

INTERNATIONAL MAIZE AND WHEAT  
IMPROVEMENT CENTER

# A SOLID FUTURE

ANNUAL REPORT  
2004-2005

 CIMMYT

# Contents

CIMMYT® ([www.cimmyt.org](http://www.cimmyt.org)) is an internationally funded, not-for-profit organization that conducts research and training related to maize and wheat throughout the developing world. Drawing on strong science and effective partnerships, CIMMYT works to create, share, and use knowledge and technology to increase food security, improve the productivity and profitability of farming systems, and sustain natural resources. CIMMYT is one of 15 Future Harvest Centers of the Consultative Group on International Agricultural Research (CGIAR) ([www.cgiar.org](http://www.cgiar.org)). Financial support for CIMMYT's work comes from the members of the CGIAR, national governments, foundations, development banks, and other public and private agencies.

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# A Reason to Be the Best

MEETING THE UNITED NATIONS FIRST MILLENNIUM DEVELOPMENT GOAL—TO ERADICATE EXTREME POVERTY AND HUNGER—WILL DEPEND ON A RANGE OF ACTIONS IN AREAS WHERE POVERTY IS ENDEMIC AND CRIPPLING.

**M**ost people in the developing world depend directly or indirectly on agriculture for their livelihoods. Maize and wheat alone provide nearly half the food by weight and a quarter of the calories for the 4.9 billion people of the developing world. In much of Africa the land—which has to produce the food, sustain the farming systems for production, and nurture the crops that farmers grow—cannot keep up with demand, even when conditions of climate and politics are stable. More than half a billion people depend on wheat or maize but have little or no access to agricultural inputs, farm on degraded soils, or have to make do in marginal climates.

With a continuously growing population, less good land for agriculture, and climate and water constraints that seem to grow more severe each year, yesterday's solutions are not sufficient for today. In this annual report for 2004-2005 we focus on one of the most severe constraints to production in wheat and maize farming systems—drought—and the approaches CIMMYT is taking to help farmers

cope. A major priority is finding ways that maize and wheat can continue to produce high, stable yields with less available water. We are working both at the breeding level to develop plants that use water more efficiently and at the plot level to help farmers to conserve and better use what moisture they have. In the reports that follow, you will find accounts of progress by CIMMYT and its partners. For example CIMMYT has devised a "smart crossing" approach to produce wheat varieties with better drought tolerance, and uses a decentralized global shuttle breeding system—an extension of its time proven method in Mexico—to test and adapt drought tolerant varieties to diverse conditions around the world. Another trend to note is the adoption of conservation agriculture practices that save farmers soil, water, money, and time, in addition to bringing environmental benefits. This is global science for local impact.

## FROM VISION TO BUSINESS PLAN

This year CIMMYT has continued to implement its strategic vision while pursuing a sound financial management plan that includes

building the reserve fund to meet CGIAR targets. Despite severe financial constraints that have resulted in downsizing of internationally and nationally recruited staff the past three years, CIMMYT has continued to deliver to its prime beneficiaries—maize and wheat farmers and consumers in the developing world.

CIMMYT's fifth External Program and Management Review (EPMR) produced a detailed, comprehensive report concluding that "...the case for the continued support of CIMMYT in developing germplasm with multiple stress resistance specifically targeted at resource poor farmers was strong and clear. Such improved germplasm that was not only accessible to resource poor farmers but specifically targeted to their needs was essential if they were to benefit from the ongoing scientific advances in genetics, genomics, and breeding." The Center has already begun to address weaknesses identified in the EPMR. A key recommendation of the panel, and one which CIMMYT wholeheartedly endorsed, was that the center write a business plan to indicate how the vision described in our strategic plan "Seeds of

Innovation" would actually be delivered. CIMMYT took the challenge and has produced "A Solid Future for CIMMYT and Those It Serves," a plan to guide CIMMYT over the next five years.

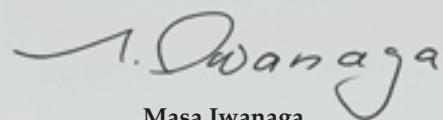
## CIMMYT: THE DEVELOPING WORLD'S MAIZE AND WHEAT CENTER

Agricultural research has achieved what looked like miracles in the past, developing ways to enhance the productivity of farming systems in both the developed and the less developed world. CIMMYT was built on the accomplishments of the researchers who created the "green revolution" of the 1960s. The high-yielding wheat varieties developed by Nobel Peace Prize winner, Dr. Norman Borlaug, in Mexico and delivered to India and Pakistan, brought the Indian Subcontinent food self-sufficiency at a time when it was facing mass famine.

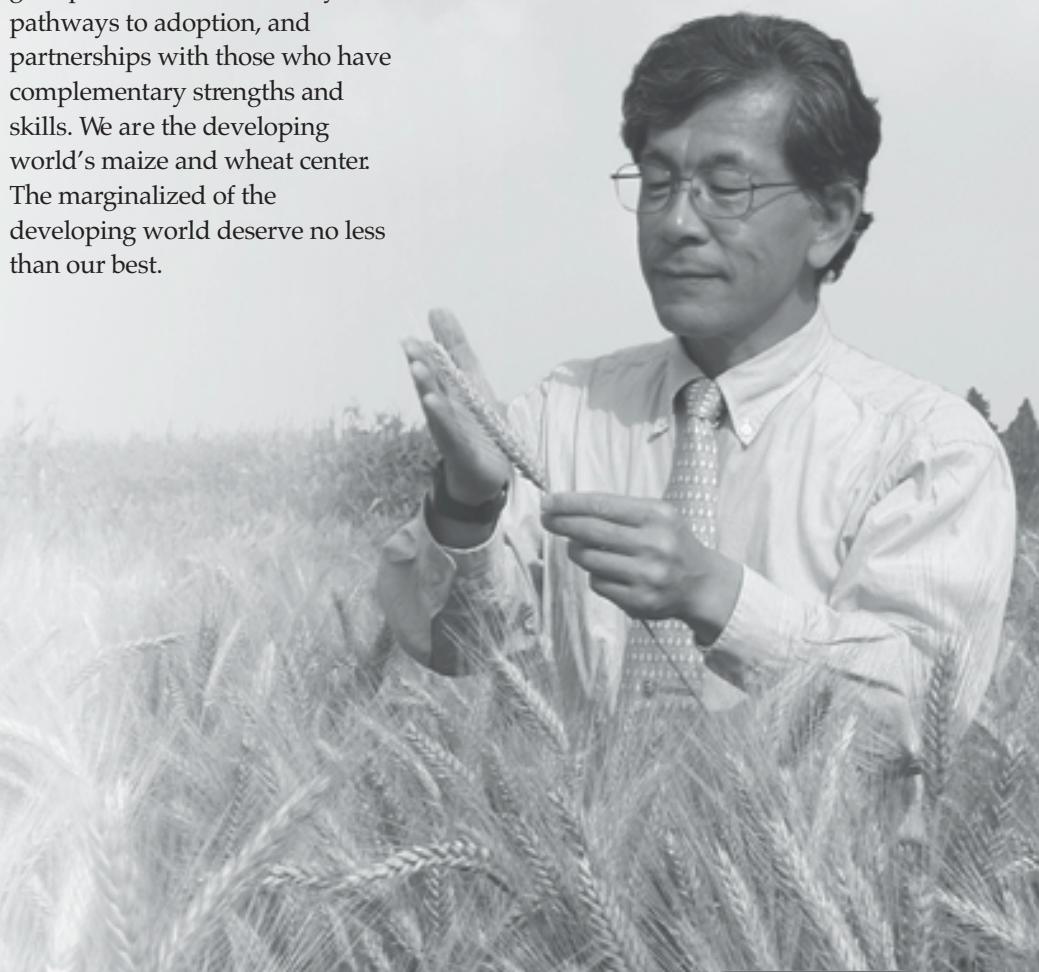
Three lessons from the time of the green revolution stand out for policymakers in all countries, rich or poor. First, agricultural research is a fundamental building block for progress in food production and global food security. Second, rapid transmission to farmers of advances from the research labs and experimental fields depends on the

effective functioning of many actors along the "research impact pathway," from researchers and policymakers to farmers. Third, the farmer is king; in the end, the decisions of millions or hundreds of millions of farmers across the world determine whether the new varieties and technologies are adopted, impacts registered and, in the end, poverty reduced and livelihoods improved.

CIMMYT will continue to deliver solutions through enhanced germplasm, efficient delivery pathways to adoption, and partnerships with those who have complementary strengths and skills. We are the developing world's maize and wheat center. The marginalized of the developing world deserve no less than our best.



Masa Iwanaga  
Director General





A SOLID FUTURE

# Drought: Grim Reaper of Harvests and Lives

WHEN ONE THINKS OF  
DEADLY NATURAL DISASTERS,  
WHAT GENERALLY COMES TO  
MIND ARE STORMS, FLOODS,  
EARTHQUAKES, OR  
VOLCANOES.

**A**ctually, mention of the world's most life-threatening natural phenomenon—drought—rarely makes the headlines. But according to a recent study<sup>1</sup> by the Columbia University Center for Hazards and Risk Research and the World Bank, drought caused nearly as many deaths during 1980–2000 as all other natural disasters combined.

Drought's despoilment falls heavily upon the rural poor in developing countries, and has been particularly onerous in Africa. In 2005, paltry rains plus diverse other factors led to southern Africa's worst harvest of maize—the region's staple food—in a decade typified by

meager harvests. A BBC News report of 3 October mentioned children dying of hunger-related illnesses in Malawi and said the United Nations World Food Programme (WFP) estimated that some 12 million people would need international help. Throughout the developing world, drought is second only to soil infertility as a constraint to maize production, and probably reduces yields worldwide by more than 15% yearly, representing annual losses in excess of 20 million tons of grain. Nearly one-third of the area planted to bread wheat and about three-fourths of the area planted to durum wheat suffer from severe drought stress during the growing season. If predictions are right, global warming, urbanization, and deforestation will increase the frequency and severity of drought and general scarcity of water in many parts of the developing world. By the same token, developing countries will need an additional 368 million tons of maize and wheat by 2020 (today, they need about 700 million tons) for food, and studies suggest that harvests from marginal lands—including areas prone to drought—will be key to meeting this increased demand.

In keeping with its mission, CIMMYT and partners are helping address the needs of oft-forgotten farmers in droughty areas, offering them hardy maize and wheat varieties that survive and give grain in drier seasons, with no yield penalty in wet years, as well as cropping practices to capture and take fullest advantage of available moisture.

The complexity of a plant's responses when faced with insufficient moisture—varying by species, cultivar, and plant growth stage—renders quick solutions or breeding breakthroughs elusive.

## WHEAT: MANY WAYS TO ATTACK DROUGHT

Historically, water deficit is more common than water sufficiency for cultivated wheat. Under human management, 36 million hectares—or roughly one-third—of all wheat sown in developing countries receive adequate water via irrigation. The remainder is grown on precipitation or residual moisture. Of this, at least 40 million hectares are regularly subject to

<sup>1</sup> Dilley, M., R.S. Chen, U. Deichmann, A.L. Lerner-Lam, and M. Arnold. 2005. *Natural Disaster Hotspots: A Global Risk Analysis*. Washington, D.C.: The World Bank.



drought at some point in the crop cycle. CIMMYT wheat researchers have worked extensively at the Center's Ciudad Obregón research station in the northern Mexican desert, where water regimes are subject to tight control. This has allowed them to "dissect" the effects of drought on wheat productivity at the various crop development stages. In this regard, wheat's life cycle may be broken down into four stages: emergence-establishment, establishment-flowering, flowering, and grain filling.

Very dry conditions are most detrimental to wheat during **emergence-establishment**. "If a plantlet lacks sufficient moisture to emerge or the ground is drying as it comes up, a yield penalty is paid regardless of conditions that follow," says CIMMYT wheat breeder Richard Trethowan. "Farmers often delay sowing until they see there is sufficient moisture, but the delay itself also reduces yield."

Dry conditions at **establishment-flowering** can retard root and canopy development.

Underdeveloped root systems are less able to extract moisture from the soil, and yields plummet should dry conditions persist. Fewer or smaller leaves and a thinner canopy create less shade, resulting in more evaporation from the soil and greater competition from weeds for moisture and nutrients.

Photosynthetic activity may also suffer. Finally, a weak root system and canopy leave the plant with lower nutrient reserves to draw on at later development stages.

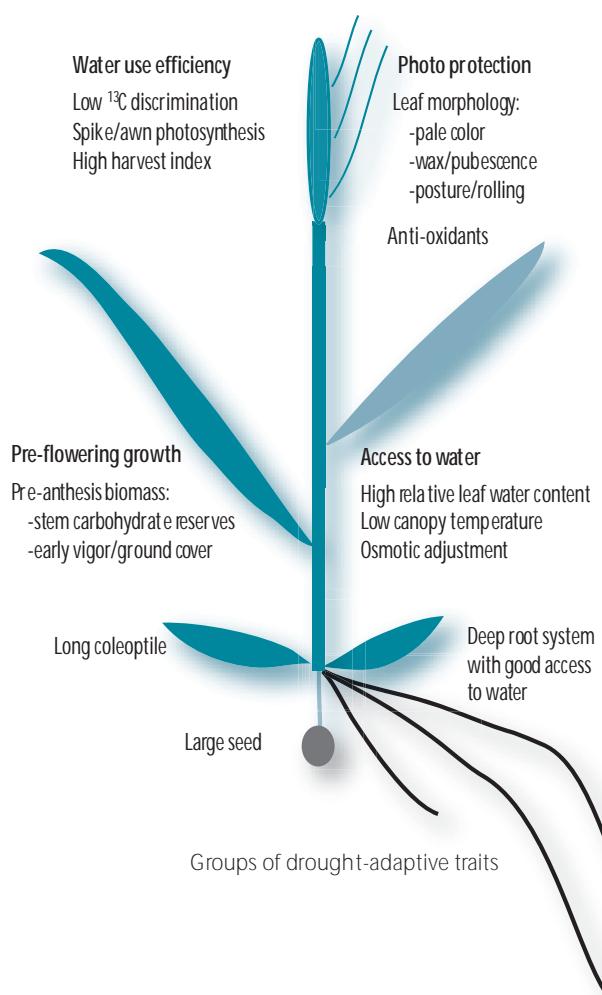
Lack of water at **flowering** can produce male sterility and fewer and more poorly formed seeds. Even if the plant gets adequate water afterwards, the dearth of fertile kernels will reduce yields. Again, stored resources may support pollination and seed setting.

Severe dryness at **grain filling** can reduce photosynthesis and thus the supply of carbohydrates needed for

plump kernels. Yield losses may be reduced if the plant can call on carbohydrate reserves. For CIMMYT and partners, drought stress during grain filling is a research priority because of its prevalence in many of the wheat environments where we work.

## **WATER-PROMOTIVE WHEAT: "SMART CROSSING" FOR SPECIFIC TRAITS**

CIMMYT recently devised a "smart crossing" approach to produce wheat varieties better able to access and use soil water. The approach works in tandem with a global "shuttle breeding" system that allows researchers to test and adapt drought tolerant varieties in diverse conditions around the world. A central precept is that drought tolerance should entail no yield penalty—that is, when rains or irrigation are adequate, the yields ►



of drought tolerant varieties should equal or exceed those of normal cultivars. Breeders are also beginning to develop varieties that complement conservation agriculture practices gaining acceptance in developing countries (see "Conservation Agriculture and Drought," p. 7).

In the past, breeders simply crossed parents that produced high yields under drought and then screened the progeny for improved performance. "The 'smart crossing' approach breaks down drought tolerance into bite-size pieces—namely, the key adaptive traits at specific plant stages—and incorporates them into the plant in a way that creates synergies among traits," says Matthew Reynolds, CIMMYT wheat physiologist (see figure). Parents with strong traits from diverse groups are crossed and their offspring screened for the desired characteristics.

Breeders, physiologists, and molecular geneticists work together to endow experimental wheat lines and varieties with some or all of the traits. "The breeders send me their crossing blocks—experimental lines and varieties—and I advise them on which lines would make good complementary crosses based on their expression profile for drought-adaptive traits," says Reynolds. "We've been doing this for almost five years now and already lines are being earmarked as candidates for international distribution."

#### Traits for pre-flowering growth:

##### **Seedling emergence and plant establishment.**

"We want seeds that can be sown deep to access available moisture, but then get out of the ground fast and grow vigorously, especially lateral growth," says Trethowan. Large seeds and embryos appear to help, as well as a long coleoptile—the first leaf above the ground that forms a protective sheath around the stem tip. The latter allows for deep planting and use of residual soil moisture, while protecting seedlings from high soil temperatures or rapid drying. Finally, a quick-growing canopy with wide, thin leaves provides good ground cover, reducing evaporation and suppressing weeds that compete for water.

Once the plant is established, storage of nutritional reserves becomes increasingly important for later growth stages. Assimilates in stems can be used for grain filling, if lack of water at that phase slows photosynthesis. This means that thicker, longer stem internodes may help. Directing assimilates to the roots increases the plant's ability to draw on water deep in the soil.

#### Traits for accessing available moisture.

A deep and vigorous root system that can efficiently extract water helps plants under drought, although devoting excessive resources to the roots may detract from other tolerance traits.

# Conservation Agriculture and Drought

## Traits for water use efficiency.

Essentially, this means more crop per drop due to traits that promote efficient use and distribution of the plant's internal water resources for cooling, metabolic functions and photosynthesis. For example, under severe stress after flowering, the photosynthetic capacity of the wheat spike itself can help fill the grain, and scientists can breed for spikes that stay green later into the season.

## Traits that protect the plant from intense sunlight.

Reduced leaf chlorophyll, leaf rolling, and waxy, hairy, erect leaves all protect against radiation and the drying effects of intense sunlight. Antioxidant systems can protect plant cells from the damaging biochemical effects of excess radiation, but more research is needed to use this for breeding purposes.

## GOING GLOBAL, SEEKING NEW DIVERSITY

CIMMYT breeders have made good progress through "smart crossing," according to Reynolds. "The resulting lines have been screened for disease resistance and a number are being tested in preliminary yield trials for possible inclusion in international nurseries." In the meantime, wheat researchers are looking far and wide for new sources of drought tolerance traits. CIMMYT's wheat germplasm bank alone has more than 160,000 unique seed samples of wild, farmer-developed, and scientifically bred ▶

In recent decades, CIMMYT has worked with partners to develop and promote new cropping methods that save time, money, soil, and water, among other resources. As described in articles further ahead, many maize and wheat farmers in developing countries are beginning to test and adopt so-called "conservation agriculture" practices, which include reducing or eliminating tillage, seeding directly into residues from previous crops, and using more diverse crop rotations. In most settings, the practices can capture, retain, or make better use of water than farming methods based on extensive cultivation and residue removal. Often, they may make the difference between an acceptable harvest and crop failure in dry years.

Research and farmer experience have shown that keeping crop residues on the soil surface protects the soil from heavy rainfall and helps capture and channel water, avoiding runoff and stemming soil erosion. Surface residues also shield the soil from sunlight and dry air, reducing evaporation. As surface residues rot, the soil gains organic matter and porosity, aiding infiltration. When stalks and roots left in unplowed soil decompose, the space they occupied becomes a network of tunnels through which water can enter and permeate the plot. With support from CIMMYT and partners, wheat farmers in Central Asia who formerly plowed away residues are discovering the benefits of letting them lie (see "Islands of Residue: Fighting Erosion and Fostering Wheat Productivity in Kazakhstan," p. 44).

Direct seeding into residues from a previous crop cycle allows the following crop to take advantage of any moisture left over. Wet soils normally complicate tillage operations; with no tillage and in the presence of residues, residual moisture is a boon. Also, the time gained by avoiding extensive

tillage—as much as two weeks—allows the crop to develop more fully and, often, mature in time to avoid late-season drought or high temperatures. These principles are part of the reason why, over the last four years, with help from CIMMYT and the Rice-Wheat Consortium for the Indo-Gangetic Plains, farmers on nearly two million hectares in South Asia have begun sowing wheat directly into rice paddies at or just after rice harvest. Previous land preparation practices for wheat required as many as seven tractor passes.

Farmers in irrigated settings are quickly becoming aware of the advantages of cropping on raised beds. Those who sow on the flat normally flood their fields, an inefficient way to distribute the water. With raised beds that measure from 0.6 to 0.9 meters in width from furrow to furrow, the water flow is channeled more effectively and penetrates the beds evenly from the sides. Irrigation is faster and the water savings are even more dramatic than those from direct seeding (see "Clarion Call to Conservation in El Bajío," p. 30). Combining permanent raised beds with direct seeding and a residue cover brings all of the benefits mentioned in this section.

Breeding strategies at CIMMYT are evolving to reflect the needs and challenges associated with conservation agriculture. On one hand, this will involve developing and selecting new varieties for raised beds or for zero-tillage. In addition, experience and research suggest that conservation agriculture brings with it a new spectrum of diseases and pests. The effects of some can be addressed through management practices such as rotations, but it will also be useful for breeders to endow new varieties with resistance to such constraints.

varieties from around the world. Researchers have also been working for a decade uncovering and accessing useful traits—including improved productivity under drought stress—from the vast pool of genetic diversity in a type of bread wheat called “synthetics,” created by crossing durum wheat with wild grasses.

Finally, genetic engineering offers the possibility of using drought tolerance genes from other plant species. CIMMYT has transformed wheat varieties with a gene called DREB provided by the Japan International Center for Agricultural Sciences. From the common flowering plant *Arabidopsis thaliana*, the gene is of interest because it conveys certain drought tolerance traits. In the first ever transgenic wheat field trials in Mexico, preliminary results showed that DREB wheat plants had cooler canopy temperatures and better developed roots, and stayed green longer under drought stress than control plants. However, grain yields of DREB and normal plants were roughly equal under drought, further indicating the complexity of drought’s effects on productivity.

## HOPPING ON THE SHUTTLE

Experimental, drought tolerant wheat lines and varieties must be tested under diverse soil and climate conditions, pest and disease pressures, to verify the expression of tolerance. Each year CIMMYT ships dozens of trials of experimental

lines and varieties of maize and wheat to hundreds of partners worldwide for testing under local conditions. Participants return data to CIMMYT and incorporate useful materials into their breeding programs. Drought tolerant varieties are tested this way.

Another practice for developing and testing varieties is “shuttle breeding,” pioneered by Nobel Laureate Norman E. Borlaug and his CIMMYT colleagues in the 1960s. They developed new wheats quickly by running two breeding cycles per year instead of one: a winter cycle in the northern desert of Sonora and a summer crop in the central Mexican highlands. This not only fast-forwarded selection, but also exposed test varieties to radically different day lengths, temperatures, altitudes, and diseases.

Shuttle breeding continues today within Mexico and between CIMMYT and partners in places like China and Central Asia. The approach is particularly appropriate for drought tolerance, given the weighty influence of environment on the expression of specific plant traits. At CIMMYT’s Ciudad Obregón station in northern Mexico, researchers use controlled irrigation to create artificial droughts of the types found in the world’s major wheat growing areas. Wheat lines that perform well under stress at Obregón are screened in the cool highlands of central Mexico under well-watered conditions and exposure to foliar diseases.

Promising lines are selected again under diverse drought regimes at Obregón, and later shuttled back and forth between Mexico and locations in Asia and Latin America.

“We’ve found that screening under drought at Obregón links up with most environments around the world,” observes Trethowan. “Where it doesn’t, we go back and look for variables in our stress regimes that may influence target environments. Environments where conventional screening in Mexico doesn’t work effectively are a high priority for shuttle breeding.”

In many wheat zones, other constraints—soil-borne diseases and pests, infertile or saline soils—heighten drought’s effects and complicate the development of tolerant varieties. With support from Australia’s CSIRO and the Molecular Plant Breeding Cooperative Research Center, CIMMYT and partners are using molecular markers to identify genes for resistance to soil-borne diseases and to pests such as nematodes.

The recent successes in developing drought tolerant wheats at CIMMYT have built on significant progress made by former breeders. “Recent improvements in productivity under stress are attributable to combining the best materials from earlier work with new and different sources of genetic variation for drought tolerance,” Trethowan says.

## MAIZE: KEEPING SILKS AND TASSELS ON TIME

Maize in the developing world is almost exclusively rainfed, often sown by smallholders using few inputs and minimal management. Drought can strike maize throughout the growing season, but extensive research has shown the crop to be most sensitive to lack of moisture at flowering time. The male and female flowers—the tassels and the silks—are physically separated on the maize plant. They must develop more or less in synchrony for ovules to be pollinated and form grain. Parched plants may suffer desiccated silks and pollen. Worse yet, they may delay or forego silking; the longer the delay, the less grain develops.

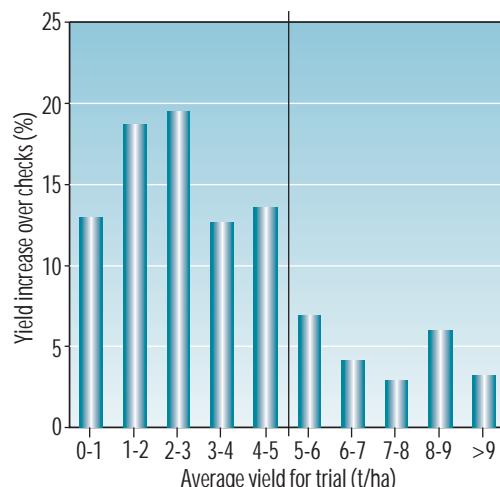
During the early 1990s, with generous support from the United Nations Development Programme, a team of CIMMYT maize physiologists perfected the measurement of flowering synchrony as a simple yardstick to identify and improve drought tolerance in tropical maize. In this system, researchers methodically stress experimental maize crops, depriving them of water, and then select the plants whose silks develop soon after tassels appear. Plant types that pass this test through several seasons can yield as much as 50% more than normal maize under harsh, mid-to-late season drought. The plants are also tested under well-watered

conditions. In the end, only those that do well in both stressed and favorable settings are used to develop varieties for farmers, thus ensuring superior harvests in both good years and bad. The approach is relatively easy and does not require special equipment, making it ideal for use in developing countries. As an added bonus, the method also improves the performance of maize in nitrogen-poor soils.

## MAIZE STRESS BREEDING: APPLICATIONS AND IMPACTS

Field-based screening and selection for drought tolerance have become key components in most CIMMYT maize breeding efforts. Breeders try to “pyramid” multiple traits—including drought tolerance—into varieties destined for stress-prone ecologies in Africa, Asia, and Latin America. The overall approach is to:

- Test experimental lines and varieties under prevalent stresses in the target environment, carefully applying abiotic stresses such as drought and using natural “hot spots” or artificial inoculation/infestation to select for resistance to pests and diseases.
- Work with partners to recycle and test elite, stress-tolerant lines.
- Develop new experimental varieties that carry the desired combinations of traits for performance under stress-prone conditions and are acceptable to clients and farmers.



Average yield advantage of CIMMYT drought tolerant hybrids over conventionally selected commercial hybrid checks, when evaluated under random stress conditions across 36–64 locations in eastern and southern Africa, 2000–2002. The further to the left the bar, the more extreme the stress—that is, the first bar indicates that yields of CIMMYT hybrids were on average 13% better than those of hybrid checks in a trial where drought and other stresses were so severe that all yields averaged 1 ton per hectare or less.

Compared to traditional breeding approaches, this has resulted in dramatic progress in drought-prone environments, and has so far led to the production of over 45,000 tons of seed of stress tolerant maize varieties in Africa alone, in response to demand. Using this breeding approach for only three to five years resulted in an *average* breeding progress of 15–20% under random stress conditions across eastern and southern Africa and at yield levels equivalent to those of drought-affected farmers’ fields (see figure). “We feel that we’ve only just scratched the surface of exploiting genetic variation for drought tolerance in maize,” says Marianne Bänziger, Director of CIMMYT’s African Livelihoods Program. ▶

# An Innovative Tool and Genetic Map Chart a Novel Course to Drought Tolerant Maize

Examples of on-going CIMMYT efforts where drought tolerance in maize is a priority trait include:

- In eastern Africa, CIMMYT and partners are developing early-maturing maize that tolerates or resists several key constraints: drought, the parasitic weed *Striga*, stem borers, and maize streak virus. High-yielding, locally-adapted varieties from this work are being adopted by farmers in numerous settings (see "CIMMYT Varieties Shine at World's First Millennium Village," p. 17). A particular focus is quality protein maize (QPM), which contains enhanced levels of the essential amino-acids lysine and tryptophan. Efforts have been funded by UNDP, the Swedish Agency for International Development Cooperation, the Rockefeller Foundation, BMZ-Germany, IFAD, and the OPEC Fund for International Development.
- Projects in southern Africa focus on tolerance to drought and poor soils, while developing and disseminating locally-adapted QPM for the midaltitudes of eastern and southern Africa. These efforts have been supported by the Swiss Agency for International Development, the Rockefeller Foundation, and the Nippon Foundation.

- With support from the Asian Development Bank (ADB), as of 2005 CIMMYT is helping national research programs to develop and deliver high-yielding varieties for drought-prone areas in southern China, Indonesia, the Philippines, Thailand, and Vietnam. This initiative builds on the achievements of the ADB-funded Asian Maize Biotechnology Network (AMBIONET), and will also focus on stem borers and acid soils.
- With support from CIDA-Canada, CIMMYT and partners are developing QPM varieties that tolerate drought, poor soils, diseases, and insect pests for the lowland tropics of Central and South America.

Several projects involve research to identify and apply molecular markers in selection for drought tolerance (see "An Innovative Tool and Maize Map Chart a Novel Course to Drought Tolerance Maize," this page). Center staff are also assessing the potential of genetic engineering to enhance drought tolerance in maize, according to Bänziger: "Our initial impression is that transgenically-based tolerance is not superior to that achieved through conventional selection, but a combination of conventional plus transgenic tolerance may hold promise." ▲

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Over the last decade, CIMMYT researchers have been using molecular and phenotypic data gathered across diverse maize populations, years, and environments to identify genes and chromosomal regions related to drought tolerance traits such as stress tolerance at flowering. The challenge was to *map* the position of the regions on the chromosomes and determine whether those identified indicated a common tolerance mechanism across maize populations and environments. A tool to visualize all the data easily would help identify the chromosome regions of interest and facilitate their use in breeding programs.

"To address biological questions more fully and to extract more information from our wealth of data, researchers needed tools to integrate data sets dynamically and analyze them in a biologically meaningful framework. This is what we set out to do," says Mark Sawkins, CIMMYT molecular geneticist.

CIMMYT assembled genotypic and phenotypic data from six maize populations and multiple environments ranging from Zimbabwe to the high plateaus of Mexico. "Making sense of this data in the format produced by the analysis software was a daunting prospect," comments Sawkins.

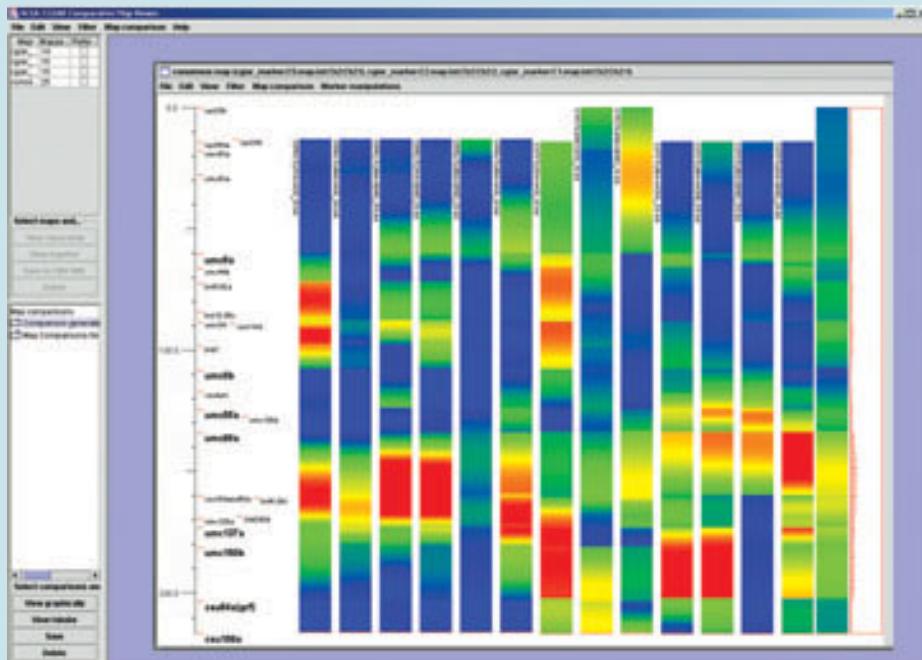
In 2001, CIMMYT, the US National Center for Genome Resources (NCGR), and three sister CGIAR centers got the ball rolling with a pilot project that assembled a rudimentary tool to compare genetic maps. From this starting point, and with support from the Rockefeller Foundation, the USAID Cereals Comparative Genomics Initiative, and, later, the Generation Challenge Programme,\* CIMMYT and UNCR developed the tremendously flexible and functional Comparative Map TV, which integrates and displays complex data and maps for drought tolerance and other traits.

"The CMTV provides a powerful tool for accessing data such as that found on the maize drought consensus map," says Sawkins. "At the click of the mouse button, users can display on a screen a broad array of trait data aligned onto a genetic map, manipulate these in any manner they choose, and easily link these data to additional data from either their own work or from a multitude of public databases."

\* The Generation Challenge Programme ([www.generationcp.org](http://www.generationcp.org)) is an international consortium that unites centers of the CGIAR, advanced research institutes, and national agricultural research systems to develop and use genetic tools and resources to meet the needs of resource-poor farmers in developing countries.

Genetic data can be retrieved based on numerous parameters and comparisons drawn through the use of "heat strips," a visual representation developed specifically for the CMTV. The heat strips indicate the correlation of chromosomal regions with the selected traits or other criteria through colors on the respective bars, thus providing users with a quick way to look for potential regions of interest over traits, environments, and genetic backgrounds.

"CIMMYT was uniquely positioned to develop and implement this 'drought consensus' map, and with it, the CMTV tool," says Jean-Marcel Ribaut, who formerly worked on the project and now heads the Generation Challenge Programme. "No other public institution has the same, large genetic data sets on segregating populations for drought tolerance traits by environment and crop. We not only advanced CIMMYT's efforts to apply molecular research to maize breeding, but we helped develop a tool that will benefit agricultural researchers across all crops and all regions."



This figure replicates the actual view from CMTV of complete quantitative trait loci (QTL) results across multiple experiments and traits for maize chromosome 2. Notated line on the left indicates marker locations on the chromosome. On the bars, red indicates that a region that is above a particular significance level or "hot" or high for a particular trait; yellow the correlation is still high but below the level of significance; and green, where the correlation is somewhat "cooler." Both yellow and green indicate a strong "tendency" that the genomic region is of importance. Blue indicates that the area is "cold" and insignificant.

AFRICA:  
HOME OF THE WORLD'S  
DEEPEST POVERTY, WHERE THE  
NUMBER OF POOR PEOPLE HAS  
DOUBLED—TO 314 MILLION—  
AND THE AMOUNT OF FOOD  
PER PERSON HAS FALLEN OVER  
THE LAST 20 YEARS. MAIZE IS  
A PRIMARY STAPLE FOOD AND  
AN OCCASIONAL CASH CROP  
THROUGHOUT THE REGION.  
FARMERS MUST USE THEIR  
VERY LIMITED SOIL AND  
WATER RESOURCES WITH THE  
GREATEST EFFICIENCY TO  
IMPROVE AGRICULTURE,  
NUTRITION, AND INCOMES.



CIMMYT IN AFRICA

# Kenyan Researchers Sow First Field of Transgenic Maize

ENCOURAGED BY RESULTS OF LABORATORY AND BIOSAFETY GREENHOUSE STUDIES, THE INSECT RESISTANT MAIZE FOR AFRICA PROJECT BEGAN FIELD TRIALS WITH TRANSGENIC MAIZE. EDITORIALS IN *THE NEW YORK TIMES* AND THE *INTERNATIONAL HERALD TRIBUNE* CALLED THE PROJECT "...A CAREFUL ENDEAVOR TO TEST GENETICALLY MODIFIED CROPS AND MAKE THEM WORK FOR THE SMALL FARMER."

**O**n 27 May 2005, staff of the Kenya Agricultural Research Institute (KARI) sowed the first insect-resistant transgenic maize seeds into Kenyan soil, under confined field trial conditions at an open quarantine site (see "What Is an Open Quarantine Site," p. 16), as part of the Insect Resistant Maize for Africa (IRMA)<sup>1</sup> project. The first genetically modified maize grown in sub-Saharan Africa outside of South Africa, the experiment—and the project itself—are aimed at helping Kenyan farmers reclaim some of the 400,000 tons of maize grain they lose each year to stem borers.

A KARI-CIMMYT partnership begun in 1999, but built on decades of fruitful collaboration, IRMA uses conventional breeding and biotechnology to develop and offer locally-adapted, insect resistant maize varieties. The controlled field trial contained a maize variety that had been genetically modified with a gene from the common soil

bacterium, *Bacillus thuringiensis* (Bt). The gene codes for a protein that impedes digestion in moth larvae like borers, and has served as the active ingredient in many organic pesticides since the mid-1900s. In contrast to South Africa, where Bt maize from private companies has been grown for nearly a decade, in Kenya the maize eventually delivered to farmers through IRMA will be free from legal restraints against planting or distributing saved seed. "It may seem trivial, but this type of contrast underlines the importance of IRMA, which applies cutting-edge science to benefit smallholders in Africa," says IRMA project manager and CIMMYT breeder Stephen Mugo.

The trial was intended to determine the effectiveness of different Bt genes and their combinations against four species of Kenyan stem borers under field conditions and to refine the

<sup>1</sup> IRMA is funded by the Syngenta Foundation for Sustainable Agriculture and the Rockefeller Foundation.



adaptation of the experimental varieties to Kenyan settings. The open quarantine trial site is a one-hectare plot on KARI's Kiboko research station 150 km southwest of Nairobi. Developed in 2003 under IRMA auspices, the facility features internationally accepted biosafety controls to ensure that plants and pollen stay within its confines.

## WORLDWIDE ATTENTION ATTENDS THE PLANTING

The worldwide media spotlight shone on the trial planting, with some of the world's most influential and prestigious outlets covering the event. The BBC science and technology radio program *Discovery* featured interviews with KARI director Romano Kiome, Mugo, and KARI scientists Simon Gichuki and Catherine Taracha. Kiboko farmer Harrison Chuma spoke on the program about the myriad setbacks he faces to feed his household on his maize crop, qualifying stem borers as second only to drought in stealing yields: "Even when I use

irrigation on my maize, the stem borers stop me from harvesting what I should."

## IRMA ARMS FARMERS AGAINST MULTIPLE THREATS

IRMA is also working to safeguard the maize harvests of Chuma and other smallholder farmers in Africa by endowing seed with resistance to another insect pest—the larger grain borer—that feeds on stored maize ears. Chemical controls for this insect are costly and potentially harmful to farm families and the environment. The associated lab and field work takes place at KARI's Kiboko, Embu, and Kakamega research stations.

Six IRMA maize varieties developed using conventional (that is, non-transgenic) sources of insect resistance are being grown in Kenya national maize performance trials, after successful completion of which some or all will be released for use by farmers.

## SETBACKS BUT STEADY PROGRESS

The project has not been completely free from problems. For example, because of an experimental error—the application of a systemic pesticide to one of the Kiboko test plots in mid-June—that plot had to be harvested prematurely. After Kenya's National Biosafety Committee (NBC) and the Kenya Plant Health Inspectorate Service (KEPHIS) granted the required permissions, the trial was replanted.

As the editorial in *The New York Times* asserts, "The Kenya study is a model of how to do it and a warning about how difficult adapting this technology for poor farmers will be." IRMA will only succeed with "...financing and permissions ...help from governments and foundations, and cooperation from biotech concerns."

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# What Is an Open Quarantine Site?



AT FIRST GLANCE, THE KIBOKO OPEN QUARANTINE SITE IS JUST AN ORDINARY FENCED-OFF FIELD. ON CLOSER INSPECTION, HOWEVER, A LARGE SIGN IDENTIFIES THE FIELD AS THE KARI/CIMMYT QUARANTINE FACILITY. ANOTHER SIGN, NEXT TO A LOCKED GATE AT THE ENTRANCE, INFORMS YOU OF ACCESS RESTRICTIONS TO THE FACILITY, AND SPELLS OUT SAFETY MEASURES FOR THOSE WITH AUTHORIZED ACCESS.

The two signs, two-meter-high chain-link perimeter fence topped with barbed wire, locked gate, and round-the-clock security are just some of the many special features that ensure genetic and material confinement within the one-hectare facility, as stipulated by the Kenya Plant Health Inspectorate Service (KEPHIS).

The distance of the site from other maize fields—some 400 meters—is another important biosafety feature. This, along with the disinfectant-treated stepping mat and drive-through at the single entry point, pits for burning biological residues from the trials, and dustcoats for use

inside, ensures that no pollen, seed, or other plant material can escape the trial area and that the transgenic maize will not cross inadvertently with maize not included in the experiments. Excess plant and other biological material is gathered, dried in the sun, and burnt, and the ash buried in pits on site. Bright yellow basins atop wooden stands are traps to monitor the diversity and numbers of flying insects in the trials. Plastic tumblers sunk into the ground and containing a preservative liquid capture and allow measurement of crawling insects. Finally, IRMA provides continuous training for on-site personnel.

## CIMMYT Maize Shines at World's First Millennium Village

THE TURN-AROUND IN THE FORTUNES OF THE VILLAGERS OF BAR SAURI, THE WORLD'S FIRST MILLENNIUM VILLAGE, MAY FIGURE AMONG THE MOST SUCCESSFUL DEVELOPMENT EFFORTS. CIMMYT MAIZE IS CONTRIBUTING TO THE VILLAGE'S NEWFOUND WELLBEING.

The millennium village concept, the brainchild of Jeffrey D. Sachs, UN Special Envoy on the Millennium Development goals (MDGs), is an experiment designed to show that, for a modest investment and support, it is possible to pull people out of hunger and poverty and set them on the road to prosperity.

Just a year ago, the 5,000-odd smallholders of Bar Sauri in western Kenya were among the poorest in Kenya. Hunger, malaria, and HIV-Aids had since the 1980s taken their toll on the community, effectively arresting any chance the villagers had for development. The normal farm in Sauri is less than half a hectare and typically supports a three-generation household numbering as many as 12 persons. Until 2003, most Sauri farmers grew *nyamula*, a local maize variety that yielded at best around 800 kilograms a hectare—insufficient to see even the smaller households through to the next harvest. Sauri residents were undernourished, particularly the women and children, and it was showing in consistently low grades at Sauri's Nyamnina Primary School. Still, the villagers' resilience and will to help themselves led to Sauri's selection as the model millennium village in 2004. The village became the beneficiary of and participant in a five-year project to show how poverty can be eliminated.

The first hurdle was to overcome hunger, making agriculture the immediate priority intervention. In early 2005 villagers received farming inputs—hybrid maize seed and fertilizers—and training on the proper way to grow their maize. "We were looking for the best hybrid maize varieties available in Kenya," says Pedro Sanchez, Co-chair of the UN Millennium Project Hunger Task Force, the Earth Institute, Columbia University, and former director general of the World Agroforestry Center. Sanchez selected two hybrids developed as part of the Africa Maize Stress project,<sup>1</sup> a joint effort of CIMMYT, the International Institute of Tropical Agriculture, and national research programs in West, Central, and Eastern Africa. Project leader and CIMMYT maize breeder Alpha Diallo explains how the two hybrids came out on top: "WH502 and WH505 are high yielding, but they're also able to tolerate locally important diseases and low nitrogen and drought stress."

Commercialized by the Western Seed Company just two years ago, they have quickly become the most popular hybrid maize varieties in western Kenya, and are sown by some 200,000 farmers on approximately 50,000 hectares.



Jeffrey D. Sachs

By July 2005 the villagers were able to witness what a combination of quality seed, proper management, and good rains could do for their crop, harvesting 4 tons of maize per hectare. "The last time we saw maize like this was 1970!" says farmer Euniah Akinyi Ogola, whose plants gave cobs the length of her forearm. The unprecedented bumper crop prompted villagers to organize a harvest festival marked by drumming, singing, and dancing. "I am thrilled that CIMMYT materials met the MDG challenge so brilliantly!" says Diallo, who took part in the festivities along with Sachs and dignitaries from around the world. ▶

<sup>1</sup> The full name of the project is "Developing and Disseminating Stress Tolerant Maize for Sustainable Food Security in West, Central and East Africa." It is funded by IFAD, Sida, BMZ and the Rockefeller Foundation.

UNICEF Executive Director and former US Secretary of Agriculture Ann M. Veneman was guest of honor. "The MDGs, with their promise for a better future, are all about the children," she said in her address. "The world has come to celebrate your harvest with you!" Hons. Mrs. Charity Ngilu, Kenya's Health Minister, remarked that if the Sauri experience could be replicated throughout Kenya, the country would have no trouble meeting the first Millennium Development Goal—halving extreme poverty and hunger—by the target of 2015.

Sanchez, a noted agronomist whom the villagers have fondly nicknamed *Odera Kang'o* (a famous chief of the Luo people during Kenya's colonial period), told Bar Sauri inhabitants they could expect sustained good harvests, thanks to the *Calliandra* trees intercropped with the maize: "These nitrogen-fixing trees will improve the soil's fertility, reducing or eliminating the need for additional mineral fertilizers."

While the final impact of the MDG project on Sauri and other villages remains to be seen, the five-year pilot phase has already strengthened the school feeding program and made a previously

defunct village clinic operational. Sachs said the project would now work with the villagers to construct safe storage facilities for harvests and start planting higher value crops. He also spoke of scaling up the MDG concept to hundreds of thousands of villages in Kenya and throughout the world. Already Koraro village in Ethiopia has started MDG-focused programs.

For Diallo, the challenge remains to continue breeding even better maize to counter the diverse climatic and biological stresses in developing world ecologies, because, as he says, "...you never know where the next Sauri will be."

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# An Extra Coat Helps Maize Seed Fight Pernicious Weed

A QUICK AND INEXPENSIVE SOAKING IN HERBICIDE MAKES MAIZE SEED IMPERVIOUS TO ONE OF ITS WORST ENEMIES IN SUB-SAHARAN AFRICA—THE PARASITIC FLOWERING PLANT, *STRIGA* SPP. THE PRACTICE, WHICH INVOLVES THE USE OF HERBICIDE RESISTANT SEED, WAS DEVELOPED BY CIMMYT AND PARTNERS. FARMERS IN EASTERN AFRICA MAY ENJOY FAR BETTER HARVESTS AND FEWER WORRIES.

**Y**early, the weed choked the crop on Zedekiah Onyango's 0.3 hectare plot, stealing half the harvest. When Western Seed Company sought farmers to test a new *Striga*-fighting maize, Onyango was eager. "Western gave me the seed, and I grew it using my usual farming techniques on this plot," says Onyango, near a five-by-five-meter patch of a healthy, *Striga*-free maize crop surrounded by *Striga*-stunted maize.

The technology comes from nine years of Rockefeller Foundation-funded collaborative research by CIMMYT and multiple partners—"...a classic example of partnership," according to Peter Matlon, director of the Rockefeller Foundation's Africa Regional Program. Partners included the Kenya Agricultural Research Institute (KARI), the Weizmann Institute of Science (effort led by Jonathan Gressel), BASF, private seed companies, and local non-governmental organizations. The practice is simple: herbicide resistant maize seed is coated lightly with Imazapyr; the herbicide kills the

*Striga* sprout when it tries to attach to the maize seedling. As part of this research, CIMMYT and partners took advantage of a natural mutation in maize to breed locally-adapted varieties that withstand imidazolinone-based herbicides. BASF is marketing the seed-and-coat control system under the commercial name Clearfield®.

Farmer field studies show that the practice restores the 50-100% production otherwise lost to the weed, and is affordable to even the lowest-income groups. For just under US\$ 4 for a 2-kg bag of the seed (enough to sow 0.1 hectares), on-farm trials found a three-fold yield increase over *Striga*-infested maize—at an average value of US\$ 53. The practice also helps protect future harvests by depleting the weed's seed reservoir.

## PUTTING *STRIGA* ON ITS HEELS REGION-WIDE

A highly invasive parasite, *Striga* infests 400,000 hectares of Kenya's farmland. The weed overruns 40% of the arable land in Africa's savannahs,

threatening the livelihoods of more than 100 million people who depend on cereal crops for food and income. Kenyan maize farmers lose at least US\$ 50 million annually in grain to *Striga*. The parasite hits hardest in the shallow, depleted, and acidic soils cropped by the poorest farmers.

Three seed companies in Kenya are producing the new herbicide-coated hybrid maize under the common name *Ua Kayongo* (literally "kill *Striga*") H1–4. The new control method will be released in Tanzania, Uganda, and, later, 16 other countries of sub-Saharan Africa, in a process spearheaded by the African Agricultural Technology Foundation (AATF) with DFID support.

CIMMYT agronomist Fred Kanampiu says the technology is not a permanent solution, "...but a stopgap that buys farmers time and resources to apply other control measures. It will also allow breeders to develop strong *Striga* resistance in maize."

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Starved of nutrients by *Striga*, infested maize develops more root hairs than normal to pull additional sustenance from the soil—thus the fluffy appearance.

LATIN AMERICA:  
MAIZE, BEANS, AND POTATOES—NATIVE  
ENDOWMENTS OF THE HEMISPHERE—  
ARE FOOD, LIVELIHOOD, AND CULTURE.  
MILLIONS OF SMALL-SCALE FARMERS  
LACK ACCESS TO THE FRUITS OF  
RESEARCH OR EXTENSION, AND HAVE  
NOT BENEFITED FROM ECONOMIC  
RESTRUCTURING, GLOBAL MARKETS, OR  
PRIVATE SECTOR OFFERINGS. POVERTY  
STILL FUELS SOCIAL CONFLICTS, AND  
WANT OF ALTERNATIVES FORCES RURAL  
FAMILIES TO MINE THE ENVIRONMENT  
OR FLOCK TO THE CITIES, SWELLING  
THE RANKS OF URBAN POOR.



CIMMYT IN LATIN AMERICA

# Colombians Take Maize with Their Coffee

DISEASE RESISTANT  
MAIZE VARIETIES AND  
AGRONOMIC TRAINING  
FROM CIMMYT ALLOW  
COLOMBIAN COFFEE  
FARMERS TO DIVERSIFY  
AND PROFIT.

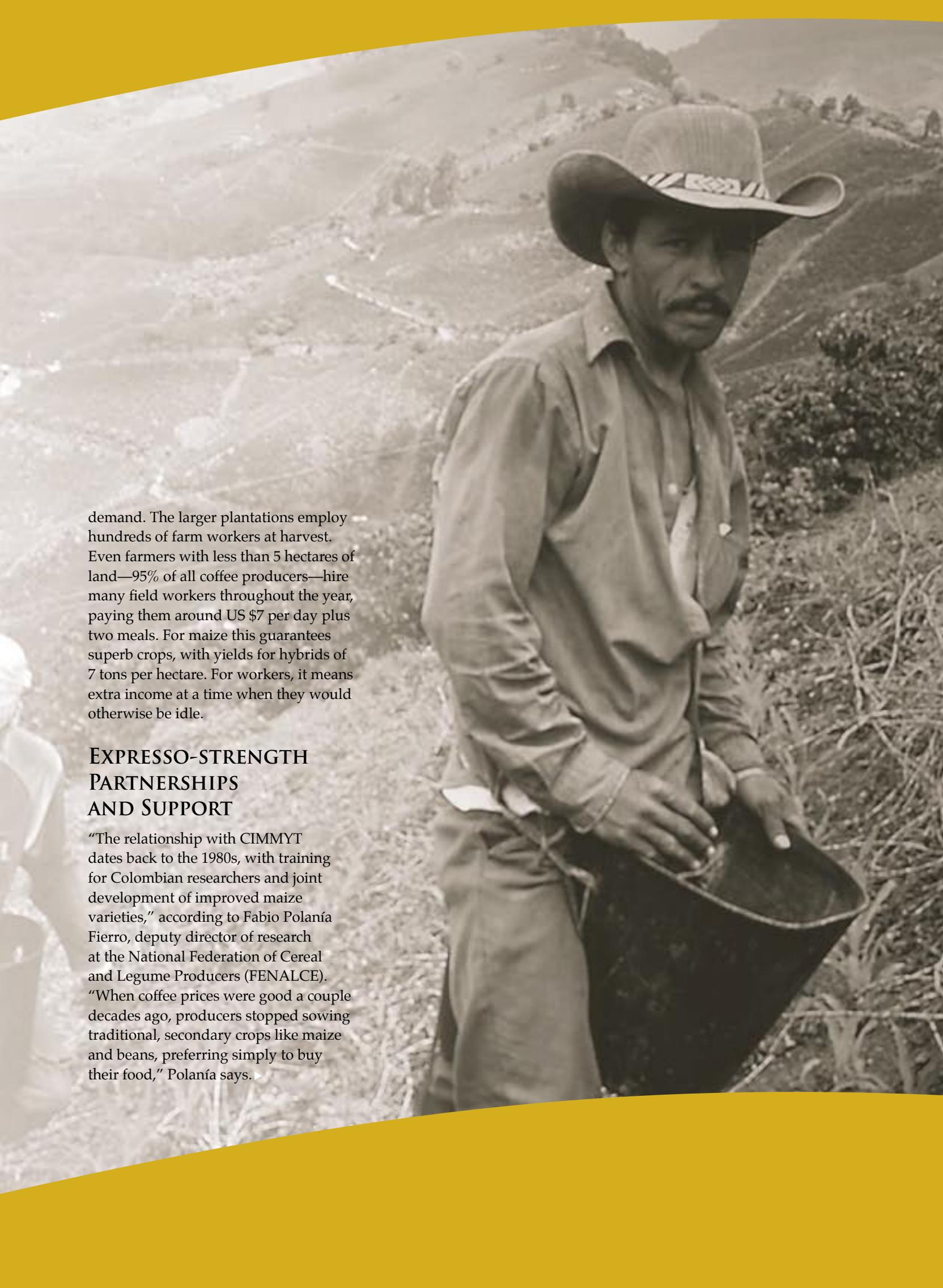
**W**ith help from CIMMYT and partners, many Colombian coffee growers have lately become convinced that sowing maize is more profitable than fighting weeds. In 2004 they raised 38,000 hectares of high-yielding maize between coffee rows in fields where coffee plants had been pruned. In the bargain, they pocketed good profits and added to the incomes and food security of hundreds of thousands of farm laborers. "A maize crop provides about 50 additional worker-days each growing season," says Gustavo Rincón, administrator of "La Holanda," a 160-hectare coffee plantation in Alegrías Valley, Risaralda Department, Colombia.

Rincón figures he gets a profit of US \$700 above cost on every hectare of maize he sows. Following recommended practices, he prunes coffee bushes to short stems after several harvests. He also replaces old plants with new ones every five years. During the 18 months or so the new or

pruned coffee plants take to yield beans, the land they occupy is normally unproductive and hosts vigorous stands of weeds. "Growing maize puts this land to profitable use, controls the weeds, protects plots from erosion, and, if proper care is taken of the soil, does not affect the coffee," Rincón explains. He sells much of his maize as whole ears for street-corner vendors in cities. The rest goes into feed for his farm animals, or is given away as a bonus to live-in plantation workers or coffee buyers. His peers generally market their output to intermediaries for use in poultry feeds.

## HANDS-ON APPROACH A BOON TO WORKERS

Growing coffee is an exacting, labor-intensive business. Producers draw on excellent soils and rainfall, good infrastructure and processing equipment, and long experience in agriculture. But no machinery is used for field operations: Andean hillslopes are too steep, and hands-on management is still the best way to get the quality consumers

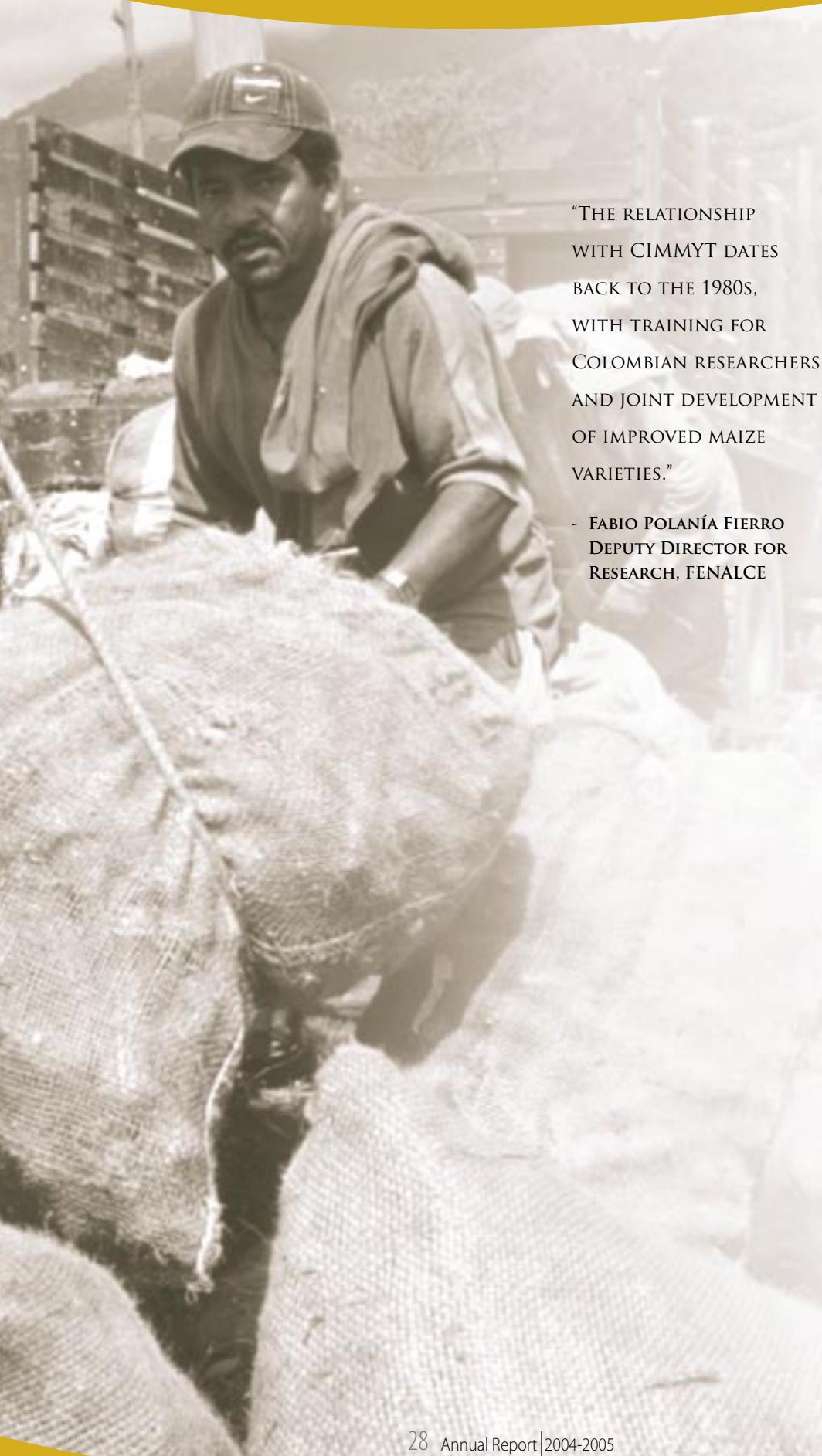


demand. The larger plantations employ hundreds of farm workers at harvest. Even farmers with less than 5 hectares of land—95% of all coffee producers—hire many field workers throughout the year, paying them around US \$7 per day plus two meals. For maize this guarantees superb crops, with yields for hybrids of 7 tons per hectare. For workers, it means extra income at a time when they would otherwise be idle.

### EXPRESSO-STRENGTH PARTNERSHIPS AND SUPPORT

"The relationship with CIMMYT dates back to the 1980s, with training for Colombian researchers and joint development of improved maize varieties," according to Fabio Polanía Fierro, deputy director of research at the National Federation of Cereal and Legume Producers (FENALCE).

"When coffee prices were good a couple decades ago, producers stopped sowing traditional, secondary crops like maize and beans, preferring simply to buy their food," Polanía says. ▶



"THE RELATIONSHIP  
WITH CIMMYT DATES  
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- FABIO POLANÍA FIERRO  
DEPUTY DIRECTOR FOR  
RESEARCH, FENALCE

This changed with free markets and falling global coffee prices throughout the 1990s, according to Luis Narro, CIMMYT maize specialist in South America. "In 2002, maize was identified as an attractive option to boost coffee producers' incomes," Narro explains, "but only if we could come up with new varieties resistant to two locally harmful maize diseases—tar spot and gray leaf spot." CIMMYT provided hundreds of experimental varieties for testing on experiment stations of the National Federation of Colombian Coffee Growers (FEDERCAFE) in 2002. "We identified two white-grained, disease resistant hybrids that yielded more than 10 tons of grain per hectare," says Narro. Later that year, FEDERCAFE, FENALCE, and CIMMYT signed an agreement to develop systems for producing maize on coffee plantations.

Meanwhile, with strong support from FEDERCAFE and the government, Colombian coffee growers have been sowing maize for several years, using commercial hybrids and applying

fungicides for disease control. "The Minister of Agriculture has given both political and financial support; this has been crucial," says Polanía, "and President Álvaro Uribe got interested and suggested the idea of a contest for the best maize crop."

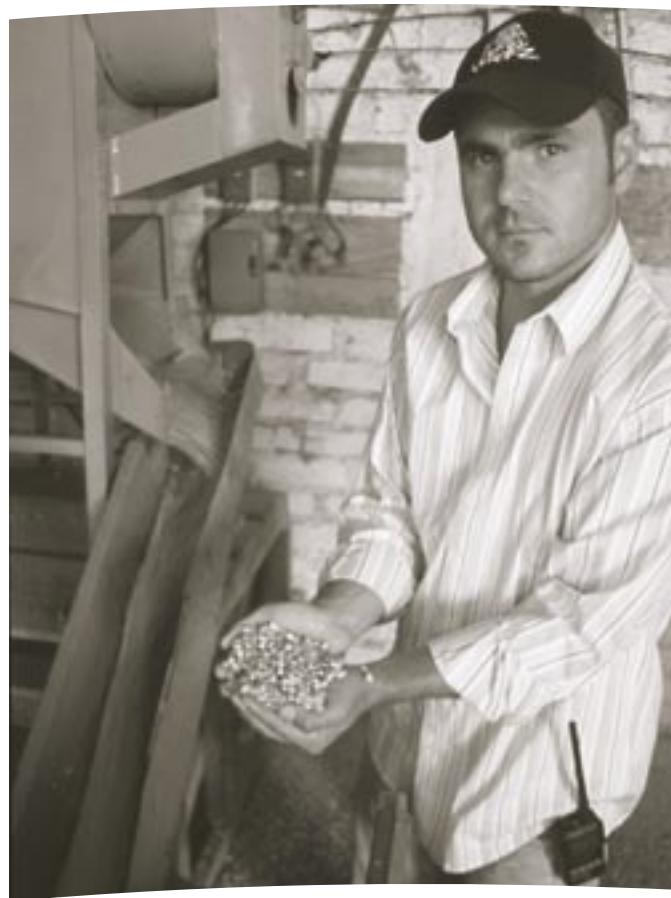
Encompassing more than half a million coffee-growing households and 800,000 hectares of coffee lands, FEDERECAFE has also thrown its considerable weight behind the coffee-maize marriage and provided diverse logistical and material support, says Edgar Echeverri Gómez, Technical Manager of the organization. Among other things, its legions of yellow-shirted, blue-capped extension agents are now knowledgeable in maize agronomy.

## DEMAND DRIVEN?

A major concern is ensuring markets for locally-grown maize. Colombians consume just over 3 million tons of maize each year as food, feed for poultry and pigs, and industry products. They produce slightly more

than a third of this and import the rest from places like Argentina or the USA. Foreign maize is cheaper than home-grown grain, although its quality is often lower.

"There's a market for Colombian maize—people prefer it for food products—but the demand is much less than for animal feed," says Alejandro Ochoa Norena, who received the first-prize trophy for maize productivity in 2004 from the hands of President Uribe. Ochoa and his sister Johana manage their father's coffee plantation near the town of Santuario, Risaralda Department. He says that marketing maize is an increasing challenge, and growers frequently go through middlemen. "This arrangement is often unfavorable for farmers," says Ochoa. Still, Ochoa and his peers are guardedly optimistic about the prospects for maize in the near term, and feel it offers a solid alternative for diversification. ▶



▲ To process maize harvests, Colombian coffee growers like Alejandro Ochoa Norena take advantage of much of the same equipment they use for sorting, washing, drying, and bagging coffee beans, but occasionally invest in specialized machinery, like the maize sheller shown here.

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# Making the Plow Passé in Mexico

WHAT STARTED AS A MONEY-SAVING TECHNIQUE AT A WHEAT STATION IS NOW TURNING HEADS FOR ITS ADVANCES IN CONSERVING RESOURCES AND BOOSTING MAIZE YIELDS.

**C**IMMYT's Toluca station is a centerpiece in wheat improvement, but is located in a mostly maize-growing part of Mexico. Station superintendent Fernando Delgado Ramos has become a pillar of knowledge on conservation agriculture and is changing the way some farmers think about the plow.

Julián Martínez, one of many farmers who have followed Delgado's recommendations to reduce tillage, keep residues on the soil, and sow on permanent, raised beds, says his maize yields have nearly doubled, since adopting the practices three years ago on his small farm in the Toluca Valley, southwest of Mexico City.

## DROUGHT OR DOWNPOURS: ZERO-TILLAGE STILL WORKS

Delgado's initiatives started out small in Central Mexico, but the conservation agriculture practices he promotes have piqued the interest of maize farmers nation-

wide, as they face water shortages, rising production costs, and low prices for their produce. From the community of San Andrés, Jalisco State, farmer Sergio Vázquez made the trip over 300 kilometers southeast to Toluca in 2004 for a demonstration by Delgado. He was immediately impressed by the savings from eliminating extensive tillage operations. Back home he tried to convince his cousin and partner, José Antonio Aranda, to apply the new methods. Aranda first refused but later relented. "That season it rained a lot and we saw we couldn't sow or, in some cases, even disk the plowed fields, so we tried zero-tillage and were able to plant 90 hectares," Vázquez explains.



► In the last few years Fernando Delgado, head of a wheat research station, has helped maize farmers, who flock to him for advice. He does this as a sideline, after a full day of office and field work.

Seeding directly into brush and residues was difficult, according to Vázquez, but not as hard as putting up with the laughter and sarcasm of local acquaintances. "Their comments changed when they saw our crop emerge and the weeds wilt away from the herbicide we'd used, and this led a few friends to try zero-tillage on some of their plots."

Suffering one of farming's cruel ironies, in spring 2005 the partners faced exactly the opposite from the previous year's dilemma: two dry spells of several weeks each, the first coming right at planting time. Vázquez had his soils tested and found enough moisture to germinate maize seeds, so he and Aranda sowed 210 hectares directly into the unplowed fields. Despite the droughts, their maize crop grew strong on the residual moisture. Neighbors using conventional tillage either had severely stressed plants or had to wait for rain and plant late, thereby risking yield losses from frost in the fall. "There are still many aspects we need

to improve," says Vázquez, "but we're convinced that zero-tillage is better than traditional tillage for profitable farming."

## THE TIDE IS TURNING

In the nearby state of San Luis Potosí, farm-group leader Carlos Rocha Cabrera has been in frequent contact with Delgado in search of ways to lower production costs for farmers he serves. "Using zero-tillage practices with irrigated maize, we've had savings of 40% in water, 80% in herbicide, and 80 and 40% in soil- and leaf-applied insecticides," says Rocha, who presides over the administrative council of "Agropecuaria y Forestal El Mezquite." Members of this farmer association are sowing some 350 hectares with no plowing and keeping residues on the soil, and have done experiments comparing the effects on soil moisture of varied amounts of residue. "Change [toward conservation agriculture] is coming from all agriculture sectors, including smallholders, those working former communal lands, and large-scale farmers," Rocha says, "and government support is growing."

## ECONOMICS: THE MOTHER OF INVENTION?

Delgado's movement toward conservation agriculture started as a way to save money in operations at the Toluca station by reducing machinery passes and use of water and fuel. Fifty percent of the station's land is used for wheat experiments, and the other half is devoted to crop rotations to sustain the land. It was there that Delgado started direct seeding on permanent beds to save money for use on other projects. Conservation agriculture caught his eye after a couple harvests, when yields went from 5-8 tons per hectare to 10.

CIMMYT agronomist Ken Sayre has traveled throughout the developing world, championing cropping diversification and use of permanent, raised beds. He heartily applauds Delgado's efforts. "People like Fernando still believe that improving crop production directly in farmers' fields is the most valuable way to achieve impact," he says. Delgado's practical initiatives are certainly finding an echo with Mexican farmers and helping many to increase their productivity and profitability in challenging times.◀

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# Clarion Call to Conservation in El Bajío

Joining the growing number of farmers worldwide squeezed by rising input costs, low grain prices, and degrading resources, farmers in Michoacán State, south-central Mexico, are moving toward conservation agriculture, assisted by researchers like Rebeca González Íñiguez. The northern section of the state is part of Mexico's El Bajío—a large region with rich soils, good rains, and extensive irrigation, but mounting problems relating, among other things, to improper use of agrochemicals and water. Michoacán farmers enjoy relatively large holdings—as big as 200 hectares—and practice an intensive rotation centered on irrigated wheat or barley in dry winter months and rainfed, summer maize or sorghum.

A cereal scientist at the Mexican National Institute of Forestry, Agriculture, and Livestock Research, González helped introduce the farmers to cropping on raised beds, a practice many are using to improve irrigation efficiency. "In 1994, we organized a visit by farmers to the CIMMYT research station at Ciudad Obregón, in northern Mexico, to learn about bed planting and better ways of managing irrigation," she says. "The furrows on either side of the beds speed up irrigation and channel the water so there are no flooded or dry spots in the field." González also brought them a bed shaping implement provided originally by CIMMYT wheat agronomist Ken Sayre, who encourages and supports González and the Michoacán farmers.

Soon after, to gain time and thus be able to sow more productive, longer-season maize hybrids, most of the farmers began seeding maize directly into residues with no tillage after wheat or barley harvest. "They picked this up from peers in another area of El Bajío, and besides allowing earlier sowing it has saved them the cost of plowing," says González. From there, it was a short leap to experimenting with year-round zero-tillage on permanent raised beds. Local farmer Moisés Orozco Velázquez began testing the approach with his brothers on part of their 100-hectare holdings in 2004, mainly to lower expenses. At first he didn't like some of the new ideas—like slashing fertilizer use—suggested by a brother studying agronomy. But he acceded



and was happily surprised at the results. "We cut our costs in half with savings in fertilizer, tillage operations, and field-hands, and our crop looks as good as or better than that of our neighbors, who used traditional tillage and lots more fertilizer," says Orozco. "We also had some heavy rains this year, and in lower-lying spots where we'd normally lose part of the crop to waterlogging, the infiltration was excellent." Now he and the family plan to apply a suite of resource-conserving practices, including year-round zero-tillage, on all their land.

Like other farmers adopting the new practices, Orozco is still struggling with diverse issues,

including optimal seeding and fertilizer rates and, above all, managing residues as plentiful as 15 tons per hectare each year. "We've found that if we spray urea on it, by sowing time the straw has begun to decompose," Orozco says. They also bundle and sell some straw for forage, but still have problems getting seeders to chop through residue and put seed in contact with the soil. González says this points up a major issue to solve: "The future of conservation agriculture in the region depends on farmers' access to effective, affordable machinery." Sayre and his associates are working on relevant designs that Mexican machine manufacturers can eventually build and market. ▶

▲ A small-grain cereals specialist, Rebeca González Íñiguez says a key part of her work involves listening to and learning from the accumulated wisdom of Mexican farmers like Agustín Orozco Velázquez, pictured here: "They know what they're doing and what they need; I simply try to provide support and guidance. If I don't know the answer to one of their questions, I call in an expert who can help them."

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# Reflected Rays Tell When to Feed Crops and Starve Sea Algae

A NEW TECHNOLOGY FROM  
CIMMYT AND OKLAHOMA

STATE AND STANFORD  
UNIVERSITIES WILL HELP  
DEVELOPING COUNTRY  
MAIZE AND WHEAT FARMERS  
TO BETTER TARGET AND  
REGULATE FERTILIZER  
APPLICATIONS. FARMER  
INCOMES AND THE QUALITY  
OF SOILS AND FISHERIES  
STAND TO BENEFIT.

**I**wish I had known about it this season—this will save me money," says Rubén Luders, a farmer who grows 400 hectares of irrigated wheat in the Yaqui Valley of Mexico's Sonora State. What Luders and more than 25 other farmers saw in a demonstration was an effective and accurate way to determine both the right amount of nitrogen fertilizer for a wheat crop and the best time to apply it. Traditionally farmers in the region fertilize before they sow and then again at first

irrigation. The new approach, developed in conjunction with Oklahoma State University (OSU), USA, uses an infrared sensor to measure the performance of wheat plants as they grow.

Conducted in the fields of four different farmer-volunteers, the demonstrations showed that farmers could maintain high yields using far less fertilizer. "We used to feed the soil first, before growing the wheat," says Luders. "Now we know we should feed the wheat." He and his peers calculated that the nitrogen sensor, which costs about US\$ 400, would pay for itself in a single season from savings in fertilizer use on just 80 hectares of wheat.

"I'd long been looking for something to determine nitrogen requirements," says CIMMYT wheat agronomist, Iván Ortiz-Monasterio. "It has taken time to calibrate it, but now we have a useful tool to determine the nitrogen a wheat plant needs."

The sensor is held above the growing plants and measures light reflected at two different wavelengths—red and invisible infrared. In technical terms this is called the normalized differential vegetative index (NDVI). After much testing, Ortiz-Monasterio and his colleagues from Oklahoma State found they could get a handheld computer to calculate plant nitrogen requirements from the readings.

## REFLECTED LIGHT ILLUMINATES SOIL STATUS AND NITRATE RUNOFFS

CIMMYT research associate and wheat agronomist Bram Govaerts has used the sensor to measure plant performance in a long-term experiment on maize and wheat conservation agriculture at CIMMYT's El Batán experiment station in south-central Mexico. "Variation of spectral reflectance within plots is a sound indicator

of agronomic mismanagement or soil quality problems," says Govaerts. "Uniform readings suggest that farming practices are sustainable."

Govaerts and CIMMYT post-doctoral fellow Mirjam Pulleman helped conduct a training course in September 2005 on the use of the sensor. Organized by CIMMYT wheat agronomist Ken Sayre and OSU researcher and former CIMMYT wheat agronomist William Raun and financed by the United States Agency for International Development, the workshop drew 27 participants, including 10 Mexican researchers and extension workers. Rebeca González Íñiguez, of Mexico's National Institute of Forestry, Agriculture, and Livestock Research, plans to use what she learned to help farmers adopting conservation agriculture in an intensively cropped area where fertilizer overuse threatens soil quality and incomes (see "Clarion Call to Conservation in El Bajío," p. 30). In this case, she will calibrate the sensor to fine-tune fertilization of farmers' rainfed, summer maize crop.

But there is more to this technology than just efficient farming. A recent Stanford University study published by the prestigious science journal *Nature* showed that excess fertilizer from northern Mexican

farms washes into the nearby Sea of Cortez. The extra nitrogen feeds blooms of algae that deplete sea-water oxygen—an effect that has spoiled fisheries in several parts of the world. Fertilizer-optimizing practices like the sensor help head-off the problem. "As farming systems intensify to feed more people, we need to minimize the environmental impacts," says Ortiz-Monasterio.

Just five days before the demonstration with Yaqui Valley farmers, researchers in Pakistan received their first infrared sensor, the result of a USAID linkage grant with CIMMYT and Oklahoma State. In this way, a technology proven in Mexican fields is going to benefit farmers worldwide and help maintain the health of coastal waters. ▲

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Iván Ortiz-Monasterio delivers a sensor to CIMMYT partners in Pakistan.



# A Maize Variety for Farmers on the Edge

PERUVIAN FARMER  
VIRGILIO MEDINA  
BAUTISTA AND HIS WIFE  
PAY FOR BOARDING  
SCHOOL FOR THEIR TWO  
CHILDREN BY GROWING  
MAIZE AND COFFEE ON  
SECTIONS OF THEIR 12-  
HECTARE HOMESTEAD.  
AFTER TESTING OTHER  
VARIETIES AND HYBRIDS,  
HE GROWS MARGINAL 28  
BECAUSE "...IT'S A GOOD  
MAIZE AND YIELDS WELL."



**O**n a hillside that abuts more than 3,000 kilometers of Amazonian expanse beginning in Peru and reaching clear across Brazil to the Atlantic, farmer Virgilio Medina Bautista weeds his maize field under the stifling equatorial sun. He and his wife Sabina Bardales typically arise before dawn to cook a meal for their field workers and work all day until bedtime, around 9 p.m. “We come to the field with the food for brunch and ready to work,” Medina says. “It’s a hard life, but there’s no other way, for someone without an education.”

Like 90% of the farmers in this region of Peru—the lowland zones east of the Andes known as the “jungle”—as well as many on the coastal plains or in inter-Andean valleys, Medina sows Marginal 28. This open-pollinated maize variety, developed in the 1980s by Peru and CIMMYT, is popular for its high yields and broad adaptation. It provides two or three times the average yield of the local variety

it replaced, and grows well in diverse environments. “Private companies have been trying to introduce maize hybrids here, but they yield only six tons per hectare,” says Edison Hidalgo, maize researcher from the National Institute of Agricultural Research (INIA) “El Porvenir” experiment station, whose staff help spread productive farming practices throughout the region. “Marginal 28 gives that or more, under similar management, and because it’s an open-pollinated variety, farmers don’t have to purchase new seed every season.”

Luis Narro, CIMMYT maize researcher in South America and a native of Peru who helped develop Marginal 28, says the cultivar’s adaptation and uses have far outstripped expectations. “This variety is sown most widely in jungle zones—truly marginal, lowland areas characterized by poor soils, heavy weeds, and frequent drought, to name a few constraints,” Narro says. “But I was just at a station in Ayacucho, ►

"THIS SUGGESTS PART  
OF THE VALUE OF A  
GLOBAL ORGANIZATION  
LIKE CIMMYT,  
WHICH CAN COMBINE  
CONTRIBUTIONS FROM  
AROUND THE WORLD  
TO DEVELOP A USEFUL  
PRODUCT FOR SMALL-  
SCALE FARMERS."

- LUIS NARRO,  
MAIZE BREEDER,  
CIMMYT, SOUTH  
AMERICA

at over 2,700 meters in the Andes, and saw seed production fields of Marginal 28 where yields were probably going to hit seven tons per hectare." Farmers in jungle areas use it chiefly for animal feed or for export to the coast. Coastal farmers grow Marginal 28 because the seed is relatively cheap and yields high-quality forage for their dairy cattle. In the Andes, the grain goes for food and snacks.

Its adaptability may be explained in part by its genetically diverse pedigree, which even includes as a parent an internationally recognized variety from Thailand. "This suggests part of

the value of a global organization like CIMMYT, which can combine contributions from around the world to develop a useful product for small-scale farmers," Narro says.

## CAN POOR FARMERS STOP CHOPPING DOWN JUNGLES?

Despite the clear benefits of Marginal 28, Peruvian farmers are still struggling as markets shift, production costs rise, and maize prices remain low. Farmer Jorge Dávila Dávila, of Fundo San Carlos, Picota Province, in the Amazon region of Peru, grows maize, cotton, banana, and beans on his 10-hectare homestead. Because he is



▲ Farmer Jorge Dávila

Dávila believes more outside assistance will be needed, if farmers in the region are to switch to environmentally friendly farming: "To stop cutting down jungle land, we need a proposal that lets us live off our farms."

relatively far from the trans-Andean highways leading to the coast, where maize is in heavy demand for use in poultry feed, middlemen pay him only US \$70 per ton of maize grain—well below world market prices. "Maize is a losing proposition; that's why so many farmers here are in debt," he says. "They can't take their maize to local companies for a better price, because they already owe it to the middlemen who provide inputs."

Unlike most farmers, Dávila makes ends meet through hard work and what he calls "an orderly approach" to farming. Many in the region slash and burn new brushland, cropping it for two or three seasons until

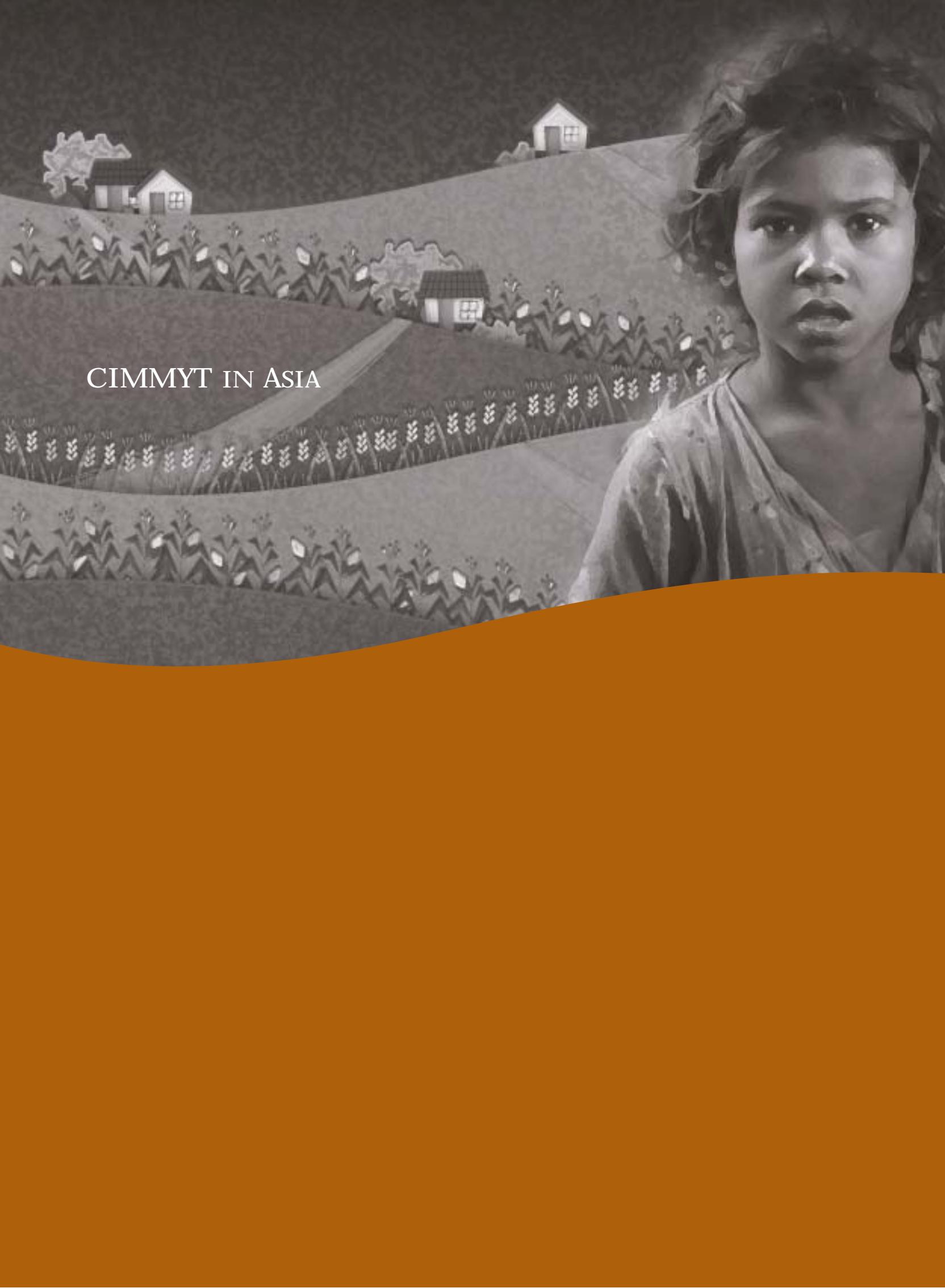
fertility falls off, and then they move to new land. Dávila has stayed put for eight years on the same fields. "I tell my neighbors not to cut down their jungle," he says. "I've seen that leaving (the brushland) brings me rain." With support from INIA researchers like Hidalgo, Dávila is testing conservation agriculture practices. For example, on one plot he plans to keep maize residues on the soil surface and seed the next crop directly into the soil without plowing. Research by CIMMYT and others has shown that this practice can cut production costs, trap and conserve moisture, and improve soil quality.◀

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ASIA:

THE REGION WITH THE  
LARGEST ABSOLUTE NUMBER OF  
POOR PEOPLE AND A RAPIDLY  
RISING DEMAND FOR CEREAL  
GRAINS. INTENSIVE, IRRIGATED,  
HIGHLY-PRODUCTIVE FARMING  
SYSTEMS FEATURE MULTIPLE  
CROPS—INCLUDING LARGE  
AREAS OF MAIZE AND WHEAT—  
AND FACE SERIOUS PROBLEMS:  
THE UNSUSTAINABLE  
EXPLOITATION OF WATER  
AND SOILS, INEFFICIENT USE  
OF CHEMICAL INPUTS, AND  
EMERGING OR WORSENING  
DISEASE AND PEST PROBLEMS.

RAINFED AGRICULTURE  
PROVIDES MILLIONS  
WITH FOOD BUT SUFFERS  
FROM POOR OR ERRATIC  
PRECIPITATION, INFERTILE  
SOILS, AGGRESSIVE DISEASES  
AND PESTS, AND, SOMETIMES,  
EXTREME TEMPERATURES.

A black and white photograph of a woman with short, curly hair, looking directly at the camera with a neutral expression. She is wearing a light-colored, patterned top. The background is a stylized, repeating pattern of fields and small houses, suggesting a rural landscape. The bottom half of the image has a solid orange background.

CIMMYT IN ASIA



IN ASIA, RISING DEMAND AND PRICES FOR QUALITY PROTEIN MAIZE (QPM) FROM CIMMYT BENEFIT FARMERS AND CHANGE LIVES.

**I** have farmed forever," says Yasam Saanim. He works the steep slopes of the mountainous land near the village of Carin on the Indonesian island of Java. From childhood his life has been one of hard labor with little reward. He and his wife struggled to raise seven children on their tiny piece of rented land. With no money of his own Yasam has to borrow from the landowner every year to buy fertilizer for his third of a hectare of rice. He also grows a few bananas, cassava, sweet potatoes and durian, a pungent Southeast Asian delicacy. In return he pays the landowner 180 kg of rice at harvest. By his reckoning that represents about 30% interest. He doesn't think it is a fair deal but says he has no choice. The family survives but Yasam has never had money. It has been that way all his life.

Now, at the age of seventy, he finally sees some light in the

seemingly endless tunnel of hopelessness that has been his lot as a tenant farmer.

The landowner has decided to plant maize—in particular, QPM—on 1.2 hectares of land adjacent to Yasam's. Quality protein maize is a high lysine, high tryptophan type developed by CIMMYT. Lysine and tryptophan are two of the amino acids required for the synthesis of protein in the human body. This maize can enhance the nutrition of the poor whose diets depend heavily on maize and raise the quality of maize-based pig and poultry feeds. The landowner's QPM production is for seed, which sells locally at five times the value of "normal" maize grain and reflects Java farmers' growing interest in QPM.

To Yasam's delight, he and some village women were hired to weed, fertilize, and harvest the QPM plot. Yasam earns 12,500 Indonesian rupiahs (\$1.30) for each half day he works. The women are paid less (7,500 rupiahs) but in a village with little money this new income is very welcome.

Indonesia has released two open-pollinated QPM varieties, one yellow and one white. They were developed using experimental varieties from CIMMYT by Marsum Dalhan, head of the

Breeding and Germplasm Section of the Indonesian Cereal Research Institute. Marsum has benefited both from CIMMYT training activities and through support for his work from the Asian Development Bank.

Virtually no maize is grown around Carin. That is good news for landowners who produce maize seed and, especially, QPM seed. Because the quality protein trait is "recessive"—that is, both parents must carry it and pass it on for it to be expressed in offspring—any plants that are fertilized with pollen from other types of maize will produce normal (not quality protein) seed.

The economics look good to the landowner. He produces two crops of quality protein seed a year. Still there is a risk. The market for this maize is in its infancy in Indonesia, where most animal feed is still artificially fortified with lysine at the feed mill. But the market is growing for the nutritionally enhanced maize. For the village of Carin the benefits are still small, a trickle-down at best. Still Yasam Saanim, a person who has farmed forever, beams with cautious optimism. "It looks like we will have a benefit from the maize," he smiles.

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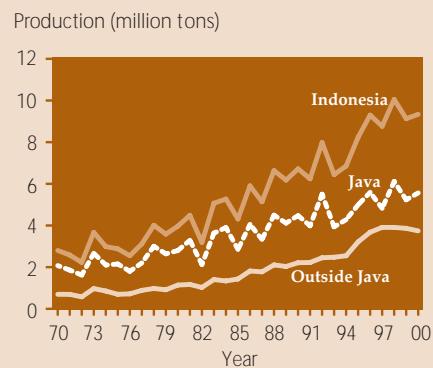
# The Call for Maize Mounts in Asia

The demand for maize is expected to skyrocket in Asia over the next two decades, driven primarily by its use for animal feed. But maize use is also increasing in the uplands of seven Asian countries. These areas are often cut off from markets and inhabited by resource-poor farmers who eat much of what they grow. CIMMYT and the International Fund for Agricultural Development (IFAD) have recently completed a project promoting food and livelihood security for upland farmers in Asia who depend on maize for both food and feed.

The International Food Policy Research Institute (IFPRI) estimates that by 2020 the demand for maize in all developing countries will surpass the demand for wheat and rice, with Asia accounting for over half of this growth. Responding to these predictions, teams of researchers visited farmers in the uplands of China, India, Indonesia, Nepal, the Philippines, Thailand, and Vietnam to learn about their maize production systems.

To further develop maize improvement recommendations, national workshops and seven publications built upon the farmer surveys. Careful planning and appropriate research and development prioritization procedures on the part of scientists and policy makers will ensure an easier transition as farmers face oncoming maize demand. A clear message from the study in Vietnam, for example, was the need to help farmers apply sustainable practices to avoid degrading natural resources—particularly in fragile, marginal settings—as demand intensifies. “The project provided a much-needed avenue for better prioritization of maize research and development in the participating countries,” says Roberta Gerpacio, former CIMMYT research associate who coordinated the effort. “The active pursuit of the right priorities, together with a supportive policy environment, can help make maize-based farming a more sustainable livelihood for marginal households in the Asian uplands.”

The conclusions, like the one above for Vietnam, were drawn from results of systematic country-level prioritization, and drew upon findings from in-depth participatory rural appraisals in marginal, isolated areas involving village leaders and groups of farmers. Details on the sociological, agro-economical, environmental,



Maize production in Indonesia, 1970-2000.

and technological aspects of maize production were assembled in a series of six publications available through CIMMYT (see “Publications/Maize Production Systems” on [www.cimmyt.org](http://www.cimmyt.org)). A seventh report on maize in China is also being developed.

“The third project component on maize sector policy research closely reviewed and examined country-level macro- and micro-economic policies, relating these to influences on farm and household-level conditions,” says Gerpacio. A separate volume on details and synthesis of the seven country maize policy studies will be co-published with IFPRI.

Project participants also included IFPRI, Stanford University, and national research programs and ministries of agriculture in the study countries.

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# Helping to Reinvigorate Agriculture in Afghanistan

WHEAT IS THE NUMBER-ONE STAPLE CROP IN AFGHANISTAN, AND MAIZE IS THE THIRD. TOGETHER THEY OCCUPY 80% OF THE AREA PLANTED TO ANNUAL CROPS IN THE COUNTRY. A CENTRAL AIM OF CIMMYT IN AFGHANISTAN IS TO MAKE IMPROVED, HIGH QUALITY SEED OF BOTH CROPS AVAILABLE TO FARMERS, ALONG WITH APPROPRIATE CROP MANAGEMENT TECHNOLOGIES.

CIMMYT has collaborated with Afghan researchers for over three decades, even during the war. Thanks to the Swedish Committee for Afghanistan and the FAO, Afghan researchers maintained contact with CIMMYT and the Turkey-CIMMYT-ICARDA International Winter Wheat Improvement Program, and continued to select the best new wheat lines/varieties from international nurseries. "The new seed moved from farmer to farmer; without it, people would have suffered even more hunger and malnutrition than they did," says Hans Braun, Director of CIMMYT's Rainfed Wheat Program.

## RECENT UPDATE FROM THE FIELD

An important component of a current project ("Wheat and Maize Productivity Improvement in Afghanistan") is collaborative work with the Agriculture Research Institute of Afghanistan (ARIA), non-government and international organizations, and farmers to verify in farmers' fields the performance and acceptability of improved wheat and maize varieties.

The project has also provided non-government organizations with seed of open-pollinated maize varieties for farmer testing and feedback, resulting in the identification of two promising varieties, and participants are



# CIMMYT in Afghanistan: A Legacy of Impact

working to identify earlier-maturing varieties that better fit farmers' requirements. Project members are also working with the ARIA and the FAO, through the Improved Seed Enterprise, to offer breeder's seed of selected varieties to recognized producers of certified seed. To ensure all have access to quality seed, they are also linking with informal farmer-to-farmer distribution systems. The latter has resulted in as much as a 10-fold increase in the area under improved varieties, in some regions. The Norwegian Project Office-Rural Rehabilitation Association for Afghanistan reported that farmers who had planted open-pollinated maize varieties from the project in 2003 had bartered and sold more than two tons of seed in 2004.

CIMMYT partners in Afghanistan include the Future Harvest Consortium to Rebuild Agriculture in Afghanistan, funded by the United States Agency for International Development and coordinated by the International Center for Agricultural Research in the Dry Areas; AusAID and the Australian Centre for International Agricultural Research; FAO; the International Fertilizer Development Center and the United States Agency for International Development, ACTED, the Aga Khan Development Network, Improved Seed Enterprise, the Afghan Ministry of Agriculture, Animal Husbandry, and Food and, in particular, the Agricultural Research Institute of Afghanistan.

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Overall, 700 CIMMYT maize and wheat nurseries have been grown and evaluated by researchers in Afghanistan since 1975.

## WHEAT

- 300 tons of quality seed of wheat MH-97 distributed to 9,000 farmers in 4 provinces.
- All winter / facultative wheat cultivars in Afghanistan are derived from nurseries of the Turkey-CIMMYT-ICARDA International Winter Wheat Improvement Program.

## MAIZE

- Tons of breeder and foundation maize seed delivered for multiplication and distribution.

## TRAINING

- 50 Afghan researchers have taken training at CIMMYT.
- 5 in-country technical workshops since 2002, diverse topics (agricultural development potential and constraints, yellow rust and field scoring, research methodologies, varietal evaluation), 70 participants (farmers, NGO workers, research station officers).

# Islands of Residue: Fighting Erosion and Fostering Wheat Productivity in Kazakhstan

THE LANDSCAPE OF NORTHERN KAZAKHSTAN IS LITTERED WITH ARTIFACTS OF THE OLD SOVIET CONTROLLED ECONOMY—VICTIMS OF THE TRANSITION TO A FREE-MARKET SYSTEM. OLD CUSTOMS TOO FALL BY THE WAYSIDE. IN PLACE OF ONCE-REQUISITE HEAVY PLOWING TO PREPARE FARMLAND, CIMMYT, KAZAKH AGRICULTURAL RESEARCH PROGRAMS, FARMERS, AND OTHER PARTNERS ARE ESTABLISHING CONSERVATION AGRICULTURE APPROACHES THAT ARE BOTH SUSTAINABLE AND WILL HELP DIVERSIFY THE ECONOMY.

“**P**low, plow, plow—that’s what we were told on the old state farms,” says Darynov Auezhan, farmer and vice-chairman of the Kazakhstan Farmers’ Union, the largest such organization in the country. He reflects back on 1988, when official policy mandated the use of “black fallow,” heavy mechanical tillage as early as permissible in spring to control severe infestations of wild oats and other weeds. “By the next spring I’d see places where 50 to 60% of the soil had been washed away. And then I’d see several ‘islands’ in the field where the straw had been retained. There the soil erosion was much, much less.”

Those “islands” illustrate the basis of zero-tillage—retaining rather

than plowing in or burning crop residues—while demonstrating an important advantage of this approach: dramatically decreased soil erosion. But saving soil alone is not sufficient cause for farmers to change their ways.

## CATCHING AND KEEPING WATER

“Retaining soil moisture is critical to seed germination, crop establishment, and, ultimately, yield,” explains CIMMYT scientist Murat Karabayev, who led the Kazakhstan/FAO/CIMMYT Technical Cooperation Project on Conservation Agriculture (2002-04). “This is particularly important in droughty northern Kazakhstan, where wheat depends heavily on residual moisture from the snow



▲ Denis Yushenok, senior scientist at the Central Kazakhstan Agricultural Research Institute and CIMMYT zero-till research collaborator, surveys gully erosion under conventional tillage and fallow. According to his measurements, erosion-prone slopes under conventional tillage lost 2 t/ha of topsoil to such gullies (not including general erosion across the field), while zero-till fields showed negligible gully erosion.

melt." Retaining residues also improves soil composition and fertility, which is eventually reflected in better yields. Through on-farm trials and demonstrations, the project promoted and disseminated such resource-conserving practices as direct seeding, zero or minimal soil tillage, and chemical fallows (a weed-killing herbicide application followed by a conventional fallow). There were also training seminars, courses, field days, study tours, and wide promotion of new practices through the mass media. The development and offering of suitable equipment for direct seeding and zero-tillage technologies was essential. Finally, project activities were backstopped by economic analyses of the new practices.

Zero-tillage plots at the Central Kazakhstan Agricultural Research Institute and the Research Production Center of Grain Farming served as the venues for initial meetings organized by the Ministry of Agriculture, the Farmers Union, and CIMMYT to introduce the technology to farmers and select candidates for on-farm trials. Maintained under the International Cooperation for Agricultural Research (ICAR) project in Central Asia and the Caucasus, the trials moved forward with direct seeding planters imported from Brazil. These were followed by locally-produced kits that could be cheaply retrofitted to existing planters. The selected farmers used zero-tillage, with technical support and agronomic analysis from CIMMYT scientists. Two independent

economic analyses were conducted by Kazakh and American economists. Approximately 500 scientists and farmers participated in workshops and training seminars, and another 800 farmers observed the trials at farmer field days. Project activities were highlighted via newspapers, radio, television, and regular coverage in the *AgroInformation Quarterly*, a widely distributed publication produced by the Farmers Union. "Given that wheat is Kazakhstan's foremost crop and the country ranks sixth globally in wheat area harvested, the potential impact on rural livelihoods and food security of zero-tillage and direct seeding into residues cannot be overstated," Karabayev says. ▶

## **FROM 100 HECTARES TO 100 PERCENT: FARMERS' EXPERIENCES**

Although Meiram Sagymbayev's farm in Alemola Province is of "intermediate" scale—3,000 hectares on the high steppes of northern Kazakhstan is indeed intermediate—he is not your average Kazakh farmer. His background includes stints as a research scientist and agronomist in the Soviet era, and, on the other side of the historic divide, he received an award in 2002 as the best businessman in the province. He has instituted profit-sharing with his farm hands, and rather than reward extra work with vodka, he gives bonuses to his staff for not drinking during planting and harvest.

Sagymbayev recounts putting together the first rudiments of a business plan while shoveling manure and starting to implement his ideas after Kazakh independence in 1991. It is no surprise then that this innovator is leading the way in zero-till farming,

and that his neighbors and others consulting with him are following . . . in a big way.

As one of the conservation agriculture project's four participating farmers, Sagymbayev sowed 100 hectares in the second wheat season of 2004 using zero-tillage. Results had been moderately encouraging the first season, but 2004 shaped up to be a very dry year in Akmola, which does not get much precipitation even in an average year, and Sagymbayev was concerned. To his surprise, the zero-tillage plot gave the highest yield in the county, and he surmised that it was time to go beyond experimentation to putting this system to work. In 2005, 100% of his wheat is planted using direct seeding and zero-tillage. He hopes over the long term to stabilize yields during both normal and dry years through zero-tillage improvement of the soil profile. His neighbor, seeing the 2004 results, sowed 2,500 of his 11,000 hectares using zero-tillage, and many more peers are watching intently—among them the county's small-scale farmers.

On an FAO-sponsored trip to the United States, Sagymbayev was impressed by how farmers there were independent yet worked cooperatively and in associations to acquire inputs and technical knowledge. Today, he is encouraged to see Kazakhstan and its farmers take fledgling steps to create cooperatives that will provide credit for purchasing fertilizer. The sharing of equipment and labor may not be far behind. In lieu of a formal extension service, he voluntarily advises neighbors on diverse farm issues, including zero-tillage. "In Kazakhstan's transition period, most farmers didn't know what to do," he observes. "Things are moving forward step-by-step and may even be accelerating, but we still have a ways to go."

Wheat farmer Viktor Surayev comes from a different place—not just on the map but in the circumstances he faces and the land he farms. Viktor's home is in Mishurino village, which prospered under the Soviet system but has since fallen on hard times, with the livestock industry declining significantly,

infrastructure deteriorating, and many people migrating from the area. Surayev was a farm engineer in those pre-independence days, and he earned degrees in agronomy and land management and mechanization. But large, soil-caked hands and an affable, down-to-earth demeanor quickly dispel any preconceptions about his being an ivory-tower academic. "Difference between farming now and during Soviet times?" he shrugs, wryly grins. "Still laboring with soil, planting seeds, fixing equipment...the hard work in the fields stays the same."

Unlike Sagymbayev, Surayev's land is relatively hilly and subject to severe water and wind erosion, which he blames for the low soil fertility in many of his fields. Thus it is no surprise that he sees the creation of humus and increased soil fertility as a major benefit of conservation agriculture systems, followed by better soil moisture retention. After the dry 2004 season, when he saw zero-tillage fields yield 40% more than their conventional counterparts, he

increased his area under the technology from 100 to 800 hectares. Even under more favorable conditions in 2003, he found that yields under zero-tillage reached 1.8 tons per hectare, versus 1.6 tons with conventional practices.

His profits increased, not just through higher yields but due to reduced fuel, labor, and machinery repair costs. Under zero-tillage, at least three fewer tractor passes over the fields are required—a reduction of 60%—and plows, harrows, and other cultivation implements are not needed. The actual wear and tear on his aging tractors is minimized, because pulling a sprayer or zero-tillage seeder exerts far less resistance than drawing soil-turning equipment.

Surayev acknowledges increased herbicide costs under the new system, but is not overly concerned, as he believes that those costs will decrease as the weed seeds in the soil are killed off, and demand for herbicide lowers per-unit cost. These converging factors, he thinks, together with what farmers see



▲ Having seen the benefits of zero-till farming, wheat farmer Meiram Sagymbayev now plants 100% of his crop with this system.

when they visit Surayev and colleagues' on-farm trials, bode well for zero-tillage farming in the wheat belt of Kazakhstan.

Auezhan of the Farmers' Union is likewise optimistic. "It will take about five years to have conclusive results from these experiments," he says, "but I think beyond a doubt that they will prove the technology is effective. I believe my grandchildren will be proud of my participation in this research—that I was one of the pioneers of what will become a widely spread and accepted way of farming." He concludes, "I thank CIMMYT for this too, because without them, we'd be far behind and simply not know about these technologies."

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# Kazakhstan: View from the Ground Level

"KAZAKHSTAN IS NOT POOR. LOOK AT THE FANCY NEW CARS IN ALMATY, A CITY REMINISCENT OF THOSE IN OLD EUROPE, OR THE CAPITAL, ASTANA, GLEAMING WITH NEW ARCHITECTURAL WONDERS. THESE ARE NOT CIMMYT CLIENTS. THEY ARE DOING FINE. THIS IS THE ARGUMENT I OFTEN HEAR," SAYS ALEXEI MORGOUNOV, CIMMYT SCIENTIST AND REGIONAL REPRESENTATIVE TO CENTRAL ASIA. "BUT GO OUTSIDE THE CITIES AND YOU WILL SEE ANOTHER STORY."

**A** drive outside of Astana, north across the steppes toward Siberia, bears out Morgounov's observation. Take a turn off the main highway and onto a deeply rutted, village dirt road and those Mercedes of the cities are quickly replaced by rickety horse-drawn carts, the occasional tractor from a bygone era chugging along accompanied by a black cloud of diesel soot, and old men and young boys in tattered clothes shepherding flocks of 10 to 20 sheep.

"Government studies show that 25-30% of the population in northern Kazakhstan lives on a dollar a day or less," Morgounov continues, "and contrary to popular wisdom, poverty is equally severe in the north as in the south, where the farms are typically much smaller. A recent FAO publication\* indicates that agriculture offers 'moderate' potential for alleviating poverty in the region and that intensification (increased productivity) is a major route to that end. It's not just the product we're talking about. It's the economic activity farming can generate in rural areas," adds Morgounov.

A case in point is the farm operation of Vyacheslav Cherezdanov, one of the zero-till project farmers. When he got into farming 13 years ago, it was with a business orientation. His goal was to produce food products, but he wanted to grow his own raw material: grain, principally wheat. In December 2002, after many long seasons of building up the farm operation, he realized his vision with the opening of a bakery. He was greatly encouraged when the breads, rolls, and pastries it produced consistently sold out in neighboring villages and the regional city center. His entrepreneurial instincts whetted, in 2005 he expanded his product line to pelemenis (akin to ravioli or perogis), meat pies, personal-sized pizzas, and other delights.

Today, Cherezdanov employs considerably more people in his food processing business (39 in all), than on the farm, which employs 12—and the economic spinoffs continue, he says. Many of the raw ingredients he uses—including milk, eggs, cheese, and honey (and soon, certified meat)—are purchased from local farmers. Sugar is bought from a nearby wholesale shop. And there is room for the spinoffs to grow as he intends to expand his product line and

\* *Farming Systems and Poverty: Improving Farmers' Livelihood in a Changing World*; by J. Dixon, A. Gulliver and D. Gibbon. Published by FAO in 2001.



markets and broaden sales to more populated areas. Thanks to the zero-till technology and input from CIMMYT, he is now growing winter rye and triticale. The rye will be used for bakery products and seed sales and the triticale will be bartered with local cereal and livestock producers.

His mother, Galina Cherezdanova, is happy to see her son's business success and its positive impact on the community. A trained economist, she conducted studies for the oblast (province) indicating that of all the "profit" generated in their county, 70% comes from agriculture and 30% from small business. Most of the province's products are sent out as raw materials, she explains, but there is a big potential for small business here. She says that past calculations made on a very conservative basis showed that one ton of raw grain generated US\$ 75 in economic activity compared to \$150, or double that, for the finished product. "With 56 grain elevators here," declares Cherezdanova, "we need to do more to boost revenue for the rural people."

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# Good (and Useful) Things Can Come in Small Packages

**S**mall grants and projects can go a long way. They can be bundled together to achieve more formidable goals, and they can serve as pilot projects for proof of concept, or to get the ball rolling in an area of study. Or they can serve as a bridge in time between larger-scale projects. In short, small projects can lead to bigger and better things.

Two noteworthy examples are the International Cooperation for Agricultural Research in Central Asia and the Caucasus (ICAR) and the Regional Network for Wheat Variety and Seed Production, both at work in Kazakhstan and the region.

## **ICAR: MANY DISCIPLINES AND MANY NATIONS**

ICAR is a USDA project managed through Washington State University (WSU), CIMMYT, and South Dakota State University, with an annual budget of \$400,000, currently divided among a set of on-farm demonstrations, on-station training and trials, collaborative research mini-projects, and organization of regional fora. Initiated in 2002, the project extends through 2007 and includes partnerships with eight countries from the former Soviet Union in

Central Asia and the Caucasus (CAC). Grants average US\$ 10,000-20,000, much less for on-farm trials.

"The research partnerships contribute to enhanced food security, preserve threatened biodiversity, support democratic and market reforms, and develop mutual understanding and appreciation in our institutions, citizens, and nations," says Kim Garland Campbell, Co-director of ICAR (also Adjunct Professor at WSU and Research Geneticist with USDA-ARS). "The project is truly a win-win scenario for all of us."



The overarching goals of the project are to:

- Rebuild capacity in the region's research institutions for agricultural education, research, and technology transfer.
- Use improved sustainable technologies, practices, and policies to improve food sector performance.
- Support agricultural policy reform to improve economic productivity and sustain the natural resource base.
- Expand the access of the rural poor to technologies and practices that improve food security.

Says Alexei Morgounov, CIMMYT regional representative, "We are looking to strengthen ties between world-class institutions and scientists in the United States and the CAC. When one considers that the winter wheat now grown in the USA came from the Ukraine, we can see it really is a two-way street. Another less obvious but very important goal is to introduce the younger generation of scientists from the USA and CAC to the world of international agriculture and to one another. Agriculture today is global in terms of trade and economics. We need to make sure that our agricultural researchers are prepared to work globally as well."

ICAR's mandate is matched by the breadth of its activities in the field, ranging from trekking through the mountains of Kazakhstan to collect genetic diversity, to high-tech molecular analysis of plant tolerance and resistance to diseases.

## SEED MONEY FOR EXTENSION SOWS NEW POSSIBILITIES FOR FARMERS

In the absence of fully functioning extension systems, delivering better varieties and technologies to farmers requires innovation and experimentation—and here again, relatively small investments in focused efforts can lead the way. The extension component of the Regional Network for Wheat Variety Promotion and Seed Production, a collaboration between CIMMYT and the German Agency for Technical Cooperation (GTZ), illustrates this point.

The overall goal of the project is to identify, multiply, and promote high yielding and disease resistant wheat varieties. After a significant outlay of funds for start-up, the project has used budget allotments of approximately US \$150,000–200,000 per year to support major meetings and smaller fora among scientists

from the region and their international counterparts; hold field days to demonstrate improved varieties and crop management systems; send about 40 scientists from Central Asia for training in breeding and agronomy at CIMMYT-Mexico, and, as noted, support a unique pilot effort to deliver useful technologies to farmers.

Agrosemconsult was established through the project as a private company to conduct on-farm and participatory trials and support technology transfer to farmers. Three mobile groups, consisting of an agronomist, mechanic or machinery technician, with backup from a wheat breeder, have been established by Agrosemconsult in southern Kazakhstan, with mirror arrangements in Uzbekistan and Tajikistan. Each group works directly with 5-10 farmers, who try the new approaches and serve as models for their neighbors. Aside from disseminating improved varieties, provided largely by the CIMMYT-Turkey-ICARDA Winter Wheat Improvement Program, the company has led the way in promoting bed planting for wheat and barley in the region, with technical support from CIMMYT, notably crop management specialist Ken Sayre, and backing for particular components from the ICAR project.

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# World Wheat Crop under Threat from New Strain of Old Disease

REPRESENTATIVES OF MAJOR DONOR COUNTRIES AND ORGANIZATIONS, TOGETHER WITH WHEAT SPECIALISTS FROM AROUND THE WORLD, AGREE THAT UG99, A NEW STRAIN OF WHEAT STEM RUST, IS A MAJOR THREAT TO WHEAT PRODUCTION WORLDWIDE. AT A MEETING IN KENYA IN SEPTEMBER TO HEAR A REPORT ON THE DISEASE STRAIN BY AN EXPERT PANEL, THEY SOUNDED THE ALARM TO THE INTERNATIONAL MEDIA AND LAUNCHED A GLOBAL INITIATIVE TO CONTROL THE DISEASE.

**N**obody's seen an epidemic for 50 years, nobody in this room except myself," said Norman E. Borlaug, Nobel Peace Laureate and former CIMMYT wheat breeder. "Maybe we got too complacent."

The new wheat stem rust strain Ug99 was first observed in Uganda, but its spores are spreading on the wind and damaging wheat crops in Ethiopia and Kenya. The greatest danger is that the new strain will hit the large expanses of wheat in Asia, according to a report by a panel of international experts: "It is only a matter of time until Ug99 reaches across the Saudi Arabian peninsula and into the Middle East, South Asia, and eventually East Asia and the Americas....the current crisis is a wake-up call about the continuing and potentially devastating impact that the rust pathogens can have on a staple food like wheat."

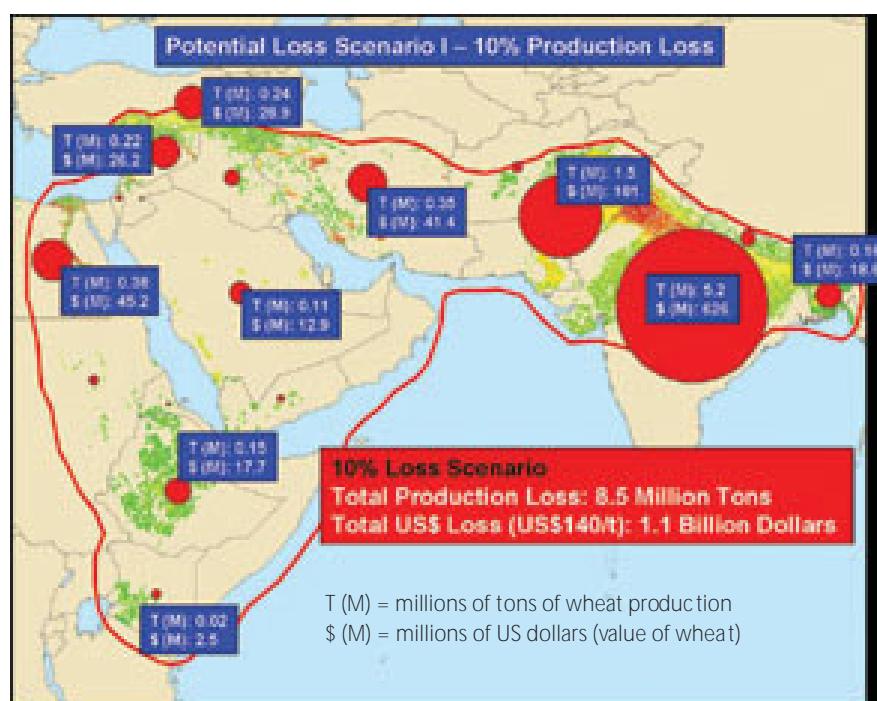
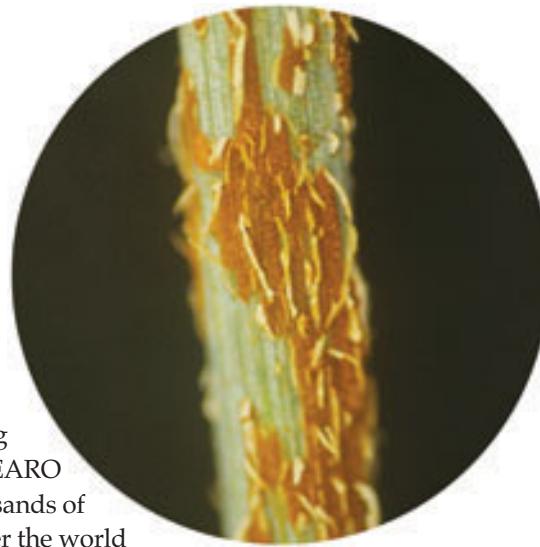
## WHAT'S AT STAKE?

Wheat is grown on more than 200 million hectares worldwide and is a source of food and livelihoods for hundreds of millions in developing countries. If Ug99 spreads unchecked, it would reduce world wheat production at least 10%—a loss of 60 million tons of grain worth US\$9 billion or more—and seriously jeopardize regional food security. "Until the advent of science-based agriculture, world wheat harvests suffered periodic attacks by evolving fungal pathogens," says CIMMYT wheat pathologist Ravi Singh. "Among the most damaging were the rusts." Modern breeding, combined with the free international exchange of experimental wheat lines, resulted in the development and wide dispersion of wheat varieties able to resist the rusts for several decades. "These resistant varieties have especially safeguarded food security in developing countries, where many farmers simply cannot afford fungicides," says Singh. But pathogens evolve and, as is occurring now, new strains emerge that break down the defenses of resistant varieties.

## TIME TO ACT— NOW!

The report says that plant breeders and pathologists still have time to screen for resistant genotypes and to get them multiplied and into farmers' fields. With this aim, delegates at the meeting in Kenya endorsed the creation of the Global Rust Initiative to monitor the spread of the disease and to work on long-term solutions—including new, locally-adapted, resistant wheat varieties and a global testing and distribution system—not just for Ug99 but for other, potentially dangerous wheat rust pathogens. Lead members of the consortium developing the initiative are CIMMYT, ICARDA, the Kenya Agricultural Research Institute (KARI), and the Ethiopian Agricultural Research Organization (EARG). Several major donors have expressed interest in participating. The meeting in Kenya was sponsored by the Rockefeller Foundation. A news conference held as part of the event was attended by more than 30 media representatives and resulted in reports being published in dozens of outlets worldwide, including a story in the "Science" section of *The New York Times* on 9 September 2005.

CIMMYT has been screening materials in its gene bank for sources of resistance to the new rust strain and has identified promising candidates. KARI and EARG are also screening thousands of wheat lines from all over the world at stations that are known hotspots for wheat rusts.



An initial analysis of global wind patterns and environmental factors conducted by CIMMYT's Geographic Information Systems unit confirms there is a high potential for the fungal spores to spread from eastern Africa into the Arabian peninsula, Iran, and the expansive wheat growing regions of Pakistan, India, and Bangladesh. The expert panel report confirmed that many of the wheat varieties grown in these regions are susceptible to the new strain of the fungus. This graphic shows a conservative scenario; in the worst-case scenario, Ug99 could ruin as much as 70% of the wheat harvest.

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# CIMMYT Financial Overview

## 2004 FINANCIAL STATEMENTS

A summary of the 2004 combined statements of activities and changes in net assets and combined statements of financial position for CIMMYT, Int., and CIMMYT, A.C., is set out in Table 1.

The major highlight of the year 2004 has been the increased operating surplus of US \$ 1.4 million, approximately double that of 2003. This surplus has allowed CIMMYT to continue rebuilding its net asset

base back to levels that will provide the operational and institutional security required to support its research agenda.

Total revenues for 2004 of US \$ 38.72 million represented an increase of US \$ 0.9 million (2.4%) over 2003 revenues.

Total net assets increased by US \$ 1.77 million to US \$ 20.17 million (2003 US \$ 18.39 million). Unappropriated, unrestricted net assets increased to US \$ 4.86 million, due to a combination of the

operating surplus of US \$ 1.4 million and a positive movement in reserves of US \$ 370,000.

## 2004 FUNDING OVERVIEW

Total funding for 2004 was US \$ 38.72 million (2003 US \$ 37.80), including other income and overhead recovery of US \$ 2.78 million (2003 US \$ 2.02 million). Grant income amounted to US \$ 37.40 million, comprising US \$ 13.71 million in unrestricted grants and US \$ 23.69 million in restricted grants (Table 2).

**TABLE 1. FINANCIAL STATEMENTS, 2004**

As of December 31, 2004 and 2003	(Thousands of US Dollars)	
ASSETS	2004	2003
<b>Current Assets</b>		
Cash and cash equivalents	14,119	7,426
Accounts receivable:		
Donor - Net	6,480	9,019
Other	1,141	1,071
Inventory and supplies	109	129
Prepaid expenses	15	
<b>Total current assets</b>	<b>21,853</b>	<b>17,660</b>
<b>Non-Current Assets</b>		
Property, plant and equipment, net	15,307	15,302
Other assets	62	62
<b>Total non-current assets</b>	<b>15,369</b>	<b>15,364</b>
<b>TOTAL ASSETS</b>	<b>37,222</b>	<b>33,024</b>
<b>LIABILITIES AND NET ASSETS</b>		
<b>Current Liabilities</b>		
Financial institutions	-	3,000
Due to related parties	-	390
Current portion of capital leases	79	222
Accounts Payable:		
Donors	14,453	9,771
Other	1,331	46
Accruals and provisions	774	605
<b>Total current liabilities</b>	<b>16,637</b>	<b>14,034</b>
<b>Non-Current Liabilities</b>		
Seniority premiums	417	513
Capital leases	-	79
<b>Total non-current liabilities</b>	<b>417</b>	<b>592</b>
<b>Total liabilities</b>	<b>17,054</b>	<b>14,626</b>
<b>Net Assets</b>		
Unrestricted:		
Designated	15,307	15,347
Undesignated	4,861	3,051
<b>Total unrestricted net assets</b>	<b>20,168</b>	<b>18,398</b>
<b>TOTAL LIABILITIES AND NET ASSETS</b>	<b>37,222</b>	<b>33,024</b>

**STATEMENTS OF ACTIVITIES, 2004 AND 2003**

For the years ended December 31, 2004 and 2003	(Thousands of US Dollars)	
	2004	2003
<b>Revenue and Gains</b>		
Grants / Revenue	37,400	35,785
Other revenue and gains	1,320	2,019
<b>Total revenue and gains</b>	<b>38,720</b>	<b>37,804</b>
<b>Expenses and Losses</b>		
Program related expenses	31,965	29,292
Management and general expenses	7,271	9,561
Other losses and expenses	862	1,346
<b>Sub-total expenses and losses</b>	<b>40,098</b>	<b>40,199</b>
<b>Indirect cost recovery</b>	(2,778)	(3,117)
<b>Total expenses and losses</b>	<b>37,320</b>	<b>37,082</b>
<b>NET SURPLUS</b>	<b>1,400</b>	<b>722</b>
<b>Expenses by natural classification</b>		
Personnel costs	16,870	18,003
Supplies and services	13,531	13,449
Collaborators / partnership costs	5,742	4,652
Operational travel	1,858	1,199
Depreciation	2,097	2,896
<b>Total</b>	<b>40,098</b>	<b>40,199</b>

**TABLE 2. CIMMYT SOURCES OF INCOME FROM GRANTS BY COUNTRY/ENTITY, 2004 AND 2003**

For the years ended December 31, 2004 and 2003		(Thousands of US Dollars)			
Donors		2004 Grant	2003 Grant	Donors	2004 Grant
<b>Unrestricted</b>					
Australia		454	377	India	
Belgium		204	86	Maharashtra Hybrid Seed Co. Ltd.	- 19
Canada		1,798	1,263	Iran, Islamic Republic of	215 297
China		140	150	Japan	
Denmark		463	598	APN (Asian Pacific Network for Global Change Research)	- 1
Germany		309	286	Economic Cooperation Bureau, Ministry of Foreign Affairs	779 644
India		113	113	Nippon Foundation	584 691
Japan		1,503	1,359	Sasakawa Global 2000	- 6
Korea		50	50	Korea, Republic of	
Mexico		25	90	Rural Development Administration	85 100
New Zealand		50	-	Mexico	
Norway		294	208	CODEPAP (Consejo de Desarrollo de la Cuenca de Papaloapan)	17 44
Peru		30	20	CONACYT (Consejo Nacional de Ciencia y Tecnología)	88 7
Philippines		7	7	SAGARPA (Secretaría de Agricultura, Ganadería,	1,033 294
Sweden		385	324	Desarrollo Rural y Pesca)	
Switzerland		312	292	Fundación Guanajuato Produce A.C.	40 9
Thailand		21	9	Fundación Hidalgo	- 6
United States		4,232	4,900	Fundación Sonora	194 50
United Kingdom		1,540	-	ICAMEX	35 69
World Bank		1,800	2,500	Grupo Industrial Bimbo (Industrial quality in wheat)	- 45
<b>Subtotal - Unrestricted</b>		<b>13,710</b>	<b>12,632</b>	Universidad Nacional Autónoma de México	6 -
<b>Restricted</b>					
ADB (Asian Development Bank)		390	566	Miscellaneous Research Grants	54 116
Australia				Netherlands	
AusAID		501	424	Ministry of Foreign Affairs	432 466
Australian Centre for International Agricultural Research		85	125	New Zealand	21 114
CRC Molecular Plant Breeding		393	320	Norway	30 30
Grains Research and Development Corporation		1,138	654	OPEC Fund for International Development	74 26
Belgium		448	345	Other	211 560
Bolivia (AGRICOM- Seeds, S.A.)		1	10	Paraguay (Camara Paraguaya de Exportadores de	6 24
Brazil		2	-	Cereales y Oleaginosas)	
Canada				Peru	30 40
Agriculture and Agri-Food		15	1	Rockefeller Foundation	2,383 1,993
Canadian International Development Agency		919	621	SCOPE	- 9
CGIAR				South Africa	
Centro Internacional de Agricultura Tropical		55	31	Agricultural Research Council	- 9
International Crop Research Institute for the Semi-Arid Tropics		4	-	National Department of Agriculture	64 47
International Food Policy Research Institute		684	147	Spain	
International Plant Genetic Resources Institute		-	2	Agrovegetal, S.A.	63 90
International Water Management Institute		75	39	Ministerio de Agricultura, Pesca y Alimentación	188 262
Standing Panel on Impact Assessment		15	9	Syngenta Foundation	647 1,097
China				Sweden	17 19
CAAS		300	300	Switzerland	
Lamsoo Milling Company		-	(8)	Swiss Agency for Development and Cooperation	909 875
Colombia				United Kingdom	464 1,417
FENALCE (Federación de Cultivadores de Cereales y Leguminosas)		103	41	UNDP (Africa Bureau)	23 -
Ministry of Agriculture and Rural Development		105	112	Uruguay	2 130
Denmark		69	151	USA	
European Commission		2,754	2,676	Cornell University	58 47
FAO		46	53	Monsanto Fund	6 214
France				National Center for Genome Resources (NCGR)	18 -
DRIC (Delegation aux Relations Internationales et à la coopération)		480	844	Oklahoma State University	3 35
Club Cinq		90	56	Pioneer Hi-Bred International	9 33
Germany				Stanford University	76 146
Eiselen Foundation		-	37	United States Agency for International Development	3,089 2,967
Federal Ministry of Economic Cooperation and Development		945	667	United States Department of Agriculture	313 289
IAEA (International Atomic Energy Agency)		10	6	Washington State University	178 91
IDB (Inter-American Development Bank)		-	9	World Bank	1,476 834
IFAD (International Fund For Agricultural Development)		165	152	Generation Challenge Programme	- 501
				<b>Subtotal - Restricted</b>	<b>23,690 23,153</b>
				<b>Total Donors Unrestricted and Restricted</b>	<b>37,400 35,785</b>

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**Masahiro Kishii** (Japan), Wheat Cytogeneticist

#### EXPERIMENT STATION

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#### BIOMETRICS AND STATISTICS

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#### SEED INSPECTION AND DISTRIBUTION UNIT

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**Efrén Rodríguez** (Mexico), Head, Seed Distribution and International Nurseries Data Analysis  
**Noemí Valencia** (Mexico), Supervisor, Seed Health Laboratory

#### ADJUNCT SCIENTISTS

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**Morten Lillemo** (Norway), Postdoctoral Fellow, Wheat Breeder  
**Hiro Nakamura** (Japan), Scientist, Wheat Grain Quality Molecular Breeder<sup>2</sup>  
**Antonio Serratos** (Mexico), INIFAP/Mexico, Scientist, Molecular Biologist<sup>1</sup>  
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**Mateo Vargas** (Mexico)  
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#### HONORARY FELLOWS

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**Wayne Powell** (UK)<sup>2</sup>

#### IMPACTS TARGETING AND ASSESSMENT PROGRAM

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**Mauricio Bellon** (Mexico), Senior Scientist, Human Ecologist<sup>1</sup>  
**Federico Carrón** (Mexico), Database Administrator  
**Jonathan Hellin** (UK), Scientist, Poverty Specialist<sup>2</sup>  
**David Hodson** (UK), Scientist, Head, Geographic Information Systems  
**Petr Kosina** (Czech Republic), Associate Scientist, Training Coordinator<sup>2</sup>  
**Tyler Kruzich** (USA), Research Assistant<sup>2</sup>  
**Roberto La Rovere** (Italy), Scientist, Impacts Specialist<sup>2</sup>  
**Erika Meng** (USA), Scientist, Economist  
**Maria Luisa Rodríguez** (Mexico), Program Administrator

#### CONSULTANTS/RESEARCH AFFILIATES

**Pedro Aquino** (Mexico), Principal Researcher  
**Leslie Cooksy** (USA)<sup>1</sup>  
**Dagoberto Flores** (Mexico), Principal Researcher  
**Roberta Gerpacio** (Philippines)<sup>1</sup>  
**Maximina Lantican** (Philippines)  
**Janet Lauderdale** (USA)<sup>1</sup>  
**Eduardo Martínez** (Mexico), GIS Specialist  
**Maxwell Mudhara** (Zimbabwe)<sup>2</sup>  
**Toon Van Goethem** (Belgium), Volunteer Research Intern<sup>2</sup>

#### AFRICAN LIVELIHOODS PROGRAM

**Marianne Bänziger** (Switzerland), Director (based in Kenya)  
**Jedidah Danson** (Kenya), Adjunct Scientist, Molecular Biologist (based in Kenya)  
**Hugo De Groot** (Belgium), Senior Scientist, Economist (based in Kenya)  
**Alpha O. Diallo** (Guinea), Principal Scientist, Breeder (based in Kenya)  
**Dennis Friesen** (Canada), IFDC/ CIMMYT, Senior Scientist, Agronomist (based in Ethiopia)  
**Fred Kanampiu** (Kenya), Scientist, Agronomist (based in Kenya)  
**Duncan Kirubi** (Kenya), Adjunct Scientist, Breeder (based in Kenya)  
**Augustine Langyintuo** (Ghana), Economist, Associate Scientist, (based in Zimbabwe)  
**John MacRobert** (Zimbabwe), Senior Scientist, Maize Seed System Specialist (based in Zimbabwe)  
**Zubeda Mduruma** (Tanzania), ECAMAW/CIMMYT, Adjunct Scientist, Breeder (based in Ethiopia)

**Mulugetta Mekuria** (Ethiopia), Senior Scientist, Economist (based in Zimbabwe)

**Stephen Mugo** (Kenya), Scientist, Breeder (based in Kenya)

**Wilfred M. Mwangi** (Kenya), Principal Scientist, Economist (based in Kenya)

**Daisy Ouya** (Kenya), Science Writer/Editor (based in Kenya)<sup>2</sup>

**Shivaji Pandey** (India), Principal Scientist, Breeder<sup>1</sup>

**Marcelo E. Pérez** (Mexico), Program Administrator (based in Mexico)

**Peter Setimela** (Botswana), Breeder, Associate Scientist (based in Zimbabwe)

**Douglas Tanneir** (Canada), Senior Scientist, Agronomist, East Africa (based in Ethiopia)<sup>1</sup>

**Christian Thierfelder** (Germany), University of Hohenheim/ CIMMYT, Post-Doctoral Fellow (based in Zimbabwe)

**Strafford Twumasi-Afriyie** (Ghana), Senior Scientist, Breeder (based in Ethiopia)

**Bindiganavile Vivek** (India), Scientist, Breeder (based in Zimbabwe)

**Patrick C. Wall** (Ireland), Principal Scientist, Conservation Tillage and Agriculture Specialist (based in Zimbabwe)

#### POSTDOCTORAL FELLOWS

**Cosmos Magorokosho** (Zimbabwe), Maize Breeder (based in Zimbabwe)

#### CONSULTANT

**Mick S. Mwala** (Zambia)

#### TROPICAL ECOSYSTEMS PROGRAM

**Kevin V. Pixley** (USA), Director

**David Beck** (USA), Principal Scientist, Breeder/Leader, Highland Maize

**David Bergvinson** (Canada), Senior Scientist, Entomologist

**Hugo Córdova** (El Salvador), Principal Scientist, Breeder/ Leader of Tropical Maize

**Maria Luz George** (Philippines), Senior Scientist, AMBIONET Coordinator (based in the Philippines)

**Daniel Jeffers** (USA), Senior Scientist, Pathologist

**Jaime López Cesati** (Mexico), Manager, Soils and Plant Nutrition Laboratory

**Luis Narro** (Peru), Senior Scientist, Breeder (based in Colombia)

**Guillermo Ortiz-Ferrara** (Mexico), Principal Scientist, Regional Breeder (Wheat), South Asia, Country Representative for Nepal (based in Nepal)

**Marcelo E. Pérez** (Mexico), Program Administrator

**Neeranjan Rajbhandari** (Nepal), Adjunct Scientist, Agronomist (based in Nepal)<sup>1</sup>

**Carlos Urea** (Colombia), Scientist, Breeder (based in Nepal)<sup>1</sup>

#### POSTDOCTORAL FELLOWS

**Alan Krivanek** (USA), QPM Breeder<sup>2</sup>  
**Natalia Palacios** (Colombia), Nutritional Quality<sup>2</sup>

#### CONSULTANT

**Philippe Monneveux** (France)<sup>1</sup>  
**Hugo Vivar** (Ecuador)

#### EXPERIMENT STATION

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#### RAINFED WHEAT SYSTEMS PROGRAM

**Hans-Joachim Braun** (Germany), Director (based in Turkey)

**Flavio Capettini** (Uruguay), ICARDA/CIMMYT Adjunct Senior Scientist, Head, Barley Program

**Arne Hede** (Denmark), Scientist, Facultative and Winter Wheat Breeder (based in Turkey)

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**Alexei Morgounov** (Russia), Senior Scientist, Regional Representative Wheat Breeder/ Agronomist, Central Asia and Caucasus (based in Kazakhstan)

**Rocío Navarro** (Mexico), Program Administrator

**Julie Nicol** (Australia), Scientist, Pathologist (based in Turkey)

**Mahmood Osmanzai** (Canada), Principal Scientist, Country Coordinator (based in Afghanistan)

**Matthew P. Reynolds** (UK), Principal Scientist, Head, Wheat Physiology

**Richard Trethowan** (Australia), Principal Scientist, Spring Bread Wheat Breeder (Marginal Environments)

**Jiankang Wang** (China), Associate Scientist, Quantitative Geneticist<sup>1</sup>

**Manilal William** (Sri Lanka), Scientist, Molecular Geneticist

#### POSTDOCTORAL FELLOWS

**Akmal Akramhanov** (Uzbekistan), Conservation Agriculture (based in Kazakhstan)<sup>2</sup>

**Rubeena** (India), Post-Doctoral Fellow, Physiology Breeder<sup>1</sup>

#### CONSULTANTS

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**David Bedoshvili** (Georgia)

**Julien De Meyer** (Switzerland)<sup>2</sup>

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**Man Mohan Kohli** (India), Plant Breeder (Wheat)<sup>1</sup>

#### EXPERIMENT STATION

**Fernando Delgado** (Mexico), Field Superintendent, Toluca ►

## INTENSIVE AGROECOSYSTEMS PROGRAM

Rodomiro Ortiz (Peru), Director<sup>2</sup>  
Karim Ammar (Tunisia), Scientist, Plant Breeder (Small Grains)  
Oscar Bañuelos (Mexico), Principal Researcher  
Etienne Duveiller (Belgium), Principal Scientist, Regional Pathologist, South Asia (based in Nepal)  
Olaf Erenstein (Netherlands), Scientist, Agricultural Economist (based in India)  
Raj Gupta (India), Senior Scientist, Regional Facilitator, Rice-Wheat Consortium for the Indo-Gangetic Plains, Country Representative for India (based in India)  
Larry Harrington (USA), Principal Scientist, Economist<sup>1</sup>  
Zhong-Hu He (China), Principal Scientist, Plant Breeder (Wheat), Country Representative for China (based in China)  
Craig A. Meisner (USA), Principal Scientist, Systems Agronomist, Country Representative for Bangladesh (based in Bangladesh)<sup>1</sup>  
Rocío Navarro (Mexico), Program Administrator  
Iván Ortiz-Monasterio (Mexico), Senior Scientist, Agronomist  
Roberto J. Peña (Mexico), Principal Scientist, Head, Grain Quality  
Wolfgang H. Pfeiffer (Germany), Principal Scientist, Head, Plant Breeder (Bread Wheat, Durum Wheat)<sup>1</sup>  
Kenneth D. Sayre (USA), Principal Scientist, Head, Crop Management  
Ravi P. Singh (India), Principal Scientist, Geneticist/Pathologist (Rust)  
Ganesan Srinivasan (India), Principal Scientist, Head, Plant Breeder (Maize)<sup>1</sup>  
Carmen Velázquez (Mexico), Head, Laboratory  
Narciso Vergara (Mexico), Senior Researcher  
Stephen Waddington (UK), Principal Scientist, Regional Agronomist, Country Representative for Bangladesh (based in Bangladesh)

## VISITING SCIENTISTS

Arun Joshi (India), Plant Breeder (Wheat)<sup>2</sup>  
Ram C. Sharma (Nepal), Plant Breeder (Wheat)<sup>2</sup>

## ADJUNCT SCIENTISTS

Parvesh Chandna (India), GIS and Remote Sensing Research Fellow (based in India)  
Nur-E-Elahi (Bangladesh), Agronomist/Breeder (Maize) (based in Bangladesh)  
A.B.S. Hossain (Bangladesh) Plant Breeder (Wheat) (based in Bangladesh)<sup>1</sup>  
Julio Huerta (Mexico), Adjunct Senior Scientist, Pathologist (Rust)  
Krishna Joshi (Nepal), Plant Breeder (Small Grains) (based in Nepal)<sup>1</sup>  
Sarvesh Paliwal (India), Specialist, Maize Seed Systems (based in India)<sup>1</sup>  
G.M. Panaullah (Bangladesh), Soil Scientist (based in Bangladesh)  
Kamal Paudyal (Nepal), Adjunct Scientist, Agricultural Economist (based in Nepal)  
H.K. Rai (India), Soil Scientist (based in India)  
M.A. Razzaque (Bangladesh) Liaison Scientist (based in Bangladesh)<sup>1</sup>  
Samar Singh (India), Agronomist (based in India)  
S.S. Singh (India), Agronomist (based in India)  
Ashish Srivastava (India), Plant Breeder (Maize) (based in India)  
Gaurav Yadav (India) Seed Production Specialist (based in India)

## CONSULTANTS

Arnoldo Amaya (Mexico), Program Administrator  
Guillermo Fuentes Dávila (Mexico), Plant Pathologist (Wheat)  
Naeem Hashmi (Pakistan), Country Representative for Pakistan (based in Pakistan)<sup>2</sup>  
Changrong Yan (China), Facilitator of Yellow River Basin Dryland Project (based in China)

## EXPERIMENT STATION

Rodrigo Rascon (Mexico), Field Superintendent, Ciudad Obregón

## POSTDOCTORAL FELLOWS

Jacob Lage (Denmark), Plant Breeder<sup>2</sup>  
Jiro Murakami (Japan), Wheat Pathologist<sup>2</sup>  
Mirjam Pulleman (Netherlands), Conservation Agriculture<sup>2</sup>  
Garry Rosewarne (Australia), Molecular Geneticist (Small Grains)

## PREDOCCTORAL FELLOWS

Bram Govaerts (Belgium), Soil Scientist  
Sybil Herrera (Sweden), Molecular Breeder (Wheat)  
Scott Justice (USA), Agricultural Engineer (based in Nepal)<sup>1</sup>

## GENERATION CHALLENGE PROGRAMME

Jean-Marcel Ribaut (Switzerland), Director<sup>2</sup>  
Kaitlin Lesnick (USA), Consultant<sup>2</sup>  
Jennifer Nelson (USA), Officer / Specialist I, Communications Coordinator  
Adriana Santiago (Mexico), Program Administrator  
Ibtisam Vincent (USA), Consultant<sup>1</sup>  
Robert Zeigler (USA), Director<sup>1</sup>

## STRATEGIC ADVISORY SERVICES FOR HUMAN RESOURCES

Nellooli Rajasekaran (India), Director<sup>1</sup>

## MANAGEMENT COMMITTEE

Masa Iwanaga, Director General  
John Dodds, Chair, Deputy Director General Research  
Marianne Bänziger, Director, African Livelihoods  
Hans-Joachim Braun, Director, Rainfed Wheat Systems  
Jonathan Crouch, Director, Genetic Resources  
John Dixon, Director, Impacts Targeting and Assessment  
Rodomiro Ortiz, Director, Intensive Agroecosystems  
Kevin Pixley, Director, Tropical Ecosystems  
Martin van Weerdenburg, Director, Corporate Services

## VISITING SCIENTISTS (PERIODS OF MORE THAN TWO MONTHS)

Reshma Gaju Oorbessy (Mauritania)  
Sophie Georges (France)  
Christelle Monier (France)  
Bukovnik Urska (Slovenia)  
Sentner Ulrich Martin (Germany)  
Browne Roy Allen (Ireland)  
Sandoya Miranda Germán (Ecuador)  
Tauber Stefanie (Austria)  
Pablo Aldo Polci Quarchioni (Argentina)  
Peter Richard Matthews (Australia)

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<sup>2</sup> Appointed during 2004-2005.

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