CIMMYT

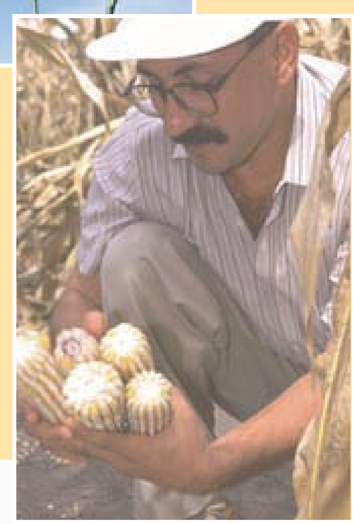
Sustainable Maize and Wheat Systems for the Poor

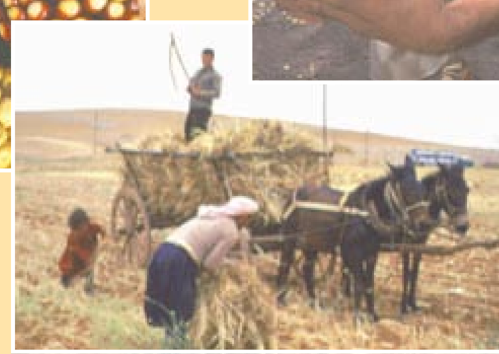
A Sampling of CIMMYT Impacts, 1998:

Ten Case Studies

CIMMYT's recent External Program and Management Review concluded that the Center "conducts high quality science and has an impressive record of achievement and impact, is well managed, and has a widely respected and vigorous leadership. The External Review has testified to the quality of research and its relevance and impact on the daily livelihood of hundreds of millions of rural and urban poor."





This welcome recognition

comes at a time when the need to achieve a positive impact in farmers' fields has never been more challenging. Many circumstances—witnessed daily in our work—lend urgency to our task: the instability of governments and economies, the vagaries of increasingly unpredictable weather systems, the volatility of the legal environment with respect to intellectual property rights, and the extreme necessity of poor people pushed to the margins of survival.

Last year we presented an overview of the impacts of research by CIMMYT and its partners. This year we provide ten detailed examples of impact:

- **Synthetic hexaploid wheats**
- **Role of disease resistant wheat cultivars**
- **Research to help maize farmers face drought**
- **Acid tolerant maize: promoting sustainable farming on acid savannas**
- **Wheat in West Asia and North Africa**
- **The Regional Maize Program for Central America and the Caribbean**
- **Cooperation to rescue seed of Latin American maize landraces**
- **Participatory plant breeding in Southern Mexico**
- **Impacts of participatory research on tillage and crop establishment in rice–wheat systems in the Indo-Gangetic Plains**
- **Exploitable production potential, the research frontier, and the wheat yield gap: spring bread wheat in Mexico's Yaqui Valley**

Aside from showing the impact of our research, these studies have several noteworthy features. They highlight the range of partnerships needed for effective research: collaboration among institutions, across disciplines, and within different kinds of regional and local initiatives. They provide examples of research impact at the farm level and across agroecological zones. They reveal proactive efforts to forecast the sources of impact in farmers' fields. Finally, they demonstrate that many researchers and funding agencies remain convinced that the lives of poor people can—and should—be changed for the better, and that agricultural research can play a major role in achieving this objetive.

Synthetic Hexaploid Wheats

Background

To develop wheats with traits that enable them to yield well under a wide range of adverse conditions, such as are found in farmers' fields all over the world, plant breeders draw upon the genetic diversity found in the crop itself, its cultivated relatives, and more recently, uncultivated species in the wild. Many of these "wild" species possess exceptional resistance and tolerance to diseases and climatic stresses.

CIMMYT Activities

Since crossing wheat with other species cannot be achieved in the usual way, CIMMYT is applying a technique called "wide crossing" to bridge the natural genetic gap between them. The lines produced using this technique are called "synthetic" hexaploid (bread) wheats because the durum wheat (*Triticum turgidum*) x goat grass (*T. tauschii*) crosses that give rise to them mimic the original cross that occurred in nature thousands of years ago and produced the first bread wheat. Synthetics are true wheats that can be crossed directly with improved wheat, facilitating the transfer of useful traits from alien species.

Impacts

CIMMYT has so far produced more than 600 stable synthetics that possess a surprising range of positive traits, including tolerance to drought, heat, and waterlogging. Of particular relevance is their resistance to diseases such as helminthosporium leaf blotch (HLB), septoria leaf blotch, and Karnal bunt (KB).

Helminthosporium leaf blotch is widely distributed all over the world but is more prevalent in humid and high rainfall areas. It is the major biotic factor limiting yields in the wheat growing areas of the eastern Asian Subcontinent. Synthetic hexaploid wheats have shown exceptional resistance to leaf blotch—for example, in several years' testing in Poza Rica, Mexico, a hot, humid site (Table 1).

Table 1. Synthetic hexaploid wheats resistant to helminthosporium leaf blotch (HLB) in Poza Rica, Mexico

Synthetic hexaploids	HLB score*
CIGM 90.590	9-2
CIGM 88.1356-OB	9-2
CIGM 90.897	9-3
Bacanora (susceptible bread wheat check)	9-9

* Using a double digit scale, where the first digit indicates height of infection: 5 = up to mid-plant and 9 = up to flag leaf; the second digit indicates disease severity: 1 = low and 9 = leaf completely destroyed.

Septoria leaf blotch causes problems in wheat in many parts of the world. The disease is capable of reducing yields by as much as 30-40% and, in some years, may cause millions of metric tons of grain to be lost. New wheat lines derived at CIMMYT from synthetic crosses are showing remarkable resistance to this important disease. For example, in 1993 and 1995, synthetics demonstrated superior resistance to septoria leaf blotch in Toluca, a cool, humid environment in the central highlands of Mexico (Table 2).

Karnal bunt is a disease that affects the quality of wheat grain and flour. An incidence of more than 3% infection makes wheat

Table 2. Synthetic hexaploid wheats resistant to septoria leaf blotch at Toluca, Mexico

Synthetic hexaploids	Septoria score 1993	Septoria score 1995
Aco 89/*Triticum tauschii*	21	21
Altar84/*T. tauschii*	31	31
Sca/*T. tauschii*	11	21
Esmeralda (bread wheat check)	89	99

grain unfit for human consumption. Infected wheat lots are rejected by the milling industry, greatly reducing farmers' profits. To help farmers solve this problem, CIMMYT scientists are working on improving KB resistance. They have found synthetics to be the best source of resistance, as shown in trials conducted in Ciudad Obregon in northwestern Mexico, where synthetic hexaploid wheats have displayed superior KB resistance (Table 3).

Synthetics—or their derivatives—are also generating major yield gains. In yield experiments conducted in Cd. Obregon in 1997, a synthetic hexaploid wheat derivative out-yielded other high-yielding wheat lines (Figure 1).

Table 3. Synthetic hexaploid wheats resistant to Karnal bunt at Cd. Obregon, Mexico

Synthetic hexaploids	% Karnal bunt score
Altar 84/*Triticum tauschii*	0
Altar 84/*T. tauschii*	0.87
WL711 (susceptible bread wheat check)	65

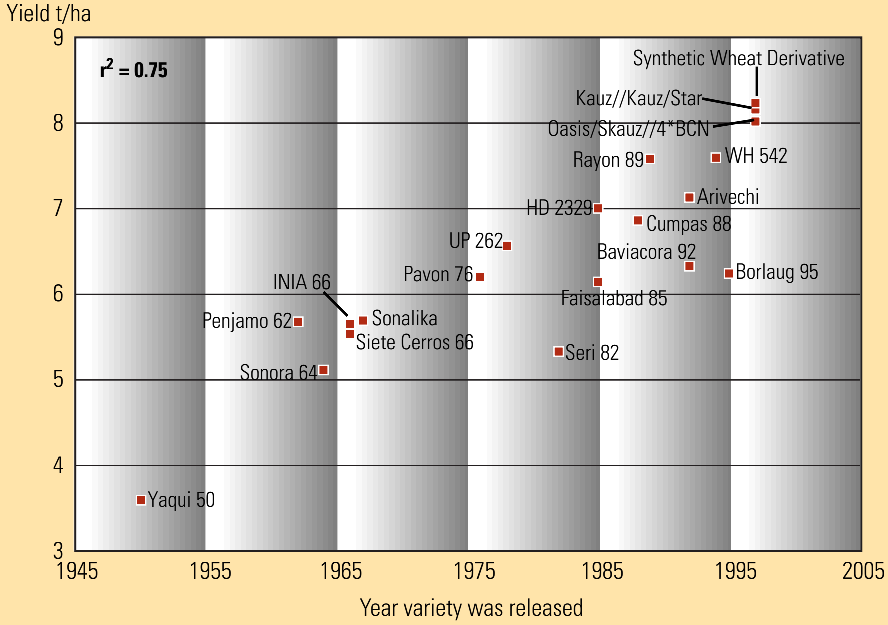


Figure 1. Yield vs. year of release, 1996-97 cycle, Ciudad Obregon, Mexico.

Role of Disease Resistant Wheat Cultivars

Background

Until a quarter of a century ago, wheat rusts, the most serious and economically important diseases of wheat, periodically devastated food production. This happened every time that susceptible varieties, favorable environmental conditions, and pathogen adaptability combined to create large-scale epidemics. A real solution, rust resistant plants, became possible with the advent, early in this century, of systematic plant breeding for disease resistance.

CIMMYT Activities

Starting in the 1950s, the CIMMYT Wheat Program (or rather, its predecessor, the Office of Special Studies) used in its breeding efforts the durable stem rust resistance in Hope, a variety bred by McFadden in the USA, and the durable leaf rust resistance in Frontana, a Brazilian variety. Since then, the Program has continued to improve resistance by broadening the diversity of sources of resistance to rust pathogens.

Based on CIMMYT's research over the last 30 years, our national program partners have released more than 500 bread wheats that trace their durable rust resistance to Hope, Frontana, and other, diverse sources. This resistance is conferred by minor genes that interact additively to protect the crop from rust pathogens. Most importantly, the resistance conferred by minor genes is durable because it allows the disease to develop slowly and at a low intensity that has a negligible effect on yields.

Impacts

Farmers all over the world have reaped the economic benefits of disease resistant cultivars, which produce the same yield with and without fungicide protection—for example, in Mexico's Yaqui Valley (Figure 1). When farmers plant disease resistant cultivars, they apply less fungicide, reduce their production costs, and lessen the damage done to the environment.

In a recent study on the benefits of incorporating leaf rust resistance into modern bread wheats, CIMMYT economist Melinda Smale estimates that gross benefits generated in the Yaqui Valley from 1970 to 1990 through the incorporation of disease resistance totaled US$ 17 million (in 1994 real terms). Similar economic benefits seem likely in many other wheat producing areas of the developing world, for example,

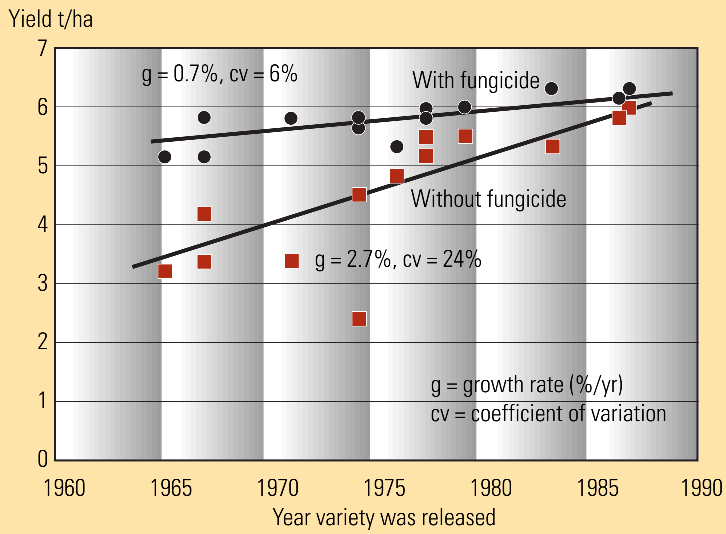


Figure 1. Yield of historically important varieties (released 1964-86) with and without fungicide, Ciudad Obregon, Mexico, 1990-91.

where disease pressure is heavy and the cost of treating disease outbreaks is high. Smale further points out that *even when costs are overstated and benefits understated*, the rate of internal return on capital invested in CIMMYT's disease resistance research is 13%, well within the range recommended for use in project evaluations by the World Bank.

On a global scale, CIMMYT Economics Program survey data indicate that semidwarf germplasm developed by CIMMYT and its national research system partners in 1977-90 contributed 15.5 million tons of additional wheat production in 1990, valued at about US$3 billion, primarily due to varieties with increased disease resistance.

Their performance in farmers' fields shows fewer fluctuations and they have not succumbed to major rust epidemics in the last 25 years. As a result, yield stability of modern semidwarfs has increased on all continents. Evidence suggests that genetic resistance, specifically to leaf rust, may be the most important contribution of wheat breeding to productivity and stability in the 1990s.

Helping Maize Farmers Face Drought

Background

Most maize in the developing world is grown without irrigation, depending solely on precipitation. Insufficient and poorly distributed rainfall is a major constraint to productivity, reducing yields overall more than 15% per year (an annual grain loss in excess of 20 million tons). Most catastrophic for developing country maize farmers, however, are periodic, severe droughts that can result in near-total crop loss. For example, after the major drought of 1991/92 in Eastern and Southern Africa, approximately US$ 800 million in food aid was needed to stave off starvation, export deficits soared from reduced agricultural production, and some countries have yet to recover economically or socially. Particularly afflicted are poor rural inhabitants who scratch out a living at the margins of subsistence.

CIMMYT Activities

CIMMYT researchers found a simple yardstick for identifying and improving drought tolerance in maize. In essence, they showed that mid-season drought tends to increase the number of days between male and female flowering, known as the anthesis-silking interval (ASI), and that this effect was tied to the dramatic loss in productivity under dry conditions during flowering. Capitalizing on that correlation, they developed a methodology for improving the drought tolerance of maize by selecting for reduced ASI under controlled drought stress. They refined the approach through work with the popular lowland tropical population Tuxpeño Crema I and several other unrelated populations.

Impacts and Follow-up

This research resulted in a 20-40% increase in the yields of experimental populations under severe mid- and late-season drought. A valuable spin-off was the discovery that selecting for reduced ASI also improves the performance of maize under low nitrogen conditions. CIMMYT maize breeders now regularly use evaluation under drought to enhance the stress performance of maize targeted for dry areas. To move the benefits of this research on-farm, in 1996 CIMMYT began two major projects with national program partners in sub-Saharan Africa to develop new cultivars that combine drought and low-N tolerance with good adaptation, disease resistance, and desirable grain type. Funded by the Swiss Development Cooperation (SDC), the United Nations Development Programme (UNDP), the International Fund for Agricultural Development (IFAD), and the Swedish International Development Cooperation Agency (Sida), these efforts are already transforming the way breeders in the region think about their work and have clearly demonstrated the superiority under stress of maize developed using this methodology over commonly used commercial hybrids (see table).

Recent performance of drought-tolerant experimental hybrids from CIMMYT compared with popular, widely grown hybrid checks of similar maturity from southern Africa. Data are from a comparison made in Zimbabwe. Local hybrid checks performed well when growing conditions were favorable, but their performance declined dramatically when grown under drought-stressed conditions. Drought-tolerant maize germplasm from CIMMYT thus demonstrates its impact potential for conditions typical for many resource-poor farmers in Africa.

Early maturing hybrids:

Growing conditions —>	Days to flowering	Optimal		Severe drought	
		Yield (t/ha)	Rank	Yield (t/ha)	Rank
Mean, drought-tolerant hybrids from CIMMYT	72.4	9.03	52	2.44	49
Mean, local hybrid checks	71.6	10.68	19	1.95	71
Highest yield among drought-tolerant CIMMYT hybrids		12.05	2	4.82	1
Highest yield among local hybrid checks		12.85	1	2.42	50

Total number of entries: 100. Drought-tolerant CIMMYT hybrids comprised 93 out of the 100 entries.

Late maturing hybrids:

Growing conditions —>	Days to flowering	Optimal		Severe drought	
		Yield (t/ha)	Rank	Yield (t/ha)	Rank
Mean, drought-tolerant hybrids from CIMMYT	80.3	10.06	109	2.84	107
Mean, local hybrid checks	79.2	11.49	55	2.08	144
Highest yield among drought-tolerant CIMMYT hybrids		13.55	2	5.27	1
Highest yield among local hybrid checks		14.00	1	3.97	17

Total number of entries: 216. Drought-tolerant CIMMYT hybrids comprised 208 out of the 216 entries.

Acid Tolerant Maize: Promoting Sustainable Farming on Acid Savannas

Background

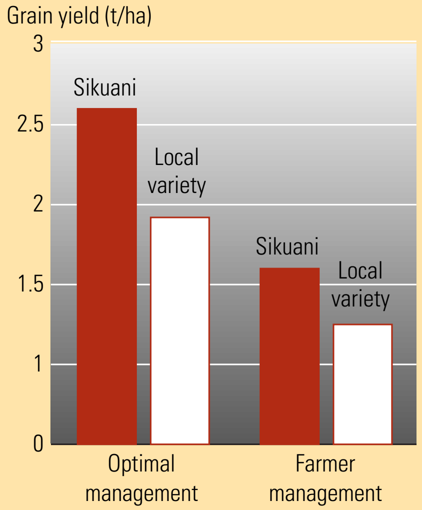
Acidic soils account for some four-fifths of agricultural lands in South America and two-fifths—more than 183 million hectares—in Brazil alone. Normal maize varieties yield as little as 0.5 t/ha of grain on even moderately acidic soils, as compared with the average in developing countries of just over 2.0 t/ha. Despite the relative unsuitability of acidic conditions for crop farming, the demand for food from rising populations has led to the increased use of acidic soil areas for agriculture. By the year 2000, for example, some 50 million hectares of acidic savannas in Brazil will be under cultivation. The continued migration of rural populations to the cities is placing heavy pressure on maize producers, and demand for maize in the region is expected to grow 3.5-4.0% *each year*. Those who stand to be most affected by the fate of maize in Latin America are the poor: poverty characterizes an estimated 40% of the region's population and more than 60 million people are malnourished or at serious nutritional risk. Increased maize production would provide more grain at the farm level and in urban centers, reducing the price of food for the poorest. It would also help relieve pressure to bring environmentally fragile lands under the plow and, by improving the fortunes of farmers, lessen migration to urban centers.

CIMMYT Activities

Through its South American Regional Program based at the Centro Internacional de Agricultura Tropical (CIAT), CIMMYT began developing maize that possessed tolerance to acidic and aluminum toxic soils in the late 1970s, demonstrating the possibility of improving the genetic tolerance of maize to these constraints. In the mid-1980s, researchers assembled sets of maize materials with high yield potential, tolerance to acidic soils, and resistance or tolerance to other key constraints, either singly or in combination. Subsequent work involved recurrent selection and crossing thousands of superior genotypes within each population at our regional experiment station in Colombia, as well as in acidic soils of Brazil, Indonesia, Peru, the Philippines, Thailand, Venezuela, and Vietnam, with help from research programs in each nation. In the early 1990s, experimental varieties from these populations were evaluated on acidic and normal soils in Latin America, Africa, and Asia in comparison with selected varieties submitted by national research programs. A strong indication of success was that the CIMMYT genotypes out-yielded checks by an average 33%, and an experimental variety from this work gave the highest yields across all environments. In subsequent tests, products of this research—all open-pollinated varieties—yielded as much as 0.7t/ha mor e than a Brazilian hybrid under non-acidic conditions in Colombia, showing that the acid tolerant maize is also productive in normal soils. In 1992 CIMMYT also initiated a four-year project with support from the Inter-American Development Bank (IDB) to study technical problems associated with maize production on acidic soils. A panel of international experts praised this IDB-CIMMYT partnership, saying that the project had achieved all of its objectives and more.

Impacts

The most celebrated output to date is the maize variety ICA-Sikuani V-110, developed by the Colombian Agricultural Research Corporation (CORPOICA) using acid tolerant maize generated through the collaborative research described above. The variety is already sown on thousands of hectares in its native Colombia and is being tested for use in neighboring countries. In trials in farmers' fields in acidic soil areas of Ecuador and Peru, Sikuani consistently out-yielded the best local varieties both under optimal and farmer management (see figure). Based on these results, Peruvian authorities are increasing seed of Sikuani for release in that country. In similar trials in Bolivia, Sikuani yielded as much as the best local variety but caught farmers' eyes due to its outstanding plant and grain type. Acidic soil tolerant hybrids derived more recently from CIMMYT's research produce as much as 70% more grain than Sikuani and should be of special interest in Brazil, where many maize farmers sow hybrids.



Sikuani out-yields local varieties in farmer's fields in Peru.

Wheat in West Asia and North Africa

Background

West Asia and North Africa (WANA) is a diverse ecoregion including widely different environments such as the irrigated Nile Valley, the dry Anatolian Plateau, the wet Mediterranean coast, and the extremely dry Atlas Mountains. In WANA wheat is sown on 28.3 million hectares, 65% of which is semiarid. The largest wheat producing countries are Turkey, Iran, Egypt, Saudi Arabia, Morocco, and Syria (Table 1). Depending on the location, major environmental stresses are drought, heat, cold, and boron toxicity superimposed on such adverse biological factors as yellow rust, leaf rust, septoria triciti leaf blotch, Hessian fly, sawfly, and nematodes.

Table 1. Wheat production in WANA

Country	Area, 1990-92 (000 ha)	Production, 1990-92 (000 t)	Growth in wheat yields, 1983-92 (%)	Growth in wheat production, 1983-92 (%)
Algeria	1,633	1,422	4.0	-0.3
Egypt	877	4,456	4.7	4.4
Libya	128	143	5.5	5.6
Morocco	2,530	3,372	0.7	4.5
Tunisia	954	1,497	7.6	0.8
Afghanistan	1,620	1,675	-2.3	-5.9
Iran	6,357	9,002	3.8	4.6
Iraq	1,338	1,091	-1.3	1.3
Saudi Arabia	761	3,894	5.4	15.6
Syria	1,330	2,419	4.6	5.9
Turkey	9,410	19,919	1.6	1.8
Jordan	59	75	5.0	0.1
Lebanon	26	56	8.3	14.2
Yemen	92	136	8.1	11.9

CIMMYT Activities

The CIMMYT/ICARDA joint dryland wheat program develops improved germplasm with drought tolerance for the WANA region. The program derives advanced lines from CIMMYT for testing in irrigated and high rainfall areas of WANA. CIMMYT has two breeders posted with ICARDA in Aleppo, Syria, to work on spring wheat germplasm for drought areas. Two CIMMYT breeders and one ICARDA breeder are assigned to Ankara, Turkey, a partner country with which CIMMYT has maintained close collaboration for the past 25 years. These researchers work on winter/ facultative wheats.

Impacts

Though working in a complex region, CIMMYT-Mexico, ICARDA, and national program researchers have dramatically increased wheat yields and wheat production in the countries of WANA. This fruitful collaboration has had significant impact in the region, of which we list the following examples:

- With the exception of Afghanistan and Iraq, most countries in WANA experienced high yield growth rates in 1983-92 (Table 1). Improved germplasm with tolerance to drought and temperature extremes, and resistance to prevailing diseases and insects, was essential to achieving these yield gains.

- The most widely grown durum variety in the dryland areas of WANA is Korifla, introduced from CIMMYT-Mexico and released in several countries under different names (Cham 3 in Syria, Haran in Turkey, Petra in Jordan, Zahra 5 in Libya, and Korifla in Algeria and Iraq). As an example of its impact, 10 years after its release, Korifla is being planted on 86% of Syria's durum area, and durum wheat production in that country has experienced a 50% increase (Figure 1).

- Since 1990, 14 countries have released about 100 varieties that are either direct releases from CIMMYT-Mexico, are CIMMYT/ICARDA lines, or had a CIMMYT line as a parent (Table 2). Farmer adoption of CIMMYT- and CIMMYT/ICARDA-derived varieties in WANA continues to increase, and today these varieties cover a large portion of the area devoted to wheat in the region.

- ICARDA economists estimate that irrigation and improved technologies have increased wheat production in the region 1.15 million tons per year; 0.31 million tons (valued at about US$ 50 million) of this increase can be attributed to improved CIMMYT- and CIMMYT/ICARDA-derived varieties.

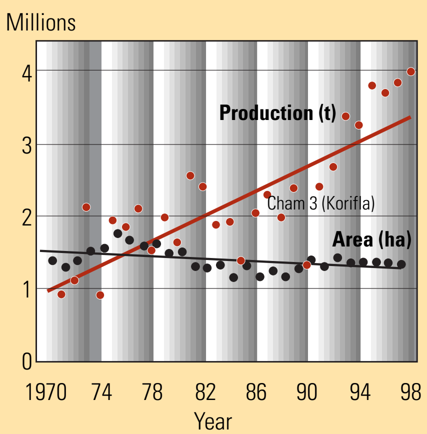


Figure 1. Durum area and production in Syria from 1970 to 1997.

Table 2. Bread and durum wheat varieties released by the countries of WANA since 1990 (note that these varieties are either CIMMYT advanced lines or have CIMMYT parents in their pedigrees)

Country/year of release	Bread wheat	Durum wheat
Afghanistan		
1994	Pamir 94*	
1996	Dayma 96, Ghori 96, Takhar 96, Roshan 96	
Algeria		
1992	Nesser, Acsad 59, Zidi Okba, Rhumel 21 AD, Soummam	Korifla, Omrabi 6
1993		Heider, Kabir 1, Omrabi 1, Belikh 2
1994	Ain Abid	
Egypt		
1990		Sohag III, Beni Suef I
1991	Gemmeiza 1, Giza 165, Sahel 1	
1995	Giza 167, Sids 4, Sids 5, Sids 6, Sids 7, Sids 8	
Iran		
1990	Falat	
1994	Dogankent 1	
1995	Tajan, Atrak, Nicknejad, Mahdabi, Darab 2	
1996	Zarrin*	
1997		Seimarah (Omrabi 5), Korifla, Heider
Iraq		
1994	Adnanya, Hamra, Abu Ghraib	Waha Iraq
1996		Korifla, Omrabi 5
Jordan		
1992	Nesser	
Lebanon		
1990	Seri 82	
1992	Nesser	Cham 1
1995	Roomy	
1998		Omrabi 3
Libya		
1992		Khiar 92
1993		Zahra 5 (Korifla)
1994	Bohouth 101, Bohouth 102	
Morocco		
1992		Sarif
1993		Jawhar, Yasmine
1994	Achtar, Mehdia, Massira	Anouar, Omrabi 6
1995		Awragh
1998		Telset
Sudan		
1992	El Neelain, Sasarieb	
1996	Argin	
1997	Nesser	Waha
Syria		
1990		Awalbit
1991	Cham 6, Bohouth 6	
Tunisia		
1992	Vaga 92	
1993		Khiar
1996	Utique 96, Tebica 96	Omrabi 3
Turkey		
1990	Yuregir	Cham 1
1991	Gun 91*	Kiziltan
1992	Seri 82	
1993		Aydin 93
1994		Firat 93
1995	Kasifbey, Basribey, Seyhan 95, Kana, Lira-SA, Sultan 95*	Ceylan 95, Salikli 95
1996		Haran 95
1997	Bandirma 97, Karacabey 97, Pamukova 97, Kinaci 97*	
1998	Yildiz 98*	Dacki, Altintoprak
United Arab Emirates		
1990	Cham 2	

* Winter bread wheat varieties released by national programs in collaboration with CIMMYT/Turkey.

The Regional Maize Program for Central America and the Caribbean

Background

Central America and the Caribbean is the center of origin of maize, with highly developed pre-Columbian slash and burn maize-bean cropping systems. Maize is the most important subsistence staple for resource-poor rural families: it is food, folklore, culture, and tradition. It is produced largely using traditional, low-input technologies that can lead to degradation of the resource base. The region's population of 30 million is growing at around 3% annually, mostly in urban centers; the demand for food is increasing without comparable increases in agricultural productivity or sustainability. Most countries import a high proportion of their total maize needs. Seed industries are weak, and improved seed is used on only a fifth of the maize area. The "lost decade" of the 1980s seriously weakened national maize research programs; the 1990s have witnessed the bankruptcy and downsizing of the public sector without a corresponding growth in private sector activities. This, together with the adoption of inappropriate macroeconomic policies, has exacerbated the already considerable difficulties of most smallholder farmers, at least for the short term.

CIMMYT Activities

Since its inception, CIMMYT has assisted national programs in Central America and the Caribbean, initially providing improved germplasm and in-service training. As of the mid-1970s, the center has supported and participated in the Regional Maize Program for Central America and the Caribbean (*Programa Regional de Maíz*, or PRM), a collaborative network involving nine national agricultural research programs, with long-term funding from the Swiss Development Cooperation (SDC). With the principle aim of increasing productivity while preserving or improving the natural resource base, the PRM 1) develops open-pollinated varieties and hybrids with improved performance under the main biotic/abiotic stresses of the region, as well as high-yielding hybrids for favorable environments; 2) generates and validates improved crop management practices; and 3) conducts socioeconomic research on technology changes relating to PRM objectives. The PRM is a model network that empowers national program staff and motivates them to excellence; notably integrates breeding, agronomy, and socioeconomics; sets its agenda through a formal, objective, democratic, annual process; conducts clearly targeted, strategic research; produces high quality scientific reports; establishes productive partnerships with leading international centers, regional institutions, and non-government organizations (NGOs); and generally provides scientific and institutional leadership. CIMMYT contributions to the PRM—seed, science, and the enthusiasm and talents of a progression of technical advisors—have gained the Center recognition, appreciation, and trust regionwide.

Impacts

The following point summary is by no means an exhaustive accounting of accomplishments, but lists several that have significantly improved the livelihoods of smallholder maize farmers in Central America and the Caribbean.

- ***Improved germplasm.*** Since the 1960s, more than 100 improved varieties or hybrids of maize have been released in Central America and the Caribbean, many that possess tolerance to key production constraints, and nearly nine-tenths containing genetic contributions from CIMMYT breeding or germplasm bank stocks.

- ***Corn stunt tolerant maize for Nicaragua.*** In Nicaragua's Pacific region, 60% of the total area and 80% of farmers (80-100,000 ha) use NB6 or NB12, PRM cultivars with tolerance to corn stunt, a disease that can seriously constrain productivity and which is is spreading quickly into Mexico and South America. Genetic tolerance to stunt provides yield gains of 1.0-1.5 t/ha over susceptible cultivars, and studies have confirmed annual impact of U$ 3-5 million in grain produced. The PRM has additional sources of resistance, and is more precisely defining this multi-pathogen disease complex through molecular genetics research in collaboration with CIMMYT.

- ***Widespread hybrid use in El Salvador.*** Of the national maize area, 60-70% is planted to hybrids. These out-yield open-pollinated varieties by at least 1.0-1.5 t/ha, bringing farmers millions of dollars worth of additional grain each year.

- ***Promotion of conservation tillage through Guaymango, El Salvador.*** Guaymango is an area of 5,000 ha with a maize-sorghum cropping system. Adoption of the practice of using crop residues as mulch, rather than burning them, as well as sowing hybrids and applying modest levels of fertilizer, gradually increased maize yields from 1.0 to 4.0 t/ha, while improving soil characteristics and properties. Guaymango has become the focal point for the promotion of soil conservation practices to thousands of farmers, extension workers, NGOs, etc., and also hosts a yearly "conservation tillage fair."

- ***Conservation tillage in Azuero, Panama.*** Azuero, Panama, an area with 10,000 ha of mechanized maize production, was introduced to conservation tillage through an on-farm research course given by CIMMYT there in 1985 (the center also donated a minimum tillage planter). The national program heavily promoted the practice and, by 1996, more than half the farmers were using it, reducing production costs, weed problems, herbicide use, and soil deterioration.

- ***Intercropping canavalia in alternate rows of maize in Azuero, Panama.*** A decade of research on intercrops involving maize and the green manure, canavalia, has generated very promising alternatives for Azuero, and rapid adoption is beginning to occur. Compared to the original system of monocropped maize, the intercropping systems provide a 200–500% economic return, eliminate weeds, substitute for non-organic fertilizers, are used to enrich cattle fodder, and result in a long-term improvement of soil properties.

- ***Seed stock loss during Panama's US invasion.*** Seed stocks of Panama's national agricultural research program were lost during the US invasion in 1989. The PRM quickly supplied remnant seed, allowing seed production for the upcoming season. The PRM has generally provided national seed security to participating countries.

- ***Continuity in the face of institutional turnover.*** For many years, the operational capacity of national agricultural research programs in the region has declined due to resource constraints, instability, and staff turnover, with a clear negative impact on research outputs. CIMMYT and the PRM have drawn together researchers and provided a venue for their professional development and long-term productivity, thus conserving and enhancing national research capacity.

Cooperation Rescues Seed of Latin American Maize Landraces

Background

Efforts to apply scientific breeding to maize genetic resources in the tropics, begun under a joint Mexico-Rockefeller Foundation endeavor in the 1940s, initially involved extensive collecting and cataloguing of seed samples of farmer varieties, known as landraces, throughout Latin America. First seen simply as raw material for plant breeding, the landrace seed soon came to represent a priceless reserve against future genetic erosion, and collections were stored in genebanks in the nations of origin. Unfortunately, budgetary constraints in the region during the 1970-80s critically hampered efforts of genebank personnel to maintain their collections properly. Specifically, the germination capacity of seed samples in banks must be monitored and, when it falls below a specified level, viable seeds must be grown out according to scientific guidelines. This provides fresh samples that represent as nearly as possible the genetic diversity of the original—a process known as "regeneration." For lack of resources, however, irreplaceable collections of landraces, many of which were no longer grown by farmers and thus existed only as seed samples, were sliding inexorably toward extinction.

CIMMYT Activities

Latin American genebank representatives sounded the alarm about this situation during a workshop at CIMMYT in the early 1990s, based on evidence of poor germination obtained through the Pioneer Hi-Bred / USDA-ARS Latin American Maize Project (LAMP). A CIMMYT genetic resources specialist began working with genebank staff from 13 nations to mount a massive rescue effort, with funding from USAID under project Noah and additional aid from the USDA-ARS National Seed Storage Laboratory (NSSL). As executing agency, CIMMYT developed and submitted the proposals, workplans, and contracts for this ground-breaking project. The center also coordinated activities; furnished technical guidance; reported to donors on progress; and organized a mid-term project evaluation workshop in 1994 and a final workshop in 1996. A CIMMYT researcher, for example, closely monitored regeneration protocols to ensure they met scientific standards, especially the recommended minimum yield of 100 ears for a successful regeneration (i.e., one that embodies nearly all the genetic diversity of the original accession, and thus avoids so-called "genetic drift").

Impacts and Follow-up

Under the collaborative project, nearly 7,000 endangered collections were regenerated and back-up samples stored in trust at CIMMYT and NSSL, ensuring their future accessibility worldwide (see table). As a spin-off of this effort, cooperation was strengthened on maize genetic resource conservation and management in the Americas, the center of genetic origin for maize. Modest funding from NSSL has allowed regeneration of additional collections during 1997-98. Cognizant of the need to continue this important work, maize genetic resource specialists regionwide will meet at CIMMYT in summer 1998 to plan a new initiative. Regenerating threatened collections will surely be on the agenda, but a key component of future work is effectively evaluating and, where feasible, improving the characteristics of landraces still grown by farmers and of race groupings from regenerated bank collections to facilitate their use by farmers, breeders, and researchers in general.

Outcomes of collaborative efforts by CIMMYT, national germplasm banks in Latin America, USAID, and USDA-NSSL over 1992-96 to regenerate endangered seed holdings of maize landraces

Country	Number of collections regenerated
Argentina	329
Bolivia	380
Brazil	390
Chile	297
Colombia	1,195
Cuba	101
Ecuador	348
Guatemala	304
Honduras	42
Mexico	2,714
Paraguay	84
Peru	422
Venezuela	130
Total	**6,736**

Participatory Plant Breeding in Southern Mexico

Background

Can collaborative breeding (between farmers and crop breeders) increase farmers' welfare while maintaining or enhancing genetic diversity? The question is significant because if farmers cannot improve either their productivity and/or the quality of their produce without eroding genetic diversity, a serious challenge is posed to conservation approaches based on *in situ* preservation of genetic diversity (Figure 1).

CIMMYT Activities

The Economics and Maize programs at CIMMYT, in collaboration with INIFAP-Oaxaca and with funding from IDRC, have initiated a two-year pilot project in the central valleys of Oaxaca to determine factors that affect farmers' management of diversity, to characterize that management, and ultimately to use that analysis to develop tools to advance effective farmer-managed *in situ* conservation.

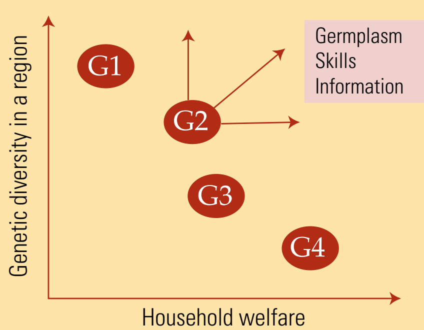


Figure 1. Starting from the G2 position, the win-win positions of increased or maintained diversity and/or farmer welfare are represented by the arrows. G1 indicates a position of increased diversity, but less benefit to farmers, while G3 and G4 represent in varying degrees increased benefits for farmers and costs to genetic diversity.

The recently completed first year of field work has concentrated on collecting benchmark data, particularly on local landraces and farmers' knowledge. Fifteen communities were identified by the project team and 153 maize samples collected. All maize samples have been planted at CIMMYT's Tlaltizapan Experiment Station for evaluation and reproduction. Trials were established at each of the 15 communities using the samples plus an additional 17 historical samples from CIMMYT and INIFAP gene banks. Data were collected from trials. Farmers in the communities were invited to evaluate crop samples and to provide demographic, socioeconomic, and agronomic data at harvest (216 farmers—117 females, 99 males).

Impacts

The results from the first year of the project will essentially provide the foundation for the following year's work. Several noteworthy outputs, however, have already been achieved.

- The farmers' management of maize diversity in the study area has been successfully characterized.
- In addition, a functional understanding has been developed of the factors affecting farmer management of maize diversity in the study area and their mechanisms of action. One somewhat surprising but extremely relevant finding is that subsistence farming for household consumption and the salient preferences associated with it outweighed even yield as the most frequently cited positive characteristic of varieties. Such findings have a direct bearing on breeder/farmer collaborations.
- The first year's research has provided the characterizations, logistical contacts, and initial conceptual framework required for the study's second phase, in

which farmers can be further classified by their management of diversity; technologies, skills, and information will be identified that can simultaneously enhance farmers' welfare and genetic diversity; and social organizations and mechanisms that can support the diffusion of these supporting factors will be identified and better understood.

- The **ultimate impacts** will be the development of methods that: 1) assist genetic resource specialists in selecting effective conservation strategies; 2) enable researchers to understand farmers' incentives for maintaining genetic diversity in their crops; and 3) allow researchers to assess the impact of collaborative breeding initiatives.

Impacts of Participatory Research on Tillage and Crop Establishment in Rice-Wheat Systems in the Indo-Gangetic Plains

Background

CIMMYT, in partnership with the Rice-Wheat Consortium for the Indo-Gangetic Plains, has helped develop improved practices for tillage and establishment for wheat after rice. In this region, rice-wheat systems cover more than 12 million hectares, and are the foundation of food security, employment, and income generation for over 150 million rural inhabitants, many of them poor (e.g., landless laborers). Introduced practices include surface seeding,[1] the Chinese hand tractor,[2] and several other zero- and strip-till drills.[3]

CIMMYT Activities

Project funding from DFID, USAID, and ACIAR has allowed us to monitor these options when managed by farmers in selected villages. At present, farmer experimentation on these options covers 156 ha in 13 sites in four countries (see table). There also are large areas under researcher-managed trials aimed at understanding biophysical processes. Impacts are beginning to appear, but quantitative impact studies remain to be done. Some impacts, anticipated as well as observed, are listed here.

Impacts

On farmers—Farmers have been astonished at the excellent performance of the options, especially during the current crop season when untimely rains delayed sowing. The new options allowed prompt sowing (5-25 days *earlier*), resulting in excellent stands and good yields (*increases* of 0.5 and 2.0 t/ha) while reducing cash costs and labor and machinery requirements (by about *half*). In some instances the new practices made the difference between a yield of 3 t/ha vs. no crop at all! Farmers are excited about possibilities for system intensification via the new practices—a third high value crop (after wheat and before rice) where previously none could be grown. In most villages, farmers

Area under farmer experimentation, by practice and site, wheat season 1997-98

Country and site	Chinese hand tractor	Surface seeding	Other
Bangladesh			
Chuadanga	10		
Dinajpur	14	1	
Netrakona	30		
India			
HAU Haryana			34
DWR Haryana			3
PAU Punjab			17
Pantnagar, UP			4
RAU, Pusa, Bihar	3	1	
ARI, Patna, Bihar	4		
Nepal			
Bhairahawa	18	6	
Parwanipur	5	1	
Naldung	1		
Pakistan			
Punjab			4
Total	**85**	**9**	**62**

1 A practice whereby pre-soaked, pre-germinated wheat seed is mixed with a slurry of water and manure, then broadcast into a standing or recently harvested rice crop. The timing of sowing is determined by the soil moisture.
2 Including a rotovator-cum-seed drill capable of establishing wheat into standing rice stubble with a single pass of a two-wheel tractor.
3 Including zero-till and strip-till drills used with four-wheel tractors, e.g., the Pantnagar drill.

plan a substantial increase in area devoted to the new practices next season.

On the poor—Higher rice-wheat system productivity—and diversification of these systems —will impact favorably on the poor through employment generation. (Rich) tractor owners may suffer as the demand for multiple plowings dwindles—but demand for labor will increase, putting pressure on rural wages when these already are rising.

On national research priorities—Scientists in national research systems have begun programs of research on tillage and establishment with their own resources, and have begun to breed rice and wheat germplasm better suited to reduced and zero tillage conditions.

On policymakers—The excitement in farmers' fields has spread in some instances to policymakers. The Minister of Agriculture of Nepal visited the Bhairahawa site. State authorities in Uttar Pradesh have purchased an additional 100 Pantnagar drills for farmer experimentation.

On the environment—The new practices improve input use efficiency and weed control, reducing the need for herbicides and for high doses of fertilizers.

Exploitable Production Potential, the Research Frontier, and the Wheat Yield Gap: Spring Bread Wheat in Mexico's Yaqui Valley

Background

What recent trends and relationships can be observed between potential (research) yields and farmer yields in the Yaqui Valley, the high production region where the Green Revolution was born? And what can these trends tell us regarding avenues for increasing yield now and in the future? The importance of these questions is nearly self-evident. Given the steady rise in wheat demand due to population and income growth, the challenge for sustaining wheat productivity is great. According to the International Food Policy Research Institute (IFPRI), to meet demand, wheat productivity growth will have to increase as much over the next two decades as it has over the past three. Growth will have to be in both high potential and marginal production environments.

CIMMYT Activities and Related Impacts

Between 1950 and 1996, spring wheat yields in the farmers' fields of the Yaqui Valley rose an impressive five-fold, from approximately 1 t/ha to 5.5 t/h (Figure 1). Much of this increase can be attributed to CIMMYT/ INIFAP varieties and breeding efforts, including varieties such as Seri 82, Rayon 89, Altar 85, Pitic 62, Yecora 70, and Ciano 79. As can be seen in Figure 1, potential wheat yields (on-station trials) and farmers' yields in the region have progressed along similar curves, with farm yields gradually narrowing the production gap. CIMMYT economists note, however, that since the mid-1980s the rate of wheat productivity growth at the farm level has slowed. At first glance it may appear that farmers may have peaked within the current parameters, but a more detailed look (Figure 2) broadly hints at a more complex story. The top 20% of farmers have neared optimally profitable production levels. CIMMYT analyses indicate that additional incremental expenditures of time and money by farmers in this group probably are not merited based on the marginal gains that can be obtained. To increase production

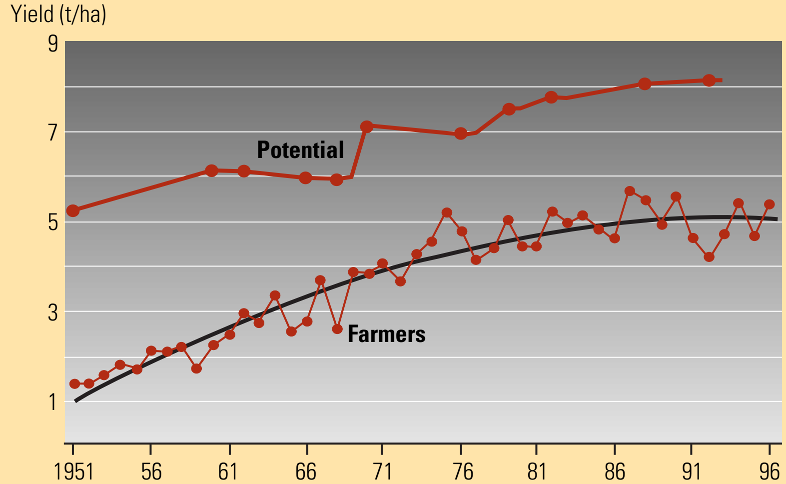


Figure 1. Wheat yields in the Yaqui Valley, Mexico, 1988-96.

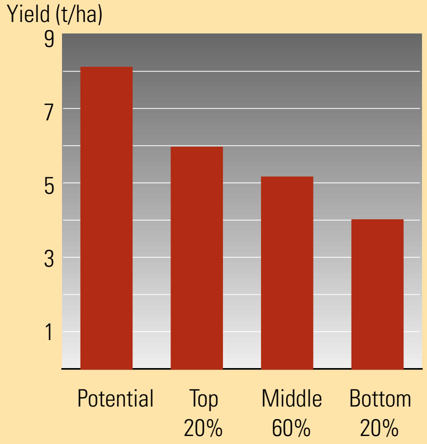


Figure 2. Wheat yields in the Yaqui Valley, Mexico, 1988-96.

significantly, this group will require a dramatic shift in the yield frontier.

The story (and hence the strategy for producing improved yields) for other Yaqui Valley farmers, particularly those producing in the bottom 20%, is somewhat different. Surveys reveal that input levels for groups cited in Figure 2 are essentially the same. The critical difference in productivity (which accounts for a 2 t/ha differential between the top and bottom groups) apparently rests on management and information variables. This strongly suggests that substantial yield gains could be obtained by this group if farming and management systems developed by CIMMYT and INIFAP for improved nitrogen use efficiency, and application timing and incorporation, were more widely adopted. Such adoption, in turn, CIMMYT economists say, rests on factors related to human capital, e.g., education and farming experience. Although farmers in the bottom 20% have the highest potential for gains from adoption of knowledge intensive technologies, farmers in the middle 60% could also boost yields significantly through better and more informed use of existing technologies.

Expanding the yield frontier, however, according to historical trends, would increase yields for all groups. CIMMYT's effort to shift the yield frontier is being pursued through three distinct but inter-related strategies:

- Changes in wheat plant architecture to produce a larger head size with a higher number of grains and no reduction in grain size. CIMMYT breeders estimate an 80% probability of success in developing the new plant architecture, which would increase yields by 10-15 % above Veery descendants.
- Hybrid wheat, originally viewed as having great promise and then falling out of favor, is being reassessed in light of recent improvements in hybridization elements, advances in biotechnology, and the emergence of a new wheat plant type. It is projected that increased grain filling and heterosis together with the new plant material could jointly shift the yield frontier by as much as 25-30%.
- Wide crossing, an important technique for introducing stress resistance in wheat, could also lead to enhanced yields. CIMMYT has produced an elite set of 95 synthetics (crosses between durum wheat and goat grass, a *Triticum* grass species) which have been partially characterized for morphological traits, yield components, growth, and abiotic and biotic stress. Major gains from such synthetics would come from using them as parent material in the production of hybrid wheat.

CIMMYT's Core Donors (1998)

The following is a list of CIMMYT's core donors, those who contribute to either our core unrestricted budget, or who provide core-restricted funds. These same donors also often provide special project funds, as well.

Australia
Austria
Belgium
Brazil
Canada
China
Colombia
Denmark
European Union
Ford Foundation
France
Germany
India
Iran
Italy
Japan
Korea
Mexico
Netherlands
Nippon Fundation
Norway
Pakistan
Peru
Portugal
Republic of South Africa
Sasakawa Africa Association
Spain
Sweden
Switzerland
Thailand
United Kingdom
United States Agency for International Development
World Bank

CIMMYT

Sustainable Maize and Wheat Systems for the Poor

International Maize and Wheat Improvement Center
Centro Internacional de Mejoramiento de Maíz y Trigo
Lisboa 27, Apartado Postal 6-641, 06600 México, D.F., México