Safeguarding the World's Wheat Harvests from

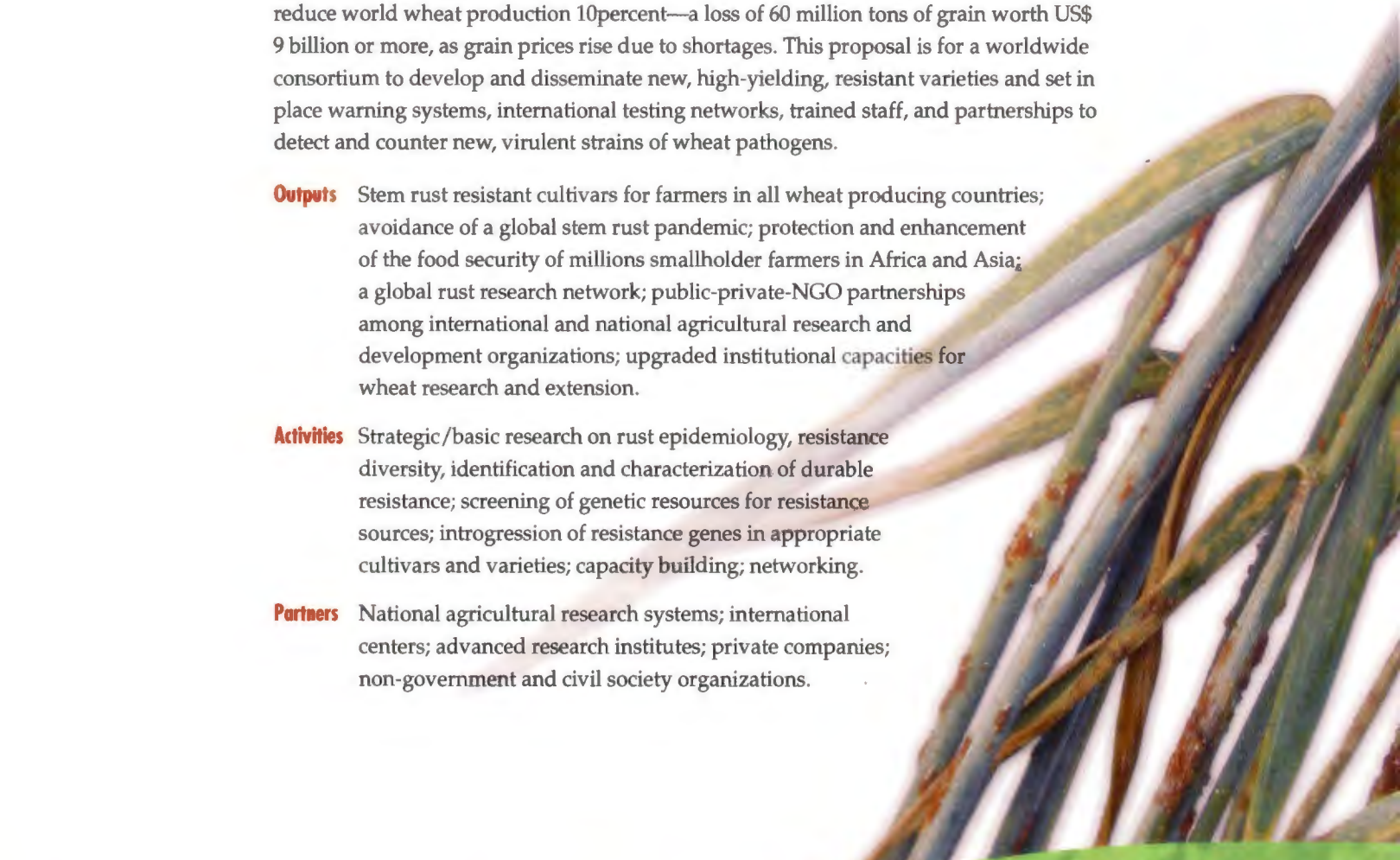
STEM RUST:
A Global Initiative

Wheat is grown on more than 200 million hectares worldwide and is a source of food and livelihoods for hundreds of millions in developing countries. Until the advent of science-based agriculture, world wheat harvests were held hostage by rapidly evolving fungal pathogens, among the most damaging of which were the rusts. Modern breeding, combined with the free international exchange of experimental wheat lines, resulted in the development and wide dispersion of wheat varieties able to resist the rusts for several decades. Many developing country farmers cannot afford fungicides, so resistant wheat varieties constitute a major safeguard of their food security. However, a new strain of stem rust has emerged in eastern Africa that is virulent to most wheat varieties currently sown. Its spread is likely, and a major stem rust epidemic could reduce world wheat production 10percent—a loss of 60 million tons of grain worth US$ 9 billion or more, as grain prices rise due to shortages. This proposal is for a worldwide consortium to develop and disseminate new, high-yielding, resistant varieties and set in place warning systems, international testing networks, trained staff, and partnerships to detect and counter new, virulent strains of wheat pathogens.

Outputs Stem rust resistant cultivars for farmers in all wheat producing countries; avoidance of a global stem rust pandemic; protection and enhancement of the food security of millions smallholder farmers in Africa and Asia; a global rust research network; public-private-NGO partnerships among international and national agricultural research and development organizations; upgraded institutional capacities for wheat research and extension.

Activities Strategic/basic research on rust epidemiology, resistance diversity, identification and characterization of durable resistance; screening of genetic resources for resistance sources; introgression of resistance genes in appropriate cultivars and varieties; capacity building; networking.

Partners National agricultural research systems; international centers; advanced research institutes; private companies; non-government and civil society organizations.



CIMMYT

Safeguarding the World's Wheat Harvests from Stem Rust: A Global Initiative

Background

The rusts, caused by the fungal pathogens *Puccinia* spp, have been a scourge on wheat agriculture since the beginning of recorded history. The many pandemics over the past 150 years have included several devastating outbreaks that resulted in major famines in India and massive grain losses in North America (1903, 1905, 1916, 1950-54).

In modern breeding programs to develop resistant wheats, scientists first intercross broad populations and grow the progeny under artificial rust epidemics to identify resistant genotypes. The resistant plants are then intercrossed to gather multiple, interactive genes for resistance within individual wheat lines. The most reliable form of rust resistance allows slow development of the disease on the plant without significantly affecting yields. Besides producing grain, the resistant plants serve as refugia for less-virulent strains of the pathogen. This type of resistance is termed "durable resistance."

Following the disastrous outbreak of a new race (15B) of stem rust to which all North American wheat cultivars were susceptible, the US Department of Agriculture (USDA) established an International Rust Nursery in 1952, by which resistant genotypes were distributed for testing and use throughout the Americas and later worldwide. This led to the development of high-yielding wheat cultivars with high levels of resistance to stem rust and moderate levels of resistance to leaf and stripe rust. The International Maize and Wheat Improvement Center (CIMMYT) and its predecessor organization, the Mexican Government-Rockefeller Foundation cooperative agricultural program, also established international yield testing and disease screening nurseries that were distributed to 150 locations globally. These international nurseries and the associated collection and sharing of data led to an unprecedented acceleration in wheat breeding around the world. Many high-yielding, broadly-adapted varieties that drew on new sources of genetic diversity and of rust resistance were introduced to national wheat breeding programs around the world.

Operating largely unfettered for more than 25 years, the system of public international nurseries—including CIMMYT's wheat disease screening nurseries—has begun to break down in the last decade or so, as a result of intensified plant quarantine restrictions, measures to block bio-terrorism, and controls on the exchange of intellectual property. Among other things, this has reduced the efficacy of wheat disease surveillance and early warning systems, and rust diseases are on the rise around the world. China, for example, no longer operates an effective national disease screening network, and has experienced successive stripe rust epidemics. The latest, in 2004, affected crops on as much as 5 million hectares; national production losses may have reached 5 percent.

Stem Rust:

The Deadliest Rust of All!

The most ominous new strain of stem rust, UG99, was detected in eastern Africa in 1999 and is now reported throughout the region. Caused by *Puccinia graminis*, stem rust is the most devastating of the three rust species, sometimes resulting in complete crop loss and capable of attacking all *Triticum* spp cereals. It has been controlled effectively through the use of cultivars developed and disseminated by CIMMYT and partners as part of the Green Revolution during the 1960s and 1970s. Over 80 percent of the developing world's spring bread wheat area is sown to cultivars derived either directly from CIMMYT lines or using them as parents. For more than 30 years, a major portion of this germplasm has remained resistant to stem rust, to the extent that the disease is often not considered important any more. In fact, in many countries wheat breeding does not include screening for stem rust resistance.

In trials in Uganda in 1998, CIMMYT wheats exhibited high susceptibility to a stem rust pathogen. The race in question was later shown to carry a combined virulence for several resistance genes in the CIMMYT wheats, including *Sr31* and *Sr38*. The first is located on the 1B/1R translocation introduced from rye, and occurs at a high frequency in CIMMYT's spring wheat germplasm. The gene is also common in several winter wheat cultivars grown in Asia and Europe. Kenyan wheat cultivars and CIMMYT wheat lines also showed high susceptibility to stem rust in a trial at Njoro, Kenya, in 2002, indicating either that UG99 is now widespread in eastern Africa or a new *Sr31*-virulent race has evolved. Research on this issue is needed, but for now it is clear that several important cultivars in the Middle East and Asia are susceptible to UG99.

Rust spores travel in diverse ways—on the clothing of travelers or even in jet streams. In the mid-1980s a new race of stripe rust (*P. striiformis*) emerged in eastern Africa. It was virulent to wheat varieties whose resistance was based on the *Yr9* gene. In a decade the new race of stripe rust had migrated to South Asia through the Middle East and West Asia. In its path it incurred severe crop damage and economic losses of several hundred million dollars. Stem rust UG99 would likely follow a migration pattern similar to that of *P. striiformis*. It is only a matter of time before UG99 crosses the Arabian peninsula into West and South Asia, and eventually, East Asia and the Americas.

UG99 could attack many of the improved spring and winter wheat cultivars sown around the world, especially those containing the IB/IR translocation, which cover as much as 50 million hectares. Most CIMMYT wheats are susceptible, meaning that most spring bread wheats in developing countries are also susceptible. A major stem rust pandemic would eventually reduce world wheat production by at least 10 percent, representing a direct economic loss of US$ 9 billion at current prices. Total economic losses would be much larger, since world wheat prices would rise in response to disease-

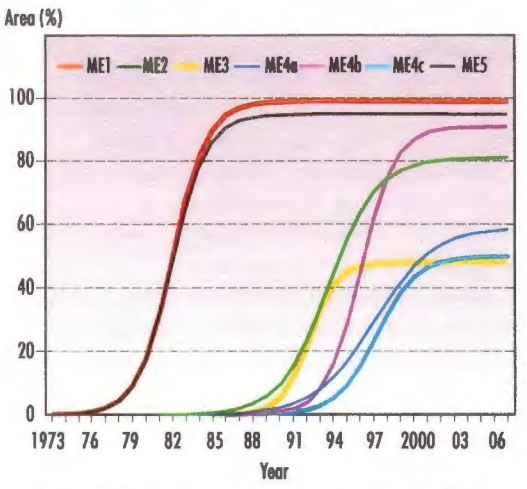


Figure 3. Percent area in post-1972 CIMMYT-related spring bread wheat releases by mega-environment from 1973 to 2007.

occasioned grain shortages. This is especially ominous, given that world grain reserves are the lowest in 20 years.

The current crisis is a wake-up call about the continuing and potentially devastating impact that rust pathogens can have on susceptible cereals, especially for a staple food like wheat. Plant breeders and pathologists still have time to screen for resistant genotypes and to get the varieties into farmers' fields. For poor farmers, who cannot afford fungicides, resistant varieties are the only protection from complete crop losses in years with a stem rust outbreak. CIMMYT and other programs have breeding materials that may offer resistance to UG99 (for example, lines that showed resistance in recent trials in Kenya), but little of the resistant material is found in currently sown cultivars.

Project Overview

To address this potential crisis, CIMMYT proposes a coordinated, interdisciplinary research and development consortium—the Global Rust Initiative (GRI)—through which appropriate wheat varieties that possess stable resistance to the new stem rust race(s) will be rapidly developed and deployed.

Expected Outputs

- High-yielding cultivars that possess durable resistance to stem rust derived from new, genetically diverse sources and are made available to farmers in all wheat producing countries.
- Avoidance of a stem rust pandemic that could cost farmers US$ 9 billion or more and put further strain on global grain markets.
- Protection and enhancement of the food security of millions of smallholder farmers in Africa, Asia, and the Middle East.
- The institutional foundations for a global rust research and varietal dissemination network (disease screening nurseries, training, capacity building) that involves public-private-NGO partnerships and international and national agricultural research and development organizations.

Proposed Activities

- Collect rust samples and characterize them in greenhouse tests, to determine the countries in Africa where the new race has established itself and monitor its spread.
- Identify resistance genes and other sources that are effective against UG99 and other races known to occur in the region; among other activities, evaluating large amounts of wheat germplasm.
- Conduct genetic and molecular studies to characterize the resistance genes and identify wheat germplasm that carries durable resistance.
- Incorporate diverse resistance genes into important wheat cultivars of Africa and Asia, as well as into CIMMYT germplasm, via shuttle breeding or other approaches.

- Strengthen wheat rust research facilities in Kenya, Ethiopia, and possibly Egypt
- Help train wheat researchers and technicians from Africa and Asia (initially in Kenya and Ethiopia) through in-service and visiting scientist programs, and MS or PhD thesis research fellowships.
- Work with countries in the path of the new virulent races of stem rust to develop and implement the replacement of susceptible commercial varieties with new, resistant ones
- Technical reporting and knowledge sharing among stakeholders.
- Develop a communications strategy to raise awareness of the problem and provide general information to donors and the public

Institutional Partnerships

A consortium of institutions, programs, products, and services to address the potential threat of a stem rust pandemic.

National agricultural research systems in Africa—In 2004, Ethiopia and Kenya were the two eastern African nations with the largest wheat areas where the emergence of UG99 had already been reported. Wheat farming in these countries is rainfed, and occurs at high elevations and in cool climates. A shuttle breeding program[1] begun in 2003 between CIMMYT-Mexico and the Njoro Research Station of the Kenyan Agricultural Research Institute (KARI) should be expanded and intensified. The Rockefeller Foundation has offered a small bridging grant for 2005 to begin addressing this and to help develop a more comprehensive program.

A new shuttle breeding program between CIMMYT-Mexico and the Ethiopian Agricultural Research Organization (EARO) will start in 2005 at one or two Ethiopian experiment stations—probably Kulumsa and Holeta—with partial emergency funding provided by the Sasakawa Africa Association, while a more comprehensive program is developed.

Egypt's wheat areas constitute high-yielding, irrigated, lowland wheat environments in which the crop is grown in the cooler winter season. These areas are similar to those of northwest Mexico and the Indo-Gangetic Plains of India and Pakistan—areas where CIMMYT has worked extensively. To address the likelihood of UG99 reaching Egypt, stations in Egypt will be involved as primary shuttle breeding locations by 2006 or 2007

South Africa has provided differential and gene postulation data on stem rust for winter wheat nurseries, and will be invited to participate in research and training.

ICARDA—The International Center for Agricultural Research in the Dry Areas (ICARDA) has mandated responsibilities for small grain cereals in Central and West Asia and Northern Africa (CWANA), and in rainfed, arid cereal-growing areas in general. Past studies on rust epidemiology suggest CWANA as a region likely to be the next affected by UG99 and, thus, one the first lines of defense in the development and deployment of resistant germplasm. The region is particularly important, given the role of wheat as a staple crop for subsistence farmers.

Advanced laboratories—Strategic collaborative research with several specialized rust laboratories in industrialized countries will be required, among them

- USDA Cereal Disease Laboratory, University of Minnesota.
- Agriculture Canada Cereal Research Center, Winnipeg.
- PBI, The University of Sydney.

Private sector organizations—
- Major private wheat seed companies.
- Wheat producer associations.
- Wheat agro-processing companies.

Non-governmental and agricultural extension organizations—While breeders are identifying new sources of resistance to UG99 and crossing these genes into the appropriate range of wheat germplasm, plans also need to be made to introduce the new varieties. Preliminary seed multiplication of promising varieties is needed for widespread farmer testing and evaluations, as part of a participatory breeding/selection program. National seed production and agricultural extension organizations, and NGOs such as the Sasakawa Africa Association, will participate in seed multiplication, farmer selection, and demonstration plots, and varietal dissemination programs.

Capacity building—There are many trained wheat pathologists in Africa and Asia, but few have experience with stem rust because there has not been a major epidemic in 50 years. They will need refresher training, at a minimum. A range of training programs is proposed to support key GRI research and capacity-building requirements and objectives, including in-service training in disease screening/resistance breeding and visiting scientist refresher courses.

[1] Screening successive generations of experimental lines in contrasting settings, normally geographically separated

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