Breeding Better Beans

Increasing Disease Resistance in Common Beans

"Beans are notoriously susceptible to pathogens," says ARS plant pathologist Marcial Pastor-Corrales. "All over the world, wherever you find beans, you find pathogens."

Anthracnose, rust, bean common mosaic, and common blight are among the world's most economically significant bean diseases. The brown cankers, rust-colored spores, mottled leaves, and lemon-yellow lesions that plague afflicted plants can foreshadow obliteration of an entire crop.

In the ARS Vegetable Laboratory of the Plant Sciences Institute in Beltsville, Maryland, Pastor-Corrales is breeding beans to improve genetic resistance to these diseases—with great success. He plans to extend his techniques soon to combat a new disease threatening the nation's common beans: Asian soybean rust.

PEGGY GREB (D509-1)

ARS plant pathologist Marcial Pastor-Corrales inoculates bean plants with spores of the bean rust fungus.

Pyramid Scheme

The United States is one of the world's top five bean producers. In 2005, American bean farmers harvested about 1.5 million acres of dry beans (kidney-shaped legumes like black, navy, and pinto) and 18,800 acres of snap beans, which grow in slender, edible pods. Although world genebanks hold about 40,000 bean varieties, only a fraction are mass-produced for regular consumption. Pastor-Corrales attributes beans' vulnerability to pathogens to this lack of genetic diversity.

For years, Pastor-Corrales and his predecessors have collaborated with scientists at the University of Nebraska, North Dakota State University, Michigan State University, and elsewhere to increase bean resistance to bean common mosaic (BCM), bean common mosaic necrosis (BCMN), bean golden mosaic, anthracnose, common bacterial blight, and common bean rust (caused by the rust fungus *Uromyces appendiculatus*).

His research has already proved successful. In 2004 he released six genetically resistant great northern bean germplasm lines. The first of their kind, they're known as "BelMiNeb-RMR" and numbered 8 to 13. In 2006, he released five equally resistant pinto lines, known as "BelDakMi-RMR" and numbered 19 to 23. Bel, Dak, Mi, and Neb represent the laboratory locations of the scientists involved, and RMR indicates rust and mosaic resistance. These lines have been snapped up by seed companies, universities, scientists, and plant breeders around the world.

To create disease-resistant beans, Pastor-Corrales identifies resistance genes in existing plants, then isolates and combines those genes in a process called "gene pyramiding." Some commercial bean varieties contain one or two disease-resistance genes. The BelMiNeb and BelDakMi lines have six—more than any other bean in the world.

Each bean contains four genes for resistance to *U. appendiculatus* and two genes for resistance to BCM and BCMN. While each gene can resist a few known disease strains, collectively they provide complete resistance.

"Gene pyramiding makes it possible to breed varieties with extremely broad resistance to all strains of certain highly variable pathogens, such as those that cause rust, BCM, and BCMN," says Pastor-Corrales.

Vulnerability and Resistance

In a Beltsville greenhouse, Pastor-Corrales examines rows of plants bred to have different disease-resistance genes. Each has been infected with several strains of common rust.

"Look at this," he says, selecting a plant that lacks complete resistance. He indicates a leaf dotted with russet pockmarks, each of which contains thousands of microscopic spores. He compares it to a fully resistant plant nearby whose leaves are green and full. Sliding a sheet of white paper under the first plant, he taps the leaf. Rust spores speckle the paper like a sprinkling of cinnamon.

PEGGY GREB (D511-1)

A rust-susceptible bean plant (pot on the left) and a rust-resistant one (pot on the right).

"You don't have to be a scientist to appreciate this," he says. "You can see which plant is healthy."

The research can benefit people around the world, Pastor-Corrales says. "Beans are a staple crop for millions of people. They provide vitamins, proteins, iron, folate, fiber, complex carbohydrates—they're really an amazing food."

Attacking Asian Soybean Rust

In April 2005, Pastor-Corrales added a new goal to his project: to identify and use genes from common beans to help control Asian soybean rust (ASR). A menacing relative of common bean rust, ASR entered the United States in 2004. The disease is caused by the highly virulent *Phakopsora pachyrhisi* fungus.

Rust decreases crop yields by causing defoliation. Without leaves, the plant cannot engage in photosynthesis, which means it cannot produce healthy pods. There are no known rust-resistance genes in commercial soybean cultivars and few usable resistance genes in noncommercial cultivars.

PEGGY GREB (D508-1)

A rust-susceptible bean leaf showing pustules (fruiting structures) of the bean rust fungus. Each pustule contains thousands of fungal spores.

CHRISTINE STONE (D521-1)

Soybean leaves infected with soybean rust.

In Asia, Africa, and South America, ASR has spread with a ferocity the United States has so far been spared. Freezing temperatures protect midwestern states, home to 80 percent of America's $18 billion soy crop, from ASR invasion. But southern states face a greater risk.

Since plant pathologists first confirmed the pathogen's presence in Louisiana, it has spread to Alabama, Arkansas, Florida, Georgia, Mississippi, Missouri, North Carolina, South Carolina, Tennessee, and Texas.

ASR has almost 100 different host species, including dry and snap beans. Can gene pyramiding create ASR-resistant lines? If so, the first step to creating these lines is to find naturally resistant beans.

PEGGY GREB (D510-1)

Plant pathologist Glen Hartman inspects soybean plants for disease symptoms that resemble rust.

Pastor-Corrales traveled to South Africa in 2001, shortly after ASR was first reported there. Though rust had devastated the soybean crop he observed, common beans growing a mile away looked fairly healthy.

"I knew that all soybean cultivars in Brazil and the United States were very susceptible to the ASR pathogen," he says. "So it occurred to me that I should look for ASR resistance genes in common bean cultivars."

With the aid of ARS scientists Reid Frederick, a molecular biologist at Fort Detrick, Maryland; and Monte Miles and Glen Hartman, plant pathologists at Urbana, Illinois, Pastor-Corrales evaluated 16 dry bean cultivars and discovered that 5 were resistant to various forms of ASR. The researchers were elated with their discovery, though they recognized it as the first step in a long process.

The genes need to be characterized and studied before they can be used to make common beans resistant to the ASR pathogen. At the ARS Foreign Disease-Weed Science Research Unit at Fort Detrick, Frederick, Miles, and Hartman have screened some of Pastor-Corrales's bean lines for resistance to different ASR isolates.

An ASR-resistant bean may be 5 or more years away, but this research brings the agricultural community one step closer to defeating this fungal foe in common bean—and possibly to developing resistance in soybeans as well.

Other Solutions

Breeding disease-resistant beans isn't the only way to combat Asian rust. America's soy farmers now have eight chemical fungicides to choose from to defend against ASR.

Currently, six ARS laboratories—at Beltsville; Fort Detrick; Urbana; Ames, Iowa; Stoneville, Mississippi; and St. Paul, Minnesota—conduct rust research, often in collaboration with land-grant universities and others. With funding from the United Soybean Board and the Iowa Soybean Promotion Board, their tests have furnished U.S. growers with basic information on timing, application methods, rates, efficacy, and residual activity of the fungicides.

Five of the compounds tested by Frederick, Hartman, and Miles were approved for use under a Section 18 exemption from the U.S. Environmental Protection Agency. That means farmers can use the fungicides once ASR has been officially confirmed in their state. All five reduce ASR's severity, though their effectiveness and residual activity vary.

Frederick has spearheaded detection efforts using a form of genetic fingerprinting called "real-time PCR" (polymerase chain reaction) to develop a rapid diagnostic assay that is specific for ASR. His patent-pending assay works by homing in on a tiny nucleotide region that's unique to the ASR fungus.

The assay is now used by USDA's Animal and Plant Health Inspection Service to confirm first-time identifications of rust in each state as well as in new plant species. It's also in use at four USDA regional plant diagnostic laboratories.

CHRISTINE STONE (D522-1)

At the Biosafety Level-3 Plant Pathogen Containment Facility at Fort Detrick, Maryland, molecular biologist Reid Frederick (left) rates plants for resistance to Asian soybean rust while plant pathologist Monte Miles inputs the data on a laptop computer.

Under development is a hand-held, immunological-based assay for field-friendly ASR detection. Eventually, farmers, crop consultants, extension personnel, and others will be able to use it to help decide when to spray fungicides. Easier and cheaper than real-time PCR, "it will allow people to do things more quickly in remote sites," says Frederick, who is co-developing the assay with research leader Douglas Luster and scientists with Ohio State University and the U.S. Navy Biological Defense Research Directorate.

In Fort Detrick's biosafety level-3 containment facility, Hartman, Miles, and Frederick have screened more than 16,000 soybean accessions for resistance by spraying them with a cocktail of ASR isolates from Brazil, Paraguay, Thailand, and Zimbabwe. Of the accessions, 805 proved moderately resistant. They're now undergoing secondary trials with individual strains of ASR.

From that group of 805, researchers chose 776 for outdoor trials at several U.S. locations. They'll be grown to maturity, marking the first time adult plants will be evaluated for resistance under U.S. field conditions.

These efforts, combined with Pastor-Corrales's pyramiding techniques, will help protect America's soybean and common bean industries from potentially devastating diseases.—By **Laura McGinnis** and **Jan Suszkiw,** 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.

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