Plant Pathologists Gear Up for Battle With Dread Fungus

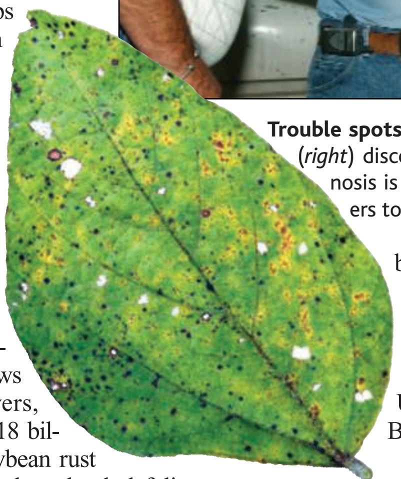
No soybean can resist a rust that has finally arrived in the United States, spurring a search for new varieties, predictive models, and monitoring techniques

On 6 November, plant pathologist Ray Schneider of Louisiana State University AgCenter gave a routine tour of the research fields near Baton Rouge to a visiting soybean farmer. "I offered to show him diseases he probably didn't have in Illinois," Schneider recalls saying. Both got a shock. In the course of the tour, Schneider came across signs of a disease never seen before in North American fields: the devastating fungal disease called soybean rust.

Schneider alerted the U.S. Department of Agriculture's Animal and Plant Health Inspection Service (APHIS) and FedEx'ed samples to a USDA lab in Beltsville, Maryland. When DNA tests came back positive on 9 November, APHIS sent in its soybean rust SWAT team the next day. Four groups of plant pathologists then fanned out across the state, surveying fields in 14 counties. Samples from four came back positive. Within days, APHIS had detected soybean rust in Arkansas, Mississippi, Alabama, and Florida.

The arrival of this fungus, although expected, could be very bad news for U.S. soybean growers, who raised more than $18 billion worth last year. Soybean rust spreads rapidly and hits plants hard, defoliating fields in less than 2 weeks. "It's an aggressive, hungry beast," says Martin Draper, a plant pathologist at South Dakota State University in Brookings. All commercially planted soybeans are susceptible to the fungus. If applied quickly, fungicides help, but USDA has estimated that losses could still range from $240 million to $2 billion a year, depending on the severity of outbreaks.

Unfortunately, the invader is the most aggressive kind of soybean rust, *Phakopsora pachyrhizi*. The spores are thought to have blown in with September hurricanes from South America, where farmers have incurred huge costs from fighting the disease. "In my country, we have two eras," says Alvaro Almeida, a plant pathologist at the Brazilian Ministry of Agriculture, EMBRAPA Soja, in Londrina, "before the arrival of soybean rust and after." The good news for the United States is that almost all soybeans had already been harvested this year, and researchers have a few months to refine their plans. This week, top experts are gathering at a USDA conference in Baltimore, Maryland.



Trouble spots. Leaf lesions (*inset*) helped Ray Schneider (*right*) discover soybean rust in Louisiana. Early diagnosis is crucial, so pathologists are teaching farmers to identify signs of the pathogen.

Work is already under way, as infection has long been seen as inevitable: Every major soybean-producing area of the world except North America has the fungus. Over the past few years, plant epidemiologists have created computer models to predict its arrival and spread. Others have been working out ways to track the disease from airplanes and satellites. USDA researchers have been testing the efficacy of various fungicides in countries already infested and screening germ plasm for signs of resistance that could be bred or genetically engineered into commercial varieties. "We're throwing everything we can at this," says molecular biologist Reid Frederick of USDA's Agricultural Research Service (ARS) in Fort Detrick, Maryland.

Searching for resistance

Soybean rust is a formidable foe. Unlike most rusts, *P. pachyrhizi* has a broad range of hosts—more than 95 species including other crops and common weeds such as kudzu—so it's impossible to eradicate. It releases massive numbers of wind-blown spores that have been reported to hang like haze over infected fields. "There's just no way to contain it," Schneider says. First reported in Japan in 1902, soybean rust was later found in China and other Asian countries, where it sometimes slashes yields by as much as 80%. The fungus jumped to Africa in 1996, with alarming effects. Worries among USDA scientists heightened when the fungus arrived in South America in 2001, spreading north from Paraguay. In Brazil last year it cost farmers $2 billion. The United States is likely to be spared such huge losses; the rust cannot survive freezes, so it will live year-round only in the southern states. From there it could spread north each spring.

About 2 years ago, USDA researchers set up field experiments in Zimbabwe and Paraguay to test the efficacy of 15 kinds of fungicides. All seem to work well, including the two that are currently approved for use in the United States. Concerned that supplies might be inadequate, 25 states have applied to the Environmental Protection Agency for emergency exemptions that would allow farmers to spray other fungicides. Researchers also want a variety of fungicides at farmers' disposal to lessen the chances of the fungus evolving resistance. "It's a recipe for disaster if you use the same thing over and over," says Kent Smith of USDA's Office of Pest Management Policy in Washington, D.C.

The best defense, however, would be a soybean variety that resists rust. That has been a challenge to researchers. For starters, the pathogen can't be cultured. A sequencing effort launched in 2002 hit snags when the genome turned out to contain at least 700 million base pairs—14 times larger and much more difficult to assemble than expected. And because APHIS considers soybean rust a bioterrorism "select agent," it must be studied at biosafety level-3 greenhouses, located only at Fort Detrick, Maryland.

Frederick and others there have been evaluating the most commonly planted varieties and their ancestral stock. All of the roughly 1000 lines tested so far have proved highly susceptible to soybean rust. But there is reason to hope. In the 1970s, researchers

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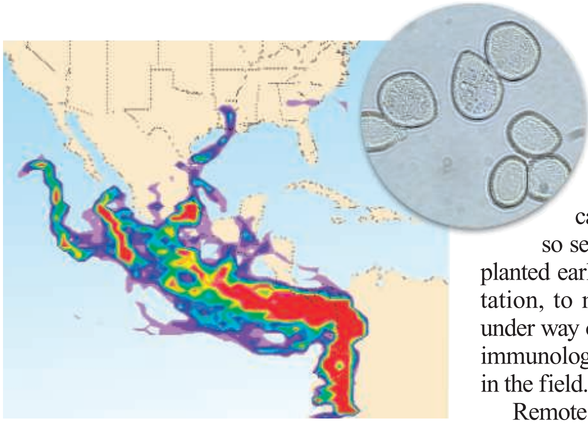

Rust belt. A model predicted the path of soybean rust spores (*inset*) and will forecast their spread.

found four varieties that each exhibited resistance to a single strain of *P. pachyrhizi*. These varieties didn't succeed in the field, however, succumbing to other strains of the pathogen. Plant breeders are now trying to broaden crop resistance by combining the genes from these varieties.

Researchers are also racing to find other sources of resistance. In the last 18 months, Frederick and Glen Hartman of the ARS in Urbana, Illinois, have tested all 17,000 types of soybean in the USDA germ plasm collection. Nothing has shown exceptional resistance, but the team is now examining 500 candidates that suffered lesser symptoms, such as fewer lesions or delayed onset of spores. To get a better feel for how these traits might fare in the field, USDA researchers have sent 180 varieties to collaborators in South Africa, Zimbabwe, China, Thailand, Brazil, and Paraguay. Progress has been bumpy so far, with comparisons hindered by differences in experimental conditions.

Resistance traits could also come from other plants. This year Frederick and Marcial Pastor-Corrales of ARS tested 16 varieties of common beans (*Phaseolus vulgaris*), such as pinto and black beans, and found that five were much more resistant to the pathogens than were soybeans. If those resistance genes can be cloned, they could potentially be genetically engineered into soybean.

In another approach, plant physiologist Bret Cooper of the ARS in Beltsville is using mass spectrometry to search through thousands of plant proteins for those that play a role in disease resistance. They've also begun working on dry bean rust, which can be studied outside the biosecure greenhouse, and plan to expand the search to *P. pachyrhizi*. In collaboration with James English of the University of Missouri, Columbia, Cooper will be looking for peptides that would interfere with infection or block spore germination. Such peptides might eventually be turned into sprays or engineered into soybean.

Early warning?

In the meantime, plant pathologists and extension agents are gearing up to educate farmers. Rust is easily confused with other diseases, and early identification is crucial. Researchers are also setting up a system of sentinel plots, planted early with prime conditions for infestation, to monitor for the disease. Work is under way on a hand-held sensor, based on an immunological assay, to detect the pathogen in the field.

Remote sensing could provide early detection, too. Forrest Nutter, a plant disease epidemiologist at Iowa State University (ISU) in Ames, has been working in Brazil and elsewhere on satellite detection of soybean rust. The spectral signature of leaf loss, although not unique to rust, can pinpoint outbreaks on the scale of meters. The same approach may work from airplanes, a cheaper and faster way of getting images, he says. Nutter plans to try tracking the disease this way next spring. "There's no doubt that rust is going to be established in the United States. The question is how it's going to spread," he says.

Farmers may also eventually get even earlier warning from a model developed by plant pathologist X. B. Yang of ISU and atmospheric modeler Zaitao Pan of St. Louis University in Missouri. They use a short-term climate model to project likely trajectories of spores over the next 120 days. In August, they predicted that spores would be more likely to enter because of the hurricane season and highlighted Louisiana as a probable beachhead.

Now the model can be adapted to predict the spread of spores from southern states north each spring. If it works, Pan says, a 3-month prediction could help farmers decide whether to stock up on fungicides, reserve spraying equipment—or even whether to plant soybeans at all.

–ERIK STOKSTAD

Clinical Trials

Nail-Biting Time for Trials of COX-2 Drugs

Preliminary studies suggest that the COX-2 inhibitor Celebrex may stem cancer and Alzheimer's disease, but testing these possibilities has just gotten tougher

Psychiatrist John Breitner was in a hotel room in Sun City, Arizona, when he heard the news on television. It was 30 September, and CNBC was reporting that the COX-2 inhibitor Vioxx would be yanked off the market by its maker, Merck, after experts saw a frightening increase in cardiovascular side effects. Breitner's own heart skipped a beat. In an instant, he realized that his effort to stop Alzheimer's disease using Celebrex, a Vioxx competitor, had just gotten trickier.

Breitner, an expert on aging based at the University of Washington, Seattle, is one of dozens of researchers exploring whether COX-2 inhibitors can do more than they were designed to do—ease the painful inflammation of arthritis. Over the years, animal studies have suggested that these medications, along with more traditional nonsteroidal anti-inflammatory drugs (NSAIDs), may be able to lower the risk of cancer and reduce inflammation suspected in Alzheimer's.

In the past few years, scientists have launched one study after another to put these hopeful ideas to the test. The pace picked up after the U.S. Food and Drug Administration (FDA) confirmed data in 1999 showing that Celebrex reduces intestinal polyps in patients with familial adenomatous polyposis, a hereditary condition that leads to colon cancer. Excitement has focused on COX-2 inhibitors because they are believed to be less likely than NSAIDs to cause stomach problems, a big drawback in long-term prevention trials.

Similar but different. The withdrawal of Vioxx has put Celebrex in the spotlight.

Few Vioxx prevention studies have been conducted or were planned, researchers say, partly because Merck was less willing than

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