PLANT PATHOLOGY

Geminiviruses Emerge as Serious Crop Threat

Geminiviruses, once thought to cause only limited crop damage, are spreading worldwide, thus ratcheting up their potential impact on farmers

About 15 years ago, when plant scientists first seriously studied geminiviruses, they thought they might have found some new friends. The viruses, so called because they consist of two twinned particles, were known to be pathogens, but their range seemed to be limited, and they looked like promising vehicles to carry genes for desirable new traits into plants. As it happened, though, the geminiviruses lack the necessary enzymes, and now, far from being friends, they are emerging as serious enemies that are devastating crops worldwide.

"In the past, not much attention was given to geminiviruses because they hunkered down in remote places," says Claude Fauquet, director of the International Laboratory for Tropical Agricultural Biotechnology at the Donald Danforth Plant Science Center in St. Louis. But global transportation networks have aided the spread of the virus and its carrier, the white fly, and new geminivirus strains have emerged thanks to the viruses' penchant for swapping genetic material. "Now, it's not unusual to see destruction of whole crops, such as tomato, cotton, and cassava, with the viruses causing serious plant disease in at least 39 nations," says Fauquet.

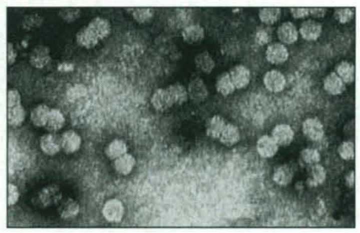
Year after year in the early 1990s, for example, geminiviruses destroyed up to 95% of the tomato harvest in the Dominican Republic, and in just the 1991–92 growing season in Florida, they caused $140 million in damage to the tomato crop. With the virus continuing to spread and other control measures, such as insecticides, falling short, plant genetic engineers are struggling to create resistant plants. So far they have had no lasting successes, although they do have promising leads.

Robert Goodman, now at the University of Wisconsin, Madison, and Brian Harrison and colleagues of the Scottish Crop Research Institute in Dundee first described geminiviruses in the mid-1970s, but records from Africa suggest they probably caused diseases of maize and cotton there in the 1930s or earlier. They've also been attacking bean fields in the tropics of the Western Hemisphere for decades. But geminiviruses didn't draw much scientific attention until early in this decade, when serious outbreaks flared up in Africa, India, Pakistan, southern Europe, South and Central America, and elsewhere.

The viruses also struck in the Caribbean in the early 1990s, and the first serious geminivirus infections appeared in Florida and Texas in the United States at about the same time. Since then, they have been spotted, in 1997, as far north as Virginia, South Carolina, and Tennessee. "The more you look for geminiviruses, the more you find them," says John Stanley of the John Innes Centre in Norwich, U.K.

Geminiviruses are versatile, too, infecting everything from monocots such as maize to dicots such as cassava and tomato. The infections can produce leaf mottling that interferes with photosynthesis, decreasing yields of starchy foods such as cassava, and they also disrupt flower and fruit formation in crops such as tomato, pepper, and cotton.

The transportation networks that are spreading the virus from tropical to temperate regions have also brought different species—there are more than 66 of them—into close contact. This may have set the stage for the viruses to swap DNA, a phenomenon first noted in 1997 by Fauquet and Roger Beachy, also of the Danforth Center. So far, the researchers have identified more than 1000 recombinant strains, in some cases involving species whose DNA sequences indicate that they are not closely related. "This was not expected," says Fauquet. "It is like having a recombinant between a human and a chimpanzee."



Double trouble. This tomato plant is infected by a geminivirus. The electron micrograph *(right)* shows the double structure of the geminivirus particle.

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And while the virus generates new, virulent strains, measures to control it are falling short. Plowing under plant debris after harvest limits the food supply for the white flies and the virus, but the measure has limited effectiveness, as do insecticides. White flies are developing resistance to commonly used chemicals.

So researchers are searching for resistant cultivars, created either by classical crossbreeding or through genetic engineering. Crossbreeding has produced more resistant cassava, beans, and tomatoes, although the new resistant varieties have such drawbacks as small fruit or poor taste. And although modern gene transfer techniques are faster and more precise than classical plant breeding, the diverse, changeable viruses have already demonstrated that they can outwit the genetic engineers.

To create virus-resistant varieties, researchers equip the plants with the genes for certain viral proteins—a modification that, for unknown reasons, protects the plant cells from the same virus. In 1992, in the wake of the devastation of the Florida tomato crop, virologist Jane Polston of the University of Florida, Bradenton, and Ernest Hiebert of the University of Florida, Gainesville, put a gene for geminivirus replicase—the enzyme that copies the viral DNA—into tomatoes. The resulting plants had good horticultural qualities and were resistant to the virus, but before the new tomato variety could be commercialized, a new gemini variant moved in on Florida tomatoes that had no problems infecting the plants.

So researchers are also attempting to endow plants with broad-scale resistance to the rapidly expanding family of gemini pathogens. One strategy Fauquet and his colleagues are exploring is to equip plants with a protein from a bacterial virus that binds viral DNA and prevents movement of geminiviruses within plants, thereby blocking infection. They report good lab results and plan to test their transgenic plants in greenhouses in the spring of 2000. Researchers are also hoping to arm susceptible plants with a protein that attacks a structural element common to the replicase proteins of many geminis.

Whether growers will accept plants genetically engineered to resist geminiviruses, given the current controversy over genetically modified crops, is an open question (*Science*, 26 November, p. 1662). Fauquet, for one, believes that they will: "Growers, worldwide, will love it," he maintains. "When you have plenty of food on your plate, you may choose against transgenic techniques. But when you lose 35% percent of your income to crop losses, you don't care whether disease resistance comes from transgenic means."

–ANNE SIMON MOFFAT