Breeding Oats for Rust Resistance

KEITH WELLER

A chromosomal pair from corn manifests itself in these oats by producing a hooked grain head. Among other differences from normal oats (left) being sought by geneticist Howard Rines is resistance to rust. (K7080-1)

The next generation of amber waves of grain may carry the genetic code for not one crop, but two.

ARS plant geneticist Howard Rines has successfully crossed oats, *Avena sativa,* and corn, *Zea mays,* in a quest to develop an oat plant more resistant to a crown rust, *Puccinia coronata f.* sp. *avena.*

Oat crown rust, an airborne fungus, causes between $7.5 million and $30 million in crop losses each year in the upper Midwest. It infects the leafy tissue of oats, reducing yields and lowering grain quality.

"Often, individual fields have been so badly damaged that they're not even worth harvesting," Rines says.

Planting disease-resistant varieties of oats is the most common defense against crown rust. But even these varieties are eventually overcome by fungus, he explains.

"The problem is, mutation, or changes in the genetic makeup of the fungus, allow it to get around the resistance bred into the oat varieties. It's getting harder and harder to find new sources of resistance."

Corn is not only resistant to crown rust, but has other qualities that scientists want to incorporate into oats—including heat tolerance, improved grain composition, and increased productivity.

Working with researchers at the University of Minnesota (UM), Rines set out to breed haploid oat plants for genetic research. Haploid plants contain only one set of genetic material—from only one parent—rather than the normal two inherited from two parent plants. Offspring from haploid plants are an exact copy of the parent, with no chance of interference by genes from another line. This enables scientists to produce a genetically pure line and do it faster, says Rines.

Having pure breeding lines is essential for producing new disease-resistant varieties of oats, because it means progeny will also be pure.

Researchers have traditionally had two methods to produce a pure breeding line. One requires self-fertilization of the progeny of two different parent lines over several generations, a time-consuming process that does not guarantee a pure breeding line.

The other involves the use of anther culture, growing plants from pollen grains. "We tried this approach for years and got 1 plant in 100,000 attempts," says Rines.

The ARS-UM research team decided to try trans-species breeding after reading about the crossing of wheat and corn at the Plant Breeding Institute in Cambridge, England. The English researchers successfully produced haploid wheat embryos.

Their success prompted Rines and his colleagues to attempt a cross-species fertilization between oats and corn. "To our delight," says Rines, "we not only got haploid oat plants, but haploid oat plants that were self-fertile. Self-fertility isn't expected in a haploid plant, regardless of species."

Embryos resulting from such trans-species crosses are especially fragile because there is very little nutritive tissue for the embryos to grow on. They must be put in an artificial medium to increase their chances of surviving to maturity.

Rines says that those offspring of the oat-corn crosses that survived looked like normal oat plants, but a few grew much more slowly than others.

Then, graduate student Oscar Riera-Lizarazu, working with Rines and UM cytogeneticist Ronald Phillips, discovered that many of the slower growing plants contained both oat and corn chromosomes. About a third of them had 21 chromosomes—the normal haploid number for oats—plus 1 to 4 corn chromosomes. Corn usually has 10.

Using a technique in which DNA extracted from corn was labeled and used as a genetic stain that would adhere to other corn DNA, the scientists were able to determine if any corn DNA was present in the oats.

"It was important to show these chromosomes were from the corn parent," says Rines, "because they could otherwise have been just broken oat chromosomes."

The next task was to determine which corn chromosomes were present and whether the same or different genes of the 10 corn chromosomes were being retained in these unique plants.

The researchers were able to show the resulting oat embryo could have up to eight different corn chromosomes retained from the initial cross. Two corn chromosomes—No. 1 and No. 10—were not present in any of the crosses.

An even bigger surprise was that some of the surviving progeny were sexually fertile. The researchers self-fertilized some of these offspring to create a second generation of hybrids.

"These partial hybrids are by far the widest combination of crop species that we have known to be fertile from one generation to the next," Rines says.

A partial hybrid is a combination of all the genes of the oat, plus a portion of the corn genes.

In answer to everyone's first question—"What do these plants look like?"—Rines responds, "Some looked normal; you couldn't see any difference. Others showed distinct differences. "For instance, we've seen some develop a hooked panicle—the grain-bearing structure of the oat plant—instead of the usual straight one. And we had some that produced large amounts of a red pigment found in the corn parent."

Ironically, the disease-resistance trait the scientists had hoped to incorporate into oats was not among the corn genes passed on to the first generation of offspring.

Says Rines, "We have tested the fertile lines that contain the corn chromosomes, but unfortunately none showed the disease-resistant traits we were looking for."

Undaunted, the scientists have shifted their focus to discovering how they can "turn on" genes that are carried over from the parent lines to get the desired traits expressed. Rines points out that there may be corn genes present in these oat plants that are simply not active.

"We believe this because some of the oat plants with corn chromosomes are so normal-looking. The next area of study is to figure out how these genes are kept off and how they can be turned back on."—By **Dawn Lyons-Johnson,** ARS.

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University of Minnesota cytogeneticist Ronald Phillips examines a radiogram from DNA hybridization techniques used to identify which of the 10 possible corn chromosomes are present in various oat-corn partial hybrid lines. (K7081-1)