CIMMYT in 1993

Helping the Poor through
Innovative
Agricultural Research
Innovation
Imagination
Dedication

What will it take to reduce poverty in developing countries during the coming decades and, in doing so, protect the environment and slow population growth? Success will hinge on many things, but arguably the most important will be sustainable improvements in agricultural productivity — and those will require innovative and imaginative long-term research, the work of CIMMYT staff and their many colleagues around the world. Such research will be the source of new technologies that both increase productivity and protect natural resources.
A Message from the Director General

In last year's annual report I posed a provocative question: With the world's attention focused on the poverty, environmental, and population problems of developing countries, why should anyone be concerned about agricultural research? In answering that question, we argued that the three problems interact strongly, that poverty is the pivotal element, that long-run solutions to environmental and population problems rest on reducing poverty, that alleviating poverty in the poorest countries requires improved productivity in agriculture, and that sustainable increases in productivity require new technologies from agricultural research — technologies that both raise productivity and conserve natural resources.

To be most effective in raising productivity and protecting the environment, agricultural research must be innovative. Innovation itself is the driving force behind practical economic advance. As we see it, the term covers the discovery or the introduction of something different from existing norms. It includes new insights, as well as new applications of old insights, and it occurs at many levels of research.

CIMMYT is in the innovation business. At times, through the pursuit of the pragmatic in our research, we gain new scientific insights. Such is the case of drought tolerant maize varieties based on new insights about the plant's physiology (see page 3). For the most part, however, innovation in CIMMYT — as the next 10 pages of this report will show — means translating new ideas from science into useful new applications. We transform ideas into practice, for our own use and the use of others. We do this extraordinarily well.

We begin our report with examples of innovative efforts to build better plants — new maize and wheat varieties with improved yield potential, greater efficiency in the use of scarce agricultural resources, and stronger built-in resistance to pests, all of which give higher and more stable yields while lowering the environmental and health risks associated with pesticides. Our stories here range from marker-assisted selection for insect resistance in maize, to work on nitrogen-use efficiency.

We follow with research that both protects nature's genetic diversity and builds on it. We report on imaginative efforts to increase the diversity of bread wheat, the development of new tissue culture protocols that will eventually enable gene banks to regenerate old, apparently dead seed in their collections, and on progress toward producing apomictic (true breeding hybrid) maize, a potential boon to developing country maize farmers.

The growing importance of managing plant breeding information as a strategic resource provides a third focus in this report, and we highlight three of our more recent efforts in that domain.

And finally, we look at examples of creative networking, an activity that has long been an inherent part of CIMMYT's modus operandi and one that is taking on ever greater prominence as an efficient means of achieving impact in farmers’ fields.

One of CIMMYT’s major challenges, indeed one confronting the entire Consultative Group on International Agricultural Research, is to ensure an atmosphere — including a culture and appropriate physical and financial support — within which innovation can flourish. Pages 16-19 of this report present financial highlights, and there we trace funding trends of the past five years, noting consequences of declining budgets for the products and services we supply. Specialists will want to request our 1993 Audited Financial Statement for more detail.

As always, our aim in this report is to be brief and to focus on the information needs of CIMMYT's many stakeholders. We trust you will find it useful.

Donald L. Winkelmann
Director General
Modern maize and wheat varieties foster sustainable agriculture. These new varieties — products of innovative research — use resources more efficiently, require fewer pesticides, and slow the assault on delicate environments by increasing food production elsewhere.

Molecular Biotechnology provides a universe of new techniques that can streamline the process of plant breeding. One of these — molecular markers — is now being applied for the first time to the breeding of subtropical maize. CIMMYT staff are using them to speed the selection of varieties resistant to corn borers, serious insect pests in many subtropical maize areas.

Molecular markers are bits of DNA that adhere to specific places on a chromosome and serve to indicate whether plants possess the genes for a given trait. The technology has been around for some time, but is only now becoming a practical tool for maize breeders, thanks to another innovation by CIMMYT's molecular geneticists: the first genetic map of tropical maize. "The map provides a detailed understanding of the maize genome," says Mireille Khairallah, one of the geneticists involved in the project. "It shows the regions where the genes for particular traits are located on the maize chromosomes and is essential to marker-assisted selection."

Khairallah and her colleagues Martha Willcox (a maize breeder), Diego González de León (head of the applied molecular genetics lab), and David Hoisington (head of the Applied Biotechnology Laboratories in CIMMYT), are collaborating on the application of this technology. "The objective is to transfer naturally occurring borer resistance to elite maize lines destined for Africa that are already resistant to several locally important diseases," says Willcox. "We expect that molecular markers will allow us to transfer this resistance in as little as two years. Conventional methods would require at least twice that much time."

Why choose insect resistance for this ground-breaking work? First, insects cause enormous economic losses for developing country maize farmers, and effective pesticides are often beyond the reach of poor farmers; moreover, pesticides present serious environmental and human health hazards. Second, the selection of truly resistant varieties is difficult because resistance is a complex trait controlled by many genes and because environmental factors can easily camouflage genetic resistance during field testing.

CIMMYT will make this technology available to national program scientists and offer training in its use, so as to speed their breeding work as well.
Drought Tolerant Maize: Helping Farmers through Dry Spells

Drought in developing countries reduces maize production by at least 15% each year, and in specific areas the impact can be much worse. In 1991-92, for example, southern Africa lost two-thirds of its maize harvests to drought, leading to US$800 million in food aid for the region.

To help farmers through the dry spells, CIMMYT maize breeders are developing drought tolerant tropical maize varieties. Selecting for this trait, however, has always been difficult because there was no practical yardstick for identifying tolerance in the field. In the course of their drought selection work, CIMMYT scientists discovered that when maize is deprived of water around flowering time, female flowers (the silks) appear several days later than normal. "The male flower (the pollen-producing tassel) apparently monopolizes the limited supply of plant carbohydrates, leaving little for the silks and ears," explains CIMMYT physiologist Gregory Edmeades.

Turning the tables on the tassel, Edmeades and his team placed eight successive generations of maize under extreme drought at flowering and selected only plants in which silks appeared soon after male flowers. This reduced "anthesis to silking interval" (ASI) has proven to be a clear indicator for selecting for tolerance to mid-season drought in tropical maize. "The payoff of this work is two-fold," says Edmeades. "We’re now producing varieties that give normal yields under drought conditions that would otherwise reduce production as much as a third, and we have a new selection methodology that our colleagues in developing countries can use."

Even though ASI is a reliable indicator of drought tolerance, its use still requires putting plants under controlled drought stress, something that can be difficult to do. For that reason, CIMMYT’s applied molecular genetics lab is now developing markers that will enable selection for reduced ASI even in the absence of drought (see previous story for more on marker-assisted selection).

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Fluorescent In-situ Hybridization

First developed for human genome research and later applied by others to plant species, fluorescent in-situ hybridization has now been adapted to maize and wheat research by CIMMYT researcher Nurul Islam-Faridi and his colleagues. The modified technique makes it easier to gauge whether useful DNA from related species has been retained in the offspring of various wide crosses. It uses nonradioactive chemical processes to make the alien DNA light up like a neon sign. As but one example, CIMMYT has used the technique to confirm that certain bread wheats, developed through Australian/Chinese collaboration, carry genetic material (the red segments in the photo) from Thinopyrum intermedium—a wild relative of wheat—that imparts resistance to barley yellow dwarf viruses that cause a ubiquitous disease of wheat.
How can developing country farmers get more yield from “tired” topsoils and at the same time avoid the environmental risks that can go along with the excessive use of chemical fertilizers? CIMMYT staff are following up on two complementary avenues of research devising practices that complement this improved efficiency. In recent experiments, CIMMYT agronomist Iván Ortiz Monasterio has shown that timing of application greatly affects the efficiency with which nitrogen is used by improved wheats, especially under low to moderate application rates. “When 150 kilograms of nitrogen per hectare are applied at planting,” he says, “the crop recovers about 50% of it. If we break with tradition and instead apply the same amount around 50 days after planting, the crop recovers close to 65%.” (See Figure.) There are clear payoffs from this change: grain yield, for example, is increases slightly and protein content rises nearly 20%. And, of course, less nitrogen is lost to the environment in the form of air and water pollution.

Nitrogen application rate (kg/ha)

Delaying the application of nitrogen fertilizer can dramatically improve its recovery by wheat plants.

Over the years, CIMMYT wheat breeders have significantly improved the ability of bread and durum wheats to extract nitrogen from the soil and convert it to grain. Our wheat agronomists are now

Addressing these two concerns involves something of a new twist for our maize breeders and crop management specialists. "The higher yields from our improved varieties have always come from the interaction between management and genotype, but traditionally that synergy has been most noticeable under favorable production conditions," says Lafitte. "With increased pressure on natural resources, we now need maize varieties and farming techniques specifically tailored to more marginal environments."

Breakthroughs in this work are rare, partly because of the greater variability in soil quality in marginal environments. This makes varietal improvement difficult. But after several years of research we now have promising selection methods, a pool of maize that can serve as a source of low-nitrogen tolerance, and even experimental varieties that produce more grain in both fertile and poor soils. In addition, research on genotypic variation in maize response to nitrogen availability complements studies on the timing of organic nitrogen release by green manures, part of the research agenda of the Swiss-funded Regional Maize Program in Central America and the Caribbean (see page 10).
Nurturing Nature's Diversity

CIMMYT preserves nature's bounty and builds upon it. Our maize and wheat banks are treasure chests of genetic diversity, open to all, and we apply inventive science to amplify their value.

Duplicating Nature to Increase Diversity in Wheat

Some 6,000 years ago, through a random occurrence in nature, a wild grass with 28 chromosomes captured the pollen of another having only 14 chromosomes. The resulting 42-chromosome offspring became one of the world’s most important cereal grains — bread wheat. CIMMYT scientists are now duplicating that chance encounter hundreds of times over in an unprecedented effort to broaden the genetic diversity of this long-domesticated crop and, in so doing, further increase its reliability as a vital source of food.

Explains Abdul Mujeeb-Kazi, head of the CIMMYT wheat wide crosses laboratory, “Breeders want additional diversity for disease and stress resistances, and we’ve developed an efficient method for transporting useful genes from an untapped wild species called goat grass (Triticum tauschii) — the 14-chromosome ancestor of bread wheat — into elite bread wheat varieties.”

The early 28-chromosome parent of bread wheat evolved into durum wheat. Mujeeb-Kazi and his colleagues decided to cross elite durums with accessions of T. tauschii to produce “synthetic” bread wheats. Those synthetics could then serve as a bridge to elite bread wheats, across which useful genes from T. tauschii could be moved with relative ease.

Converting that idea into practice is not so straightforward: after each cross is made, embryo rescue techniques and chemical treatment to double the chromosome number of the resulting plants are required to create the synthetic. Only some 525 of these new wheats exist today, nearly 450 of which were produced at CIMMYT.

The synthetic wheats do not thresh well and so are of little direct use to farmers. “However,” says Sanjaya Rajaram, CIMMYT wheat breeder, “since the synthetics are true bread wheats, we can immediately cross them with our elite lines.” In 1989, one of our best bread wheats, Bacanora, was crossed with the synthetic, Chen/T. tauschii. In a 1992-93 preliminary yield trial, Chen/T. tauschii//Bacanora yielded far more than the other 838 lines in the trial and surpassed its Bacanora parent by over 20%.

In addition to higher yield potential, the synthetic bread wheats provide breeders with new sources of resistance to certain diseases, including septoria, helminthosporium, fusarium, and Karnal bunt. Other useful traits also appear to be in the offing, including improved quality, salt tolerance, higher rates of photosynthesis, and drought tolerance. “We’ve only touched the surface,” concludes Mujeeb-Kazi. “Many synthetics still await screening for useful traits, and many other T. tauschii accessions can be used to make new synthetics.”

Synthetic bread wheats provide a “bridge” across which we can move useful genes from wild species into wheat. Here an elite durum wheat (far left) is crossed with a wild relative of bread wheat, T. tauschii, to produce a synthetic bread wheat (middle spike). The synthetic is then crossed with an elite bread wheat to produce an improved line (near right) that can retain the desirable traits from T. tauschii.
Recovering Life from “Dead” Seed

Innovations in research are sometimes spinoffs from efforts directed at entirely different goals. Such was the case recently for Natasha Bohorova, head of CIMMYT’s applied genetic engineering laboratory, who in the course of other work devised new protocols for recovering living cells from apparently dead seed.

“Old, non-germinating seeds often contain living cells. The trick is to coax these few survivors into multiplying and producing new plants,” says Bohorova. Working with non-germinating maize seed from CIMMYT’s maize bank, she used tissue culture techniques to try to revive the seed. After much study and experimentation, she hit upon just the right combination of essential nutrients and other factors that would induce the cells to divide and grow.

An embryo taken from a “dead” seed was placed in this special medium and began to produce new cells, forming a “callus.” The callus was transferred to another nutritive medium and, eventually, produced plantlets. “We’re now refining the technique and soon we expect to be able to use it in regenerating other materials besides maize,” notes Bohorova.

The new procedure will be particularly important to gene banks all over the world. These banks preserve seed for long periods at very low temperatures. Time takes its toll, however, and eventually stored seed loses the capacity to germinate — for all practical purposes, it dies. All gene banks have old seed that will no longer germinate, but the problem is particularly acute among developing country banks that often lack the resources needed for regular field regeneration programs. “Up to now, there was no hope of resurrecting the dead seed,” says Suketoshi Taba, head of CIMMYT’s maize bank. “In the case of rare or apparently extinct materials, this is a real tragedy. The regeneration procedure developed by Bohorova will help broaden the array of genetic material available to meet future challenges to food security.”

Natasha Bohorova and David Hoisington (head of CIMMYT’s Applied Biotechnology Labs) examine plantlets regenerated from old, non-viable seed.
Apomixis: Helping Improved Maize Keep Its Edge

Unlike wheat, maize plants freely cross-fertilize, a trait that has allowed maize to adapt to more diverse production environments than any other major food crop. But that trait also means that farmers who use improved varieties must purchase fresh seed regularly. Otherwise their crop quickly loses its “edge” — the improved qualities that contribute to high yields. Seed production and distribution systems, however, are generally poor in developing countries, and even where quality seed is available, many farmers lack the money needed to purchase it.

A CIMMYT-based research team is now developing a new type of maize that will keep its productive edge almost indefinitely, cycle after cycle. The plants will reproduce asexually through a process called “apomixis,” which means that nearly all seeds produce an exact clone of the mother plant. Farmers will need only purchase an initial installment of improved apomictic seed to reap the benefits season after season.

Posted at CIMMYT under a collaborative project with the French National Institute for Development Cooperation (ORSTOM), cytogeneticist Yves Savidan and his research group are already more than halfway toward their goal of producing apomictic maize. They are transferring the trait from *Tripsacum*, a close relative of maize, through a complex series of crosses.

The first steps — crossing maize with an apomictic *Tripsacum* species — once seemed to lead to a dead end. “The pollen of maize-*Tripsacum* hybrids is sterile. And since the hybrids are apomictic, they apparently couldn’t be fertilized with pollen from other plants,” explains Savidan. But he and his group found a chink in nature’s armor: apomixis malfunctions in 2-3% of the hybrids, allowing them to be crossed with maize. From the progeny of this second cross, the researchers again selected the few in which apomixis would misfire and fertilized the plants using maize pollen. This repeated “back-crossing” to maize eventually dilutes the *Tripsacum* heritage, leaving what is essentially a maize plant that contains only a part of a single *Tripsacum* chromosome. The final goal is to reduce the *Tripsacum* component until only the specific gene or genes for apomixis remain. “The most difficult steps have been completed,” says Savidan. “We are confident of getting apomictic maize by 1997.”

While apomictic maize should prove valuable to farmers in many circumstances, it is no panacea. Careful seed management, for example, is a prime concern, as is maintaining resistance to evolving insects and disease pathogens. Still, Savidan sees practical, research-based solutions to these potential problems, and is keeping the needs of farmers firmly in mind as his research moves forward.
Plant Breeding in the Information Age

Plant breeding is becoming ever more information-intensive. CIMMYT, working with others, is developing imaginative systems that put vital information within easy reach of the world’s plant breeders.

CIMMYT created the wheat pedigree management system, an extensive relational database containing information on genealogies and selection histories.

“This database is the core of CIMMYT’s International Wheat Information System (IWIS), which integrates information from different sources, provides a secure, flexible mechanism for data storage, and facilitates powerful associations between genetic information and performance data. Concludes Fox, “Integrating CIMMYT’s system with those developed by other groups, like those funded under the USDA Plant Genome Initiative, will make it possible for the IWIS to store, query, and disseminate data on wheat germplasm held by many countries much more efficiently than in the past. This system clearly represents a giant step forward in data management, one that will permit agricultural scientists to pool their findings and apply them in ways never before possible.”

The CIMMYT-developed software can be used with any self-pollinated crop (the International Rice Research Institute, for example, has expressed interest in applying the system to rice). It is now being converted to a PC-based system to broaden its usefulness, both in developed and developing countries.

Information

Thirty years ago, a revolution in plant breeding occurred that centered on the exchange of germplasm among breeders in many countries. CIMMYT was a leader in that revolution.

Today, we are again taking the lead in a breeding revolution, one based not only on the free exchange of germplasm, but also on the free exchange of information about it. “This revolution is not only adding value to the germplasm,” says Paul Fox, CIMMYT statistician, “but it’s also strengthening the bonds between research institutions and scientists right around the world.”

National agricultural research systems together invest more than US$1 million each year to grow CIMMYT experimental wheat trials; yet the data derived from those experiments are not, so far, easily shared. “The major barrier to exchanging data,” notes Fox, “has been the multiple names used for the same cultivar or the use of the same name for different ones.” To bypass this identification roadblock,
Researchers from the Kenya Agricultural Research Institute (KARI) and CIMMYT have developed an innovative way to organize maize research, one that literally extends from the remote realm of satellite mapping to the more down-to-earth level of research in farmers’ fields. Using state-of-the-art geographic information systems, researchers can now target their work far more accurately on major farming systems.

A comprehensive database was formed that links, for the first time in Kenya, geographic and agroecological information, data on farming system priorities, data from experiments, population statistics, information on markets, and selected socioeconomic variables. The special thing about this database, however, is the information it contains from farmers. Researchers surveyed some 1,400 farmers throughout Kenya’s major maize-producing zones, assembling data on agricultural practices, problems, and priorities. Kenyan maize farmers had never been surveyed in such numbers. “This information constitutes the human element that’s often missing when research priorities are set,” says Cyrus Ndiritu, Director of KARI.

Researchers using the database can trace the adoption of new technologies and show how production systems are changing over time. “Better information on the dynamics of agricultural change allows us to keep pace with farmers’ evolving needs and with trends in the quality of the natural resource base,” says Daniel Karanja, a KARI economist. The database has already helped pinpoint areas where farmers did not adopt recommended maize varieties. These are transitional areas between the intermediate maturity (midaltitude) and late maturity (high tropics) zones defined by KARI. “Apparently, farmers did not adopt recommended varieties because they weren’t suited to that transitional area, which actually comprises Kenya’s largest maize production zone,” says Rashid Hassan, a CIMMYT economist collaborating in development of the database. In response, KARI has created a special program to identify late-maturing varieties adapted to these relatively cooler, midaltitude locations.

Although use of the database is still in the experimental stage, KARI scientists and administrators are keen to explore its potential applications. Kiarie Njoroge, KARI’s National Maize Research Coordinator, says, “We’re quite proud of this work and have used it in developing KARI’s 20-year strategic plan.” KARI is among the first national agricultural research organizations in developing countries to train its scientists in the intricacies of geographic information systems, and they are documenting their methods so researchers elsewhere can use them.

ADaM

“It’s like going from a hand-held calculator to using a personal computer,” says Rick Ward, Michigan State University plant breeder, reflecting on the productivity payoff that will come from the new Agricultural Data Management system (ADaM) he is helping to develop under the auspices of CIMMYT’s Maize Program. Imagine a totally integrated software package that puts mountains of data at the fingertips of plant breeders, incorporates cutting-edge statistical tools from the Scottish Agricultural Statistics Service, takes full advantage of the latest interface technology, and does everything from maintaining lists of germplasm to designing large, complicated trials — even printing the books and labels needed to manage the experiments in the field. “Imagine all that,” says Ward, “and then imagine having it on a portable PC, so that breeders can pack it with them when they visit colleagues all over the world. The implications for improved research productivity are immense.”

“ADaM will be especially useful to national programs,” says Charlie Wedderburn, Associate Director of the CIMMYT Maize Program. “One person will be able to organize and manage more research than ever before. I predict ADaM will be an essential part of every breeder’s toolbox.”
Networking for Sustainable Agriculture

CIMMYT has a long tradition of active outreach programs, on-farm research, training, and networking. Originally, we provided leadership. Today, we join in innovative partnerships.

With budgets shrinking at an alarming rate, agricultural research managers must seek inventive ways to join forces and ensure timely access for farmers to improved agricultural technology. Networking is one collaborative framework that has proven exceptionally effective for research on maize and economics in Central America and the Caribbean.

For nearly two decades, the Swiss Development Cooperation (SDC) has funded the Regional Maize Program (Programa Regional de Maíz, or PRM), an innovative network that pools the labor and talents of nine national research programs from the region and CIMMYT. Network participants point out several qualities as central to the PRM’s success: members plan and budget each year’s activities in an annual meeting that includes a rigorous assessment of progress toward prior commitments; decision making is democratic and representative; and a coordinator from the region expedites day-to-day operations with a notable lack of bureaucracy. All products developed by the network — improved seed, new methodologies, and information — are freely shared among participants. Outside observers cite as essential ingredients the dedication of its members, the high level of technical support from CIMMYT, and the active interest of SDC, which has provided valuable guidance on network planning and organization.

The impact of the PRM is impressive. It was instrumental in adapting popular varieties and hybrids that resist corn stunt, a disease that in Nicaragua alone reduced harvests by an estimated US$ 5 million in 1986. It also refines and disseminates crop management techniques that help conserve soil fertility and moisture and prevent erosion. Finally, the PRM strengthens national programs in the network by providing hundreds of researchers with opportunities for training and professional association, by fostering the integration of breeding, crop management research, and socioeconomics, and by funding useful research that the programs alone could not support.

CIMMYT believes the PRM model could function well under different circumstances, and is working to establish similar research networks in Asia and in eastern and southern Africa.

Sustaining Rice-Wheat Cultivation in South Asia

The productivity of South Asia’s vast rice-wheat area is declining (see CIMMYT 1990 Annual Report). In 1993, several major donors expressed interest in supporting ongoing collaborative research (initiated in the mid-1980s) aimed at reversing this trend. As national programs assume leadership for network activities, CIMMYT and IRRI will continue their close collaboration in providing technical support.
Fostering Farmer-to-Farmer Extension in Veracruz, Mexico

By enabling greater numbers of farmers to share information on the use of green manures and other resource-conserving technologies for maize cropping systems, an imaginative extension project in Veracruz, Mexico, is building on what a few farmers in the region have done for nearly half a century. The project uses a farmer-to-farmer extension model that encourages farmer experiments with resource-conserving technologies.

Tight budgets for public extension programs in Veracruz mean that agricultural information is less readily available, which makes farmer-to-farmer extension and experimentation all the more important for poor farmers in the region. This innovative strategy also helps farmers articulate their needs so that research and extension can become more “demand driven.”

Experimentation is not new to the farmers of southern Veracruz. In the 1950s, indigenous Nahua and Popoluca maize farmers in the Sierra de Santa Marta started experimenting with the leguminous plant velvetbean (*Mucuna* spp.) as a green manure. They found that the plant controlled erosion and weeds, conserved soil moisture, and improved soil fertility.

But despite its advantages, velvetbean diffused slowly among Santa Marta’s isolated farming communities; in 1991, only about 150 farmers, concentrated in a few areas, knew about its agricultural virtues. This situation is changing rapidly. What started as a small series of experiments by farmers and researchers evolved into a local extension program and is now entering a third phase. This phase involves government and non-governmental organizations (NGOs), academic institutions, and CIMMYT in a farmer-to-farmer extension strategy for cover crops/green manures, contour hedgerows, and conservation tillage in an indigenous region where population growth is exerting pressure on the remaining rain forests of Veracruz.

The first steps toward implementing this strategy were taken at a recent workshop on policy issues affecting the adoption of these technologies, organized by CIMMYT with support from the Ford Foundation. Future workshops targeting farmers, researchers and extensionists, and government officials will involve them in disseminating resource-conserving technologies and implementing incentive schemes at the local level. Because Mexican farmers have a tradition of legume intercropping that can be adapted to green manuring and other methods for conserving natural resources, research and extension now have an unusual opening for contributing to a process of innovation started by farmers decades ago.
### Highlights from the Research Programs

**Impressive Payoffs from Wheat Breeding**

A comprehensive study of the impacts of international and national wheat breeding research in the developing world was completed in 1993. According to this study, adoption by farmers of modern varieties just during the period 1977-90 contributed — in 1990 alone — an additional US$3.0 billion to the incomes of developing world wheat producers and consumers. The study estimates that the rate of return to investment in such research continues at a very high level, on the order of 50-60%. Moreover, a related study concludes that contrary to the opinions of some, modern varieties have fostered sustainability in agriculture, both indirectly (as land-saving technologies) and directly (by using inputs more efficiently and by increasing the stability of production in many areas). Further diffusion and release of modern varieties will continue to promote sustainable agriculture.

### Natural Resources Research in CIMMYT

In 1993, the Center established a natural resources management research group whose work cuts across our major research undertakings. The group is concerned with, among other things, developing new research methods and sharing knowledge across related research activities. Current projects include sustaining productivity in the extensive rice-wheat rotation in South Asia (photo) and the development of resource-conserving technologies for the maize-based systems of Central America and Mexico.

### Genetic Advantages for CIMMYT Wheats

A series of experiments concluded in 1993 verified that the 1B/1R translocation — in which the short arm of the 1B chromosome in wheat is replaced by the short arm of the 1R chromosome from rye — is responsible for up to a 10% increase in the yield potential of wheat. The short arm of the 1R chromosome also carries genes for resistance to important diseases of wheat. These genetic advantages explain the worldwide popularity of CIMMYT-developed Cim-wheats, which carry the translocation.

### Maize That Wins against Weeds

Evidence from several years of research shows that selected CIMMYT maize varieties developed at our mid-altitude station in Harare, Zimbabwe, yield nearly 40% more under heavy weed competition than do the hybrids most commonly planted by smallholders in that country.
Potential New Tool in the Search for Higher Yielding Wheats

CIMMYT physiologists verified that genetic progress in wheat yield potential since the 1960s is closely associated with greater photosynthetic activity — both have increased by some 25%. These results have implications for future yield selection strategies. Higher rates of photosynthesis correlate with lower canopy temperatures, which can be easily measured using a hand-held thermometer "gun" (photo). Breeders may be able to use these measurements to increase the efficiency of yield selection in the field, and the technique holds considerable promise for selecting wheats that can tolerate hot climates.

Saving Endangered Maize Collections

The effort to save endangered collections of maize landraces in Latin America continued apace in 1993. The CIMMYT maize germplasm bank received back-up samples of some 1,500 accessions regenerated by the seed banks of 11 countries in the region. This continuing project is funded by two United States agencies: the Agency for International Development and the Department of Agriculture, through the National Seed Storage Laboratory (NSSL).

"Doubly-Resistant" Maize

During 1993, CIMMYT's maize entomologist and his Nicaraguan colleagues identified several maize varieties that have combined resistance to multiple species of insect pests and to corn stunt, a major disease threat to maize production in Central America. These resistant varieties will be used in collaborative breeding work with national programs in the region.

New Varietal Releases

At least 44 maize and wheat varieties derived from CIMMYT germplasm were released during the year by national programs in 21 countries.
The Indian Council of Agricultural Research recognized CIMMYT's Maize Program for its "outstanding contribution to maize improvement in India." Delbert Hess, Program Director, accepted the award "on behalf of all those who have dedicated themselves to the unending struggle to improve the lives of India's poor." CIMMYT maize scientists Surinder K. Vasal, Carlos de León, and Gonzalo Granados were also recognized by ICAR for their extraordinary individual contributions to maize improvement in India.

Surinder K. Vasal, maize breeder, was named a Fellow of the American Society of Agronomy for his more than two decades of notable efforts in maize breeding for developing countries and for his significant research accomplishments on quality protein maize.

Tony Fischer, Director of the CIMMYT Wheat Program, was made a Fellow of the Crop Science Society of America in recognition of his distinguished and widely published research on wheat physiology and for his many special contributions to international agricultural research and development.

Sanjaya Rajaram, wheat breeder, received the 1993 E.C. Stakman Award for his "outstanding career contributions to the discipline of plant pathology." The award is presented in honor of Elvin C. Stakman, the eminent plant pathologist who established the principles of breeding disease resistance into wheat and many other crops.

CIMMYT's 1993 External Review

In February, CIMMYT became the first CGIAR center to undergo an interim external review. The review panel was chaired by Sir Ralph Riley, Consultant to the CGIAR, and included Mr. John Griffith, Chief Financial and Administrative Officer of the World Bank's Multilateral Investment Guarantee Agency; Dr. John Monyo, Executive Secretary of the CGIAR's Secretariat for its Technical Advisory Committee (TAC); and Ms. Elizabeth Field, Management Analyst for the CGIAR Secretariat. The "interim" review format was used in response to the TAC's recommendation that the CG system find less costly ways to assess the state of its centers. CIMMYT was chosen as the place to test this new format on the grounds that its last full review in 1988 was so favorable that the CGIAR expected no major issues or concerns to emerge. Both the panel and CIMMYT management and staff felt that the new approach was an effective, efficient use of increasingly scarce financial and human resources, and recommended to the CGIAR that other centers undergo similar reviews. Some of the review panel's main conclusions follow.
The role of agricultural research in economic development was the focus of a March visit by Mr. Lewis Preston, President of the World Bank. He was accompanied by Mr. Shahid Husain, World Bank Vice President for Latin America; Mr. Angel Torres, World Bank Executive Director, Mexico, Central America, and Spain; Mr. Eugene McCarthy, the Bank’s Representative in Mexico; and Lic. Ramón Benítez, Director General, External Credit, Ministry of the Treasury, Mexico.

The congruence of Canada’s goals in development assistance and the work of CIMMYT and other CGIAR centers was discussed with the Honorable Charles Mayer, Canada’s Minister of Agriculture, who visited the Center in May.

In April, Dr. Hisashi Kukimura, Ministry of Agriculture, Forestry, and Fisheries, Japan, led a group of visiting government dignitaries from Japan and Mexico who are interested in strengthening ties with the Wheat Program. Mr. Abdel Adel Hammid Ezz, Egypt’s State Minister for Scientific Research, also visited the Center in April, along with Mr. Anis G. Nematalla, Egyptian Ambassador to Mexico, and Lic. Carlos Valera, Office of Technical Cooperation, Ministry of Foreign Relations, Mexico.

Mr. Nguyen Cong Tan, Minister of Agriculture of Vietnam, in March headed a delegation of distinguished visitors who came to discuss a range of collaborative activities involving CIMMYT and Vietnamese researchers.

Ambassador Mario Alessi, FAO Assistant Director General for General Affairs and Information, visited CIMMYT headquarters in January for discussions on the Center’s participation in FAO’s international agricultural information system (AGRIS).

In September, Ms. Sarita J. Das, Managing Director of India’s State Farm Corporation, led a delegation of visiting dignitaries from India who came to discuss opportunities for future collaboration.

“...it is certain that CIMMYT will be needed in the 21st century. The demand for wheat and maize will expand in developing countries and CIMMYT will be essential because it institutionalizes knowledge of these crops for the tropics and subtropics.”

Visitors to CIMMYT enrich our experience, bringing new ideas and perspectives that contribute to innovation in our work. We gratefully receive hundreds of visitors each year, and regret that here we can mention only a few.

In addition to CIMMYT’s interim external review, several of the Center’s specific activities were assessed in 1993 by panels of outside experts, all part of a continuing effort to encourage innovation and research of the highest caliber.
During the past five years, core funding for CIMMYT's activities has declined dramatically in real terms, a trend accentuated by Mexico's dollar-denominated inflation. This trend has serious implications for our ability to meet the needs of national programs and, by extension, the poor in developing countries. From early 1989 to the end of 1993, we reduced our core-funded, senior international staff by about one-third. And even though we have significantly reduced our expenditures over that period, they still exceeded our CGIAR income in 1993, forcing us to implement our contingency plan to draw down savings from earlier years. Working capital also declined to notably less than the level recommended by the CGIAR Secretariat.

Not only have we reduced staff at all levels, we have actively pursued other ways to reduce costs, including investments in new, more efficient equipment and out-sourcing via competitive bids. These efficiencies, welcome as they are, cannot compensate for the loss of funding.

How have these trends affected our activities? The criteria that guide the allocation of resources in CIMMYT reflect the broad priorities of the CGIAR, with its emphasis on alleviating poverty and protecting the environment, and on using resources efficiently to accomplish those goals. Given those priorities and our sense of opportunities, we have opted to protect our plant breeding work at the expense of crop management, training, networking, and various support activities. Even in the face of declining budgets, we increased the amount of resources for research aimed directly at protecting the environment and we maintain a significant commitment to biotechnology, which we see as a means of increasing the efficiency of our breeding efforts.

However, core resources have been cut for all classes of maize and wheat breeding, and notably so for prebreeding for wheat, early lowland tropical maize, and stress resistance in maize. The maize wide cross research unit has been eliminated. Progress in disease resistance (wheat and maize) and insect resistance (maize) will be slower, as will longer-term progress in raising yield potential.

Research on production systems suffered one of the largest percentage declines among activities (about 52%). Most of this decline occurred in the regions, which means less support for national program work on crop management and, taken as a whole, resources for institution building have fallen by over 50%.

### Financial Highlights

#### Balance sheet (US$ 000s)

<table>
<thead>
<tr>
<th>Year ended December 31</th>
<th>1993</th>
<th>1992</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Assets</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cash and short-term deposits</td>
<td>1,453</td>
<td>3,516</td>
</tr>
<tr>
<td>Accounts receivable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Donors</td>
<td>6,351</td>
<td>4,524</td>
</tr>
<tr>
<td>Other</td>
<td>1,156</td>
<td>1,404</td>
</tr>
<tr>
<td>Inventories</td>
<td>280</td>
<td>200</td>
</tr>
<tr>
<td>Property, plant and equipment</td>
<td>27,151</td>
<td>26,783</td>
</tr>
<tr>
<td>Accumulated depreciation</td>
<td>(14,652)</td>
<td>(14,100)</td>
</tr>
<tr>
<td><strong>Total assets</strong></td>
<td>21,739</td>
<td>22,427</td>
</tr>
<tr>
<td><strong>Liabilities and fund balances</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Liabilities</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accounts payable and other liabilities</td>
<td>2,716</td>
<td>2,156</td>
</tr>
<tr>
<td>Accrued staff obligations</td>
<td>572</td>
<td>700</td>
</tr>
<tr>
<td>Short term loan</td>
<td>1,000</td>
<td>0</td>
</tr>
<tr>
<td>Payments in advance from donors</td>
<td>2,936</td>
<td>2,966</td>
</tr>
<tr>
<td><strong>Total liabilities</strong></td>
<td>7,224</td>
<td>5,822</td>
</tr>
<tr>
<td><strong>Fund balances</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Property, plant, and equipment</td>
<td>12,311</td>
<td>12,037</td>
</tr>
<tr>
<td>Capital fund</td>
<td>199</td>
<td>374</td>
</tr>
<tr>
<td>Operating fund</td>
<td>2,005</td>
<td>4,194</td>
</tr>
<tr>
<td><strong>Total fund balances</strong></td>
<td>14,515</td>
<td>16,605</td>
</tr>
<tr>
<td><strong>Total liabilities and fund balances</strong></td>
<td>21,739</td>
<td>22,427</td>
</tr>
</tbody>
</table>
CIMMYT’s spending reached US$ 32.8 million in 1993. About $26.6 million was spent on essential work and $6.2 million on complementary efforts. These allocations were derived from $23.1 million in core funding, $6.2 million in complementary funding, $0.4 million from interest and other income, as well as $2.2 million from prior-year unexpended funds.

The $2.2 million from savings was available because of a plan initiated in 1991 to start "belt tightening" in anticipation of funding declines and to minimize disruptions in our activities. By the end of 1993, however, the Center was well below recommended liquidity levels. Additional reductions in our liquidity would be imprudent, and any further declines in real funding will necessarily play out immediately in our activities and products.

During the year, the Center’s total assets declined, largely due to a decrease in liquid funds. (We carefully protect our fixed assets through appropriate maintenance and timely replacement.) Compared with 1992, total operational costs diminished only slightly because of increases in local costs. Cash plus short-term deposits and accounts receivable were down significantly for the second year in a row, reflecting the decline in liquidity. Liabilities increased moderately.

In 1993, funding for core and complementary work arrived from numerous sources (see Table, above right). Donor pledges in currencies other than US dollars are recorded at their dollar equivalents on the date of deposit. In Mexico, the effect of a 7.6% dollar-denominated inflation rate continued to erode the purchasing power of dollar revenues received by the Center.

For detailed information on CIMMYT’s financial circumstances, see our Audited Financial Statement (published separately), available from our Publications Office in Mexico.
Selected Special Projects

Some funds derived from grants are earmarked by investors who have an interest in a specific area of research. A cross-section of these projects is presented here to reflect the breadth and variety of CIMMYT’s efforts and of the interests of those who support them. All funding is expressed in US dollars. For a complete listing of special projects, see our Audited Financial Statement (published separately).

Belgium
Non-specific Foliar Pathogens
Improve control of the important non-specialized wheat foliar pathogens affecting major cropping systems.

Funding period: 1993-1997
Total pledge: $820,000
1993 expenditures: $113,000

Canada
East Africa Cereals Program, Phase III
Increase national research capabilities in East Africa while introducing improved production technologies.

Funding period: 1992-1997
Total pledge: $3.83 million
1993 expenditures: $931,000

Bangladesh Wheat Project, Phase II
Improve food security and alleviate poverty in Bangladesh by increasing the productivity of resources in wheat production.

Funding period: 1991-1993
Total pledge: $1.3 million
1993 expenditures: $274,000

Ghana Maize Project, Phase III
Increase the productivity of resource-poor maize and legume farmers in Ghana.

Funding period: 1990-1995
Total pledge: $7.04 million
1993 expenditures: $1.12 million

Denmark
Wheat Information Project
Support a Danish associate scientist to develop an integrated wheat information system.

Funding period: 1989-1993
Total pledge: $206,000
1993 expenditures: $40,000

New Life for Ancient Seeds
Use tissue culture techniques to rejuvenate old, non-viable seeds.

Funding period: June - December, 1993
Total pledge: $20,056
1993 expenditures: $20,056

France
Tripsacum Research Project
Support a team of visiting scientists from the French National Institute for Development and Cooperation (ORSTOM) to gather and evaluate accessions of Tripsacum for use in maize improvement.

Funding period: 1989-1994
Total pledge: $485,000
1993 expenditures: $76,000

Islamic Republic of Iran
Improvement of Maize and Wheat
Enhance development of maize and wheat, using the best available varieties, technology, and training.

Funding period: 1989-1993
Total pledge: $482,000
1993 expenditures: $131,267

Italy
Barley Yellow Dwarf Virus, Phase II
Transfer technology to developing countries to reduce crop losses caused by BYDV.

Funding period: 1988-1993
Total pledge: $89,000
1993 expenditures: $89,000

Japan
Training Fellowships
Identify and support former CIMMYT trainees, who can earn advanced university degrees in various disciplines.

Funding period: 1986-1993
Total pledge: $1.3 million
1993 expenditures: $134,000

The Netherlands
Disease Resistance Research
Collaborative work with the University of Wageningen, Ethiopia, and Ecuador on durable resistance to stripe rust.

Funding period: 1989-1994
Total pledge: $700,000
1993 expenditures: $55,000

RFLP Research
Develop a linkage map for wheat and an RFLP Network for maize. Collaboration with the University of Missouri and Cornell University.

Funding period: 1989-1993
Total pledge: $700,000
1993 expenditures: $33,000

Norway
Training in Wheat and Maize
Support short-term visiting scientists at CIMMYT, Mexico; emphasis on scientists from South Asia and East Africa.

Funding period: 1988-1993
Total pledge: $303,000
1993 expenditures: $60,000
Switzerland
Maize and Economics Research
Strengthen national program capacity to conduct maize improvement and economics research in Central America and the Caribbean.
Funding period: 1992-1994
Total pledge: $1.12 million
1993 expenditures: $365,718

Wheat Disease Research
Support a Swiss pre-doctoral fellow to study the epidemiology of wheat diseases in the rice-wheat cropping system of the Nepalese terai.
Funding period: 1990-1993
Total pledge: $154,000
1993 expenditures: $28,963

United Kingdom
Crop Management Physiology Research
Investigate the feasibility of introducing genetic material from wheat’s wild ancestors to increase photosynthetic efficiency and yield potential of bread wheat.
Funding period: 1992-1993
Total pledge: $29,000
1993 expenditures: $20,000

United States
Maize Genetic Resources Project
Regenerate maize accessions stored in national germplasm banks in Latin America and the Caribbean.
Funding period: 1991-1994
Total pledge: $320,000
1993 expenditures: $66,539

Maize Genetic Resources Project
Regenerate maize landrace collections in Colombia, Mexico, and Peru.
Funding period: 1991-1996
Total pledge: $160,000
1993 expenditures: $38,184

Wheat Crop Management Research
Investigate management aspects of the rice-wheat cropping system in Nepal.
Funding period: 1991-1994
Total pledge: $150,000
1993 expenditures: $33,704

The Ford Foundation
Sustainable Agricultural Development
Support regional training and research programs in sustainable agricultural development in Central America, the Caribbean, and Mexico.
Funding period: 1991-1993
Total pledge: $236,000
1993 expenditures: $176,350

Inter-American Development Bank
Maize Varieties for Acid Soils
Develop maize varieties tolerant to acid soils prevalent on some 2 million hectares of Latin America maize lands.
Funding period: 1990-1994
Total pledge: $2.03 million
1993 expenditures: $431,000

OPEC Fund for International Development
Streak Resistance in Maize
Support research to improve lowland tropical maize germplasm for streak resistance in West Africa.
Funding period: 1991-1993
Total pledge: $30,000
1993 expenditures: $5,000

The Rockefeller Foundation
Maize Research in Malawi
Analysis of maize varietal preferences and maize farming systems in Malawi.
Funding period: 1989-1993
Total pledge: $300,000
1993 expenditures: $98,554

Kenya Maize Database
Build a maize database to guide maize research priorities in Kenya. Collaborative project with the Kenya Agricultural Research Institute and USAID.
Funding period: 1992-1994
Total pledge: $160,000
1993 expenditures: $46,556

UNDP
Stress Resistance in Maize Genetic Resources
Develop source germplasm with resistance or tolerance to major biotic and abiotic constraints of maize production in developing countries.
Funding period: 1990-1995
Total pledge: $6.6 million
1993 expenditures: $1.27 million

Wheat in Warmer and Stressed Environments
Support breeding, agronomy, and physiology research to increase the productivity of wheat in warmer environments.
Funding period: 1990-1993
Total pledge: $3.4 million
1993 expenditures: $1 million

Enhancing Host Plant Resistance to Insects
Reduce maize losses due to insect pests by enhancing host plant resistance with Bt toxin genes.
Funding period: 1993-1997
Total pledge: $5.7 million
1993 expenditures: $584,000
In 1993, two CIMMYT trustees completed their six-year terms on the Board. Our sincere thanks to Drs. Khem Singh Gill (India) and Ricardo Magnavaca (Brazil) for their many contributions, especially to further strengthening of our ties with the national research systems in their respective regions.

We welcome Drs. V.L. Chopra (India), Abderrazak Daaloul (Tunisia), and Bruce Hunter (Canada), who were elected to the Board at its March 1993 meeting. Dr. Chopra is a plant geneticist who serves as the Director General of the Indian Council for Agricultural Research and as the Secretary of India's Department of Agricultural Research and Education. Dr. Daaloul is a wheat breeder and heads the Tunisian Institute for Agricultural Research and Higher Education. Dr. Hunter is a maize crop scientist and leads the program on International Maize Breeding and Development at CIBA Seeds, based in the United States. Mr. Carlos Morales Topete (Mexico) succeeded Dr. Ernesto Samayoa Armienta as Director of Mexico’s National Institute of Forestry, Agriculture, and Livestock Research in September 1993, thus becoming a new ex officio member of the Board.

Four trustees retired from CIMMYT’s Board in April 1994: Drs. Donald Duvick (USA), Gao Liangzhi (China), Burton Matthews (Canada), and Gerhard Pollmer (Germany). Dr. Matthews served as Chairman of the Board and of the Executive and Finance Committee; with his retirement, these leadership positions pass on to Dr. Louisa van Vloten-Doting of the Netherlands. Dr. Lloyd Evans (Australia) will become the Chairman of the Board’s Program Committee. Three of the four Board vacancies will be filled in 1994.

### Trustees (as of March 1994)

<table>
<thead>
<tr>
<th>Name</th>
<th>Country/Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burton C. Matthews, Chairman</td>
<td>Chairman of the Board and of the Executive and Finance Committee, University of Waterloo</td>
</tr>
<tr>
<td>Donald N. Duvick, Chairman</td>
<td>Chairman, Program Committee, Iowa State University</td>
</tr>
<tr>
<td>V.L. Chopra</td>
<td>Indian Council for Agricultural Research</td>
</tr>
<tr>
<td>Abderrazak Daaloul</td>
<td>Institute for Agricultural Research and Higher Education</td>
</tr>
<tr>
<td>Lloyd T. Evans,</td>
<td>Commonwealth Scientific and Industrial Research Organization</td>
</tr>
<tr>
<td>Carlos Hank González</td>
<td>Secretary of Agriculture and Water Resources</td>
</tr>
<tr>
<td>R. Bruce Hunter</td>
<td>CIBA Seeds, USA</td>
</tr>
<tr>
<td>Gao Liangzhi</td>
<td>Jiangsu Academy of Agricultural Sciences</td>
</tr>
<tr>
<td>Ramón Martínez Parra</td>
<td>National Institute of Forestry, Agriculture, and Livestock Research</td>
</tr>
<tr>
<td>Carlos Morales Topete</td>
<td>National Institute of Forestry, Agriculture, and Livestock Research</td>
</tr>
<tr>
<td>Edgardo Moscardi</td>
<td>Interamerican Institute of Cooperation for Agriculture (IICA) representative, Colombia</td>
</tr>
<tr>
<td>Boniface N. Ndimande</td>
<td>Ministry of Lands, Agriculture, and Water Development</td>
</tr>
<tr>
<td>W. Gerhard Pollmer</td>
<td>Hohenheim University</td>
</tr>
<tr>
<td>Dolores Ramirez</td>
<td>Institute of Plant Breeding, University of the Philippines</td>
</tr>
<tr>
<td>Hirofumi Uchimiya</td>
<td>Institute of Applied Microbiology, University of Tokyo</td>
</tr>
<tr>
<td>Louisa van Vloten-Doting</td>
<td>Department of Agriculture, Nature Management, and Fisheries</td>
</tr>
<tr>
<td>Donald L. Winkelmann</td>
<td>CIMMYT, Mexico</td>
</tr>
</tbody>
</table>

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3 Ex officio position
Office of the Director General
Donald L. Winkelman, USA, Director General
Claudio Caffi, Chile, Deputy Director General of Administration and Finance
Paul Roger Rowe, USA, Deputy Director General of Research
Gregorio Martinez V., Mexico, Government and Public Affairs Officer
Norman E. Borlaug, USA, Consultant
Anne Starks Acosta, USA, Assistant to the Director General

General Administration
Kathleen Hart, USA, Financial Officer*
Donald A. McArthur, Canada, Financial Officer**
José Ramírez S., Mexico, Administrative Officer
Linda Ainsworth, USA, Head, Visitor and Conference Services
Hugo Alvarez V., Mexico, Purchasing Officer
Carmen Espinosa C., Mexico, Head, Government Documents
Manuel López L., Colombia, Supervisor, Accounting Services*
Martha de la Fuente M., Mexico, Head, Human Resources
Maria Gatty A., Mexico, Head, Food and Housing
Gilberto Hernandez V., Mexico, Training Coordinator
Robero Martinez L., Mexico, Head, Building Maintenance**
Domingo Moreno, Mexico, Head, Telecommunications
Roberto Rodriguez, Mexico, Head, Workshop
Manuel Terrazas M., Mexico, Internal Auditor

Maize Program
Delbert Seegmiller, USA, Director
Richard Webber, Barbados, Associate Director
Héctor J. Barreto, Colombia, Agronomist
Magni Bjarnason, Iceland, Breeder, Subtropical Germplasm**
Hugo Córdova, El Salvador, Breeder
James A. Deutsch, USA, Breeder, Lowland Tropical Germplasm and Stress Tolerance Research**
Gregory Edmeades, New Zealand, Physiologist/Agronomist
Daniel Jeffers, USA, Pathologist
René Lafitte, USA, Physiologist/Agronomist
James Lothrop, USA, Breeder
John A. Mihm, USA, Entomologist
Ganesan Srinivasan, India, Breeder, International Testing/Highland Maize
Suketoshi Tabata, Japan, Breeder, Germplasm Bank
Surinder Vasal, India, Breeder, Lowland Tropical Germplasm
Willy Villena, Bolivia, Breeder and Training Officer

Andean Region
(Staff based in Colombia)
Hernán Cevallos, Argentina, Breeder
Shivaji Pandey, India, Breeder

Asia (Staff based in Thailand)
Gonzalo Granados R., Mexico, Entomologist
Carlos de León G., Mexico, Pathologist

Eastern Africa (Staff based in Kenya)
Francisco R. Arias M., El Salvador, Agronomist**
A.F.E. Palmer, UK, Agronomist
Joe K. Ransom, USA, Agronomist

Central America and the Caribbean (Staff based in Guatemala)
Jorge Bolashos, Nicaragua, Agronomist

Southern Africa (Staff based in Zimbabwe)
David Jewell, Australia, Breeder
Kevin Pixley, USA, Breeder
Stephen Waddington, UK, Agronomist

Cooperative Program with ITA in West Africa
Alpha O. Diao, Guinea, Breeder
(based in Côte d'Ivoire)

Ghana
Roberto F. Soza, Chile, Agronomist

Associate Scientists
Julien Berthaud, France, Geneticist
Scott Chapman, Australia, Physiologist
Nural Islam-Faridi, Bangladesh, Molecular Cytogeneticist
Harish Kumar, India, Entomologist
Yves Saüvan, France, Cytogeneticist

Pre- and Postdoctoral Fellows
Marianne Banhödt, Switzerland, Physiologist
Marc Barre, France, Geneticist
Baldev Dhillon, India, Breeder*
Catherine Girouffet, France, Breeder
Daniel Grimacrelli, France, Geneticist*
Olivier Leblanc, France, Geneticist
Scott McLean, USA, Breeder
Harold Mickelson, USA, Breeder
Jean Marcel Ribaut, Switzerland, Geneticist*
Martha Willcox, USA, Breeder

Visiting Scientists
Shihuang Zhang, China, Breeder*

Wheat Program
R. A. Fischer, Australia, Director
George Varughese, India, Associate Director and Leader, Genetic Resources
Osman S. Abdalla, Sudan, Head, Durum Wheat
Edmundo Arevado, Chile, Leader, Crop Management and Physiology
Etienne Daveiller, Belgium, Pathologist

Paul Fox, Australia, International Nurseries
Guillermo Faentnes D., Mexico, Pathologist
Lucy Gilchrist S., Chile, Pathologist/Trainer
Maarten van Ginkel, The Netherlands, Bread Wheat Breeder
A. Mujeeb-Kazi, USA, Head, Wide Crosses
Iván Ortiz-Monasterio, Mexico, Agronomist
Roberto J. Peña, Mexico, Cereal Chemist
Wolfgang H. Pfeiffer, Germany, Head, Triticale
Sarayya Rajaram, India, Leader, Germplasm Improvement, and Head, Bread Wheat
Eugene E. Saari, USA, Leader, Crop Protection
Kenneth D. Sayre, USA, Agronomist
Ravi P. Singh, India, Geneticist/Pathologist
Bent Skovmand, Denmark, Head, Germplasm Bank
Reynaldo Villareal, The Philippines, Head, Training, Germplasm Improvement
Hugo Vivar, Ecuador, Head, ICARDA/CIMMYT Barley Program

East Africa
Douglas G. Yannet, Canada, Agronomist (based in Ethiopia)

South Asia (Staff based in Nepal)
H. Jesse Dabin, USA, Pathologist/Breeder
Peter R. Hobbs, UK, Agronomist
Markus Rockstuhl, Switzerland, Pre-doctoral Fellow**

Southeast Asia
Christoph E. Mann, Germany, Breeder (based in Thailand)**

Southern Cone of South America (Staff based in Paraguay)
Man Mohan Kohli, India, Breeder
Patrick C. Wall, Ireland, Agronomist

CIMMYT/ICARDA Cooperative Program (Staff based in Syria)
M. Mikusi, Syria, Head, Durum Wheat Breeder
Guillermo Ortiz F., Mexico, Bread Wheat Breeder

Bangladesh
Craig A. Meinzer, USA, Agronomist

CIMMYT/Turkey Winter/Facultative Wheat Program
(Staff based in Turkey)
Hans-Joachim Braun, Germany, Breeder/Pathologist
Thomas S. Payne, USA, Facultative Wheat Breeder, Joint CIMMYT/ICARDA Program
Associate Scientists

Lucas Bertschinger, Switzerland, Virologist/Entomologist
Leon Broers, The Netherlands, Pathologist/Breeder
Masanori Haagak, Japan, Wheat Wide Crosses*
Almei Mongunov, Russia, Breeder
Deborah Rent, UK, Physiologist**
Matthew P. Reynolds, UK, Physiologist
Gurdev Singh, India, Breeder
Maddanasinghe William, Sri Lanka, Cytogeneticist

Pre- and Postdoctoral Fellows

Enrique Autrique, Mexico, Breeder*
Jeanne Bindrahan, The Netherlands, Physiologist*
Aman Idris, Sudan, Physiologist**
Sylvie Lewicki, France, Physiologist**
Heidi Mickelson, USA, Breeder**
Francisco Santiveri, Spain, Physiologist***
Peter Steffany, Germany, Physiologist/Physiologist**

Economics Program

Derek Byerlee, Australia, Director
Robert Tripp, USA, Assistant Director
Larry Harrington, USA, Economist
Miguel Angel Lopez-Pereira, Honduras, Economist

Central America and the Caribbean

Gustavo E. Sain, Argentina, Economist (based in Costa Rica)

Eastern and Southern Africa

Nasir Hamann, Sudan, Economist (based in Kenya)
Paul W. Heseney, USA, Economist (based in Malawi)
Wilfred M. Mwangi, Kenya, Economist (based in Ethiopia)

South and Southeast Asia

Michael Morris, USA, Economist (based in Thailand)

Associate Scientist

Daniel Buckles, Canada, Anthropologist
Marion van Nieuwkoop, The Netherlands, Economist**

Pre- and Postdoctoral Fellows

Laura Saad, Mexico, Economist
Maurice Saade, Syria, ICARDA/CIMMYT Economist (based in Tunisia)**
Meredith Soule, USA, Economist**

Visiting Research Fellows

M. K. Chaudhary, India, Economist**
Hari Gurung, Nepal, Economist**
Luis Macagno, Argentina, Economist**
Zahid Mustafa, Pakistan, Economist**
Rooq Tomais, Brazil, Economist**
Gregory Traxler, USA, Economist**

Applied Biotechnology Laboratories

David Hoisington, USA, Head, Applied Biotechnology Laboratories
Natalia Bohorova, Bulgaria, Head, Applied Genetic Engineering Laboratory
Diego Gonzalez de Leon, Mexico, Head, Applied Molecular Genetics Laboratory

Associate Scientists

Miriam Fischer, Australia, Molecular Biologist**
Mireille Khairallah, Lebanon, Molecular Geneticist

Visiting Scientists

Heshan Agrema, Egypt, Maize Breeder

Pre- and Postdoctoral Fellows

Francisco Acevedo, Chile, Molecular Geneticist**
Martin Bohn, Germany, Quantitative Geneticist

Biometrics

Jose Cossua, Uruguay, Biometrician

Computing Services

Jesus Vazques G., Mexico, Systems and Operations Manager
Guillermo Borrero B., Mexico, PC Support and Integration Manager

In 1993, CIMMYT staff published 93 refereed journal articles. They also contributed 17 book chapters and 47 CIMMYT-imprimatur publications. For a complete listing, contact our Publications Office in Mexico.

Experiment Stations

Mark Bell, Australia, Agronomist/Head of Stations
Fernando Gonzalez C., Mexico, Breeder
Francisco Magalanes, Mexico, Field Superintendent, El Batan
José A. Miranda, Mexico, Field Superintendent, Toluca
Rodrigo Rascón, Mexico, Field Superintendent, Cd. Obregón
Abelardo Salazar, Mexico, Field Superintendent, Poza Rica
Alejandro López, Mexico, Field Superintendent, Tlahuizapan

Geographic Information Systems

John D. Corbett, USA, Agroclimatologist**

Information Services

Tiffin D. Harris, USA, Head, Information Services
Kelly A. Casady, USA, Writer/Editor
Edith Hessel, Austria, Head, Scientific Information

Eugene P. Hettel, USA, Writer/Editor
G. Michael Lizman, USA, Writer/Editor
Alma L. McNab, Honduras, Writer/Editor and Translations Coordinator
Fernando Garcia P., Mexico, Supervisor of Scientific Information Services
Corine de Gracia, Mexico, Supervisor of Library Services
Miguel Mellado E., Mexico, Publications Production Manager

General Laboratories

Jaime Lopez C., Mexico, Supervisor, Soils and Plant Nutrition Laboratory

Seed Health

Larry D. Butler, USA, Head, Seed Health

Software Development

Ronald van Wachem, The Netherlands, Software Development Manager
Rafael Herrera M., Mexico, Software Systems Coordinator
Carlos López, Mexico, Software Systems Coordinator
Héctor Sánchez V., Mexico, Project Leader, Wheat Systems
Henrik Schou, Denmark, Associate Scientist, Software Development**

* Appointed in 1993
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CIMMYT collaborates with researchers in more than 100 countries worldwide. To sustain our global reach, we maintain offices in 15 countries other than Mexico.

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— D.L. Winkelmann
CIMMYT is an international agricultural research and training center, headquartered in Mexico and with offices in 15 other countries around the developing world. The Center's work focuses on maize and wheat, two of the most important commodities produced and consumed in developing countries. Major activities include the development and worldwide distribution of improved varieties, the conservation of maize and wheat genetic resources, the creation and documentation of new knowledge about these crops, research on natural resource management in maize- and wheat-based cropping systems, training of various types, and consulting. All these activities are undertaken for, and in collaboration with, national program partners. These partnerships lead to higher productivity in agriculture, greater economic growth, higher incomes, and to enhanced environmental protection.

Primary financial support for CIMMYT's work comes from the Consultative Group on International Agricultural Research (CGIAR), a consortium of public and private agencies representing some 35 countries, international and regional organizations, and private foundations. The CGIAR was formed in 1971 with cosponsorship by the Food and Agriculture Organization of the United Nations, the International Bank for Reconstruction and Development (World Bank), and the United Nations Development Programme (UNDP). This unique global research and training system is committed to improving the well-being of the poor in developing countries through the work of CIMMYT and 15 other international agricultural research centers.