients."

Senior pathologist Hugh Wallwork, SARDI, Australia.

Benefits are already accruing for Australia, according to Hugh Wallwork, head of the CRC-MPB's program on biotic stresses and a senior pathologist with the South Australian Research and Development Institute (SARDI). The association with CIMMYT, he says, has promoted access to expertise in both the ABC and the Wheat Program, while at the same time providing "strong and useful links to other international organizations and people." He observes that the closer relationships engendered by the CRC-MPB should allow Australia to make greater use of CIMMYT's extensive collection of wheat germplasm and also provide payoffs in the realm of bioinformatics, as CIMMYT is a primary player in the development of the International Crop Information System (ICIS).

Both Hoisington and Wallwork agree that the consortium has produced a win-win situation for its members, which is exemplified by work on molecular markers for disease resistance and transformation to introduce resistance to fungal diseases of wheat.

Markers for Disease Resistance

Breeding for disease resistance is nothing new, but a strategic shift in research from depending on major genes for resistance to using sets of minor genes to create more durable resistance has made wheat researchers' jobs considerably more difficult. Molecular markers—the DNA signposts that indicate the presence of specific genes—provide scientists with a powerful tool that allows them to identify sources of minor resistance at the molecular level, putting more durable disease resistance within breeders' reach. These markers also contribute to a better understanding of the genetic control of resistance in general.

CIMMYT molecular geneticist Manilal William, funded by the CRC-MPB, is tackling the task of identifying markers for important minor or durable genes that help confer long-lasting resistance to leaf rust (*Puccinia recondita*) and stripe or yellow rust (*P. striiformis*), important diseases in many developing countries. Leaf rust is not a major problem in Australia, which also has wheat varieties resistant to stripe rust, but the development of markers for minor genes will provide breeders and farmers with a prudent extra line of defense should certain resistances break down in the Australian wheats.

Seeking Markers in a Complex Plant Species

"Finding molecular markers for disease resistance generally is a challenging task," says William, "and wheat, because of its large genome full of repetitive DNA sequences, is not a particularly 'friendly' species to work with. But we have made good progress toward our objectives."

CIMMYT cell biologist Alessandro Pellegrineschi developed a wheat transformation system that quadrupled the efficiency of this critical procedure.

* The others are the University of Adelaide, Southern Cross University, the South Australian Research and Development Institute (SARDI), and the Victorian Department of Natural Resources and the Environment.

Considerable headway is being made in marker identification using bulked segregant analysis (BSA). Utilizing data from several years of CIMMYT Wheat Program trials for leaf and stripe rust resistance, the project team selects approximately ten of the most resistant and ten of the most susceptible wheats and puts equal amounts of each wheat's DNA into either a "resistant" or "susceptible" bulk. These two distinct bulks are analyzed along with the wheats' parental lines against different marker systems to detect molecular-level variations (polymorphisms), which are the basis of marker technology. To date, the project team has run bulks against more than 330 microsatellites and 235 restriction fragment length polymorphisms (RFLPs).

A promising step forward was taken recently when William identified an amplified fragment length polymorphism (AFLP) marker that indicates the presence of a gene locus strongly associated with leaf rust and stripe rust resistance. He is now establishing the location of the marker within the genome. Additional polymorphisms have since been observed with other markers in different populations, providing the basis for identifying other minor resistances. William is also creating genetic maps of populations drawn from crosses of Avocet, a susceptible Australian wheat, with three rust-resistant CIMMYT wheats. These populations provide critical genetic material to refine the location of the genes identified by BSA and for further molecular characterization of the resistance mechanisms.

Future plans include similar marker identification efforts for septoria tritici blotch (*Mycosphaerella graminicola*) and Karnal bunt (*Tilletia indica*), diseases that are prominent in the developing world, and in the case of septoria, in Australia as well. A doctoral student funded by CRC-MPB will soon join William to work toward identifying genetic factors associated with drought tolerance in wheat.

Transforming the Transformation Rate

Sometimes in scientific work, substantial benefits grow out of tangential components of a project. According to CIMMYT cell biologist Alessandro Pellegrineschi, this occurred with his CRC-MPB-funded work on introducing and characterizing the effects of potential resistance genes to fungal pathogens. On the way to this goal, a wheat transformation system was developed that quadrupled the efficiency of this critical procedure in the ABC lab.

"When I entered this project," says Pellegrineschi, "our transformation rates—in layman's terms, 'the percentage of plants into which we successfully introduce new genes'—were inadequate for the job at hand. We needed a reliable transformation system before we could work on pathogen resistance."

Starting with a transformation rate of less than 0.2%, over eight months Pellegrineschi raised the rate to 0.9-1.0%. This was accomplished through incremental improvements in the transformation protocol, including more refined selection criteria for embryos used for particle bombardment with the gene gun and the use of "cleaner" DNA. Pellegrineschi even identified greenhouse temperatures for the plants supplying the embryos as a factor in transformation efficiency.

Getting the transformation rate up is fundamental to employing transgenics in a major breeding program. "It's essentially a numbers game," says Pellegrineschi. "If we get our rates up to 5%, which is our target, by shooting 1,200 wheat embryos a week we could produce 60 transformations, enough to test one gene construct and produce at least one viable plant capable of transferring the trait to its progeny. Over the course of a year, we could insert more than 50 different genes into plants, which the breeders can use in their pursuit of new characteristics."

Exploring Fungal Resistance through Transgenics

While progress continues toward the 5% transformation goal, the CIMMYT team has shared its improved transformation approach with CRC-MPB scientists and has commenced work on fungal resistance. Pellegrineschi seeks to introduce genes into wheat that will produce pathogen-related (PR) proteins such as b-1,3 glucanase, chitinase, and ribosomal-inhibiting protein (RIP), which have shown evidence of slowing or arresting fungal growth in some cereal plants. Once transgenic plants that incorporate these and other PR proteins are created, they need to be "characterized" to determine the effects the gene has on the plant. In other words, the scientists look to see whether the plant displays resistance to fungal diseases, and if so, which fungal diseases and what levels of resistance; whether there are any secondary effects, such as sterility; whether any yield reduction is detected; and so forth. A second doctoral student funded by CRC-MPB will start on the characterization assignment in the latter part of 1999.

Simply characterizing the modified plants, however, may be only the first step in developing a resistance strategy and complementary wheat plants, explains Pellegrineschi. The PR proteins may work better with an "inducible promoter," so that the plant produces the proteins only under a particular biotic stress. "Another approach is to have the proteins express only in particular tissues," he says, noting that when a gene expresses, there is always a metabolic cost to the plant. "It may be a long road we're traveling here," he adds, "but I'm very encouraged with our first steps."

A Model for Collaboration

The ABC's Hoisington is also encouraged by the first steps the CRC-MPB members have taken. "This is the first time ABC has entered into an arrangement like this with developed country institutes, and we've found the experience has been very positive. In fact, it could serve as a model of how we could interact with other universities and even the private sector in a way that builds a consortium of expertise in a non-exclusive fashion, that produces benefits for all of our respective clients."

Most important of all, says Hoisington, "It serves as a heartening demonstration of how research institutes of the industrialized world that are very strong in the theoretical aspects of technology can work with an institute like CIMMYT, which represents the developing countries and which brings a practical orientation toward these technologies to the table. What results is the realistic application of these tools to real-life problems in the developing world."

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"Wheat is not a particularly friendly species to work with," says molecular geneticist Manilal William (assisted here by ABC technician Juan José Olivares). "But we have made good progress toward our objectives."

"Many well-qualifield scientists have left agricultural research," says Yuriy Zelenskiy, a breeder at the A.I. Baraev Kazakh Cereals Research Institute.

New Life for Wheat in Central Asia and the Caucasus

The nations of Central Asia and the Caucasus were catapulted into a deep economic crisis in the early 1990s when the Soviet Union disintegrated. The agricultural crisis has been equally profound. In a region where some researchers earn less than a dollar a day, how can agricultural and economic development be revived?

Yields of basic food and export crops in Central Asia and the Caucasus (CAC) have fallen dramatically in recent years. The CAC countries—Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan—no longer produce enough food to meet domestic demand. The situation was exacerbated by the loss of access to regional markets as the countries in the region set up trade barriers. Importing food is not an option. Neither the countries nor the people can purchase food at international prices.

Agricultural modernization is a critical component of overall development in CAC, both to ensure food availability and to promote economic growth. According to A. Satybaldin, Director General of Kazakhstan's National Academic Center of Agricultural Research, "Sustainable grain production means, first of all, food security, but essential economic, scientific, and technical prerequisites must be met if we are to achieve this goal."

The difficulty of meeting the prerequisites for food security must not be underestimated. Agencies for generating technology and serving farmers have been decimated. Research institutions are unprepared to respond to farmers' needs under a market economy; nor are they developing and releasing new varieties to replace cultivars that are susceptible to pests and diseases. In this region, where wheat cropping is the most important agricultural production system, CIMMYT and collaborating institutes hope to jump-start economic growth by renewing the research network and improving wheat productivity.

New Beginnings in Kazakhstan

Two CIMMYT scientists, one of them a Kazakh national, are now assigned to the region. They work out of Almaty in Kazakhstan, which is by far the largest wheat producer in CAC. For this reason, and because conditions in Kazakhstan resemble those in the rest of the region, CIMMYT opted to begin its regional activities there.

The CIMMYT Economics Program commissioned a study of Kazakhstan's wheat sector in 1998 to learn about local agricultural research and production infrastructure and help target research correctly. As a complement to that study, in July 1999 the CIMMYT Wheat Program dispatched a multidisciplinary team of researchers to the region for a traveling workshop that covered the wheat-growing areas of Kazakhstan and southern Siberia. Scientists from different research institutions in those areas participated in the workshop and had the opportunity to visit research stations and establish links with colleagues there. CIMMYT scientists focused on becoming acquainted with the conditions and most pressing problems limiting wheat production in the region; their findings added to the information gathered earlier through the Economics Program study.

Harsh Realities for Farmers and Researchers

The traveling workshop revealed the many harsh realities faced by farmers and researchers. Kazakhstan produces wheat mostly under rainfed conditions, with an average yield of less than one ton per hectare. The capacity to produce wheat for internal consumption and export has been eroded by long years of input-deficient farming. Since the demise of state-supported agriculture, farmers have lacked cash and credit to invest in new machinery, inputs, and other technologies.

Public-sector research and extension have also suffered from a lack of funding. Very little agricultural research was conducted between 1991 and 1997. Since 1990, Kazakhstan's national agricultural research program has lost half of its scientists. The spirits of the remaining researchers are flagging as they contemplate further budget cuts and job losses. "Many well-qualified scientists have left agricultural research, and that has limited the scope and lowered the standards of our work," says Yuriy Zelenskiy, a breeder at the A.I. Baraev Kazakh Cereals Research Institute. A similar flight is occurring in other CAC countries such as Azerbaijan, where a breeder with a PhD earns less than US$ 1 a day.

Kazakhstan inherited many of its institutions from the Soviet Union, and the transition to a new way of doing things has varied in different sectors of the economy. Systems for marketing wheat and delivering inputs to farmers remain inefficient, although farmers now pay market prices for inputs and receive market prices for their crops, when they manage to sell them. The old network of collective and state farms was privatized in 1993, and by 1997, new farming entities had emerged: partnerships, joint stock companies, cooperatives, and peasant family farms. Titles to private land are now issued, but banks do not accept them as collateral, leaving farmers with no credit to buy inputs and cover other operating costs. Farmers have resorted to bartering, using few or no inputs, and employing fewer people to help on the farms.

"The lower intensity of agriculture today is probably driven largely by the move to a market-based economy," comments Jim Longmire, the economist who conducted the study of the wheat sector. "Kazakh farmers face considerable price and production risks and don't have strong credit or financial support for dealing with these risks." Longmire points out that the recovery of the agricultural sector will depend on the establishment of adequate policies and wheat prices, as well as on agricultural research and development and improved farming circumstances.

Field equipment lies idle in Kazakhstan. Zero tillage and superior wheat varieties could raise yield beyond the current average of less than one ton per hectare.

Reversing the Production Decline

Kazakh agricultural scientists have a good idea of what needs to be done to reverse this downward trend, but implementing solutions is totally out of their hands. “They’re doing the best they can with what they have,” comments Ivan Ortiz-Monasterio, a member of the wheat team that visited the region. “They’re already practicing reduced tillage and residue retention. What would really turn things around would be to go from reduced tillage to zero tillage,” says Ortiz-Monasterio. “The challenge is to enable farmers to adopt it.”

Zero tillage would contribute to conserving soil moisture, cut production costs, increase the amount of organic matter in the soil, and produce higher yields even in dry years. The technology would also require farmers to use herbicides to control weeds, and herbicides are neither available nor affordable for the farmer. “A solution may lie in persuading private companies in the developed world to barter their products for grain in the CAC region, as an American machine manufacturer recently did,” says Ortiz-Monasterio.

Better seed should also help. Many widely grown cultivars have become susceptible to diseases and do not fully meet producers’ needs. Farmers need higher yielding varieties that are resistant to diseases such as the smuts, bunts, and rusts, and are well adapted to the region. Other priorities in spring wheat are drought tolerance, early maturity, and superior grain qualilty. Winter wheat varieties should possess higher yield potential, improved disease resistance, and good grain quality. Key parental lines have been collected from Kazakhstan and are being crossed with elite parents at CIMMYT headquarters in Mexico in the hope of developing high-yielding, disease-resistant wheats adapted to the dryland conditions prevalent in CAC.

To reverse soil degradation, cropping the land less frequently would probably help, as would crop diversification and the shift to zero tillage. For years Kazakh scientists have worked on soil conservation methods, such as the use of blade plows, stubble retention, windbreak crops, and snow plowing. Further research is needed to encourage farmers to adopt these methods and alternative crop and pasture rotations.

Reinventing Research Systems

Stronger research systems are an essential component for improving wheat production in CAC, where scientists are still relatively isolated from the world scientific community and even from other researchers in the region. Through the recent traveling workshop, Kazakh researchers gained the opportunity to contact peers across the region and identify problems they could tackle jointly.

Agricultural professionals in CAC are also participating in wheat improvement training at CIMMYT in Mexico. In 1999, four breeders—two from Kazakhstan, one from Azerbaijan, and one from Uzbekistan—attended the course for the first time. In the long run, attendance at this and other courses, plus visiting scientist fellowships, will strengthen ties and collaboration not only with CIMMYT but also with many other countries and institutions.

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Science to Protect

Natural Resources

WHEAT PLUS WATER:

A VANISHING EQUATION?

EARTH IS THE BLUE PLANET, ITS AZURE HUE A REFLECTION OF THE VAST EXPANSES OF WATER ON ITS SURFACE. A SPECTATOR VIEWING OUR BLUE GLOBE FROM OUTER SPACE WOULD NEVER IMAGINE THAT THE EARTH'S DOMINANT SPECIES IS SUFFERING FROM SHORTAGES OF SUCH A PLENTIFUL RESOURCE. THE FACT THAT IT IS POINTS UP SOME FUNDAMENTAL CONCERNS ABOUT THE EFFECTS OF SUCH SHORTAGES ON AGRICULTURE NOW AND IN THE FUTURE.

These are the facts. Water covers 70% of the earth's surface, but 97.5% of this water is saline. Only 2.5% of all the planet's water is freshwater, and nearly 70% of it is locked in icecaps and glaciers or lies in deep underground reservoirs. An infinitesimal proportion (.007%) of all water on earth is readily available freshwater.*

This small proportion of water (according to the UN, less than one million cubic kilometers) is insufficient to satisfy the many needs of the earth's human population. As the world population grows at the incredible pace of 100 million people a year, the relatively small amount of available freshwater is fast shrinking in proportion to demand. A few data bring home the urgency of the situation:

- In the 20th century global water use has grown twice as fast as global population and continues to rise rapidly in many regions of the world.
- Since the 1970s, the theoretically available amount of water per capita in the world has decreased by almost 40%.
- Presently about one-third of the world population lives in areas suffering from moderate to severe water stress.
- Unless action is taken, two-thirds of the world population (close to 5.5 billion people) will face such shortages by 2025.

WATER IN AGRICULTURE

Water shortages are already having a negative impact on agriculture, the biggest water user in the world. A serious concern is what this implies for the world's food supply, given that a large portion of the human diet is based on cereal grains and other crops. (Another concern is the impact on women in agriculture; see "Getting Their Fair Share of Water.") The rising world population puts greater demands on freshwater supplies while requiring more

* We thank our colleagues in the International Water Management Institute (IWMI) for their contributions to this story.

and more food to subsist. The burgeoning population also drives urban development and industry, which siphon off increasing amounts of freshwater, leaving less to produce food.

Increasing and competing demands for water are plunging many countries into an era of severe water shortages. Water-scarce countries (in West Asia and North Africa, for instance) may have to divert water from irrigation to supply domestic and industrial needs, and be forced to import food. Shortages could be solved by developing new sources of water and making more rational use of water across all sectors—in irrigation, industry, potable water, and the environment. Development of new water supplies will be needed for all sectors in 2025.

The chief sources of irrigation water are rivers, lakes, and (often controversial) government-built dams. Water from reservoirs deep within the earth has been brought up with giant pumps, but massive pumping, once viewed as a solution for farmers, actually worsens water shortages by quickly depleting underground water that may take decades to be replenished. This strategy, in the long run, actually threatens to reduce global food supplies.

How CIMMYT Helps

CIMMYT tackles water problems in many different environments as part of its research to improve developing world agriculture. According to analysts, irrigation uses up two-thirds of the world's supply of freshwater, but waste and improper management cause less than half of that water to reach the roots of plants. Developing methods that improve irrigation water use efficiency is just one of several water-related research areas investigated at CIMMYT, where researchers are well aware that water scarcity is becoming the single most important constraint to increased food production in many parts of the world.

For this reason, the Wheat Program has worked for some years on developing agronomic practices to help farmers cope with diminishing water supplies. (Our Maize Program has conducted extensive research on developing maize that can tolerate drought; see "Maize Minus Water," next page.) Researchers have found that planting wheat on permanent beds improves water use efficiency. Scientists testing bed planting in South Asia's irrigated production systems report a 30% savings in water use in those particular irrigation systems. In other, more marginal environments, partial or complete residue conservation in conjunction with reduced tillage and crop rotation helps conserve soil moisture. Conservation tillage reduces runoff of valuable water. A five-fold increase in water infiltration into the soil using conservation tillage was recorded in a long-term CIMMYT trial. CIMMYT is also developing agronomic practices that reduce nitrogen contamination of water systems.*

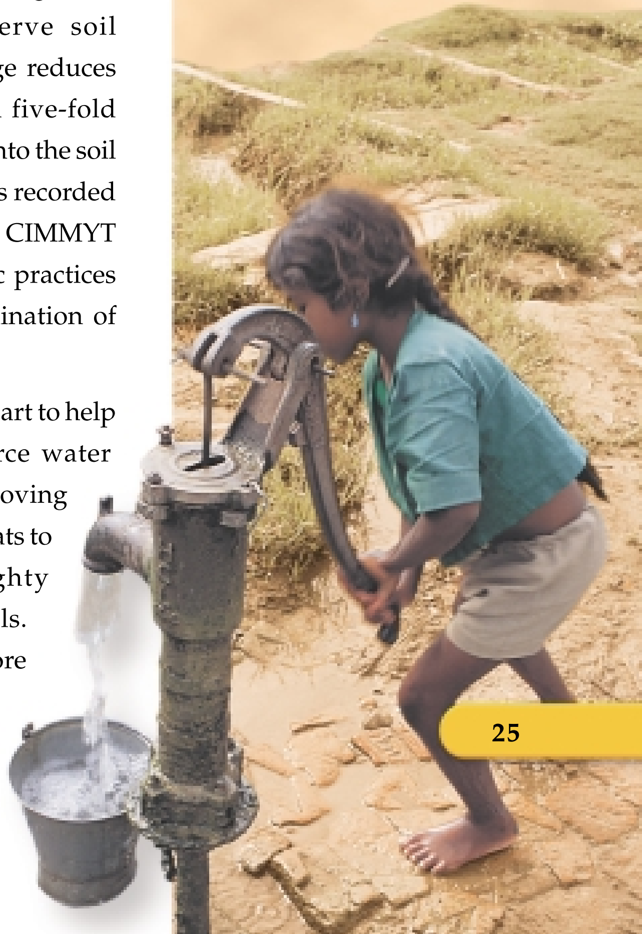
Breeders are doing their part to help plants get more out of scarce water supplies by constantly improving the capacity of CIMMYT wheats to yield well under droughty conditions and in saline soils. Crop varieties that yield more

* See *CIMMYT in 1997-98*, p. 10.

Getting Their Fair Share of Water

A fair share of water must be given to women and children, who bear most of the costs of too little or unsafe water. Apart from spending long hours collecting and carrying water, they get less water for personal hygiene and suffer most from poor water quality and water-related diseases. Each year, 3.8 million children in the developing world die from water-borne diseases, and every eight seconds a child succumbs to a water-related illness.

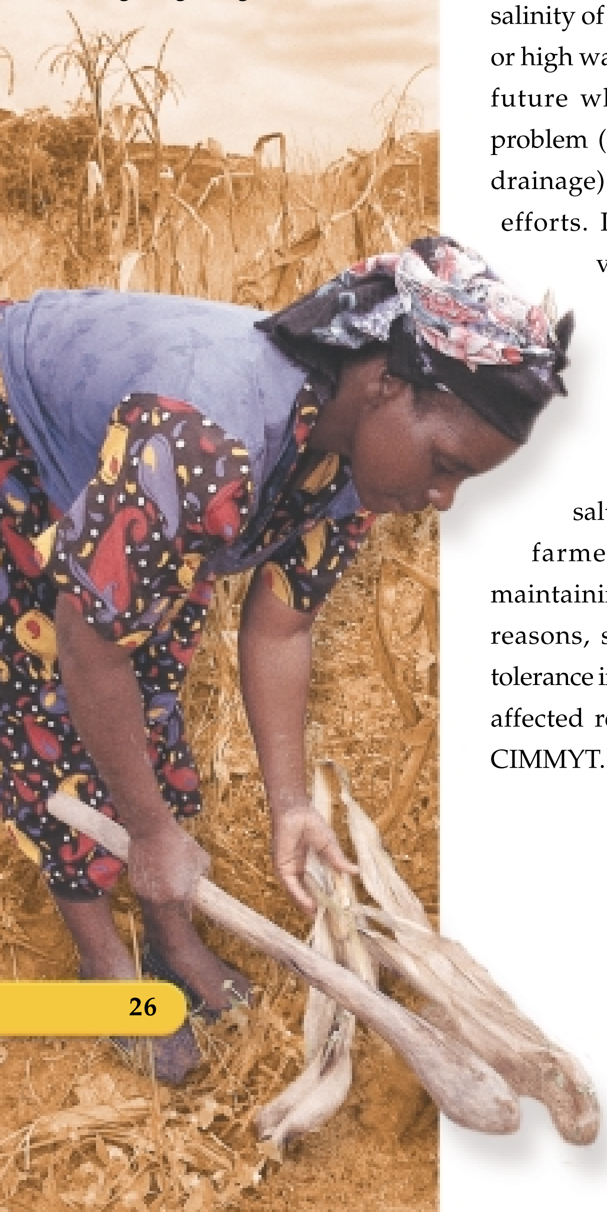
Experts estimate that each year women and girls in developing countries spend a total of *10 million person years* hauling water from distant and frequently polluted sources. In many parts of the developing world, women do not have the same rights to water as men, including women farmers who may have limited or no rights to water for irrigation. As the number of women in agriculture continues to grow, this problem will have many implications for the welfare of their families, especially their children.



Maize Minus Water: Progress in Breeding Drought Tolerant Maize for Africa

In southern Africa, maize is a highly valued staple for small-scale, resource-poor farmers and their families, but drought frequently threatens or destroys maize harvests. CIMMYT staff are working with breeders in southern Africa to generate locally adapted maize varieties and hybrids that produce more grain than currently sown cultivars under severe drought stress. The tolerant maize is also bred for higher and more stable yields on low fertility soils, as well as responsiveness to favorable conditions. In first results from on-station trials in the region, experimental maize hybrids from CIMMYT outyielded popular, locally adapted hybrids by a dramatic 25-50% under drought stress.

For more information see *CIMMYT in 1997-98*, p. 22; contact m.banziger@cgiar.org



per unit of water will improve water productivity in arid areas (see "Durum Wheat Yields Hit a New High," p. 49). Drought occurs in different patterns—for example, early or late in the cropping cycle. Breeders are working on early maturing varieties that escape moisture stress at the end of the cycle, as well as late maturing wheats that slow their development to benefit from late rains when there is drought early in the season. Breeders are also working on developing varieties that are well adapted to being planted on beds.

When we think of water problems what generally comes to mind is a lack of water. However, excessive amounts of water can also generate problems. In large tracts of India and Pakistan, where millions of the world's poorest live, wheat is cultivated under irrigation. The ever-increasing salinity of soils due to inadequate drainage or high water tables poses a major threat to future wheat production. Solving this problem (for example, through improved drainage) will require great engineering efforts. In the meantime, salt-tolerant varieties could contribute to maintaining yields until a more permanent solution to the problem is implemented. In areas where such radical solutions are not feasible, salt-tolerant varieties may provide farmers with the only means of maintaining their yield levels. For these reasons, studies aimed at breeding salt tolerance into wheat varieties adapted to the affected regions have been conducted at CIMMYT.

Looking to the Future

Water is a renewable but poorly distributed and finite resource. Making sure everyone on earth has enough water to cover their basic needs will necessitate great and ingenious solutions. Perhaps a way will be found to melt some of the water trapped in the polar ice caps and use it to supplement current resources, or perhaps new and inexpensive methods of desalinization will allow us to tap into virtually inexhaustible amounts of ocean water. Efficiency in using water could be improved through drip irrigation (where this technology is economic) or by recycling waste water for crop production. These and other solutions are feasible, but in the end, the biggest challenge may not be accessing new sources of water or making better use of it, but rather finding ways to share water resources more equitably.

The water crisis the world faces will take years to solve due to its scope and intensity, and whether it can be solved at all is not clear. The problem is multi-faceted and complex, and many actors are involved. Perhaps the best we can hope for is to make sure that we have enough water to ensure the survival of our species. If we do not, the blue planet will keep rotating around the sun, but it will most probably not be dominated by a species that requires freshwater to survive.

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Reduced Tillage for Tropical Maize and Wheat: From Moldboards to Mulch and Profits

Conventional tillage is an energy-intensive process whereby, for each hectare of farmland, several hundred tons of soil are chopped and pushed around to sow at most a hundred kilograms of seed. Is there a better way?

Conventional tillage can provide weed control, get organic residues into the soil, aerate upper layers, and mix fertilizer evenly while forming a good seedbed, to name a few benefits. But if you stand on a sun-baked, conventionally plowed field in central Mexico in March—at least a month before the rains arrive—and watch heat-driven winds carry off brown clouds of dry topsoil, you begin to wonder if there is a better way.

Many agricultural researchers believe there are alternatives. There is great interest in conservation tillage for cropping systems in the tropics, as rising populations intensify the pressure to produce more food from finite and overworked land resources. The term "conservation tillage" describes a multiplicity of practices, ranging from extremely simple to fairly complex, which may be implemented in different ways in different settings. Most methods involve reducing or eliminating the moldboard plow—a tool that turns over the soil and exposes it to erosion—and advocate leaving crop residues as a protective mulch. The advantages include reduced erosion, labor and fuel savings, more timely land preparation, improved water infiltration and retention, beneficial bio-activity, and increased organic matter.

CIMMYT has catalyzed research on reduced tillage with partners throughout the developing world, working alongside farmers, developing alternative tillage and residue management techniques, assessing the biophysical performance of different options, and anticipating (through modeling) and measuring (through monitoring) long-term consequences for productivity and resource conservation. The sheer volume of work defies exhaustive reporting here, but a few examples highlight important directions, achievements, and challenges.

WATER FOR RAINFED MAIZE IN MEXICO

Six years of collaborative research by CIMMYT, the Mexican National Institute of Forestry, Agriculture, and Livestock Research (INIFAP), and the Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), France, at a low-rainfall site in western Mexico has shown that conservation tillage has significant effects on system sustainability. Short-term benefits after five years of conservation tillage with moderate levels of residue retention (from 1.5 to 4.5 t/ha of maize residues) included a 50-80% increase in water infiltration over other tillage techniques, with notable reductions in run-off and evaporation. "Average rainfall is only 400 millimeters per crop cycle, so reducing water losses by half is a significant achievement," says Eric Scopel, CIRAD researcher posted at CIMMYT who led the research.

Longer-term effects were equally impressive. In the presence of fresh organic matter on the surface and because of the reduced soil movement, the earthworm population increased five- to ten-fold, depending on the amount of residue retained; their activity and that of other non-microbial fauna greatly improved soil porosity without increasing soil-borne pests. Erosion—in this case from runoff associated with scattered, intense rainfall events—is reduced by at least half, relative to traditional tillage. Organic matter in the upper soil increased from just over 1% to nearly 3% in five years.

"SUSTAINABILITY" MUST BE PROFITABLE

Despite the convincing biophysical data, conservation tillage may not work for every farmer. Damien Jourdain, CIRAD economist at CIMMYT, analyzed the economics of farmers' conservation tillage practices in an area of Jalisco, Mexico. "Cost-benefit studies show improvements in the productivity and stability of maize cropping systems in dry areas where improved seed, fertilizer, and other inputs are used," says Jourdain. "There was an average 35% reduction in risk and double the return on investments."

Jourdain cautions that in traditional systems where no improved inputs are used, adoption of conservation tillage alone did not increase average returns and, in fact, increased risk. "In this situation conservation tillage saves what low-input farmers have most—*labor*—and demands what they have least—*cash*," Jourdain explains. "Also, in the traditional system farmers intercrop beans or squash, but conservation tillage requires herbicides, so they would lose the intercrop. Finally, without improved seed or the intercrop to take advantage of the moisture saved, little is gained."

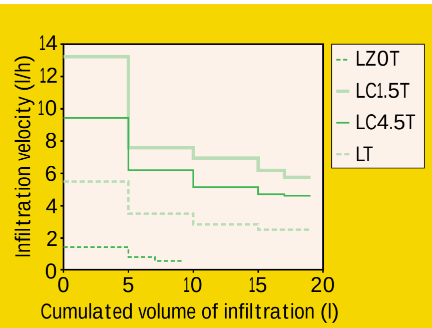
There is a lesson in all this, according to Jourdain: resource-conserving technologies cannot benefit the environment unless farmers use them. Adoption will occur only if farmers perceive a clear, near-term profit in using the technologies, as in some parts of Chiapas, Mexico, where farmers practice a traditional form of conservation tillage.

CIMMYT RESEARCH SUPPORTS MAIZE FARMERS ON STEEP HILLSIDES IN GUATEMALA, WHO USE RESIDUES TO TIE DOWN FRAGILE SOILS.

Future DIRECTIONS in Mexican maize SYSTEMS

To capitalize on these results and address the issues they raise, CIMMYT, INIFAP, and CIRAD will begin a new phase of collaborative research on maize conservation tillage in 2000. "Among other things, we'll be looking at the diversification of production systems and management options, the development and adaptation of special planting equipment, and the short- and long-term impacts of conservation tillage and associated practices on system sustainability and the environment," says Bernard Triomphe, the CIRAD researcher who took over from Scopel in July 1999. Management options to be assessed include integrated biomass management, forage systems, and rotations and associations with legumes and cover crops.

"A key strategy will be to increase the participation of different stakeholders," Triomphe says. "We will involve farmers and farmers' associations, extension services, private companies, agricultural economists, and local government in the design and testing of new options." In this way, Triomphe and his colleagues hope to promote the adoption of suitable maize conservation tillage practices at sites throughout Mexico where the approach can make a difference.



Infiltration velocity after 5 years in La Tinaja, Mexico.

Under conservation tillage with moderate levels of residue (4.5 t/ha), water soaked into the soil more than twice as quickly as under conventional tillage.

ALTERNATIVE planting and tillage systems for wheat

As in any business, farmers can increase profits by boosting productivity, reducing production costs, or both. For some 10,000 wheat farmers in northwestern Mexico, cost savings are a crucial part of an alternative tillage system they developed, in which they sow their crop on raised soil beds set apart by irrigation furrows. "Farmers shifted to bed planting—albeit with tillage—because the system offers greater efficiencies in weed control, water management, and fertilizer management, along with less crop lodging and even some reduction in tillage," says Kenneth Sayre, CIMMYT wheat agronomist, who has observed this system for some time. Farmers using the system report that yields improve by at least 10% and production costs fall by 25-35%.

Conservation tillage is the next innovation in bed planting, according to Sayre. For the past six years, Sayre has worked to develop appropriate planters and bed-shaping equipment so that farmers can maintain "permanent" beds and retain crop residues—giving bed planting a conservation tillage advantage. "Dramatic reductions of tillage, combined with proper management of crop residues, should reduce costs another 20 to 25% and create a more sustainable production system for farmers," predicts Sayre.

Sayre and other CIMMYT researchers are working with partners in Asia to tailor the system to irrigated wheat settings there—in some cases beginning with conventional-tillage bed planting, as in Mexico, and then adding reduced-tillage permanent beds. They have found that, in addition to the above-mentioned benefits, bed planting requires nearly one-third less water than traditional, flood-irrigated wheat cropping systems—a major boon in a region where the demand for water will grow dramatically over the next two decades. Interest in the practice is intense (see "Accolades for a 'Powerful' Technology," p. 48), and researchers from all over the world have come to work with Sayre in Mexico for first-hand experience with the new planting system.

Sowing wheat on time in Bangladesh

After six years of promoting minimum tillage and placing over 1,000 demonstrations in wheat growers' fields in northwestern Bangladesh, the Wheat Research Centre and CIMMYT-Bangladesh recently received proof of their impacts. The Deputy Director of Extension for the Northwest estimated that, in 1999, 70% of all wheat cropping in Bangladesh was done using minimum tillage.

Why is minimum tillage important? Just three decades ago, wheat was a minor crop in Bangladesh and tillage practices resembled those used for rice. As production expanded, knowledge of wheat production increased. "Growers at that time tilled their soil after monsoon rice slowly, using six passes with oxen and a country plow, allowing 15-25 days to pass to get what they thought was proper tilth," says Craig Meisner, CIMMYT agronomist in Bangladesh and member of the Natural Resources Group (NRG). "However, our research with partners in the region has shown that *timely* sowing is more important than seedbed preparation. In fact, for every day wheat is sown late, yields fall 1.3%."

According to Meisner, farmers reduced their tilling to two or three passes of a country plow, shortening the turnaround time from rice harvest to wheat planting and boosting wheat productivity. Together with new, high-yielding varieties that possess enhanced disease resistance, several improved management practices, and area increases, timely sowing has contributed to a recent series of bumper wheat crops. Production in 1998 was some two million tons—nearly double the output of just four years prior.

"Now that growers understand the importance of timely sowing, we are trying to promote other technologies, such as surface seeding, which further reduce tillage and increase the timeliness of wheat planting," Meisner says. Surface seeding—sowing wheat on the water-saturated soil surface after rice harvest—provides wheat yields equal to those for conventional tillage but greatly reduces costs.

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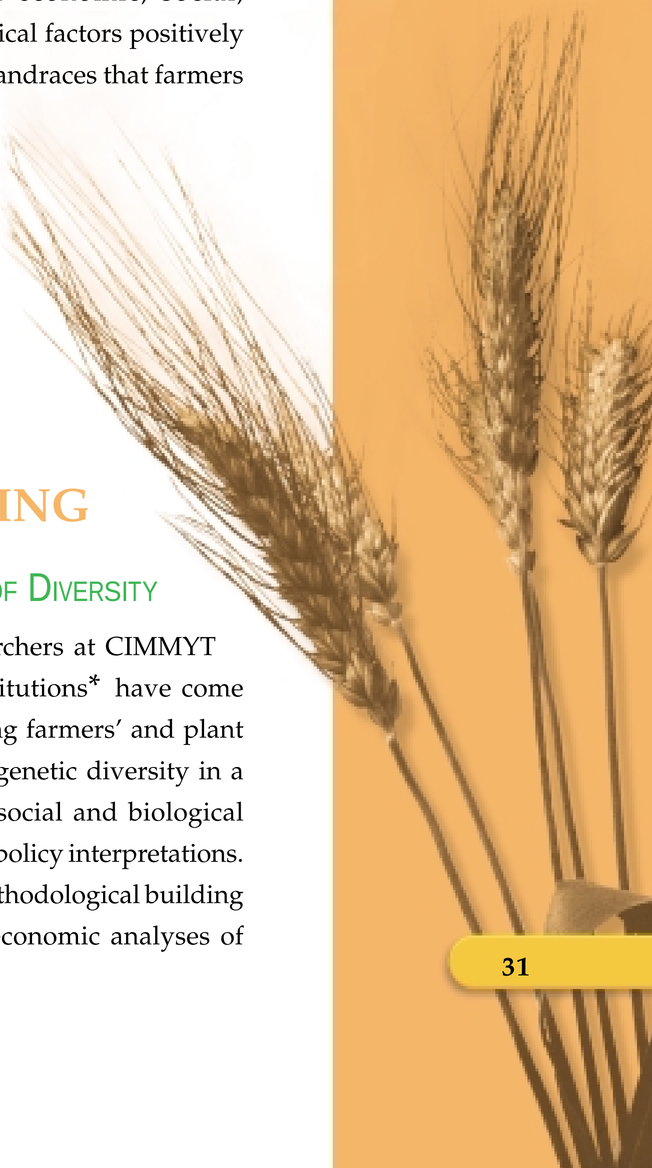
ARE GENETIC DIVERSITY

AND AGRICULTURAL DEVELOPMENT COMPATIBLE?

ECONOMIC ISSUES RELATED TO CROP GENETIC DIVERSITY CANNOT BE UNDERSTOOD WITHOUT EXAMINING COMPLEX HUMAN CHOICES AND BEHAVIORS. ECONOMISTS ESSENTIALLY STUDY DECISIONS OF THE FARMERS, PLANT BREEDERS, AND POLICYMAKERS WHO ARE THE GUARDIANS OF DIVERSITY IN OUR FOOD CROPS. THE ULTIMATE QUESTION THEY SEEK TO ANSWER IS WHETHER GENETIC DIVERSITY IS COMPATIBLE WITH AGRICULTURAL DEVELOPMENT.

The management of genetic diversity in food crops, whether *ex situ* in genebanks or in geographical areas dominated by modern cultivars or landraces, is part of the global initiative to conserve biodiversity. Economists, like other researchers concerned about crop genetic diversity, have their own particular way of thinking about it. The kinds of diversity questions that can be explored through economic analysis are:

- In cropping systems where farmers grow modern wheats, is greater diversity in the varieties farmers grow associated with greater or lesser economic efficiency?
- Which combinations of economic, social, technical, and agro-ecological factors positively influence the diversity of landraces that farmers grow in centers of crop diversity?
- Has the genetic diversity of CIMMYT wheats decreased, remained constant, or increased over time?



NEW THINKING

ABOUT THE ECONOMICS OF DIVERSITY

During the past year, researchers at CIMMYT and associates in other institutions* have come closer to their goal of relating farmers' and plant breeders' decisions to crop genetic diversity in a way that is meaningful to social and biological scientists and is amenable to policy interpretations. They have assembled the methodological building blocks needed to conduct economic analyses of crop genetic diversity.

* Research team: Melinda Smale, Erika Meng, Mauricio Bellon (CIMMYT Economics Program); Alfonso Aguirre (CIMMYT/INIFAP); Flavio Aragon (INIFAP); John Brennan (Wagga Wagga Agricultural Institute); Jikun Huang, Hu Ruifa (CCAP/CAAS); Scott Rozelle (University of California-Davis); David Godden (University of Sydney); researchers from other CIMMYT programs, NGOs, universities, and national research systems.

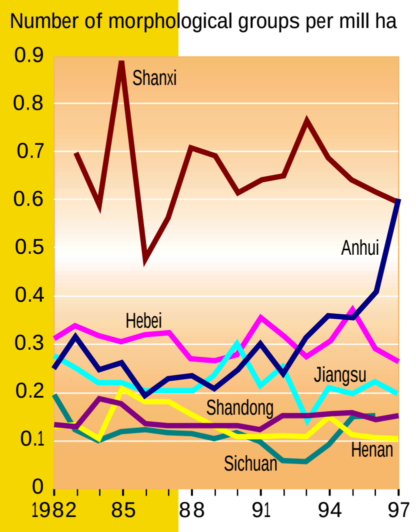


Figure 1. Richness in wheat, morphological groups (China, selected provinces, 1982–97).

These building blocks are: the development of appropriate diversity indicators for use in economic models; models of farmer decision-making that relate economic variables to biological variables; and econometric models that enable economists to test hypotheses related to important conservation issues and possible policy interventions. Team members have adapted indices used by ecologists in the study of species diversity and applied an award-winning statistical technique developed by CIMMYT's Biometrics Unit to classify plant populations (Figure 1). Interdisciplinary and inter-institutional cooperation between members of the research team has been a unique aspect of the work.

Integrating Diversity Indices and Decision-Making

"To be useful in economic analyses, diversity measures or indices that make sense to biological scientists must be integrated into economic models of human decision-making," explains Erika Meng, a CIMMYT economist and member of the research team. For Meng and other team members, the challenge is to integrate diversity indices and economic models in a way that makes it possible to analyze how policies affect diversity.

Melinda Smale, another member of the research team, describes the nature of this challenge. "With molecular markers, researchers can establish the genetic similarity or dissimilarity between two crop lines or populations, but farmers cannot gauge diversity this way," she says. "Farmers' decisions are based on what they see—on how genes are expressed as observable plant characteristics." Although information on the morpho-phenological traits that farmers observe can be linked with genetic data by drawing samples of the crop populations that farmers grow, and socioeconomic variables can be used to explain farmers' choice of varieties, the sample sizes for such studies are small because of their high cost. Smale emphasizes that to understand how policies influence genetic diversity, many such case studies must be accumulated or conducted and integrated across levels of analysis of crop production systems.

Models for a Range of Settings and Questions

Researchers in CIMMYT's Economics Program are applying diversity indices to data in various economic decision-making models. The structure of the models is similar, but their application depends on the level of analysis (e.g., the household, the province), the crop in question, the material (landraces or modern varieties), and the empirical setting (e.g., an isolated farming community, a region of commercial wheat production).

The models should help answer questions such as those mentioned earlier. For example, some of them test hypotheses about farmers' incentives and the effects of policies and environment on landraces at the local level. They are used in case studies. Others test the effects of crop genetic diversity, measured at the level of a national production system with modern varieties, on crop productivity and economic efficiency. These models will contribute to policy analysis. (See "Diversity Questions in Search of Answers," next page.)

The Ultimate Question: Are Agricultural Development and Genetic Diversity Compatible?

These innovative models and studies should help guide policy development by delineating the costs and benefits of *in situ* conservation, determining whether diversity in a crop production system involves costs or benefits, and by indicating which policy levers are appropriate for influencing genetic diversity. "We are beginning to come to grips with which issues are major economic questions and which are trivial," says Smale. "Our work this past year moved us forward on a much larger and more difficult question. Ultimately, we would like to know under what circumstances maintaining crop genetic diversity in farmers' fields is compatible with agricultural development and just how it may be accomplished."

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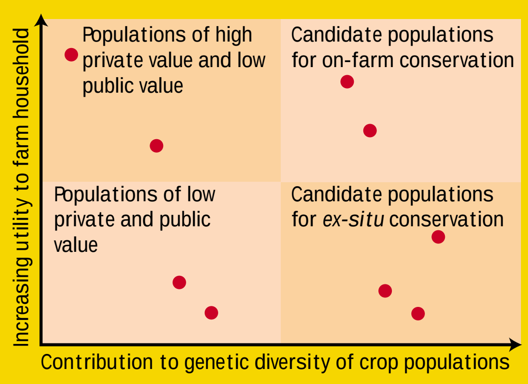


Figure 2. Framework for choosing crop populations to conserve on-farm and *ex situ*, in a given reference region.

Diversity Questions in Search of Answers

What is the relation between wheat diversity and productivity in China and Australia? CIMMYT researchers, with colleagues in China and Australia, are looking at the relationships between wheat genetic diversity and productivity and economic efficiency. The project, funded by the Australian Centre for International Agricultural Research (ACIAR), has collected data at the regional and household levels. In the regional studies, the analysis uses data that combine variety characteristics with cross-sectional, time-series data on area planted to different varieties, input use, costs of wheat production, the environment, and policy factors. Australia provides an interesting contrast to China because it represents a fully commercial, export-oriented wheat production system. The Australian study also includes a survey of breeders' perceptions of wheat genetic diversity and related policies. The goal of the next phase of this project is to develop more focused policy analyses.

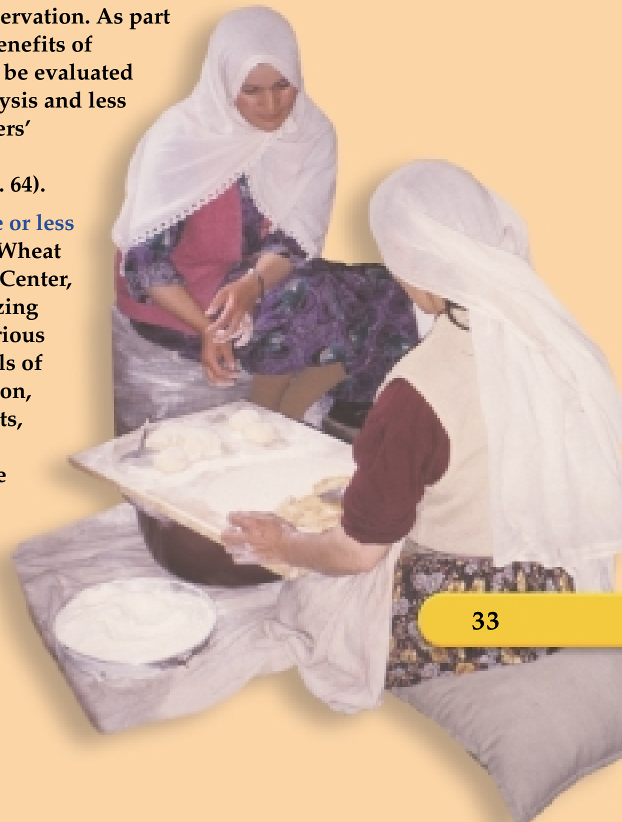
How can household surveys in China and Turkey illuminate the links between diversity and productivity at the local level and beyond? During the past year, researchers amassed farm-level data on wheat through household surveys in three provinces of China and six provinces of Turkey. In China, farmers described production practices and constraints, as well as consumption preferences with respect to specific wheat varieties. Data from these surveys will provide information on factors influencing wheat farmers' decisions and will enable researchers to examine links between diversity, cost, and productivity at the household and aggregate levels.

The study in Turkey, done in collaboration with the Agricultural Economics Research Institute of the Ministry of Agriculture, will assess the economic feasibility of conserving crop genetic resources *in situ*, as well as potential inequalities across households that could stem from the continued cultivation of landraces. This study is particularly interesting for two reasons. First, Turkey is an important center of diversity and domestication of wheat, and landraces are still widely grown in some areas. Second, some of these households were surveyed in 1992, giving researchers the rare opportunity to examine changes in farmers' choice of varieties over time.

Do traditional maize farming communities have incentives for maintaining diversity? In a study of maize biological diversity in Guanajuato, Mexico, researchers have related the diversity of maize measured at the community level to farmers' incentives for maintaining diversity at the household level, testing hypotheses concerning the effects of variety characteristics, agroecology, and market development on the crop genetic diversity maintained by farmers. This model uses the notion of public and private characteristics of varieties to examine the relationship of farmers' decisions to crop genetic diversity. (A similar theoretical approach was first employed by CIMMYT economists in analyzing wheat rust diseases and genetic diversity in the Punjab of Pakistan.)

In the Mexican states of Chiapas and Oaxaca, researchers designed and implemented studies to analyze farmers' incentives to maintain diverse crop populations in centers of crop diversity. Figure 2 shows part of the conceptual framework researchers are using to identify which maize populations are least-cost candidates for *in situ* and *ex situ* conservation. As part of the Oaxaca project, the costs and benefits of participatory breeding strategies will be evaluated using standard economic impact analysis and less conventional analyses based on farmers' perceptions (see "Farmers Work with Diversity Principles and Practices," p. 64).

Are CIMMYT wheats becoming more or less genetically diverse? Scientists in the Wheat Program, the Applied Biotechnology Center, and Economics Program are synthesizing analyses of genetic diversity from various perspectives, including historical trials of CIMMYT wheats, pedigree information, data on the impact of CIMMYT wheats, and molecular marker data. This collaborative research should indicate whether the genetic diversity of CIMMYT wheats has increased, remained constant, or declined over time.



Molecular Markers Help

Create An Unbeatable Resistance/Tolerance Punch

Finding ways to accelerate or facilitate long-term research is every scientist's dream and the primary appeal of biotechnology. Practical applications of biotechnology in wheat breeding have been uncommon, partly because of wheat's complex genetic makeup. In the past two years, however, the CIMMYT Wheat Program has used molecular markers to breed for resistance to a serious wheat disease called barley yellow dwarf.

Ligia Ayala, an Ecuadorian student doing her doctoral research at CIMMYT, struck paydirt when she found a molecular marker that will help track a particularly important gene in generation after generation of bread wheats. Dubbed WMS (for wheat microsatellite) 37, the marker flags a snippet of DNA, taken from a wild grass, that contains a gene conferring barley yellow dwarf (BYD) resistance.

WMS37 is proving to be an invaluable tool for CIMMYT breeders as they seek to incorporate the BYD resistance gene into high-yielding bread wheats using conventional breeding techniques. It is helping them clarify how the gene is passed from one generation to the next and allows them to more quickly and definitively distinguish wheats that have inherited the gene from those that have not.

Developing BYD-resistant wheats without molecular markers relies on running other laboratory tests that are time-consuming and expensive. "An important consideration in the decision to use molecular markers was that our research partners, national agricultural research programs in developing countries, find testing for BYD resistance expensive and complex," relates Maarten van Ginkel, head of bread wheat breeding at CIMMYT. Field observation is also unreliable because, depending on how sensitive they are to the virus, resistant plants may show disease symptoms despite their low infection levels, which causes them to look like susceptible plants.

These difficulties make the process of incorporating the BYD resistance gene into wheat ideal for the application of molecular markers, since markers allow researchers to delve into the genetic makeup of experimental wheats and see which ones carry the gene.

Safe, Durable BYD Control

Barley yellow dwarf is the most widespread viral wheat disease in the world, though it attacks all cereals and their wild relatives. As its name implies, BYD stunts and yellows plants, producing wheat crop losses estimated at US$ 400 million a year.

The BYD virus is spread by aphids that feed on wheat plants. The disease may be kept at bay by killing the aphids with insecticides, but insecticides are not only costly and beyond the reach of most developing country farmers, their excessive use could incite the aphids to develop insecticide resistance. Insecticides are not completely effective against the spread of the BYD virus and may cause serious ecological damage, especially if used to excess. The safest, most effective, and inexpensive BYD control measure is for farmers to plant wheats that have inbred protection against the disease.

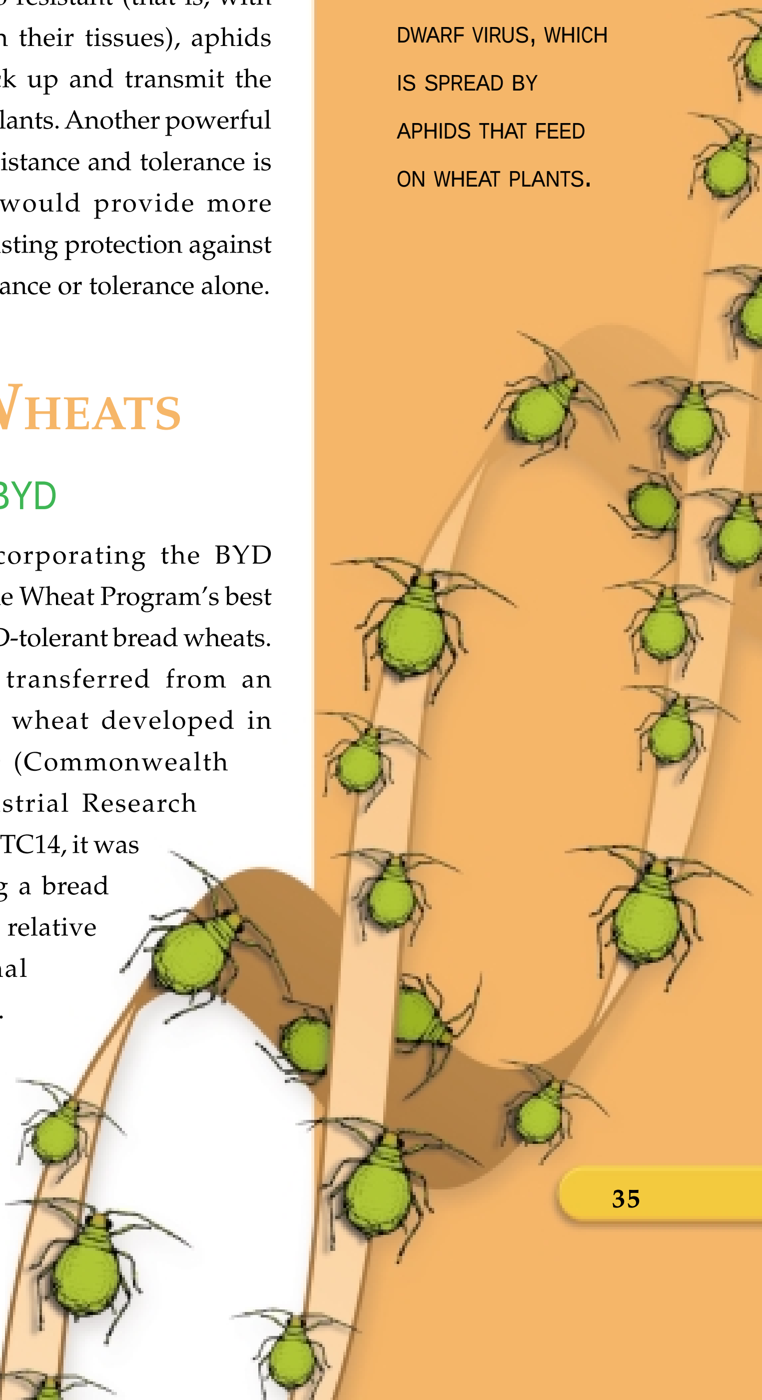
CIMMYT researchers have developed bread wheats that are tolerant to BYD. *Tolerant*—but not *resistant*. What is the difference? "Tolerant plants may be infected with high levels of the virus, but they show few external symptoms and yield well despite the infection," explains CIMMYT virologist Monique Henry. "Resistant plants, on the other hand, have a defense mechanism that keeps the virus from multiplying within them. As a result, resistant plants have very low levels of infection in their systems." Henry works closely with bread wheat breeders on combining the two types of disease protection.

CIMMYT wheat virologists have been working since 1993 to develop bread wheats that have BYD *resistance* in addition to BYD *tolerance*. Why combine the two? Wheats that have both qualities would allow farmers to reduce crop losses and at the same time prevent the virus from spreading. Tolerant plants are unaffected by the viral infection in their systems, but aphids may spread the virus from them to other plants that lack such tolerance, with potentially devastating consequences. If aphids were to feed on plants that are not only BYD tolerant, but also resistant (that is, with low levels of virus in their tissues), aphids would less easily pick up and transmit the virus to unprotected plants. Another powerful reason to combine resistance and tolerance is that together they would provide more effective and longer lasting protection against BYD than either resistance or tolerance alone.

High Yielding Wheats to Beat BYD

Researchers are incorporating the BYD resistance gene into the Wheat Program's best high-yielding and BYD-tolerant bread wheats. The gene is being transferred from an experimental bread wheat developed in Australia at CSIRO (Commonwealth Scientific and Industrial Research Organization). Called TC14, it was produced by crossing a bread wheat with the wild relative that was the original source of the gene.

Breeding breakthrough: CIMMYT scientists have identified a molecular marker for a gene conferring resistance to barley yellow dwarf virus, which is spread by aphids that feed on wheat plants.



Given that the wild relative passed on negative traits along with BYD resistance, the CIMMYT research team is now working on improving the agronomic traits of wheats descended from TC14.

The micro-satellite found by Ayala provides a shortcut in the breeding process. Lab tests using WMS37 pick out lines carrying the BYD resistance gene, so there is no need to plant all the lines in the field, wait for them to grow, and use complex lab methods to select the resistant ones. In this way, the marker is effectively helping to identify BYD-tolerant wheat lines that also have lower levels of the BYD virus in their systems (resistance).

Further Protection

against Yield and Quality Losses

The research team is planning on finding markers for BYD tolerance, which may be conferred by many genes working together. Tolerance based on many genes is desirable because it affords protection from different viruses and is more durable than tolerance based on one gene. In an associated effort, virologist Henry is looking for resistance to aphid feeding, which in itself induces yield losses and poor grain quality. Some wheat plants (for instance, hairy ones) repel aphids or resist being eaten by them. If Henry is successful in her quest, feeding resistance will be combined with BYD resistance and tolerance to endow CIMMYT wheats with a virtually foolproof defense.

"The progress we're making with markers is significant, though we're proceeding slowly in this experimental phase. Once markers become routine, we expect BYD resistance breeding to take less time and cost less money," says Henry. This is likely just the first of such successes in CIMMYT's Wheat Program. As the genetic structure of wheat is elucidated and the search for markers facilitated, their application in conjunction with conventional wheat breeding will become more commonplace, making their considerable promise come true.

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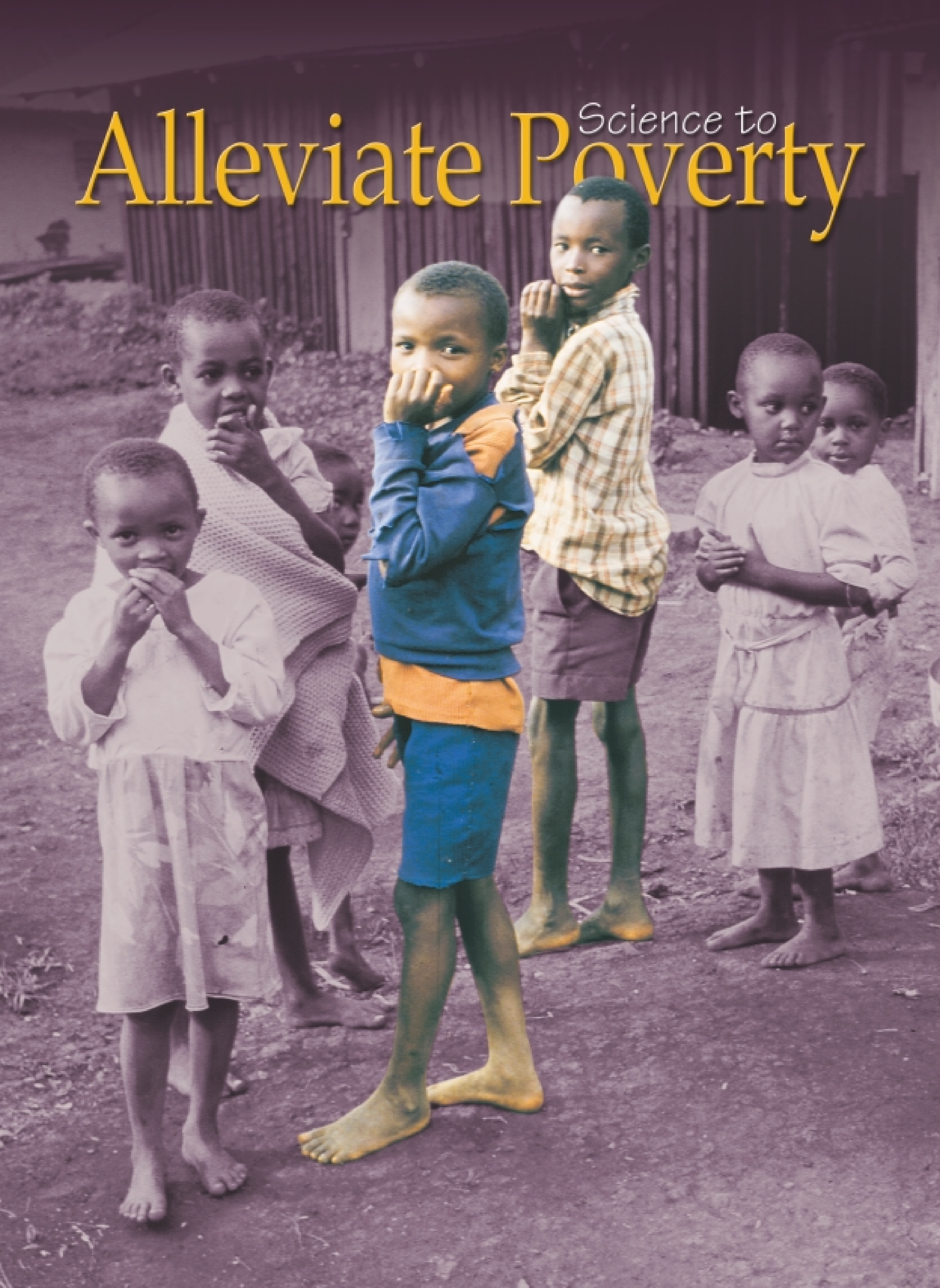
Ligia Ayala (left) and Monique Henry (right) collaborate on research to combat barley yellow dwarf virus in wheat. Barley yellow dwarf is the most widespread viral wheat disease in the world, costing producers US$ 400 million each year.

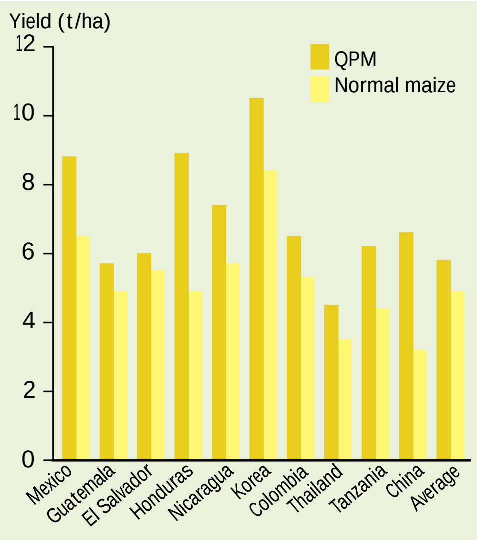
Science to Alleviate Poverty



Quality Protein Maize: Food of the Poor Becomes Inexpensive, Accessible Protein Source

What if the grain that is the chief energy source for hundreds of millions of consumers and farmers—many of them subsistence smallholders—throughout Asia, Latin America, and sub-Saharan Africa, suddenly became a valuable protein food as well?

This scenario may soon turn into a reality, given the recent, dramatic interest of developing country breeders and development organizations in quality protein maize (QPM). QPM looks and tastes like normal maize and yields as much or more, but it contains nearly twice the amount of the essential amino acids lysine and tryptophan. The nutritive value of QPM protein approaches that of protein from skim milk. Children can meet 90% of their protein needs by eating 175 grams of QPM. Pigs and chicken raised on QPM gain weight at roughly twice the rate of animals fed on normal maize, a boon for smallholder farmers, who often cannot afford balanced feeds.



QPM hybrids vs normal maize hybrids: A direct comparison for yield at multiple locations worldwide.

"QPM can help remedy nutritional deficiencies from diets heavy in maize, especially among women and children in impoverished rural and urban areas of Africa and Latin America," says Surinder K. Vasal, CIMMYT breeder who began research on QPM in the early 1970s, with funding from the United Nations Development Programme. Vasal and associate Evangelina Villegas combined field and lab research—especially novel techniques for rapid and accurate grain quality assays—to overcome undesirable traits (lower yields, unacceptable grain quality, susceptibility to ear rot) originally associated with the protein quality gene, *opaque-2,* after its discovery by US scientists in the 1960s. By the early 1990s, CIMMYT breeders had developed experimental QPM varieties suited to a range of developing country production environments, improving disease resistance and other key traits and growing trials in collaboration with research partners worldwide.

Convinced of QPM's importance for the poor, Norman E. Borlaug—Nobel peace laureate and former Director of the CIMMYT Wheat Program—threw his weight behind development and dissemination efforts. Sasakawa Global 2000, an international non-governmental organization that works to spread improved farm technology in Africa and whose co-founders include Borlaug and former US President Jimmy Carter, has strongly promoted QPM in Ghana and several other African nations.

Most recently, with support from the Nippon Foundation, CIMMYT breeders have worked with partners worldwide to test promising new QPM varieties and hybrids and demonstrate their superior performance and protein quality. Data from 32 locations across Africa, Asia, and Latin America show the QPM hybrids outyielding current commercially produced hybrids by an average of 10%. Results in Mexico, for example, have been so dramatic (one experimental hybrid yielded 16 tons per hectare—2 tons more than its closest normal maize competitor) that the country has launched an intensive program to produce certified seed of QPM and get it into farmers' hands. Experimental QPM hybrids from CIMMYT are yielding 14 tons per hectare in on-farm trials in coastal Peru.

Finally, to better document the nutritional benefits of QPM, CIMMYT is seeking support for several projects that include developing baseline profiles of the nutritional status of inhabitants at high poverty locations in selected developing countries.

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QPM Initiatives Around the World

Quality protein maize figures in the development plans of many maize-consuming nations with which CIMMYT works. Examples are provided below. The Center supports these efforts with improved seed and expertise from three decades of QPM research in concert with partner countries.

- **In 1998 nearly 70 shipments of experimental QPM seed were sent by CIMMYT to researchers in 55 countries worldwide. Colombia, Ethiopia, and India all have near-term QPM releases planned, and experimental varieties are being tested in a score of other countries.**
- **In China, an additional 200,000 hectares will be sown to the new QPM hybrid Zhongdan 9409 by the end of next year, adding to the nearly 100,000 hectares of QPM already grown.**
- **Guatemala and El Salvador will each have an additional 50,000 hectares under new QPM hybrids by 2001, if not sooner.**
- **According to a recent study in Ghana, nearly one-sixth of the national maize area is sown to QPM.**
- **With new plans for sowing some 2.5 million hectares of QPM by 2001, Mexico stands to become the global leader in the production of this specialty maize. More than 100 hectares of seed of parents of superior hybrids had been sown as of June 1999.**

Participatory Research: Making Farmers Partners in Development

Researchers are looking critically at their role in development and seeking new ways to do the job better. One way is to make research a truly participatory activity.

Participatory research approaches—where farmers themselves set the research agenda, implement experiments, and assess outcomes—can help increase crop yields, promote resource-saving farm management and, especially, deliver suitable products to marginal areas. "Farmer participation increases both the focus on truly important problems and the likelihood that research will result in options that are attractive to farmers, given their resource base and livelihood strategies," says Larry Harrington, Director of CIMMYT's Natural Resources Group (NRG).

For several years, CIMMYT and the Mexican National Institute of Forestry, Agriculture, and Livestock Research (INIFAP) have worked with farmer-breeders in the Central Valleys of Oaxaca, Mexico, to preserve selected maize landraces and improve them for farmers' preferred traits (see "Farmers Work with Diversity Principles and Practices," p. 64).

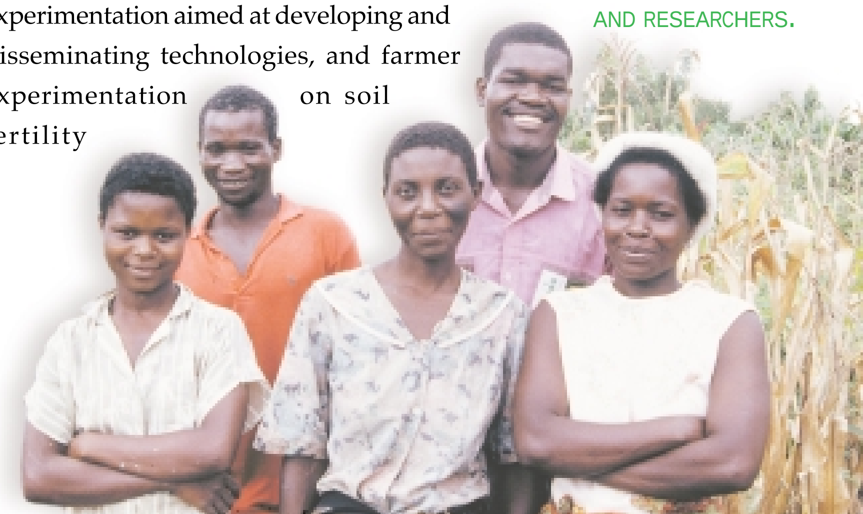
More recently, the Center has used participatory approaches for research to improve soils, conserve water, and enhance agroecosystem diversity. Payoffs to farmers are evident in southern Africa, Mexico, and South Asia.* This work, as well as the Center's participation in a Rockefeller Foundation exploratory initiative on participatory research, is helping refine the methodologies and provide a better sense of how they fit with other research activities.

Southern Africa: Scarce Resources, Enormous Risks

Climatic risk, particularly from erratic rainfall, is a major constraint to the development and adoption of improved technologies for smallholder maize farmers in southern Africa. Some 70% of maize in the region comes from farms of less than 5 hectares, virtually all of it rainfed. Besides facing the constant threat of drought, farmers work some of the world's poorest soils in an environment where fertilizer use is both costly and risky.

Begun in 1998, the Risk Management Project links three previously separate areas of research: analysis of climatic risk through crop modeling, researcher-managed experimentation aimed at developing and disseminating technologies, and farmer experimentation on soil fertility

Devising farmer- and environmentally-friendly practices to manage soil fertility in densely populated southern Malawi requires close teamwork by farmers and researchers.



* For details on work in South Asia, see *CIMMYT in 1997-98: Change for the Better* and *A Sampling of CIMMYT Impacts, 1999*.

management. Funded by the Australian Agency for International Development (AusAID) and the Australian Centre for International Agricultural Research (ACIAR), the project is a spin-off of the CIMMYT Maize Program's highly successful soil fertility network (SoilFertNet),* in which researchers, extension specialists, and farmers develop, test, and share improved management options for nutrient-poor soils in Malawi and Zimbabwe.

"This unique and challenging project brings together scientists, extension workers, and farmers in a shared arena to generate and refine new options for soil fertility management," says Christopher Vaughan, NRG predoctoral fellow in the Risk Management Project. "It offers great scope for influencing the way research is conducted, increasing the sustainability of agriculture, and improving the livelihoods of resource-poor farmers in southern Africa."

Among other things, the project uses crop simulation models to assess the biophysical performance of several "best-bet" technologies under a wide range of soil and climate conditions—a much wider range than would be possible through the use of field experiments. Many of these technologies, particularly the use of legumes in crop rotations and the timely application of inorganic and organic fertilizers, were developed by SoilFertNet.

Farmers participate by:

- Furnishing information (for example, indigenous taxonomies for soils and climate) to make simulation experiments more realistic.
- Providing a reality check on the simulation outputs; for instance, cross-checking them for compatibility with household livelihood strategies.
- Posing questions and new research areas to modelers and soil fertility researchers, thus helping set and adapt the agenda.
- Providing farmer assessment of researcher-developed technologies.
- Developing innovative approaches to soil fertility management through farmer experimentation.

Crop simulation modeling takes place in parallel with farmer participatory research, with farmers involved in the testing, evaluation, and adaptation of researcher-developed technologies. Through feedback from farmers to research and extension, combined with modeling outcomes, both the biophysical and socioeconomic merits of alternative technologies can be judged in a broader, systems context. "The combination of *quantitative* modeling, which is 'hard' systems and data centered, and *qualitative* participation, a 'soft' systems and process-centered approach, results in more integrated, holistic research and development and allows all stakeholders a voice," Vaughan says.

"Alternativas" for Southern Mexico

Low-income farmers in Mexico's dry Mixteca region are central actors in efforts to improve maize-bean farming systems that support half a million inhabitants, with help from CIMMYT and the non-governmental organization, Alternativas. Funding from the Hilton and Ford Foundations enables participant to assess new maize varieties—particularly drought-tolerant genotypes from CIMMYT—and experiment with composts, organic insecticides, foliar fertilizers, and cover crops.

* SoilFertNet is funded by the Rockefeller Foundation. For details see *CIMMYT in 1997-98: Change for the Better*.

"Rainfall is low and poorly distributed, and farmers report yields of zero to 700 kilograms per hectare," says Julio César Velásquez Hernández, NRG research affiliate on the project. "At that rate, grain from November harvests lasts till maybe March; then families must start buying maize with whatever money they can obtain." Cash being in short supply, people sell their goats, get help from family members working in the US, or engage in other short-term, uncertain money-making pursuits.

The project began in 1998, but Velásquez has already organized and conducted a workshop involving farmers and other stakeholders, identified farmer participants from the major communities, and helped them prioritize their major concerns and establish their own plans of action. "In all communities there are enthusiastic and talented farmers ready to try new options and share their knowledge," he says. "They'll put their only resources—land, experience, and labor—on the line to test promising technologies, if we support them."

Participating farmers have requested training in the selection and improvement of maize and have already overcome some supposedly insurmountable obstacles, according to Velásquez. "Some people thought that composting would be impossible, given the low available crop biomass," he says, "but farmers somehow managed to scrape up enough forage residues, foliage, manure, or stems to generate good compost." After a training session on foliar fertilizers given by several Mexican NGOs, farmers went ahead and developed their own fertilizer using materials and substances available on the homestead. With guidance from specialists of the University of Puebla, they are testing the effectiveness of wild plant species known to have insecticidal properties, as a natural control for insect pests. Finally, a formal experiment is being set up to assess system productivity and constraints, complemented by regular monitoring of rainfall and topsoil runoff.

Velásquez sees this as only the beginning. "Work on these options, which farmers consider to be fairly low-risk, will open the door to a range of more ambitious, longer-term experiments involving more complex technologies," he says.

Bringing Participatory Research on Board

CIMMYT is working to integrate participatory approaches into its mainstream research "toolbox." The Center is also exploring ways to extrapolate results and methodologies that prove successful at specific sites. Geographic information systems—which allow researchers to define and identify additional areas similar to a target site—can help with the latter.

With regard to the former, learning is an essential part of the Center's current efforts, according to Mauricio Bellon, member of the CIMMYT Economics Program and resource person on participatory research. Among other things, Bellon is spearheading the social science side of participatory breeding research in Oaxaca, Mexico. "To improve our use of participatory approaches, we need to know how effective they are, who they reach, and how much participation costs, both for farmers and researchers," Bellon says. Bellon and his associates are conducting baseline studies in Zimbabwe and Mexico to help assess the expense and value of CIMMYT's participatory initiatives to farmers there.

Other specialists, though, point out that participatory approaches' chief strength lies precisely in helping researchers "get their priorities right," thereby improving efficiency and reducing costs. "Bringing hard-nosed, technical scientists into an evaluation and adaptation process from the beginning helps everyone to identify and capitalize on comparative advantages and synergies," Vaughan says.

Whatever their merits, participatory methodologies face cultural and other barriers to their widespread implementation, according to Peter Hobbs, NRG wheat agronomist who has contributed to participatory research efforts in South Asia. "In many parts of the world, educational systems foster a top-down approach to delivering information," he says. "In such areas, it may be more difficult to use farmer participatory approaches—it takes time and positive results to convince research managers to commit staff to this type of activity."

Sharing and Comparing

Experiences

To address these and other issues, CIMMYT is developing linkages with recognized leaders in participatory research. An example is the Center's participation in the Rockefeller Foundation Exploratory Initiative on Participatory Approaches to Technology Generation and Farmer Experimentation. "This inter-institutional project aims at systematizing and comparing experiences worldwide and developing linkages among key players in the field," says Bernard Triomphe, an agronomist who is facilitating the initiative and working with the French Center for International Cooperation in Agricultural Research for Development (CIRAD) and the CIMMYT NRG in research on conservation tillage, cover crops, and farmer experimentation. "The Rockefeller initiative involves networking across continents and a wide range of institutions, as well as documenting how selected projects have addressed critical issues," Triomphe says. Target issues include the institutionalization of participatory approaches and their interactions with formal research. A preliminary report was submitted to the Foundation in early 1999. Subsequent activities will focus on developing case studies, organizing a series of regional workshops in Latin America, Africa, and Asia, and establishing a strategy for long-term networking in this area. The NRG is providing logistical support for the initiative, as well as assistance in accessing experience from outside Latin America and identifying collaborators and case studies based on the work of CIMMYT outreach staff.

Finally, CIMMYT is a founding co-sponsor and active member in the CGIAR's System-wide Program on Participatory Research and Gender Analysis, convened by the Centro Internacional de Agricultura Tropical (CIAT). CIMMYT thus shares information on participatory methods and experiences with other members of the System-wide Program.

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PARTICIPATORY APPROACHES CAN HELP GIVE WOMEN FARMERS A VOICE IN SETTING RESEARCH AGENDAS AND EVALUATING ALTERNATIVE TECHNOLOGIES.

Creating a Maize Renaissance in Peru

The elements of a maize renaissance are being assembled in a collaboration between the Government of Peru—a new member of the CGIAR—and CIMMYT. The goal is to offer farmers productive options for working with the land rather than emigrating to an uncertain future on the margins of the nation's cities.

"Peru imports maize—more than a million tons each year. This is absurd, since Peru has great production potential and people *do* produce maize!" Rodolfo Muñante Sanguineti, special advisor to President Alberto Fujimori and former Minister of Agriculture, sips a cup of strong, hot coffee to ward off the damp cold of a winter morning in Lima. He talks about replicating for maize a comprehensive program to stimulate rice production, which allowed Peru to halve its rice imports in just one year. What would CIMMYT's role be in a similar plan for maize? "Brother! With the varieties CIMMYT has given us, what more can we ask for?" Muñante says.

Some 200 kilometers south of Lima, near the coastal town of Pisco, farmer Alberto Nestares echoes Muñante's enthusiasm, discussing the performance of an experimental CIMMYT hybrid he was given to sow. "In wide-scale production, this variety could outyield by far other varieties grown around here," he says. (The "other varieties" are several leading commercial hybrids.)

Food for Peace

In 1998, Peru produced just over 700,000 tons of yellow maize—chiefly for animal feed—and 230,000 tons of the large-grained, floury maize that people consume. Yellow maize production has increased steadily over the last decade, but not as quickly as utilization (see figure, p. 46). Moreover, 38% of the population has a monthly budget of only US$ 50—considered extreme poverty—and nearly 60% of the rural populace is impoverished, compared to just 25% in cities.

To improve national self-sufficiency in maize and the livelihood of the rural poor, Peru has sought increased collaboration with CIMMYT in the past two years. "There is a recognition by the government that, without food, there is no peace or social tranquility," says Shivaji Pandey, director of the CIMMYT Maize Program. A former breeder who spent 10 years in Colombia as leader of the Center's maize research program for South America, Pandey sees great potential for increased productivity in Peru: "Maize yields on the Peruvian coast are the highest of all tropical areas of the developing world."

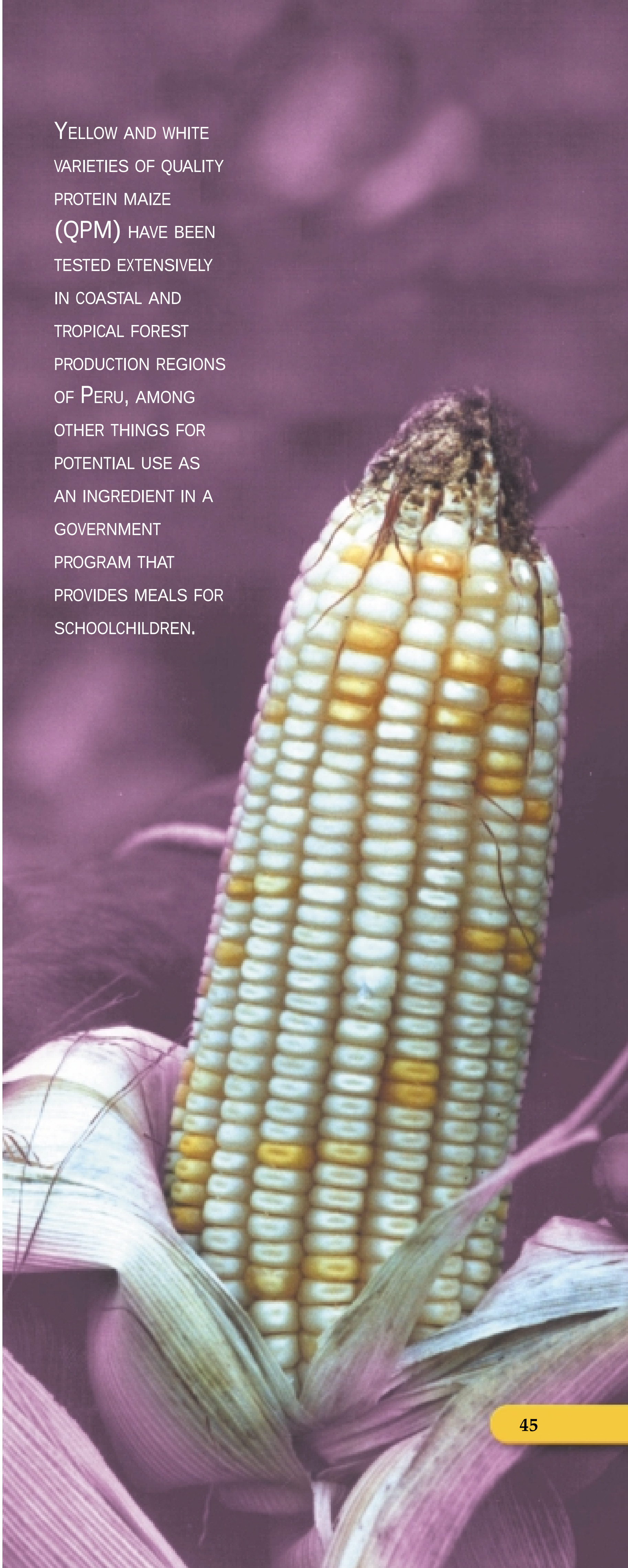
Intensified Commitments

CIMMYT is not a newcomer in Peru, according to Pandey. “The country’s most widely grown maize variety, Marginal 28, released in 1984, is derived directly from CIMMYT Population 28,” he says. “The variety is sown on nearly 150,000 hectares in tropical forest and even coastal areas.” CIMMYT is now testing several new materials of the same background that significantly outperform Marginal 28.

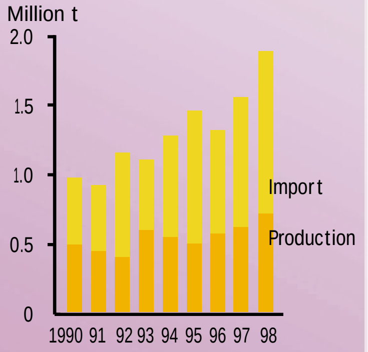
As of mid-1999, the Center also assigned Miguel Barandiarán, Peruvian maize specialist and associate scientist at CIMMYT since 1997, as adjunct scientist to the Ministry of Agriculture and special liaison to the country’s maize research organizations. “I plan to collaborate with all institutions involved in maize research and production in Peru, both public and private, as well as with farmers, to help increase maize productivity and meet domestic demand for this cereal,” Barandiarán says. His location at the National Agrarian University La Molina, whose maize research program has an illustrious record in Peru, will afford him a strategic venue for the inter-institutional networking he envisions. “I would like to thank La Molina’s rector, Francisco Delgado de la Flor, who has graciously offered the University’s facilities to house a CIMMYT office,” he says.

Peru Joins the CGIAR

Muñante suggests that more productive maize cropping can help stem the flight of the rural populace to overcrowded Lima, and even foster the return of many who came to the city in times of social unrest. “The social impact could be huge,” he says. “If you



Yellow and white varieties of quality protein maize (QPM) have been tested extensively in coastal and tropical forest production regions of Peru, among other things for potential use as an ingredient in a government program that provides meals for schoolchildren.



In 1990, domestic production met fully half Peru's yellow maize needs; by 1998, production was meeting only 38% of demand, the remainder coming from imports.

improve maize production, you'll encourage people in marginal, urban areas to go back to the land."

With these and other goals in mind, Peru joined the Consultative Group on International Agricultural Research (CGIAR) in 1997. According to Josefina Takahashi Sato, head of Peru's National Institute of Natural Resources and coordinator for the nation's collaborative activities with CGIAR centers, farmers are increasingly aware of the importance of improved technologies. "They are saying, 'We want new varieties and improved production practices,' " Takahashi explains. "It's important that donors keep contributing to agricultural research and development; this is precisely what will allow sustainable agriculture into the future."

When Takahashi requested help from CIMMYT with a study concerning the profitability of maize farming in Peru, Prabhu Pingali, director of the CIMMYT Economics Program, provided technical advice and training. "Pingali came and talked to me and an economist here, helping to define the parameters of the study and terms of reference," Takahashi says. "The preliminary results are surprising: in some zones, there are definite advantages to maize, even under nonfavorable conditions. In addition to changing some people's minds about the advisability of continuing maize research and development, these results will guide suggestions for concrete technical interventions."

Takahashi also mentioned the outstanding role of CIMMYT maize researcher Carlos De Leon, current leader of the Center's South American regional program, in establishing linkages and collaborative research arrangements with Peru. "Carlos has worked effectively with our country, whether or not Peru was a member of the CGIAR," she says. De Leon's associate in the South American program, Luis Narro, a Peruvian breeder, has also been instrumental in getting potentially useful varieties into the country's testing and dissemination pipeline. "Some of the hybrids we're testing on the coast yield as much as 15 tons per hectare," Narro says. "For tropical forest areas, Peru is about to release its own version of the popular, acid-soil tolerant variety, Sikuani, developed and distributed in Colombia several years ago with help from CIMMYT."

Enrique Aguilar, production agronomist at La Molina, sees CIMMYT impacts that include more productive varieties and other benefits: "As CIMMYT brings in better seed, companies have felt pressured to compete, and even the poorest farmers have begun demanding quality seed." In his own case, he cites a CIMMYT training course some 20 years ago as pivotal in his professional life and outlook: "The CIMMYT school—a work ethic where everyone is part of a team, and scientists are there to work, answer questions, follow through, whatever—is something I've not seen anywhere else. When I look for a young researcher to do a job, that's the kind of attitude I want."

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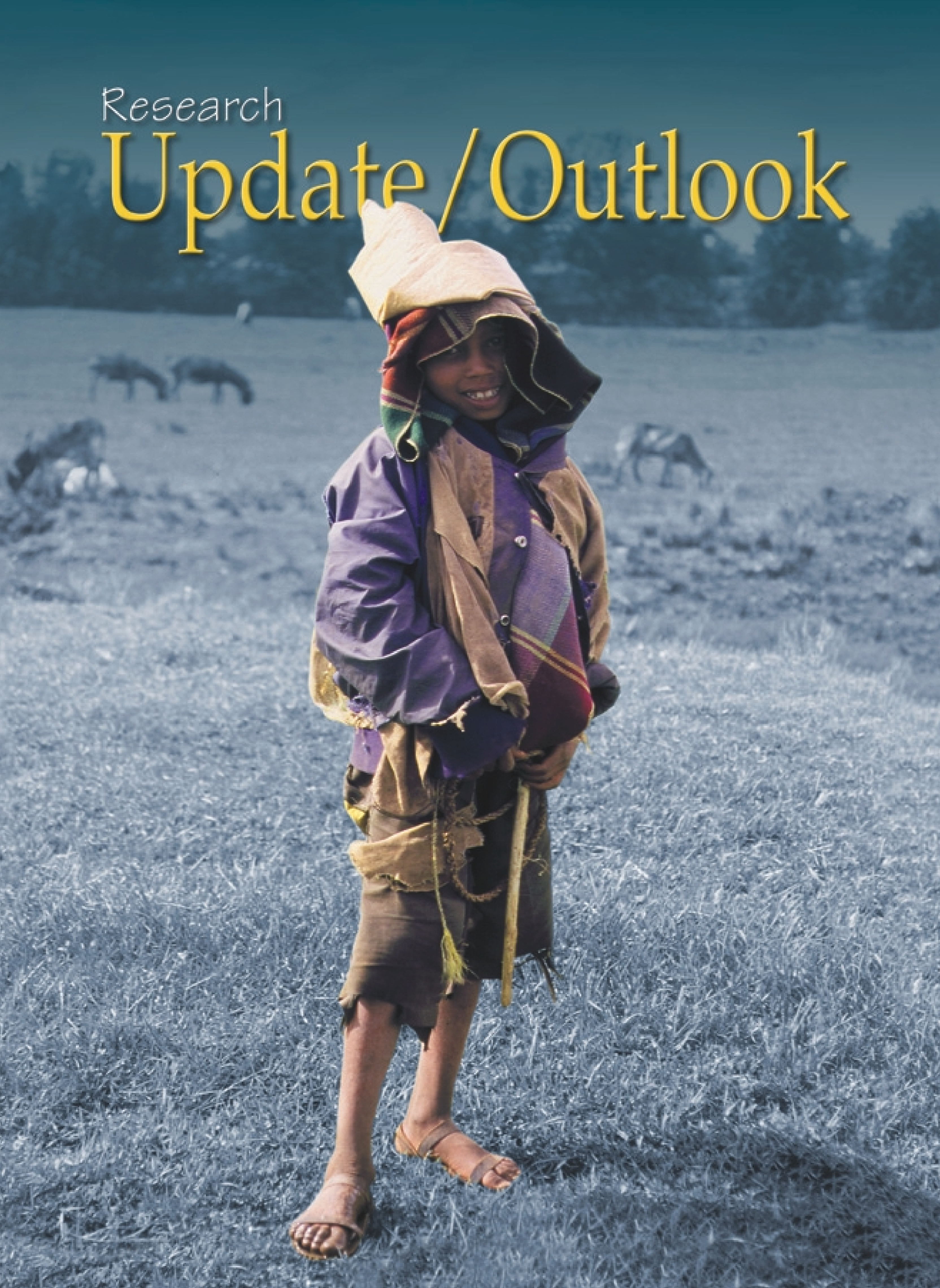
Peruvian promoters of maize (from left to right): Enrique Aguilar, production agronomist from the La Molina Agricultural University; Rodolfo Muñante, special advisor to the President; and Iván Ballena, head of the Ministry of Agriculture's crop program.

Research Update/Outlook



Accolades for a "Powerful" Technology in Shandong, China

Extracts from a letter to Director General Timothy Reeves show the intense interest generated by CIMMYT's new approach to bed planting systems.

Dear Prof. Reeves:

Greetings from Shandong Province of China.

It was our great pleasure and honor to have you at our institute for three days at the end of May. We are writing to you to express our strong interest in bed planting system and we believe that this technology will contribute greatly to wheat production improvement in Shandong Province and in other parts of China.

You have visited our bed planting trial at four locations during your staying in Shandong. Based on the results obtained this year, we are very pleased to report that it has several advantages compared with conventional planting system, i.e., reduction of plant height and improvement of lodging resistance which will have positive effect on yield and quality, saving water by 30% and improvement of soil construction, improving fertilizer use efficiency by 10-15%, less occurrence of sharp eyespot, total input reduction by 30%, and yield increase by 5-8% (we used our new variety Shandong 935031 in the trial). Therefore, we strongly believe that this powerful technology will make great contributions to the sustainable wheat production system in China. The bed planting system has also received great interest from the Ministry of Agriculture and Shandong Provincial government, and it will be extended very rapidly. We would appreciate if you could kindly train more visiting scientists in bed planting system for our academy and work together with us for improvement and extension of this new system in China.

Thank you in advance for your support.

With best regards, Sincerely yours

Prof. Xu Huisan, President of Shandong Academy of Agricultural Sciences
Dr. Wang Fahong, Senior agronomist, Shandong Academy of Agricultural Sciences

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Durum Wheat Yields

Hit a New High

Short-cycle, semidwarf durum wheat varieties in northwestern Mexico produced an unbelievable 89 kilograms of grain per hectare each day of the 1998-99 crop cycle, for a final tally of 11.7 tons per hectare at harvest time. To grasp the full significance of the achievement: "Normal" durum yields in farmers' fields in northwestern Mexico are in the 5-6 ton-per-hectare range, and the world average is just 2-3 tons.

"These wheats aren't just good yielders; they're also very tolerant to drought and heat, and to problems found in high rainfall conditions," explains Wolfgang Pfeiffer, head of durum wheat breeding at CIMMYT. "And because they are what we call input efficient—that is, they take full advantage of whatever nutrients are present in the soil—they produce higher yields in marginal conditions than other wheats."

Durum is used chiefly for making pasta in industrialized countries, but in many other parts of the world it is utilized mostly for making flat bread and local food products such as bulghur and couscous. In the countries of the West Asia / North Africa (WANA) region, poor people in low rainfall environments rely on this type of wheat for a high proportion of the calories in their diet. For many resource-poor farmers in those environments, durum is also a source of income, since good quality durum fetches premium prices on the local markets.

Although durum wheat is not as widely cultivated as bread wheat, it occupies a special niche in the developing world. From 1991 to 1997, 98% of the durum varieties released to farmers by the national research programs of developing countries had CIMMYT ancestry in their pedigrees. In these countries, wheat is sown in marginal environments where great climatic fluctuations can occur during the growing season. The durum crop may thus experience heat and drought at different times during its growth cycle. In parts of India, durum wheat production has been relegated to the hottest and driest environments.

Breeding to Raise Yields

How did researchers manage this surprising increase in yield? "The different factors that contribute to high yield are not balanced in the older durum wheats," says Pfeiffer. "We tinkered around to raise the number of heads and grains the plant produces." He emphasizes the importance of having the support of scientists in other disciplines. Fundamental to their success was the collaboration of Ken Sayre, CIMMYT wheat agronomist who helped develop the bed planting system and agronomic practices used with the new wheats.

Looking to the future, Pfeiffer estimates that new gains in durum's yield potential will be facilitated by the use of molecular markers and physiological selection criteria during the breeding process. "But," he adds, "nothing substitutes for a well integrated, multi-disciplinary team of scientists making a concerted effort to achieve the same goal."

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AMBIONET Moves

Biotechnology Forward in Asia

"Year one for AMBIONET has really set the stage," says network coordinator Maria Luz George. "The actual work of doing good science has begun."

During the past year, AMBIONET—the Asian Maize Biotechnology Network—has indeed set the stage for its regional efforts through a successful training course held at CIMMYT headquarters in November / December 1998, a second network meeting in Beijing in April 1999, and most of all through the participation of its national members. Funded by the Asian Development Bank, AMBIONET comprises biotechnology programs from the national agricultural research systems of India, China, Thailand, Philippines, and Indonesia, as well as CIMMYT. The stated goal of the network is to "increase maize productivity through the development via molecular genetics of improved cultivars with high yield potential, combined with durable resistance to pests and diseases and tolerance for abiotic stresses." By sharing knowledge, training opportunities, and germplasm, network participants can advance their research efforts beyond what each may achieve alone.

Seventeen participants from member countries came together for the month-long training course, "Molecular Marker Applications to Plant Breeding," to start engaging in the science at the core of the network. Course activities focused on hands-on learning and strategic planning.

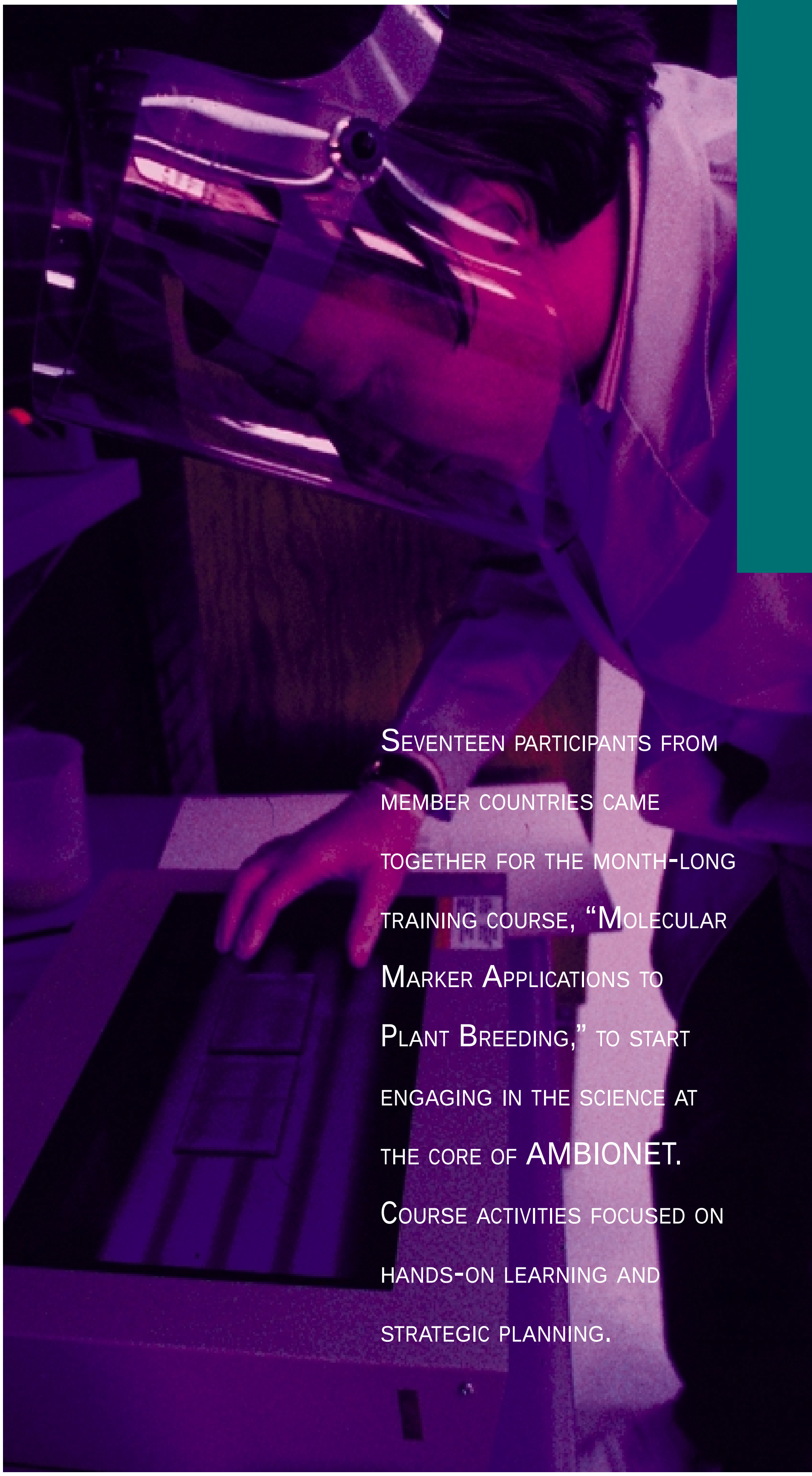
On the applied side, scientists learned how to set up a molecular marker laboratory, how to fingerprint maize lines and the downy mildew fungus, and different approaches to marker-assisted selection and quantitative trait loci (QTL) mapping.

Putting Knowledge To Work in China

"We have the theory from books, but the hands-on practice we've had at the course will prove most useful" says Shihuang Zhang, AMBIONET coordinator for China and Director of the Maize Program at the Institute of Crop Breeding and Cultivation at the Chinese Academy of Agricultural Sciences. Zhang came to the course with a definite goal in mind: to upgrade his knowledge and proficiency with markers. Upon his return to China he quickly put this knowledge to work.

"In China we have developed many hybrids, but the older scientists didn't pay attention to the pedigrees. Often in the nurseries, maize lines are placed aside in a special place, but no one knows the pedigrees," explains Zhang. "When the young scientists take over, they find their breeding efforts are hampered by a lack of information about pedigrees and heterotic groups and patterns. This information could be obtained through a statistical approach, but this would be very time-consuming and labor intensive. With the molecular marker techniques I've learned, we can analyze our commercial inbred lines in a very short time and possibly even with less cost."

Zhang projected that in the latter part of 1999, his team would analyze 130 commercial inbred lines, nearly all such lines currently available in China. Although he sees data management posing some problems in the near future, he is hopeful that the network will address this universal constraint. "With a new generation of breeders, with new tools and a new philosophy," he concludes, "I'm very hopeful of making good progress in our work."



SEVENTEEN PARTICIPANTS FROM MEMBER COUNTRIES CAME TOGETHER FOR THE MONTH-LONG TRAINING COURSE, "MOLECULAR MARKER APPLICATIONS TO PLANT BREEDING," TO START ENGAGING IN THE SCIENCE AT THE CORE OF AMBIONET. COURSE ACTIVITIES FOCUSED ON HANDS-ON LEARNING AND STRATEGIC PLANNING.

COURSE PARTICIPANTS RETURNED HOME WITH A THOROUGH KNOWLEDGE OF HOW TO LOAD, "RUN," AND LATER ANALYZE ELECTROPHORETIC GELS, A KEY TECHNOLOGY FOR CHARACTERIZING AND IDENTIFYING PLANTS WITH SPECIFIC TRAITS OF INTEREST.

A Viable Approach for the Philippines

Art Salazar, Head of the Philippines National Corn Research and Development Program, is looking forward to applying what he learned about molecular genetics to his work on downy mildew resistance in maize. Recent reports of the evolution of pesticide-resistant strains of this destructive pathogen have added new urgency to this research.

"I've always felt I should learn these molecular techniques [marker-assisted selection], but I just never had the opportunity," says Salazar. "Now I can talk with our geneticist and we can really understand one another. In terms of using this technology in our program, it's a much more viable approach than ever before. We intend to learn from the experiences of other network countries, and certainly the technical backstopping from CIMMYT will be crucial. Taken together, the network gives me the added confidence that we can make all this work."

Gaining Momentum

The course participants also addressed planning issues, which they reviewed five months later at the network's second annual meeting. The scientists presented the state of their respective work to the group, identified and prioritized problems, set research goals, and developed three-year workplans aimed at producing improved maize varieties. Specific goals and collaborations presented in the workplans include (1) the characterization of heterotic groups; (2) the molecular characterization of downy mildew pathogens; (3) the development of molecular markers for downy mildew resistance; (4) the use of marker-assisted selection to introduce downy mildew resistance into a popular local maize variety in the Philippines; and (5) the development of markers for sugarcane mosaic virus, maize rough dwarf virus, drought tolerance, and low-nitrogen tolerance.

AMBIONET gained cohesiveness and momentum, observes coordinator George, between the training course and the network's second annual meeting. Many research advances by network members were made during that period and shared at the meeting. Linkages within the network also flourished as the spirit of comradeship that grew out of the training course took root.

"At the Beijing meeting," says George, "the team leaders saw for themselves how the network has progressed and they became keenly aware that working together is key to getting things done. The meeting generated a heightened sense of involvement, a willingness to share experiences and resources, and a healthy dose of the competitive spirit within the network that, I think, helps spur the teams to excel. The challenge now is to translate all this into outputs that will benefit maize farmers in the field."

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EFFECTIVE, ENVIRONMENTALLY SAFE APHID CONTROL

WHEAT FARMERS IN DEVELOPING COUNTRIES ARE VIRTUALLY DEFENSELESS AGAINST APHIDS, THE MOST WIDELY DISTRIBUTED INSECT PESTS OF WHEAT IN THE WORLD. FOR THESE FARMERS, CIMMYT IS DEVELOPING ENVIRONMENTALLY SAFE STRATEGIES TO MANAGE APHID POPULATIONS.

FORTIFYING WHEAT FARMERS' DEFENSES AGAINST APHIDS

Aphids have great potential to do damage. They are highly mobile, to the point that winged forms may ride in low-level jet winds and spread over long distances in this way. They can produce 10 to 15 overlapping generations in a single growing season. In recent years, aphid problems have increased as cropping has intensified, tillage practices have changed, and the area under irrigation has expanded.

Aphids damage crops directly, when they feed on plants, and indirectly, through the viruses they transmit. Some aphid species transmit viruses that cause diseases such as barley yellow dwarf (BYD), the most serious viral disease of small grain cereals worldwide.

Aphid feeding can reduce wheat kernel weight by 26%, and it affects grain quality as well. South Africa has reported wheat yield losses of 21-92% from the Russian wheat aphid (RWA), and Ethiopia reported losses of up to 68%. In the US, cumulative economic losses attributable to the RWA from reduced yields and control costs between 1986 and 1992 were

estimated at US$ 657 million. With the exception of the RWA, which has been investigated at CIMMYT and other institutions in the past decade, aphids have not been studied in depth.

Safe, Effective

Control Strategies

In the long run, failure to control aphids may prove to be more costly in economic and environmental terms than investing in research targeting the problem. Farmers in developing countries have applied little chemical control because of the high cost and scant availability of chemicals; as a result, aphid damage is reaching significant proportions. In the few developing countries where farmers do apply insecticides, these chemicals are contaminating the environment, especially the waterways, and harming humans, livestock, and wild animals. Excessive use of insecticides may prompt aphids to develop resistance to chemicals, and chemical aphid control is not completely effective against the transmission and spread of viruses.

Farmers clearly need new, more effective ways of managing aphid populations. One of the most promising is to develop high-yielding wheats that are resistant to aphid feeding. Little is known about aphid resistance, however, and with the exception of the RWA, little has been done to breed for aphid resistance in cereals. The large number of aphid species that attack cereals makes it difficult to develop effective resistance against all of them, so most research has focused on looking for resistance to species that are important vectors of viruses such as BYDV.

Integrated

Aphid Control

There is new evidence of resistance to several aphid species in emmer wheats (primitive wheats) stored in CIMMYT's wheat genebank. Though emmer-derived resistance is not fully understood, preliminary studies at CIMMYT have found that plants endowed with this resistance remain free of insects in fields that have been infested with different aphid species. The finding raises the possibility that emmer-derived resistance may provide effective protection against feeding by most, if not all, aphid species. In other words, generalized aphid resistance may become a reality—if funding becomes available to conduct this research.

Effective aphid feeding resistance would complement CIMMYT's efforts to breed for BYD tolerance. Over the years, CIMMYT has developed high-yielding wheats with good tolerance to BYD (tolerant plants may show few symptoms and yield well; however, they may be highly infected with the virus) (see "Molecular Markers Help Create an Unbeatable Resistance / Tolerance Punch," p. 34). Most importantly, combining generalized aphid resistance with BYD tolerance in high yielding wheats would:

- provide wheat farmers in developing countries with highly effective yet affordable protection against both the aphids and the BYD virus;
- contribute to ecological conservation, since genetic resistance has no deleterious effect on the environment; and
- reduce the use of insecticides, thus decreasing the pressure on aphids to develop insecticide-resistant strains.

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Losing Genetic Diversity:

Can We Afford the Risk?

The international scientific, development, and donor communities rely on CIMMYT to carry out a mission that is indispensable for humankind, now and in the future: conserving the genetic diversity of maize and wheat. Will this mission succeed?

What today is a task expressly assigned to CIMMYT began as a natural offshoot of CIMMYT's early crop improvement work. Collecting and conserving maize and wheat genetic materials provided indispensable support to the breeding programs. As these activities became more formalized, special facilities were built to house the growing collections. Awareness of the importance of plant genetic resources increased, and people came to view these activities as an essential part of the mission not only of CIMMYT but of other CGIAR commodity centers.

It is difficult to think of other organizations better suited to carry out these activities. The Centers are the ideal venue to conserve genetic resources on behalf of all people. For one thing, they attract and collect all types of materials—some of them endangered—in the course of their work. Also, they are impartial, apolitical institutions that, even in the face of growing restrictions such as intellectual property rights, make their germplasm stores available to researchers all over the world, with preference to those from developing countries. In addition, the Centers have the technical know-how and facilities to perform the activities implicit in genetic conservation work, including collecting, characterizing, and regenerating genetic resources and distributing related information. Finally, it is highly efficient to have a genebank at a Center whose breeding programs are constantly using the stored genetic materials and adding to them.

The Wellhausen-Anderson Plant Genetic Resources Center

CIMMYT's genebank, the Wellhausen-Anderson Plant Genetic Resources Center (PGRC), houses the largest collection (150,000 accessions) of wheat and triticale (a wheat x rye cross) in the world, in addition to 19,000 accessions of maize and related species. The PGRC acquires and maintains in its wheat-related collections seed samples of old varieties and landraces, materials in danger of "genetic wipeout," and materials that have never before been collected.

Other crucial functions discharged by the PGRC are to organize, maintain, and distribute data related to bank accessions and to conserve duplicates of collections in developing country genebanks as backups in case of loss. An especially critical role of the PGRC is to support initiatives aimed at helping farmers restore seed of local varieties of maize and wheat that have been lost in natural and civil disasters, as happened with maize in Rwanda in 1994, wheat in Afghanistan in 1995, and, more recently, with maize in Central America in the wake of Hurricane Mitch (see "Seed Security in Central America," p. 6).

Not long ago, bank facilities were refurbished. The bank's capacity expanded to hold 450,000 maize and wheat seed samples in long- and medium-term cold storage, thanks to the generosity of the Japanese government and other donors. The expansion ensured that the bank will have sufficient space to store collected materials well into the the new century.

This expansion came at an opportune time, given that the wheat collection has increased three-fold just in the past 10 years, and that maize and wheat collections are growing constantly. On average, 5,000 new wheat accessions are sent to the bank every year. Before this seed can be introduced into bank collections, it must be multiplied and treated, and information on its place of origin and adaptation must be recorded and entered into a database. These basic activities must be carried out meticulously and supervised by well-qualified staff year after year. Needless to say, this work requires considerable resources—which are increasingly difficult to come by.

Doing More with Less

The wheat genebank has operated with essentially the same budget for years. "Ten years ago, the bank's wheat holdings totaled 45,000 accessions. Today we're trying to

Photo, previous page: Norman Borlaug, Nobel Laureate and CIMMYT consultant (left) stands with Bent Skovmand, head of CIMMYT's wheat germplasm bank. Borlaug is looking at a wheat landrace.

conserve and manage more than three times as many accessions with the same amount of money," says Bent Skovmand, in charge of Wheat Genetic Resources at CIMMYT.

This amounts to a *de facto* reduction in bank funding and strikes at the very heart of the PGRC. "Some bank functions are not absolutely vital to genetic resource conservation," points out Skovmand, "but preparing and processing incoming materials and regenerating stored accessions that are no longer viable are essential."

Seed Conservation

and Regeneration

Seed stored in the bank is kept in a dormant state induced by low temperatures. In this state, seed will stay viable—that is, it will germinate and produce a normal plant when sown—for 25-40 years, in the case of the active collections stored at –3 ºC, and more than 50 years, in the case of the base collections kept at –18 ºC. After that, the stored seed *must* be regenerated or *it will die*. The genetic diversity it contains is lost forever.

The regeneration process puts a stop to seed deterioration. It entails planting the stored materials to produce enough seed for multiplication. That seed is then multiplied in sufficient quantities for storage, while ensuring that it faithfully embodies the genetic diversity of the original sample. The two-step process is conducted under strict supervision in disease-free locations.

Financial Support

Is Crucial

CIMMYT's capacity to conserve maize and wheat diversity hinges on maintaining viable and genetically "true" seed in the bank. This constitutes the *raison d'être* of the PGRC. If the stored seed is not kept alive, then CIMMYT's commitment to preserve genetic resources for future generations is a hollow promise. Maintaining seed viability is also indispensable to maize and wheat breeders at CIMMYT and all over the world, whose research depends greatly on tapping into diverse sources of useful traits—such as the seed in the PGRC—to develop improved varieties adapted to farmers' needs in all types of environments. Their ability to fulfill this objective would be severely restricted were the bank to lose even part of its accessions.

The task of conserving maize and wheat genetic resources has been explicitly apportioned to CIMMYT, but the responsibility for preserving these invaluable resources for future generations is shared by all of us, and all of us are called upon to contribute whatever we can to the task. CIMMYT extends an invitation to parties interested in conserving irreplaceable genetic resources to participate in fulfilling this universal responsibility.

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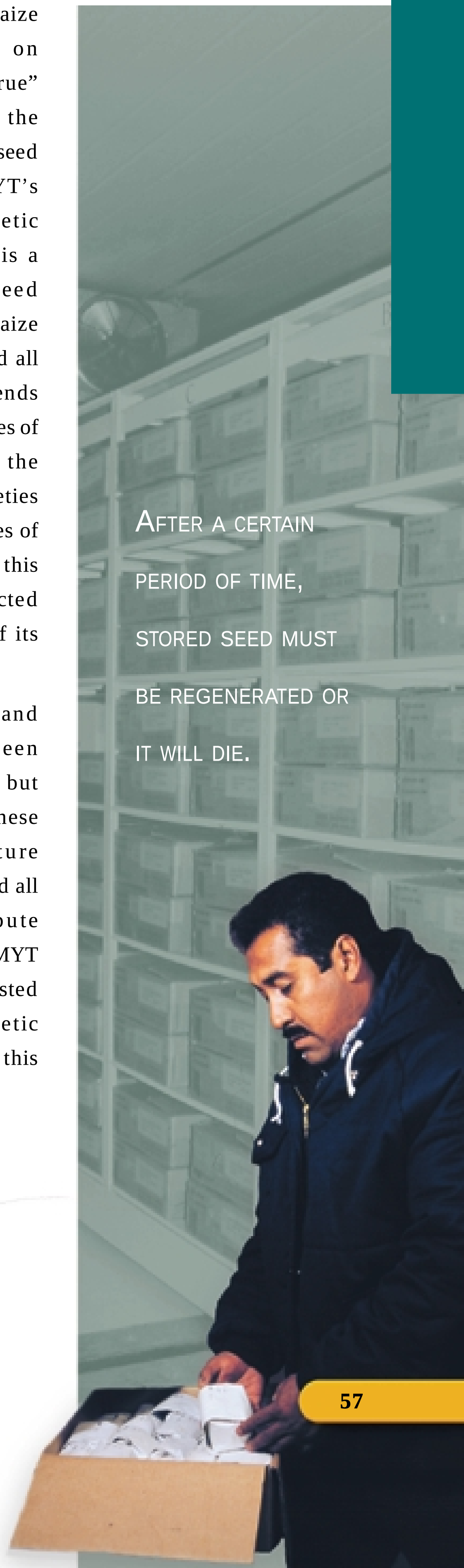

Central American Project Finds Remedies to Land Degradation

Central America's steep slopes and rough terrain have long posed severe obstacles to the hardened campesinos who toil to produce the maize and beans needed to feed their families. In recent years, burgeoning populations and increased pressure on arable land have presented a new set of challenges to farmers and policymakers alike: soil erosion and rapidly declining soil fertility are robbing the land of its ability to feed its inhabitants.

In Guatemala, for example, approximately 60% of the country's basic grains are grown on small farms that cannot produce enough to satisfy the basic nutritional needs of a typical family of 5-6 people. Slash-and-burn agriculture, which proved adequate in the past, now only intensifies erosion and productivity problems, and farmers are generally too poor to invest in maintaining their farmlands' fertility.

Despite 20 years of work by diverse institutions, both inside and outside the region, the adoption of sustainable farming practices and soil and water conservation techniques remains low. To help address this problem, CIMMYT and the region's national agricultural research programs (through the Regional Maize Program, or PRM), launched a project entitled "Accelerating the adoption of productivity-enhancing, resource-conserving (PERC) practices in maize-based cropping systems in Central America." The project, funded by the German Ministry of Economic Cooperation and Development (BMZ), has also received support from regional networks, non-governmental organizations such as CARE, and institutions specializing in public policy, such as the Sistema de Integración Centroamericana de Tecnología Agropecuaria (SICTA) and the Instituto Interamericano de Cooperación para la Agricultura (IICA).

The Search for Compatible Technologies

The multifaceted project, slated for completion in December 1999, began by investigating the economic characteristics of 16 soil-conserving technologies that were promoted in the region over the past two decades. Following evaluation, the technologies were compared with the needs and resource capabilities of small-scale farmers.

"The analysis," says CIMMYT economist and project leader Gustavo Sain "revealed that, with two exceptions, most of the technologies showed a certain degree of incompatibility with farmers' circumstances. For example, the cash costs and knowledge needed to implement terracing, a very effective conservation technology, was beyond the means of most farmers." CIMMYT and PRM economists conducted several case studies to determine the effects of various factors on the adoption of two PERC technologies—zero tillage with residue management (conservation tillage) and legumes used as cover crops—and on the adoption of improved maize varieties.

"We found that the opportunity cost of land and labor (in other words, the best net value the farmer can get from alternative uses of land and family labor) plays a fundamental role in the adoption or disadoption of legume intercropping," explains Sain. "The adoption of soil conservation technologies," he continues, "showed strong relationships to the farmer's perception that the practice was an investment activity. Access to information and how it was acquired were also important factors. Meanwhile, adoption of improved varieties seemed more closely related to more immediate consumption needs."

Importance of Community-level Solutions

Data and findings from the case studies were disseminated among stakeholders at five national and regional workshops. Later, says Sain, project staff generally concurred that these sessions relied too heavily on promoting policy actions at the national level. "Our results," Sain comments, "showed that community-level solutions through the design and execution of formal and informal agreements among community members would be more effective." Indeed, Sain believes further research directed toward harnessing community resources in this effort would be most worthwhile.

Sain is quick to point out that public-sector research is still needed to support the implementation of community projects. Despite the rapid expansion of the private sector in agriculture, he stresses that profit-oriented companies are not likely to address broad problems such as the alleviation of land degradation, in which the aim is to produce a "public good." Economic returns to well-targeted collaborative research in the region (based on field-level adoption rates) remain high. With that in mind, the PRM, with the strong support of the Swiss Agency for Development and Cooperation (SDC), is striving to create a regional body to promote and engage in collaborative agricultural work and to take on the associated problems of natural resource management and poverty among the region's farmers.

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Boom/Bust Breeding

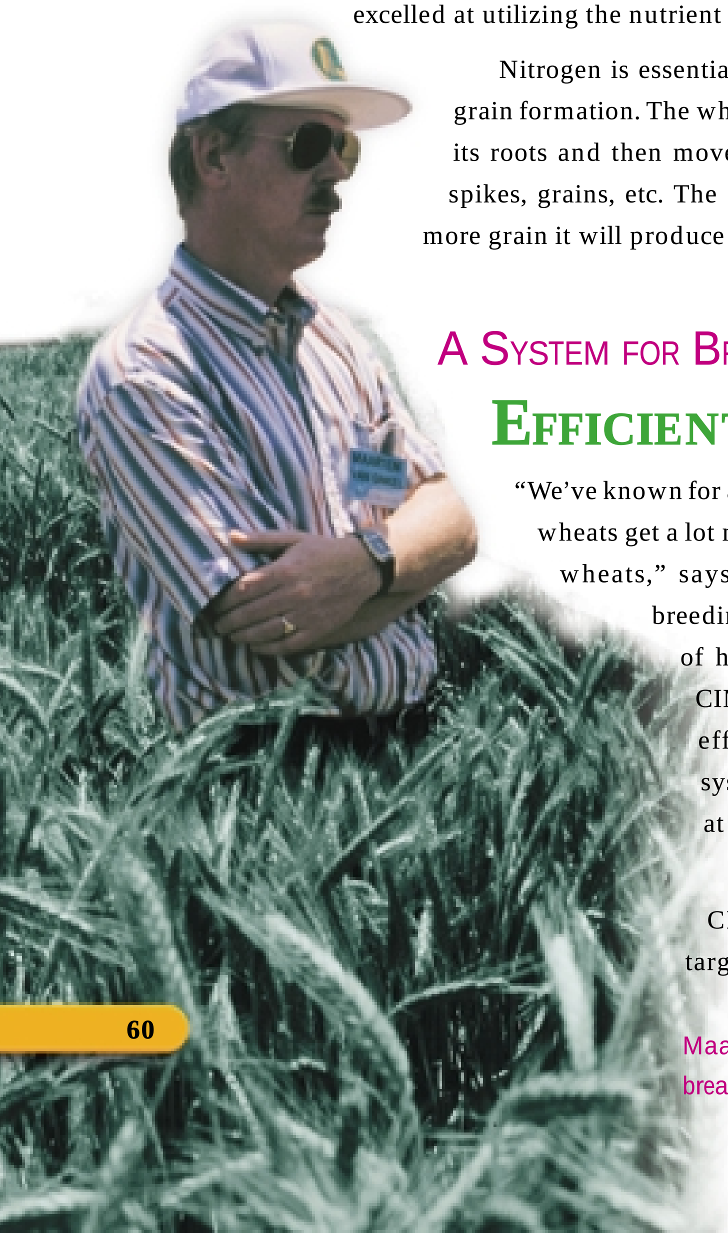
Improves Wheat's Nitrogen Efficiency

CIMMYT breeders seeking to improve wheat's nitrogen efficiency have hit upon an unexpected technique: applying high and low levels of nitrogen fertilizer to successive generations of wheat plants. These boom/bust fertilization cycles provoke an astute reaction in the plants.

When nitrogen is scarce, the plants concentrate on absorbing as much as they can from the soil. When faced with abundant nitrogen, they put all they can into producing lots of grain.

It should be pointed out that these are not ordinary wheat plants. They descend from select parents: one absorbed nitrogen exceptionally well, while the other excelled at utilizing the nutrient to make grain.

Nitrogen is essential to the wheat crop, vital for plant growth and grain formation. The wheat plant absorbs nitrogen from the soil through its roots and then moves it around to its different parts: stem, leaves, spikes, grains, etc. The more nitrogen a plant invests in the grain, the more grain it will produce and the better its quality.



A System for Breeding Nitrogen-Efficient Wheat

"We've known for a long time that high yielding, CIMMYT-derived wheats get a lot more 'mileage' out of nitrogen than unimproved wheats," says Maarten van Ginkel, head of bread wheat breeding at CIMMYT. "But we didn't know the details of how they did it." Now a study conducted at CIMMYT has revealed the mechanisms behind this efficiency and has suggested a method for systematically breeding wheats that are even better at getting the most out of nitrogen.

Up to now, the good nitrogen efficiency of CIMMYT varieties has not been the result of targeted selection for this trait; varieties that have

Maarten van Ginkel, head of bread wheat breeding at CIMMYT.

undergone years of testing for other yield-related traits at CIMMYT just turned out that way. “Interestingly, over the years CIMMYT agronomists noticed differences in the ways that efficient wheats made use of nitrogen: certain varieties were better at absorbing nitrogen from the soil, while others were better at utilizing nitrogen to make grain,” explains Ivan Ortiz-Monasterio, CIMMYT wheat agronomist. Furthermore, plants that absorbed nitrogen well performed better under low nitrogen conditions, while plants that utilized it well did better under high nitrogen conditions.

“These observations raised an exciting possibility,” relates Richard Trethowan, a bread wheat breeder involved in the study. “Could these two types of lines be crossed to produce wheats that were good at absorbing and utilizing nitrogen—that would yield well at *all* nitrogen levels? If so, what was the best way of doing this?”

To answer these questions, van Ginkel and Ortiz-Monasterio crossed two wheats that are good at absorbing nitrogen with two that are good at utilizing it. After eight years of testing, they and their colleagues found that alternately applying first high and then low nitrogen levels to successive cycles of offspring produced lines that yielded better than all the others, including the ones that had been bred using standard CIMMYT practice, intermediate levels of nitrogen.

“For years it’s been the standard practice at CIMMYT to breed our wheats under intermediate nitrogen levels,” says van Ginkel. “These results are suggesting a new way to accelerate and improve the breeding of nitrogen efficient plants. Alternating high and low nitrogen levels throughout the breeding process would ensure that all the wheat we produce combine good nitrogen uptake and good nitrogen utilization.”

Stable Yields and Savings for Farmers

Wheats that take full advantage of whatever level of nitrogen there is in the soil will improve the stability of wheat production in all types of growing environments, from favorable with high nitrogen levels to marginal with low nitrogen levels. They will be especially helpful to subsistance farmers who cannot afford to apply adequate levels of nitrogen.

As for yields in more favored environments, the new varieties will fit well, for example, in the well-watered regions where 40% of developing world wheat is produced. These wheat plants will not leave excessive amounts of unused nitrogen in the soil to contaminate the environment. Farmers can sow the new wheats using the most recent fertilizer management practices, such as applying nitrogen just when the plants pull it out of the soil to produce grain. In the end, less nitrogen is wasted and grain quality is better.

The nitrogen-efficient wheat lines will enter CIMMYT’s International Wheat Nurseries to be distributed to CIMMYT collaborators all over the world. Cooperators in developing countries will be able to select and keep these materials to use in their own breeding efforts. This is the first step to getting the new wheats out to farmers, especially those in disadvantaged environments who need them the most.

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Farmers can sow the new wheats using the most recent fertilizer management practices, such as applying nitrogen just when the plants pull it out of the soil to produce grain. In the end, less nitrogen is wasted and grain quality is better.

National Scientists Take Biotechnology Lessons from Training Sessions to the Field

Bringing the benefits of biotechnology to the farmers of eastern and southern Africa was a lofty goal envisioned in the early 1990s by some scientists in the region. Simply importing the knowledge or the technology alone would not produce long-term impact, however. What was needed was capacity building—the development of facilities and the human resources to utilize them.

In March 1997, two Kenyan and two Zimbabwean scientists arrived at CIMMYT headquarters in Mexico to begin two-year training stints in preparation for the establishment of applied biotechnology programs in their respective countries. Each "team" consisted of a maize breeder and a biotechnologist / molecular geneticist; the teams were later augmented by a lab and a field technician, who underwent three months of training at CIMMYT. The project, supported by the Directorate General of International Cooperation (DGIS) of the Dutch Ministry of Foreign Affairs, focused on these two countries because of their research capacities and because their divergent farming circumstances would yield insights into the effective application of biotechnological tools. Maize was selected as the target crop because of its important role as a staple cereal in the region. Research would address two major challenges to maize production: drought and insects.

Coming Home to a New Biotechnology Program

By May 1999, the visiting scientists had completed their training and returned home to start their work. Although the training is finished, says Jean-Marcel Ribaut, molecular geneticist with CIMMYT's Applied Biotechnology Center (ABC), the Center's interest and support for the project is far from over. "This is the first time we've dedicated this much time to a concerted training of a key set of individuals," he says. "The geneticists are now familiar with the use of several kinds of molecular markers to identify polymorphisms (molecular-level variations between plants), construct linkage maps, and do fingerprinting for work in genetic diversity. They are now prepared to engage in a wide range of biotech activites."

The establishment of small labs in both countries began in 1998, and with the return of the biotechnologists, the labs are being made operational. Equipment purchased with funds from DGIS and advice from CIMMYT should be up and running well before the end of 1999, enabling the scientists to begin producing data before 2000. "It was decided to focus the teams' efforts on polymerase chain reaction (PCR) technology because it allows one to work on a large scale and it doesn't require very complex technology," says Ribaut. "We're ready to provide backstopping and troubleshooting for the teams, but with the training they've undergone, we expect they'll be pretty independent."

The breeders also took part in molecular manipulations in the CIMMYT labs, according to Ribaut, but the main focus of their training was on the theory and practices required for developing good segregating populations, measuring the level of insect resistance and drought tolerance in the field, and how to employ fingerprinting and marker-assisted selection in their breeding efforts. "The idea," says Ribaut, "is that the breeders and the geneticists have laid the foundations here at CIMMYT for their interactions in their home countries. They will be talking the same scientific language and be on the 'same page' conceptually."

Field Trials

Already Underway

The breeders are already conducting trials in the region, and the resulting data will be combined with molecular mapping data to identify genomic regions that contribute to insect resistance or drought tolerance. After that, marker-assisted selection will be conducted to identify which genotypes "accumulated" the target alleles, thus promoting the incorporation of traits of interest into productive maize varieties.

In late June, 1999, just weeks after his return from CIMMYT headquarters, Zimbabwean maize breeder Godfree Chigeza had already finished gathering data from a collaborative field trial with J.B.J. Van Rensberg of the South African national agricultural research system. The trial was based on a cross between a borer-resistant CIMMYT line (CML123) and a good, but susceptible, regional line (K64R). The following week Chigeza was supervising the planting of a trial at the Chiredzi Research Station in Zimbabwe. The trial, set to be harvested in October, will be used for the genetic investigation of drought resistance.

"My CIMMYT training was an eyeopener on how basic research can be designed to further our knowledge of agricultural production in marginal areas," declares Chigeza. "Although our resource base here is still low, my training at CIMMYT has allowed me to design efficient trials that help keep this work going forward. I think the training also gave me the confidence to collaborate on an equal basis with other scientists at the regional level."

Indeed, if the energy and dedication embodied by Chigeza and his colleagues can be maintained, the use of this new technology will soon make its impact felt in the maize fields of eastern and southern Africa.

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"My CIMMYT training was an eyeopener on how basic research can be designed to further our knowledge of agricultural production in marginal areas."

- Godfree Chigeza, Zimbabwe

FARMERS WORK WITH DIVERSITY PRINCIPLES AND PRACTICES

A SMALL PILE OF BLACK-KERNELED MAIZE LIES AT HIS FEET AS MAURICIO BELLON, A HUMAN ECOLOGIST WITH CIMMYT'S ECONOMICS PROGRAM, LISTENS TO OAXACAN FARMERS DISCUSS THE PROS AND CONS OF THE MAIZE VARIETY. THE FIVE WOMEN AND MEN ARE NOT RETICENT.

In fact, the farmers are animated and involved with the exchange as they examine the ears more closely. Their comments range from a simple but emphatic "Don't like it" to one woman's short demonstration of the variety's shelling characteristics. Members of the group record their opinions of the variety (their "votes") on small red paper "ballots." As the group moves on to the next pile of maize, Bellon reminds them that at the end of the walk, they can purchase seed for experimenting with any of the varieties that appeal to them.

Since 1997, Bellon, CIMMYT economist Melinda Smale, and Suketoshi Taba, head of CIMMYT's Maize Germplasm Bank, together with Alfonso Aguirre and Flavio Aragón Cuevas from the Mexican National Institute for Forestry, Agriculture and Livestock Research (INIFAP), have worked with farmers in six villages in Oaxaca, Mexico, one of the country's poorest regions. The aim of their work is to determine whether maize breeding based on a collaboration between farmers and breeders can increase farmer welfare while maintaining or enhancing genetic diversity.

The project, funded by Canada's International Development Research Centre (IRDC), has completed its first, primarily diagnostic, phase and entered its intervention phase. "We're really getting to the interesting stage now," says Bellon. "Before, we got things from the farmer—maize varieties, information, and their preferences. Now we're beginning to bring things back to them."

OAXACAN WOMEN IDENTIFIED EASE OF SHELLING AS A DESIRABLE TRAIT IN MAIZE—A TRAIT OVERLOOKED BY THE LOCAL MEN. ACCOUNTING FOR SUCH PREFERENCES BY GENDER WILL HELP RESEARCHERS DEVELOP SUCCESSFUL STRATEGIES FOR CONSERVING GENETIC DIVERSITY IN THE FIELD.

The Give-and-Take of Participatory Research

What Bellon and his colleagues are providing to farmers is training on the basic concepts of plant breeding, 17 selections of local germplasm (about half of them improved through the efforts of Taba and Aragón), and a spirit of empowerment as farmers see how to apply new knowledge to their maize crops. In the process, researchers will determine whether such interventions can promote greater genetic diversity in farmers' fields.

"Farmer management has by and large been successful in promoting maize diversity over the centuries," says Bellon, "but some farmer practices present strong constraints to diversity." If farmers can avail themselves of more knowledge and new varieties, the project team hopes they will experiment further and generate new and more productive ways of working with diversity in their landraces.

"Our emphasis in working with farmers has been on principles and practices," says Bellon. For instance, the concept of male and female components of the maize plant, though taken for granted by scientists, is novel to the Oaxacan smallholder. "When we discussed this principle with farmers," he explains, "many at first thought that the big plants were obviously the males. They were surprised to learn that males and females were on the same plant. A useful practice drawn from this principle is that if you find a plant that is truly inferior, you detassel it, thereby eliminating what we called the 'bad or weak fathers' in the plot. The farmers already pull off the tassels to feed to their cows—but now they can employ this same practice to eliminate poor parents and improve their overall crop."

Other practices and principles taught by the team focused on creating greater stability in the crop (that is, reducing the risk of yield losses in poor years) through a broader selection of seed by farmers, tips on cleaning and storing seed, and the introduction of a system of farmer seed exchange, which INIFAP's Aguirre had documented in Guanajuato, Mexico.

A Rigorous Farmer Participatory Model for Working with Diversity

The second intervention, the selection, evaluation, and procurement of diverse seed by farmers, was based on a rigorously designed farmer participatory model. Earlier in the project, more than 150 local varieties, varying in color, ear size, and consumer characteristics, were collected from throughout Oaxaca. Trials were established using these varieties together with 17 landraces selected by genetic resource specialists. These were later grouped into five homogeneous clusters reflecting their phenotypic diversity.

At harvest, more than 200 farmers (54% female) assembled to examine and evaluate the varieties, marking their votes for each variety's characteristics on their ballots. Project researchers selected eight top vote-getting varieties to plant the following season, along with another nine varieties that underwent breeding at CIMMYT to better establish the positive characteristics that farmers had identified in the varieties. During the first harvest season of 1999, farmers walked the demonstration plots where these varieties were planted, evaluated plant and ear characteristics, and later were offered the opportunity to buy seed with which to conduct their own trials.

Later in 1999 and during 2000, the project team will visit the villages again. They will answer farmers' questions, assess whether the farmers applied what they learned, and ask how they used the seed acquired through the project. According to Bellon, the team will also ascertain whether the farmers actually carried out their own experiments; what their evaluations revealed; what they liked or disliked about different varieties; which farmers participated, which did not, and why; and so forth. In 2000, after researchers have assimilated the farmer feedback into the development of varieties and of the participatory research methodology, another series of field days will be held.

Some interesting findings have emerged, especially regarding gender and maize preferences and how these factors could influence genetic diversity. Bellon emphasizes that "we are not presupposing that this is a useful approach. However, our methodology has been rigorous and if the study does show benefits to farmers' welfare and genetic diversity, we will have a system to offer up as a model. With all the talk about farmers' rights and how to compensate them for maintaining diversity, this could be a very promising option."

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Financial Summary, 1998-99

Funding for 1998 was US$ 31.969 million, consisting of US$ 31.182 from donors and US$ 0.787 from other sources. Expenditures were US$ 32.705 million. Sources of income from grants are summarized in the table, p. 68.

Figures 1-3 highlight funding levels and trends. Contributions of the agencies that provided the bulk of our funding in 1998 are shown in Figure 1. CIMMYT allocated these funds among the five CGIAR research activities as indicated in Figure 2. From Figure 3, the continuing rise in targeted contributions and decline in unrestricted contributions is evident. This trend has continued into 1999.

CIMMYT ended 1998 with an operational deficit of US$ 481,000, owing primarily to a gap in core unrestricted funding that could not be offset by the end of the year. The gap was charged against our operating reserve, as approved by the CIMMYT Board in March 1998. Also charged to the reserve were: US$ 100,000 in outstanding costs from the EPMR (billed in 1998); US$ 155,000 arising from 1996 exchange rate losses; and half of the 1997 EU contribution, paid in 1998.

Our efforts to fulfill a very demanding research agenda have been supported by funding from more than 30 new special projects initiated in 1998-99. These projects range from extremely specialized research initiatives to wide-ranging efforts such as farmer participatory research on tillage and nutrient management interactions to improve the sustainability and productivity of rice-wheat cropping in South Asia, or a project to increase the scope and efficiency of global maize breeding and genetic resource conservation through an improved understanding of maize genetic diversity.

It is important to note that the vast majority of additional funding for 1998 and 1999 has been targeted funding (i.e., core special projects). The increase in targeted contributions reflects a concerted effort to develop research partnerships directed at specific major research challenges in our mandate crops. It also reflects a trend to support research through less traditional sources of income. These new partnerships have broadened the spectrum of institutions with which we collaborate, made it possible for us to pursue several innovative research initiatives, and have also made it possible to direct additional funding to partners in national agricultural research systems.

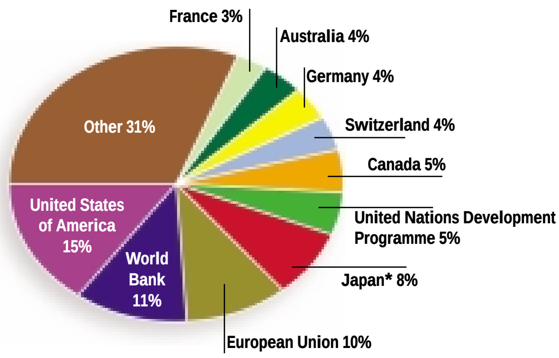

Figure 1. Top ten donors to CIMMYT, 1998.

* "In-kind" contributions included.

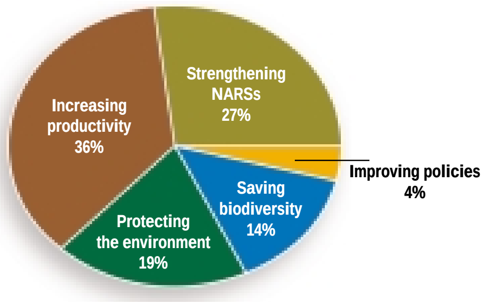

Figure 2. Allocation of CIMMYT research funding by CGIAR activity, 1998.

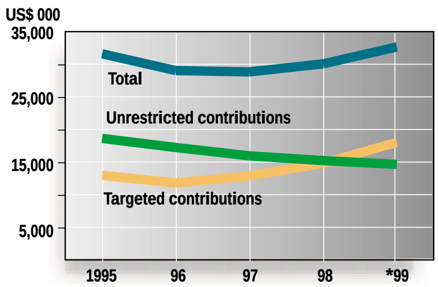

Figure 3. Trends in grants to CIMMYT, 1995-99.

* "In-kind" contributions included.

A growing challenge in balancing the Center's research portfolio is to attract funding that permits us to conduct the longer term, strategic research that will enable CIMMYT and its partners to continue to make a lasting contribution to broad development goals: reducing poverty, improving food security, and preserving natural resources well into the next millenium. Such research is a valuable and significant investment in itself, and it can also provide important inputs into downstream research that has more immediate goals and highly focused impacts.

In light of the volatile global economy and increasing competition for resources, both from inside and outside the CGIAR System, our budget estimates for 1999 have been generally more conservative. Our most recent Medium Term Plan (2000-2000+) projects an increase of about 2% per year, in real terms, to the CIMMYT budget, which allows for moderate growth in key areas of research. Total salaries and allowances are targeted to remain below 60% of the operating budget. Other operating costs will be consistent with long-term trends. Costs in Mexico are projected to increase gradually as the economy recovers further and the Mexican peso stabilizes.

CIMMYT sources of income from grants

for the period from January 1 to December 31, 1998

Donor	Grant
United States of America (USAID, USDA, US Universities)	5,000
World Bank	3,385
European Union	3,084
Japan (Government of, JIRCAS, TARC)*	2,479
United Nations Development Programme (Africa Bureau, SEED)	1,622
Canada (CIDA, IDRC, Agri-Food)	1,573
Switzerland (SDC)	1,319
Germany, Government of	1,198
Australia (ACIAR, AusAID, DIST, GRDC)	1,193
France, Government of	959
United Kingdom (DFID)*	896
Denmark (Danida)	889
Inter-American Development Bank	656
Rockefeller Foundation	619
Sweden, Government of (Sida)	587
Netherlands, Government of (Ministry of Foreign Affairs)*	585
Asian Development Bank	527
Ford Foundation	433
International Fund for Agricultural Development	416
Mexico, Government of (Nafinsa)*	386
Portugal, Government of	250
Norway, Government of (Ministry of Foreign Affairs)	234
Nippon Foundation	230
CGIAR Centers (CIAT, ICRAF, IFPRI, IPGRI)	228
Iran, Islamic Republic of	187
Bolivia, Government of*	178
Austria, Government of	166
Private sector (Monsanto Company, Agrovegetal)	161
Colombia, Government of (Colciencias)	148
Korea, Republic of*	136
Bangladesh, Government of	122
South Africa, Republic of	113
India, Government of	112
China, People's Republic of	100
Pakistan, Government of	100
Thailand, Government of	100
Spain, Government of	97
Uruguay, Government of (INIA)	92
Brazil, Government of (EMBRAPA)	90
Belgium, Government of	85
Fundación Telmex	78
Peru, Government of	70
Miscellaneous research grants*	53
Novartis Foundation	50
Hilton Foundation	49
Fundación Guanajuato Produce A.C.	39
Consultative Group on International Agricultural Research (IAEG)	29
Fundación Sonora	28
OPEC Fund for International Development	27
Philippines, Government of	25
Total	**31,182**

* "In-kind" contributions included.

TRUSTEES AND PRINCIPAL STAFF

(as of October 1999)

TRUSTEES

1 *Ex officio* position

PRINCIPAL STAFF

Office of the Director General

Timothy G. Reeves, Australia, Director General
Claudio Cafati, Chile, Deputy Director General, Administration and Finance
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Lucy Gilchrist S., Chile, Senior Scientist, Head, Seed Health Unit
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Gregorio Martínez V., Mexico, Government and Public Affairs Officer
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Richard Wedderburn, Barbados, Associate Director*
Marianne Bänziger, Switzerland, Scientist, Physiologist (based in Zimbabwe)*
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David Bergvinson, Canada, Senior Scientist, Entomologist*
Jorge Bolaños, Nicaragua, Principal Scientist, Agronomist (based in Guatemala)*
Hugo Córdova, El Salvador, Principal Scientist, Breeder/Leader of Tropical Maize*
Carlos de León G., Mexico, Principal Scientist, Pathologist/Breeder (based in Colombia)
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Adjunct Scientists
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Salvador Castellanos, Guatemala, Breeder (based in Guatemala)
Andreas Oswald, Postdoctoral Fellow, Agronomist (based in Kenya)

Pre- and Postdoctoral Fellows
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Efren del Toro, Mexico, Administrative Manager
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Lucy Gilchrist S., Chile, Senior Scientist, Pathologist (Fusarium/Septoria)
Monique Henry, France, Scientist, Virologist
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Mohamed Mergoum, Morocco, Scientist, Winter Wheat Breeder (based in Turkey)
A. Mujeeb-Kazi, USA, Principal Scientist, Head, Wide Crosses
Alexei Morgounov, Russia, Senior Scientist, Regional Representative Breeder, Central Asia and Caucasus (based in Kazakhstan)

* Project Coordinator. (CIMMYT research is organized into a series of multidisciplinary projects described in our Medium-Term Plan.)

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Kenneth D. Sayre, USA, Principal Scientist, Head, Crop Management
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Financial Summary, 1998-99

Funding for 1998 was US$ 31.969 million, consisting of US$ 31.182 from donors and US$ 0.787 from other sources. Expenditures were US$ 32.705 million. Sources of income from grants are summarized in the table, p. 68.

Figures 1-3 highlight funding levels and trends. Contributions of the agencies that provided the bulk of our funding in 1998 are shown in Figure 1. CIMMYT allocated these funds among the five CGIAR research activities as indicated in Figure 2. From Figure 3, the continuing rise in targeted contributions and decline in unrestricted contributions is evident. This trend has continued into 1999.

CIMMYT ended 1998 with an operational deficit of US$ 481,000, owing primarily to a gap in core unrestricted funding that could not be offset by the end of the year. The gap was charged against our operating reserve, as approved by the CIMMYT Board in March 1998. Also charged to the reserve were: US$ 100,000 in outstanding costs from the EPMR (billed in 1998); US$ 155,000 arising from 1996 exchange rate losses; and half of the 1997 EU contribution, paid in 1998.

Our efforts to fulfill a very demanding research agenda have been supported by funding from more than 30 new special projects initiated in 1998-99. These projects range from extremely specialized research initiatives to wide-ranging efforts such as farmer participatory research on tillage and nutrient management interactions to improve the sustainability and productivity of rice-wheat cropping in South Asia, or a project to increase the scope and efficiency of global maize breeding and genetic resource conservation through an improved understanding of maize genetic diversity.

It is important to note that the vast majority of additional funding for 1998 and 1999 has been targeted funding (i.e., core special projects). The increase in targeted contributions reflects a concerted effort to develop research partnerships directed at specific major research challenges in our mandate crops. It also reflects a trend to support research through less traditional sources of income. These new partnerships have broadened the spectrum of institutions with which we collaborate, made it possible for us to pursue several innovative research initiatives, and have also made it possible to direct additional funding to partners in national agricultural research systems.

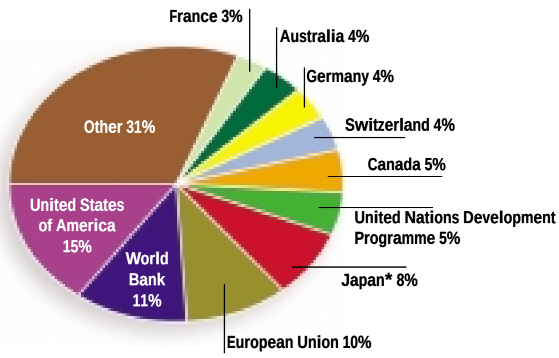

Figure 1. Top ten donors to CIMMYT, 1998.

* "In-kind" contributions included.

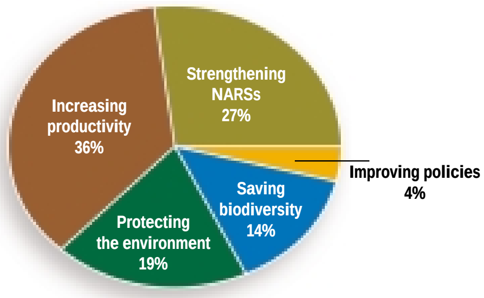

Figure 2. Allocation of CIMMYT research funding by CGIAR activity, 1998.

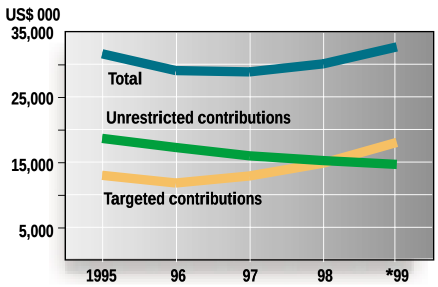

Figure 3. Trends in grants to CIMMYT, 1995-99.

* "In-kind" contributions included.

A growing challenge in balancing the Center's research portfolio is to attract funding that permits us to conduct the longer term, strategic research that will enable CIMMYT and its partners to continue to make a lasting contribution to broad development goals: reducing poverty, improving food security, and preserving natural resources well into the next millenium. Such research is a valuable and significant investment in itself, and it can also provide important inputs into downstream research that has more immediate goals and highly focused impacts.

In light of the volatile global economy and increasing competition for resources, both from inside and outside the CGIAR System, our budget estimates for 1999 have been generally more conservative. Our most recent Medium Term Plan (2000-2000+) projects an increase of about 2% per year, in real terms, to the CIMMYT budget, which allows for moderate growth in key areas of research. Total salaries and allowances are targeted to remain below 60% of the operating budget. Other operating costs will be consistent with long-term trends. Costs in Mexico are projected to increase gradually as the economy recovers further and the Mexican peso stabilizes.

CIMMYT sources of income from grants

for the period from January 1 to December 31, 1998

Donor	Grant
United States of America (USAID, USDA, US Universities)	5,000
World Bank	3,385
European Union	3,084
Japan (Government of, JIRCAS, TARC)*	2,479
United Nations Development Programme (Africa Bureau, SEED)	1,622
Canada (CIDA, IDRC, Agri-Food)	1,573
Switzerland (SDC)	1,319
Germany, Government of	1,198
Australia (ACIAR, AusAID, DIST, GRDC)	1,193
France, Government of	959
United Kingdom (DFID)*	896
Denmark (Danida)	889
Inter-American Development Bank	656
Rockefeller Foundation	619
Sweden, Government of (Sida)	587
Netherlands, Government of (Ministry of Foreign Affairs)*	585
Asian Development Bank	527
Ford Foundation	433
International Fund for Agricultural Development	416
Mexico, Government of (Nafinsa)*	386
Portugal, Government of	250
Norway, Government of (Ministry of Foreign Affairs)	234
Nippon Foundation	230
CGIAR Centers (CIAT, ICRAF, IFPRI, IPGRI)	228
Iran, Islamic Republic of	187
Bolivia, Government of*	178
Austria, Government of	166
Private sector (Monsanto Company, Agrovegetal)	161
Colombia, Government of (Colciencias)	148
Korea, Republic of*	136
Bangladesh, Government of	122
South Africa, Republic of	113
India, Government of	112
China, People's Republic of	100
Pakistan, Government of	100
Thailand, Government of	100
Spain, Government of	97
Uruguay, Government of (INIA)	92
Brazil, Government of (EMBRAPA)	90
Belgium, Government of	85
Fundación Telmex	78
Peru, Government of	70
Miscellaneous research grants*	53
Novartis Foundation	50
Hilton Foundation	49
Fundación Guanajuato Produce A.C.	39
Consultative Group on International Agricultural Research (IAEG)	29
Fundación Sonora	28
OPEC Fund for International Development	27
Philippines, Government of	25
Total	**31,182**

* "In-kind" contributions included.

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(as of October 1999)

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