Chromosome 'Oddity' May Hold Key to Making Plants Disease-Proof

If (Hans) Van Etten's hypothesis proves true, plant scientists may be able to someday control plant diseases by engineering plants to produce phytoalexins that are foreign, and deadly, to pathogens.

By Jan McCoy

TO FEND OFF DISEASES, MANY PLANTS HAVE EVOLVED ingenious defense systems that pit their own toxins against infection-causing microorganisms. Some plants store toxins in strategic locations, such as the cyanide in peach seeds that is released only when the seed is damaged. Still others can quickly synthesize large amounts of toxins, called phytoalexins (Greek for "plant warding-off chemicals"), when threatened by pathogens.

So why, with such an impressive arsenal, do plants still get sick?

Because pathogens have also evolved their own unique defense systems, says plant pathologist Hans VanEtten. Certain microorganisms, particularly fungi, appear to have a highly efficient enzyme system that quickly reduces plant toxins to non-toxic chemicals.

VanEtten has studied the relationship between phytoalexins and pathogens for years. But a recent look at the genetic structure of a pathogenic fungus gave VanEtten and his colleagues new information about its defense mechanism — and a big surprise. Their finding raises hopes that genetic engineering could someday be used to turn the tables on plant pathogens.

Not only could this aid in protecting food crops in a hungry world, using natural compounds to control plant diseases would reduce the risk of environmental contamination, VanEtten says. Although natural chemicals can be just as toxic as synthetic ones, natural chemicals leave no toxic residues in the environment.

Compared to the chromosomes of higher organisms, fungi chromosomes are very small and until recently, hard to study. But a new method to study these small chromosomes, called pulse field electrophoresis, led VanEtten and his colleagues at the University of Arizona to a startling discovery about the pathogen, *Nectria haematococca*, which attacks pea plants.

The fungus thrived by manufacturing a chemical which could detoxify the pea's own chemical defenses, its phytoalexin. VanEtten and his colleagues, however, have learned that the chromosome containing the gene for detoxing the pea phytoalexin can be removed from the fungus. "When we reproduce this fungus in the laboratory, many offspring no longer have this chromosome," VanEtten says.

"That was a startling observation, how can you lose something as fundamental as a chromosome and not die?"

Part of the answer comes by looking more closely at N. *haematococca*, which has adapted itself to a number of biological niches. In addition to peas, the fungus is also pathogenic to chickpeas, cottonwood, several other plants and even shrimp. *N. haematococca* can also live harmlessly in soil.

"Obviously, the one gene on that chromosome that is needed for life on peas is the one for detoxifying the pea toxin," VanEtten says. "Our theory is that the organism only needs the chromosome when it come up against the phytoalexins. It does not need the chromosome if it is living in the soil or is a parasite on another plant. We think these chromosomes are a reservoir for a number of very specialized genes."

This observation could change the way genetic researchers view these so-called "B" chromosomes, whose function until now has not been known.

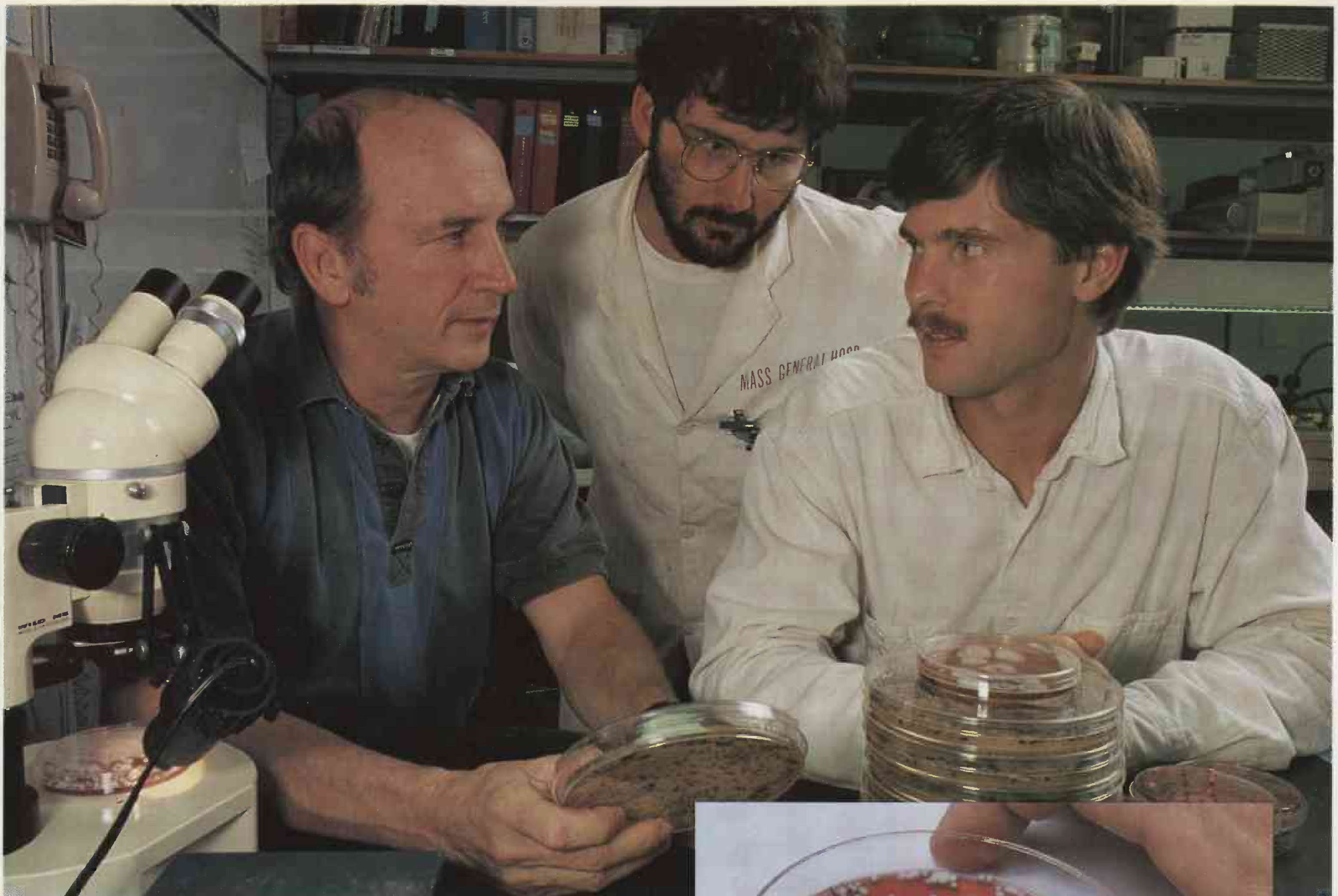
"In the past, geneticists studying higher organisms would find these small chromosomes that would come and go. For years, these little chromosomes seemed to be an oddity with no known function. They were called B chromosomes to distinguish them from the generally larger, normal A chromosomes.

"This is the first time it has been shown that B chromosomes have a distinct gene and function."

This important finding adds to the growing body of research VanEtten has conducted on the role of phytoalexins in preventing microbial diseases and how genetic engineering may figure in the future.

Phytoalexins were first identified in peas in 1960. Since the discovery of the pea phytoalexin, pisatin, phytoalexins have been found in many plants. Each phytoalexin is thought to be specific to the plant in which it is found. The question that remains is, how specific is a pathogen's tolerance to phytoalexins?

VanEtten theorizes that pathogens are tolerant of the phytoalexins produced by the plants they parasitize, but lack



UA plant pathologist Hans Van Etten and assistants Kevin McCluskey and Robert Sandrock are experimenting with genetic-engineering techniques to bolster the ability of plants to fight off pathogens. *Ken Matesich photos*

Pathogens such as the *Nectria haemotococca* are able to detoxify the chemical defenses of the plants they attack, causing millions of dollars in damage to crops.

the mechanism to detoxify chemicals made by other plants.

VanEtten's current research, both at the University of Arizona and in collaboration with colleagues at other universities, tests that theory with two different approaches.

The first approach involves creating mutant pathogens with and without the ability to detoxify phytoalexins to determine how the detoxification mechanism affects pathogenicity. The second seeks to understand the biochemical natures of both the phytoalexins and the detoxifying enzymes of pathogens.

If VanEtten's hypothesis proves true, plant scientists may be able to someday control plant diseases by engineering plants to produce phytoalexins that are foreign, and deadly, to pathogens. A pea plant that is genetically altered to produce both bean and pea phytoalexins, for example, could resist *N. haematococca* because the fungus would be killed by the bean toxin it is unable to detoxify.

"The additional beauty of this type of engineering, though it is still only conceptual, is that this technique should make a plant resistant to all pathogens that cannot detoxify the chemicals," VanEtten says. "Many current engineering strategies are geared toward making plants resistant to only one disease."

But even with a multitude of current and yet-to-be-developed ways to engineer disease resistance into plants, the battle against pathogens will never be over, just ongoing.

"As evolution does not stand still, we will always be modifying our strategies against pathogens," VanEtten says.