CORNELL UNIVERSITY

DURABLE RUST RESISTANCE IN WHEAT
EXECUTIVE SUMMARY

Prospective Donor:	The Bill & Melinda Gates Foundation (BMGF)
Project Description:	This project will support the development and adoption of wheat varieties resistant to emerging, dangerous strains of rust diseases, and catalyze a coordinated, sustained global response to protect world wheat supplies in vulnerable regions of the developing world in Africa and Asia
Grant Term	36 months
Award Amount:	$26,830,848
Future Funding:	Project includes planning component for future funding

OVERVIEW

The livelihoods of resource-poor wheat farmers and consumers in the developing world are threatened by new variants of stem rust disease emerging from East Africa. In order to prevent widespread crop losses, farmers need access to wheat varieties that can resist these emerging rust pathogens. This grant will catalyze a coordinated global response to the threat of wheat rust diseases, with a focus on developing improved wheat varieties that protect resource-poor farmers in vulnerable regions of Africa and Asia

The award consists of a planning component to develop a follow-on comprehensive proposal within two years to deal with the long-term threat of emerging wheat rust variants, and a large, rapid implementation program consisting of the following objectives:

- (a) advocacy to foster global awareness, cooperation and support to combat the threat of emerging wheat rust diseases;
- (b) tracking the global spread of wheat rust pathogens;
- (c) support for critical wheat rust screening facilities in Kenya and Ethiopia;
- (d) conventional and molecular breeding to produce rust resistant wheat varieties protected by combinations of minor and/or major genes designed to impart durability;
- (e) marker development and optimization for rust resistance traits;
- (f) making potentially useful sources of rust resistance accessible to breeders by reducing linkage drag associated with rust resistance genes;
- (g) discovering new sources of rust resistance in wild and primitive wheat and wild barley; and
- (h) exploring the potential of rice immunity to rust diseases as a future disease control strategy in wheat and other cereal crops.

The project will be managed by Cornell University, and will enlist national program partners in Kenya and Ethiopia, three international agricultural research centers including the International Maize and Wheat Improvement Center, known by the Spanish acronym CIMMYT, in Mexico; the International Center for Agricultural Research in the Dry Areas (ICARDA) in Syria; and International Rice Research Institute (IRRI). The Food and Agriculture Organization of the United Nations (FAO), and advanced research laboratories in the United States, Canada, China, Australia, and South Africa will also be collaborators. Impact through testing, multiplication, release and adoption by farmers of durably resistant wheat varieties requires close collaboration with all national programs in at-risk areas.

SUMMARY

The ability of the world's farmers to meet current and future demand for wheat is gravely threatened by new strains of stem rust disease emerging out of East Africa. Stem (or black) rust of wheat, caused by the fungus *Puccinia graminis,* is the most feared of the rusts of wheat. Stem rust can rapidly reduce a healthy looking crop to a black tangle of broken stems and shriveled grain in a matter of weeks. Historically, wheat farmers have suffered enormous losses from rust diseases: from the Romans who prayed to a “stem rust god” called Robigus, to U.S. and Canadian farmers in the 1950s, who saw yield losses of 40% across spring wheat growing areas. The success of wheat breeders led by Norman Borlaug has protected wheat farmers from the scourge of rust diseases for the last half century, and certainly contributed to the stable yield gains of the Green Revolution.

The problem is urgent: About 90% of the wheat grown around the world is vulnerable to severe damage to the new types of stem rust disease emerging out of East Africa. Stem rust variant Ug99, identified in Uganda in 1999, is the only known type of *P. graminis* that has virulence against historically durable resistance genes used in breeding programs, notably *Sr31*.

The problem is spreading: Stem rust Ug99 is spreading out of East Africa via airborne spores. In early 2007, Ug99 was detected in Yemen and Sudan. Ug99 is now known to be in Iran. Based on prevailing wind patterns, the spores are likely to migrate to other regions of Asia including India and Pakistan, although exact timing of dispersal is difficult to predict. Colonization of North Africa by Ug99 is also likely. International travelers could also spread rust spores on their clothing: similar rapid spread by (inadvertent) human transport has been documented for other plant diseases, including yellow rust of wheat.

The problem is becoming more severe: Stem rust is continuing to evolve in East Africa. New derivatives of Ug99 were isolated in Njoro, Kenya in 2006 and 2007 and can overcome resistance genes *Sr24* and *Sr36*, both important sources of disease resistance for international breeding programs.

The problem is solvable: Breeders do have access to a limited number of undefeated stem rust resistance (*Sr*) genes from various wheat varieties, landraces and wild relatives. Some of these sources of resistance are “minor” genes that are additive and need to be deployed together in one variety to provide effective protection (also known as Adult Plant Resistance, APR). A small group of elite high-yielding breeding lines possessing resistance are being tested already in several countries. Other sources, particularly from wild relatives, need to be “cleaned up” by having linked deleterious traits (linkage drag) removed before they can be used effectively in wheat breeding programs. Marker assisted technologies can speed up these breeding approaches. The project envisions multiple approaches to achieve long-lasting stem rust resistance, from “bread and butter” breeding, to marker assisted selection (MAS) and high-end basic science explorations. This combination of approaches has been judged highly likely to succeed by a panel of 10 diverse external experts who reviewed the proposal for BMGF.

Resource-poor farmers are especially vulnerable: Commercial wheat farmers can access chemical protection again rust diseases, although available fungicides are expensive (estimated at $40 per crop cycle to protect one hectare in Kenya) and pose risks to human health and the environment. Chemical protection offers, at best, a limited short-term fix and is unlikely to be accessible to vulnerable resource-poor farmers in countries like Ethiopia, Pakistan and India. We can protect the livelihoods and food security of these farmers by supporting development and delivery of improved, resistant wheat varieties that do not require additional inputs for crop protection.

Protecting wheat supplies is important for global food security: Wheat represents approximately 30% of the world's production of grain crops. The FAO predicts that 598 million tons of wheat will be harvested this year on 220 million hectares of land. Nearly half of that production will be harvested in developing countries. On average, each person in the world consumes 68.2 kilograms of wheat each year. That equates to about 630 calories per day per person, or 1/3 to 1/2 of the minimal energy requirements of most adults.

Africa imports about 9 million tons of wheat a year (more than 80% of its wheat needs) and this gap is predicted to increase steadily in the future. Poor consumers in Africa and elsewhere are particularly vulnerable to price increases.

Increases in wheat productivity were a major driver for the Green Revolution, especially in India and Pakistan. In India, wheat yields grew from a total production of 12 million tons (MT) in 1965, to 76.37 MT in 2000 (at average rates of 4.00% annual growth from 1966-1977, down to 2.37% between 1985-2000). More recently, production levels in India have dropped (68.64 MT in 2005), most probably due to reductions in the use of fertilizer, and changes in economic policies on trade and subsidized distribution. After six years of being a net exporter of wheat, a substantial wheat deficit reemerged in India in 2006 (Figure 1). The Government of India has projected that wheat demand could grow to 109 MT by 2020.

Crop shortfalls are also occurring in other key wheat producing nations, such as Australia, where recurring droughts in recent years have reduced production. The global demand for wheat has driven prices in the U.S. to an October 2007 level of close to $10 a bushel, up from about $4.50 a year earlier. Global markets are scrambling for adequate wheat supplies.

Using a very conservative estimate of 10% loss in regions hit by Ug99, annual global losses by the year 2016 are predicted at 25 million tons (equivalent to about $8.3 billion at today's prices). Our largest target market are the 50 million farming families in the Indo-Gangetic plain who rely on wheat production, who stand to lose over 7 million tons of annual production ($2.3 billion) for each 10% drop in yield. The reality could be much more frightening since much higher losses are possible. Between Rabat and Vladivostok, there are over 100 million hectares of wheat under cultivation, all genetically susceptible to Ug99. The 1953 rust epidemic in North America resulted in average yield losses of 40% across U.S. and Canadian spring wheat growing areas.

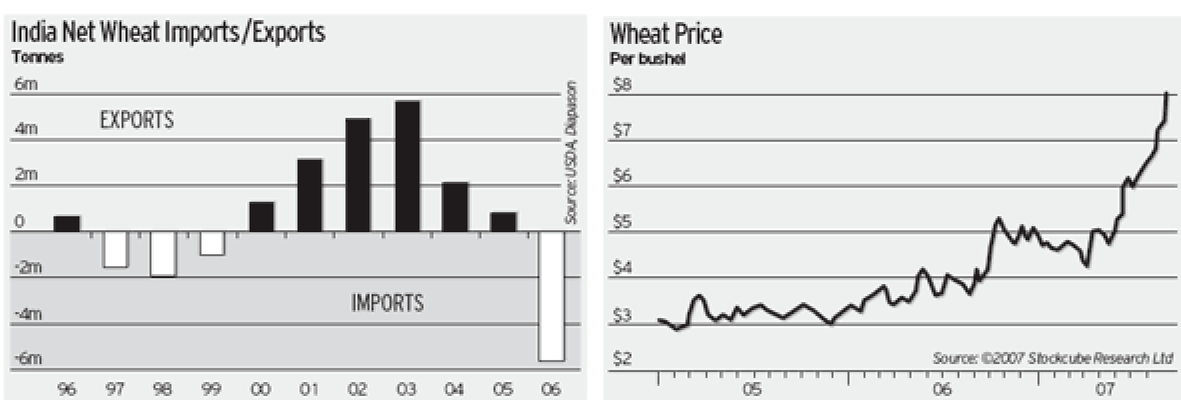

Fig. 1: Indian wheat trade and world wheat prices.
Source: "Global growing problem of wheat production," The Daily Telegraph, September 6, 2007

Goals and Objectives

The overall mission of this project is to protect world wheat production from the urgent threat posed by new variants of stem rust disease emerging out of East Africa. The expected impact is to prevent catastrophic losses of wheat production among resource-poor farmers in Africa and Asia.

Objective	Contribution to combating wheat rusts
Objective 1: Planning to develop a comprehensive program to deal with the long-term threat of emerging rust variants.	Planning activities will engage additional partners to develop a wide-ranging, inclusive and coordinated global program to deal with the emerging stem rust threat. This will result in detailed plans for seed dissemination and adoption in vulnerable regions, improved integration of knowledge of pathogen biology in solutions, resolution of the role of leading edge marker technologies in rust resistance breeding, and appropriate engagement in socio-economic aspects of the problem.
Objective 2: Advocacy to foster global awareness, cooperation and support to combat the threat of wheat rust diseases.	The first measurable accomplishment for this objective will be a catalog of known rust research activities and donors that will allow for effective planning and coordination. The project will facilitate international coordination by supporting the Borlaug Global Rust Initiative (jointly led by the FAO, CIMMYT, ICARDA, and Cornell University). Improved cooperation among international wheat scientists will be encouraged through joint meetings and exchange visits, so that relevant material is shared among wheat breeders. Finally, increased future funding support will be encouraged by educating appropriate government officials and stakeholders in wheat-growing countries.
Objective 3: Tracking of cereal rust pathogens.	A wheat rust monitoring system with data generated by national surveillance teams compiled by a UN-FAO based International Focal Point will monitor the spread and evolution of Ug99 and derivative stem rust races in at-risk countries. This will inform targeted intervention to reduce the impact of the disease.
Objective 4: Support for critical screening facilities in East Africa.	National research facilities in Kenya and Ethiopia allow breeders from around the world to incorporate stem rust resistance as a selection criteria in international and national breeding programs, thus accelerating development of wheat varieties that are resistant to the evolving pathogen. The capacity building necessary to support screening facilities in Kenya and Ethiopia will also facilitate in-country surveillance.
Objective 5: Conventional and molecular breeding to produce stem rust resistant wheat varieties.	The breeding objective will result in resistant wheat varieties that can directly protect farmers from losses to rust diseases, without additional inputs. This represents the heart of the project. Support for eight wheat breeding programs at the wheat oriented international centers (CIMMYT and ICARDA) will enable addition of stem rust resistance to selection criteria already applied. This was deemed the most rapid way to develop and disseminate improved varieties with durable rust resistance.

Objective	Contribution to combating wheat rusts
Objective 6: Marker development and optimization for rust resistance traits.	Breeders need more and better markers to speed up their efforts to incorporate *Sr* genes into wheat. The research under this objective will focus on rust resistance traits.
Objective 7: Reducing linkage drag for potentially useful sources of rust resistance.	Most of the effective *Sr* genes are derived from wild relatives of wheat, and are attached to long segments of DNA that include deleterious traits, e.g. yield reduction. The measurable output from this objective will be desirable *Sr* genes on shorter fragments of DNA, separated from deleterious traits. This will make it possible for breeders to incorporate these *Sr* genes into improved, protected wheat varieties.
Objective 8: Discovering new sources of rust resistance in wild wheat and wild barley.	Multiple sources of disease resistance relying on different genetic mechanisms are required to provide long-lasting protection against evolving rust fungi. It will be hard or impossible for new races of stem rust to overcome a wheat variety that incorporates several different types of disease resistance genes, operating by different molecular mechanisms. Because so many known *Sr* genes have already been defeated by Ug99 and derivatives, new sources of resistance are urgently needed.
Objective 9: Exploring the potential of rice immunity to rust as a future disease control strategy in other cereal crops.	Rice is effectively a non-host for puccinias and other rusts. This basic research activity will determine if any of the large number of rice mutants shows altered response when challenged by wheat rusts. Discovery of such mutants, followed by annotation of the responsible genes, may lead to discovery of the mechanisms that render rice a non-host.
Objective 10: Project management	With 15 institutional partners and many research scientists engaged in this proposal, a strong project management unit will be housed at Cornell University. Project management will be directed by Dr. Ronnie Coffman, International Professor of Plant Breeding and Director, International Programs, Cornell University.

Contacts

Director: Ronnie Coffman, International Professor of Plant Breeding and Director, International Programs, College of Agriculture and Life Sciences, 34 Warren Hall, Cornell University, Ithaca, NY 14853 USA
+1-607-255-2554 (O), +1-607-272-7551 (H), +1-607-327-1824 (M), +1-607-255-1005 (F)
SKYPE ronniecoffman, SKYPEIN +1-607-821-1421, wrc2@cornell.edu, http://ip.cals.cornell.edu

Project Coordinator: Rick Ward, International Programs, College of Agriculture and Life Sciences, 15 Warren Hall, Cornell University, Ithaca, NY 14853 USA
+1-607-254-6558 (O), +1-517-575-7640 (M), +1-607-255-1005 (F)
SKYPE wheatbreeder, SKYPEIN +1-517-639-0214, rward@cornell.edu

The web site for the project is: http://www.wheatrust.cornell.edu