Maize and Wheat Research for the Next Millennium: A Preview of CIMMYT’s Role
Building on the Past for a Better Tomorrow

The 20th century has played host to the most remarkable transformation in agriculture’s 10,000 year history — from traditional and often low-productivity agricultural systems, to widespread, science-based systems that can provide enormous agricultural surpluses. Because of this fundamental transformation, more people are better fed, better clothed, and better housed than ever before.

Yet amidst this apparent plenty, tremendous inequalities exist. The World Bank estimates that there are about a billion people — roughly one in every five — who must survive on less than one US dollar a day. Equally alarming is the deteriorating condition of the natural resources that underpin our current agricultural production systems. And an unprecedented increase is taking place in the world’s population — nearly 200 new residents are added to this crowded planet every minute, a new Mexico City every 12 weeks; a new Mexico every year.

Moreover, the world’s food stocks, as a per cent of utilization, are at their lowest level since we began keeping such records. Clearly, we can claim only a tenuous hold on global food security.

Agricultural research has fueled the transformation to science-based agricultural systems. It is the foundation of our current productivity. And it remains our best hope for confronting the critical challenges ahead: reducing poverty, conserving the natural resource heritage of our children, and producing enough food for all.

CIMMYT’s maize and wheat technologies — more stable, efficient, and productive varieties combined with new, more effective and environmentally friendly ways of growing them — provide hope for the future. They promise more food from less land; better, more nutritious grain from fewer chemicals; and more stable yields under less predictable growing conditions.

Our research is itself being transformed — from a traditional focus on producing high-yielding, input-responsive cultivars to a focus on enhancing both the productivity and sustainability of maize and wheat systems in developing countries; from conventional plant breeding to a creative blend of proven and new research methodologies.

One tangible result of these changes is the new E.J. Wellhausen-R.G. Anderson Plant Genetic Resources Center at CIMMYT headquarters in Mexico, which combines a state-of-the-art genebank complex, refurbished seed distribution facilities, and a
revamped array of related research activities. Another is the creation of our new Natural Resources Group, including a strong in-house capacity for geographic information systems research. Still another is the development of an impressive applied biotechnology capability, closely tied to the Center’s Maize and Wheat Programs. And still another is our rededication to genuine research partnerships, to training, and to information management — all of which are critical pathways for strengthening national agricultural research systems in developing countries.

In this document, we highlight CIMMYT’s research and development strengths — both the traditional and the emerging — and we reveal the general directions that our research is likely to take as we move into the next millennium.

Think of this document as a prospectus that illustrates what investments in CIMMYT could produce over the next 5-10 years. But above all, think of our Center as a means to an end, as a highly effective way to help attack poverty, protect the environment, and increase global food security, the critical development challenges of the 21st century.

Prof. Timothy G. Reeves
Director General

CIMMYT’s maize and wheat technologies — more productive varieties combined with new, more efficient and environmentally friendly ways of growing them — provide hope for the future.
Research for Sustainable Maize and Wheat Systems

CIMMYT’s effort to develop more productive varieties has been singularly successful, and the impact of those varieties in farmers’ fields has been immense. The flow of new, more efficient and productive varieties to developing countries remains a vital part of our operation, but we are now taking a decidedly different approach to our research. We begin by seeking answers to two basic and interrelated questions: What are the untapped opportunities for environmentally safe increases in maize and wheat productivity? And how can maize and wheat technologies help slow or reverse resource degradation?

To answer these questions, we invest heavily in understanding the inner workings of maize- and wheat-based cropping systems, and in translating that understanding into effective combinations of improved cultivars and better land management practices. To expedite this critical research, we recently formed a Natural Resources Group (NRG), which is composed of a core team of Mexico-based staff who work with regionally based CIMMYT scientists and with the Center’s many research partners. NRG staff take a problem-solving, systems approach aimed at overcoming resource management problems, refining research methods, improving maize and wheat system productivity, and strengthening national research programs.

To combine better varieties with better management practices and to foster their rapid and widespread adoption by farmers, we need a full partnership with national research systems, NGOs, and advanced research institutions. The Center is rededicating itself to such partnerships and is currently exploring alternative forms of cooperation.

As but one example of that commitment, consider CIMMYT’s role in the Maize and Wheat Improvement Research Network for the Southern African Development Community. Network activities are guided by a 10-person steering committee made up of the Community’s member states, with CIMMYT serving as the executing agency. The network’s mission is to help develop better management strategies, improved varieties of maize and wheat, and stronger research capabilities for national research systems by promoting human resource development and enhancing access to information for researchers.

CIMMYT actively participates in this network, but it is not ours to direct. We feel that it typifies the institutional arrangements we need for effective, systems-focused research. We are involved in similar consortia in South Asia and in Central America, all of which share a common goal: improving food security, farm-level incomes and employment, while forestalling the potential negative impacts of modern agriculture on fragile and biologically diverse areas. Further involvement in such networks is important to CIMMYT’s future, and we believe that investments in this kind of work will have a large impact over the next 5-10 year period.
In the next five years, investments in CIMMYT will...

- Allow us to clarify sustainability problems, and what can be done about them;
- Lead to clear and useful sustainability indicators;
- Improve sustainability-related forecasting;
- Produce practical natural resource management research methods;
- Lead to much more effective participation in research consortia;
- Measureably accelerate the adoption of new, more sustainable technologies.
In the next five years, investments in CIMMYT will...

- Ensure the long-term storage of critical maize and wheat genetic resources;
- Lead to a much better use of those resources to solve practical breeding problems;
- Notably improve knowledge about trends in genetic diversity;
- Enable a clear assessment of alternative strategies for in situ conservation;
- Result in much greater knowledge of genetic diversity at the molecular level;
- Lead to a shared global database of maize and wheat genetic resources.

Genetic Resources: Providing Food Security for the Future

The key to CIMMYT’s success in producing improved maize and wheat varieties for a hungry world has been our unique ability to bring together genetic materials from all over the globe and combine them in creative ways. In the near future, genetic resources will become increasingly valuable as advances in science, especially biotechnology, permit greater access to the genetic secrets now just beyond our reach.
CIMMYT has long maintained major collections of maize and wheat genetic resources. Initially, our interest was in having genetic stocks readily available for breeding. Now our primary objective is to safeguard in perpetuity maize and wheat genetic resources, as well as related species, both in our new genebank and through various in situ efforts, thus ensuring their availability today and tomorrow.

CIMMYT is located at the center of origin for maize, and we take a strong interest in the collection and preservation of maize landraces. Our new genebank now contains over 14,000 accessions, many of which have been recently regenerated and evaluated as part of the Latin American Maize Project that links 14 national genebanks with CIMMYT’s in a collaborative network. Accessions stored in our bank are backed-up for security reasons in each country of origin, as well as in the National Seed Storage Laboratory in the US. The wild relatives of maize – teosinte and Tripsacum – have also been stored in the bank, and are preserved in situ in Mexico and Guatemala.

The wheat genetic resources we hold in trust – over 100,000 accessions of wheat and wheat-related materials – including cultivated and wild species. CIMMYT holds one of the world’s largest collection of cultivated bread wheats. Cultivated durum wheats (for pastas and flat breads), as well as wheat’s wild relatives, are held in trust by a sister international center located in Syria, but we hold back-up collections of these materials in our genebank (as they do of ours).

CIMMYT’s strengthening capabilities in biotechnology, geographic information systems, and seed population genetics offer new opportunities to learn about the extent of the genetic variation in our genebank, as well as the amount of duplication that exists. These tools also enable us to identify more clearly the gaps in our collection. Moreover, new data management and processing techniques help us analyze information about each accession, leading to more efficient preservation and use.

While we are firmly committed to the preservation of genetic resources for posterity, we believe that materials held in genebanks have more than intrinsic value; they must also be used to help people. For that reason, we seek to invest more resources in the evaluation and use of maize and wheat genetic resources. We are certain that the material in our genebank contains an immeasurable wealth of genes that can further increase natural yield potential, increase built-in resistance to pests, and impart greater tolerance to environmental stresses, all of which will dramatically increase agricultural production – as we muster the resources needed to capitalize on this unique and extremely valuable asset.
Producing Better Varieties

CIMMYT’s concerted effort to produce and distribute better maize and wheat cultivars has been undeniably successful. Over half of the area devoted to improved maize varieties in developing countries is now planted with CIMMYT-related seed; and over three-quarters of the developing world’s wheat land grows CIMMYT-related cultivars. Tremendous spin-off benefits also accrue each year to developed country agriculture, benefits that are literally worth billions of U.S. dollars.

CIMMYT is well positioned to capitalize on advances in science—ranging from new tools in biotechnology, to improved field designs and statistical analyses, to more efficient information processing and management—and is systematically bringing these advances to bear.
As we move into the 21st century, maize and wheat improvement specialists face new challenges and opportunities. Productivity must increase in favorable environments, but also in more marginal areas where such problems as drought or poor soils severely limit production. At the same time, increases in genetic yield potential are becoming harder to achieve. Pathogens mutate into more virulent forms. Voracious insects flourish. New approaches, new technologies, new sources of genetic variation – all must be used to break through the barriers before us. CIMMYT is well positioned to capitalize on advances in science – from new tools in biotechnology, to improved field designs and statistical analyses, to more efficient information processing and management – and is systematically bringing these advances to bear.

The Center has been likened to a maize and wheat “gene machine” capable of delivering hundreds of experimental varieties each year. And while this characterization takes away from the art that is plant breeding, it contains a measure of truth. CIMMYT serves as the hub of one of the world’s largest maize and wheat development and testing networks. Center staff make tens of thousands of crosses each year. Thousands of the resulting progeny are shipped to colleagues in over a hundred countries throughout the developing world. They grow the material, evaluate it, and return performance data to CIMMYT breeders to feed into the next cycle of breeding. Our colleagues also freely draw on the Center’s materials for their own purposes, usually as a resource for their breeding programs. These networks comprise an incredibly effective mechanism for producing and distributing new cultivars that, because they were selected under many different conditions, are broadly adapted to a range of environments.

CIMMYT’s ability to bring together genetic material from all over the world – to continuously stir the maize and wheat genetic pot – is one of its greatest strengths. We are uniquely well prepared, thanks to our own genetic stocks and our ready access to the stocks held by others, to respond to changing environmental conditions and to anticipate and face new challenges to the world’s food supply.

But our key asset is our people. CIMMYT’s success in developing better cultivars, and in seeing those cultivars used widely by developing country farmers, is largely due to the people that make up the Center’s “extended family.” We have assembled some of the best scientific minds and most talented agricultural specialists in the world, and placed them in strategic locations around the globe. A core group of researchers is located at our headquarters in Mexico. Their efforts are shaped by feedback from the other 40% of our staff – our regional scientists – who work out of offices in 16 developing countries, and who travel and consult extensively in their regions. Regional staff conduct their own research for CIMMYT and are closely involved in supporting the efforts of our research partners in developing countries. In doing so, they help keep CIMMYT’s research on track, ensuring that appropriate cultivars, management practices, research methods, and information are developed and distributed by the Center.

Our extended family includes many more people than are on the Center’s payroll. Thousands of research colleagues around the world have participated in joint research with CIMMYT or in the Center’s training programs, and many of these colleagues now occupy prominent positions in developing country research programs. Their efforts enable our joint success, making possible the tremendous payoffs that come from using CIMMYT-related cultivars.

In the next five years, investments in CIMMYT will...

- Result in maize cultivars with much higher levels of tolerance to environmental stresses;
- Produce wheat varieties with durable resistance to yellow rust;
- Lead to improved research methods for the development of new varieties and sustainable maize- and wheat-based production systems;
- Help us add to the genetic diversity of wheat;
- Enable development of an international crop information system.
Applying the Tools of Biotechnology

In 1990, building on a decade of experience with early biotechnologies, CIMMYT established its Applied Biotechnology Center, now widely recognized to be among the best of its type in the world. The center is staffed with exceptionally talented and practical-minded scientists, whose work is closely linked to the efforts of the CIMMYT’s Maize and Wheat Programs. Together, researchers strive toward the broad goal of adding to the efficiency of crop improvement research in Mexico and elsewhere.

The primary means of doing this is to acquire and adapt cutting-edge biotechnologies to the needs of CIMMYT, and to transfer useful technologies to our research partners in developing countries. The Biotech Center has also implemented standard biosafety procedures and constructed effective biocontainment facilities — now officially sanctioned by the Mexican authorities — two extremely important achievements.

In the next five years, investments in CIMMYT will...

- Lead to highly effective molecular marker systems for speeding the transfer of drought, insect, and disease resistance genes;
- Result in the most efficient maize and wheat transformation facility in the world;
- Produce maize cultivars with enhanced resistances via the transfer of genes from novel sources;
- Lead to the first apomictic maize plants;
- Enable identification and cloning of the genes that confer resistance to rusts in wheat.
The Biotechnology Center focuses its efforts on applying two basic sets of tools—molecular genetics and genetic engineering—to the problems being addressed by maize and wheat breeders.

Using the tools of molecular genetics, we are identifying and “marking” maize and wheat genes that bestow desirable traits, such as resistance to insects and diseases and tolerance to environmental stresses such as drought. This is the first step toward facilitating gene transfers from one variety to another. We have adapted a relatively low cost and environmentally safe, non-radioactive system for “tagging” segments of chromosomes, and we can now quickly tell whether the offspring of specific crosses contain the genetic material that breeders want, adding to the efficiency of the breeding process.

The Program is also applying the tools of genetic engineering in order to reach beyond the genes already contained in maize and wheat, so as to increase the range of genetic diversity available to breeders. Our staff recently succeeded in their efforts to “transform” tropical maize by inserting a Bt gene for insect resistance. This was a first for CIMMYT tropical maize, and the transformed plants are showing good resistance to stem borers, important insect pests that seriously limit productivity in farmers’ fields.

Bridging these two areas is our work in apomixis—“frontier research” aimed at understanding how plants reproduce asexually through seed. This major project involves isolating and cloning the genes in Tripsacum, a wild relative of maize, that confer the asexual means of reproduction. Once isolated, these genes will be genetically engineered into maize and wheat to produce apomictic cultivars. Success in these ventures will mean that, in the future, poor farmers growing hybrids will be able to select seed from their fields for planting in the next year without witnessing the drop-off in productivity that normally occurs with this practice.

As we cross into the next millennium, CIMMYT’s breeding programs will be routinely using molecular markers for such traits as drought, insect, viral, and fungal resistance. Genes for day-length sensitivity and durable rust resistance, among others, will be tagged and markers made available for screening new lines. Markers will also be used to better understand the genetic diversity available in CIMMYT’s genebank. The introduction of new genes into maize and wheat via genetic engineering will no doubt become more routine, and we expect to serve as a window to “first world science” for our research partners in developing countries.

**Enlisting New Information Systems in the Cause**

Impact. That’s the goal, after all. Impact in research, impact in farmers’ fields. The complexity and urgency of the development challenges before us demand a strong interdisciplinary approach to research—the full participation of plant breeders, biotechnologists, agronomists, social scientists, and professionals from many other disciplines. Improvements in how research information is managed will heighten this essential collaboration, fostering a new information-intensive approach to research.

How might this new approach change the way our work is done? Breeders, for example, will increasingly decide which parent plants they should cross based not on physical appearance and field performance alone, but on detailed knowledge about a plant’s genetic makeup. Breeders will also tailor the pedigrees of their new varieties to specific environmental conditions, thus enabling the broadest possible adaptation and producing end products that are preferred by producers and consumers. Evaluation data from sources as diverse as molecular marker laboratories and international nurseries will be available globally and with minimal delay. Agronomic research will focus on strategic targets identified through geographic information systems (GIS).

Closely linked databases for cultivars and breeding records, cropping systems, biophysical data, and socioeconomic data will form the foundation of this new research style. Decision support tools, such as simulation models, GIS, expert systems, and genetic analysis software will enable scientists to focus on central issues and navigate through oceans of data, synthesizing as they go. They will pool their data, reducing costly duplication. Electronic distribution will further ensure that benefits of this new research mode will spread rapidly beyond CIMMYT’s realm and lead to the impact we are all seeking. Impact on science. Impact in farmers’ fields.
Helping to Shape Better Policies

The impact of CIMMYT’s research on farmers and consumers depends not only on the quality of our science, but also on policies implemented at both the national and international level. These policies include decisions about how much will be invested in research and in which activities and how much in education, roads, ports, rail transportation, and other infrastructure. Also included are decisions about pricing policies for inputs and agricultural products in general, and even broad macroeconomic choices.

Over the next five years, CIMMYT will develop and maintain an expanded mega-environment database, which will help our decision makers understand the most cost-effective ways of reaching the Center’s objectives, particularly in crop improvement.
Recognizing the importance of agricultural policy, we maintain a modest research capacity aimed at providing decision makers in CIMMYT, national agricultural systems, and the global agricultural development community with information about the policy environment and how key policies influence the impact of research.

To date, our efforts have focused primarily on policies directly related to research. Our “domestic resource cost analyses” have helped decision makers in selected countries choose more wisely among options for allocating resources within their countries. CIMMYT’s global priority setting has been supported by development of a “mega-environment” database that helps ensure allocation of the Center’s scarce resources to the most critical research problems. And major studies of the impacts of international maize and wheat breeding research have examined how policies influence the diffusion of new varieties.

More recently, our research has grown to include studies of the institutions and policies that shape the supply of critical agricultural inputs, especially in the seed industry. We also facilitate “targeted policy workshops” in maize-based systems in Mesoamerica, which foster policy change by bringing together key people and organizations in an effort to achieve a common understanding of problems, as well as opportunities for resolving them.

We can expand the relevance of work related to improving policies by refining and extending the coverage of our mega-environment database, improving not only its technical parameters, but also including more social and economic indicators, particularly for poverty and environmental impact. Another opportunity is to use the insights of the “new institutional economics” to increase our understanding of ways to deliver new technology more efficiently. Yet another is to develop closer working relationships with colleagues in other, more policy-oriented institutions, such as IFPRI, the World Bank, and various universities.

The main product of our policy research is, of course, information. Knowledge about how different policies affect the impact of research, and about which decision makers are best placed to implement appropriate policies, will help streamline policy formulation – if it is effectively documented and communicated. Doing the latter is one of CIMMYT’s strengths. The ultimate payoffs to such research are difficult to measure, but there are observable effects, including the extent to which policy shifts at the national and international levels are based on credible information and result from informed debate.

In the next five years, investments in CIMMYT will...

- Lead to a better mega-environment database that will improve decision making about the allocation of research resources;
- Result in a synthesis and widespread sharing of knowledge about the global maize seed industry;
- Lead to identification of key collaborators and decision makers in the policy arena;
- Enable communication of the Center’s knowledge about technical maize and wheat production factors to institutions specializing in policy analysis, improving their ability to project future trends;
- Clarify the effects of policies on genetic diversity in farmers’ fields and on prospects for in situ conservation of genetic resources.
Sharing Knowledge to Strengthen National Agricultural Research

Knowledge has no meaning — is almost pointless — unless it is passed along to enter into the affairs of the world." So spoke Dr. Margaret Cotley-Carlson, then President of the Canadian International Development Agency on the occasion of CIMMYT's 20th anniversary in 1986. Her words ring as true today as they did then.

Knowledge — about better ways to manage maize and wheat systems, about new varieties, and about more effective research methods — is one of CIMMYT's main products, and its value is closely linked to our ability to share it with others.

In seeking to share knowledge widely, CIMMYT staff engage in a number of interrelated activities, ranging from research partnerships to technical consulting, from publishing to formal human resource development. While important in-and-of-themselves, the interactions among these related activities are what deserves special attention. Through our research partnerships and consulting work, for example, we not only help solve problems — such as the sustainability problems now being encountered in Asia's rice/wheat systems — we also gain insights into how to solve these problems more efficiently. In other words, we learn from our partners.

By bringing these lessons together from different parts of the world, by drawing on the experiences of our regional staff, by participating in collaborative research ventures, and by various publishing efforts, we get a feel for what works, and under what circumstances. In short, we synthesize our experiences. This synthesis then guides us as we interact further with our research partners, helping us to provide better advice and counsel and to better understand what those partners are trying to communicate.

We also build on this synthesis of experiences to develop educational materials and other publications — books, manuals, technical reports, journal articles, audiovisual materials, and increasingly as we near the next century, CD-ROMs and information packaged for delivery over the Internet's world wide web. Many of these materials then form the basis of our participation in formal human resource development activities, the entry level, intermediate, and advanced courses we offer at our headquarters in Mexico, and those we support out in the regions. And as we learn more from our interactions with research partners, we constantly update and revise our published synthesis of experience.

CIMMYT is, in a very real sense, a central clearing house of knowledge related to the development of more productive and more sustainable maize and wheat systems in developing countries. Our own staff — CIMMYT's human resources — are continuously stimulated by virtue of their involvement in sharing knowledge with others. As a result, our staff are among the strongest advocates for, and practitioners of, true research partnerships, networking, consulting, training, and other activities that strengthen national agricultural research systems throughout the developing world.

In the next five years, investments in CIMMYT will:

- Enable new intermediate and advanced course offerings in sustainable systems and biotechnology;
- Strengthen research partnerships through networking and improved information management;
- Accelerate the transition to a more information-intensive approach to research.

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

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

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

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

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

Location
Headquarters are in Mexico, but activities and impact extend to over 100 countries via 16 regional offices.

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