# Defending U.S. Grain Crops From Fungal Assault

Close-up of wheat leaf rust on wheat.

JAMES KOLMER (D519-1)

Since the early part of the 20th century, the Agricultural Research Service's (ARS) Cereal Disease Laboratory (CDL) has stood as a sentry watching for emerging diseases of cereal crops—wheat, barley, and oats. The St. Paul, Minnesota, lab is on high alert now, since an African strain of stem rust has emerged as an unprecedented international threat to wheat and barley.

Stem rust, caused by the fungus *Puccinia graminis* sp. *tritici,* has historically been one of the most destructive plant diseases. The new African strain, called "Ug99" because it first surfaced in Uganda, has spread since 1999 to Kenya and Ethiopia. It will likely spread to major wheat-growing areas of northern Africa, the Middle East, and western and southern Asia, spurred on by prevailing winds and widespread use of susceptible varieties. It could spread to the United States and other major wheat-growing areas as well. If it does, CDL would almost certainly be the first to sound the alarm through its online bulletins to farmers, crop advisors, and other interested individuals.

Nobel Peace Prize winner Norman E. Borlaug, founder of the "Green Revolution," which was responsible for outstanding yield increases in wheat and other major crops in the mid-1900s, believes that this new mutant strain of stem rust is the most serious threat to wheat and barley crops in 50 years. Wheat bred for stem rust resistance was a major reason for the Green Revolution's successes.

Borlaug is alarmed because the massive crop losses once caused by stem rust epidemics could happen again. Most of the high-yielding, rust-resistant dwarf wheat varieties he helped breed for developing countries and North America have no resistance to the new strain. In fact, most of the world's wheat is vulnerable.

## Genetic Protection on the Way

ARS has partnered with international organizations, such as the International Maize and Wheat Improvement Center (known as "CIMMYT"), to screen wheat germplasm for resistance to Ug99.

Yue Jin, an ARS plant pathologist at St. Paul, found that 80 percent of the hard red spring wheat grown in the northern Great Plains has no resistance to it. Testing also showed considerable vulnerability in other classes of wheat and barley.

"This is an unprecedented level of vulnerability," says Martin Carson, CDL research leader. The good news is that Jin has identified some genes for resistance to Ug99 in every major U.S. wheat class. This gives hope that resistant varieties can be developed before the new strain reaches here. In fact, plant breeders are already working these genes into new varieties.

ARS national program leaders Kay Simmons and Rick Bennett went to Kenya in September 2005, when Borlaug called the Global Rust Summit to confront the problem.

*An ARS scientist has found genes for resistance to Ug99, a new, mutant strain of stem rust that is perhaps the most serious threat to wheat and barley in 50 years.*

KAY SIMMONS (D516-1)

**Nobel Peace Prize winner Norman Borlaug (second from left) believes Ug99 is the most serious threat to wheat and barley in 50 years. He is shown here consulting with Kenyan and CIMMYT leaders near wheat plots in Kenya.**

XIULING ZHANG (D518-1)

**Wheat leaf rust on wheat.**

As part of the Global Rust Initiative, ARS has signed a cooperative agreement with CIMMYT to field-test U.S. wheat varieties and breeding lines for resistance to Ug99 in Kenya, where the new race has been prevalent for several years. This effort is supported by the USDA National Plant Disease Recovery System.

In April 2005, ARS collected seed from its National Small Grains Repository in Aberdeen, Idaho, and asked wheat breeders across the country for seed of wheat varieties and breeding materials. In less than 2 weeks, seeds of about 800 lines were being express-mailed to Kenya for scientists at the Kenyan Agricultural Research Institute to plant in test fields. ARS scientists will send seed to Kenya again in 2006, including seed from new breeding lines with more resistance to the disease.

**A Rust of a Different Stripe**

Besides Ug99, CDL scientists are currently watching for new races of stripe rust, leaf rust, and wheat scab. The lab maintains a collection of fungal strains, adding new ones as they are found. Inside the lab's secure greenhouses or outdoors in one of the affected countries, new crop varieties are exposed to the strains to test for resistance. The lab's scientists travel each growing season, following the emergence of cereal crops and diseases in U.S. fields, starting in warm Florida and moving north to the Canadian border as spring moves upward.

Stripe rust has broken out of the Pacific Northwest in recent years and is becoming an annual problem in the Midwest and South. ARS's focus is on maintaining and enhancing resistance to stripe rust in the southern United States—the most likely source of new infections because of its warm climate. The agency supports a stripe rust initiative, funded at $500,000 a year and administered by the National Wheat Improvement and National Barley Improvement committees.

Regional screening for stripe rust is done through a network of nurseries scattered throughout U.S. barley- and wheat-growing areas. The nurseries grow special experimental lines of wheat and barley that have different genes for resistance in them. By observing how the various lines react to the disease, scientists are able to identify the strain of rust fungus that affects them.

Les Szabo, a CDL geneticist, uses a diagnostic test he developed to monitor rust spores in rain. He's documented movement of rust spores across long distances—from South Texas to North Dakota, for example. In 2005, he and colleagues adapted the test for Asian soybean rust and found that its spores also traveled long distances.

Szabo gets his rainwater from the National Atmospheric Deposition Program's network of precipitation samplers. The network has been in existence since the 1970s to monitor air quality by collecting samples of rain, sleet, snow, or fog. "Last year, we received weekly samples from 124 locations in soybean-growing regions," Szabo says. "It's nice that we can

piggyback on this existing structure and survey such a large part of the country."

### A Rust With No Stripes

New races of wheat leaf rust have been causing problems in the United States in recent years. First, in the mid 1990s came a race that overcame leaf rust resistance in a popular wheat variety in Kansas. By 2002, this race and ones that evolved from it have become the most common group of races in the United States, having spread across all wheat-producing regions of the country.

In 2001, CIMMYT staff found in Mexico another new race of leaf rust to which many durum wheats were very susceptible. CDL plant pathologist Jim Kolmer and Maria Ordonez, a University of Minnesota graduate student, found that this race has spread across many of the world's durum-growing areas.

"We identified this race around the world with genetic markers we recently developed," Kolmer says. "We are using these markers to characterize populations of the leaf rust fungus from the Middle East, Central Asia, South America, Europe, and the United States to determine their migration patterns."

Every year, CDL also conducts a national virulence survey of the leaf rust pathogen *Puccinia triticina.* Kolmer and CDL plant pathologist Dave Long find 40 to 60 races of the pathogen in wheat fields each growing season. Their Canadian counterparts get similar counts. "Leaf rust is the most common wheat disease in the United States and worldwide, causing yearly losses in all wheat classes," Kolmer says.

### Don't Forget Scab!

Emergence of other diseases, such as wheat scab, has complicated efforts to develop rust-resistant wheat varieties. Spring wheat varieties that partially resist scab have been released to breeders since 1999, but most of them don't resist rust. For example, those released in the northern Great Plains region were susceptible to Ug99 and have only moderate to poor resistance to leaf rust.

KEITH WELLER (K8974-1)

**A healthy wheat head (left) stands in contrast to one inoculated with *Fusarium graminearum,* which shows severe symptoms of scab.**

YUE JIN (D517-1)

**Stripe rust on wheat.**

Wheat scab is caused by the fungus *Fusarium graminearum.* This disease emerged in the United States and worldwide in epidemic proportions in the 1990s. It has been the most devastating disease of wheat and barley to date. It may require new types of genetic controls, because the traditional solution of breeding resistant crops doesn't seem to work well with wheat scab.

CDL geneticist Corby Kistler and colleagues have developed a genetic map of the fungus's genome, which has led to creation of a physical map and the complete mapping of the genome.

Susceptibility of scab-tolerant wheat varieties to other rusts leads Simmons to remind that "a breeder's work is never done. ARS plant pathologists and breeders, working together, form a key infrastructure for maintaining and enhancing disease resistance critical to preventing new emerging diseases. Where resistance isn't enough, as in the case of wheat scab, they use new strategies, such as genetic interference in the plant-pathogen interaction."—By **Don Comis,** ARS.

*This research is part of Plant, Microbial, and Insect Genetic Resources, Genomics, and Genetic Improvement (#301) and Plant Diseases (#303), two ARS National Programs described on the World Wide Web at www.nps.ars.usda.gov.*

*Martin L. Carson is with the USDA-ARS Cereal Diseases Laboratory, 1551 Lindig St., St. Paul, MN 55108; phone (612) 624-4155, fax (651) 649-5054, e-mail mcarson@umn.edu.* ✷