By Steve McGill

NEW ERA OF AG MICROBIOLOGY

Scientists are finding more ways to put microorganisms to work for crop producers

Microorganisms, the tiny workhorses of agriculture, are on the verge of having a much greater impact on crop production.

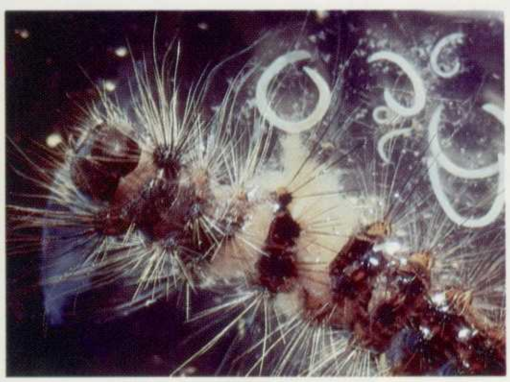
This new era of ag microbiology got its start in the 1950s, when scientists began making major strides in unraveling the secrets of molecular genetics. Knowledge of heredity and microbiology has been exploding ever since. This growing knowledge base has helped scientists develop more useful strains of naturally occurring microorganisms. What's more important, it has made it possible to create man-made microorganisms.

With genetic engineering, microbiologists are now able to move genetic material from one cell to another, and even from one species to another, to modify organisms for specific uses. The first generation of microorganisms produced in this way were merely laboratory oddities. Today, however, some man-made microbes are being used commercially. Many more are undergoing final tests and could soon be sold to crop producers or other potential users.

Microbes make medicine. Pharmaceutical-industry researchers were among the first to develop commercial man-made microorganisms. For example, several years ago they engineered a new bacterium that now manufactures most of the insulin used to treat diabetes.

Meanwhile, other researchers have been making headway with microbes that have potential utility in crop production.

One of these scientists is Steven Lindow, a microbiologist with the University of California at Berkeley. Lindow has been working with man-made bacteria that can help prevent frost from forming on fragile crop blossoms. So far, the potential usefulness of the bacteria has been demonstrated only in the laboratory. Court orders obtained by environmentalists have delayed field testing. However, Lindow hopes to field test the bacteria this year.



Bacteria carried in the bodies of nematodes killed this gypsy moth caterpillar in less than 48 hours.

Scientists say there are many other ways microbes, or products made by them, might be used in crop production. One approach would be to harness bacteria for manufacturing enzymes and other products that regulate plant growth. These might someday be used to boost crop yields or kill weeds.

A microbe that's already being used by some crop producers is the *Bacillus thuringiensis* (Bt) bacterium, which produces a toxin that kills certain insects. U.S. and Canadian farmers now use more than $20 million worth of Bt-based insecticides each year.

One problem is that existing commercial Bt insecticides lose their poisonous effects after exposure to only a few hours of direct sunlight. So the products usually have to be sprayed on crops several times during the growing season. However, scientists are overcoming this problem, and also making other improvements in Bt-toxin technology.

"We're using genetic engineering to improve Bt insecticides in three basic ways," says Holly Hauptli, a scientist with Calgene, Inc., Davis, Calif. "The first approach is merely to do a better job than Mother Nature at designing the bacteria themselves."

Toward that end, scientists are developing Bt strains that survive longer in the field. They're also trying to discover or develop strains that are effective against insects for which no toxic Bt strains are now known.

While these efforts haven't yet led to commercial products, a second approach has been more successful. Scientists at Mycogen Corporation, San Diego, Calif., have used genet-

PHOTO: LARRY VOLBRUCK

Tsuneo Kaneshiro is studying rhizobia bacteria that give soybean plants an extra growth boost.

ic engineering to endow other species of bacteria with the ability to produce the Bt toxin.

Mycogen scientists modify *Pseudomonas flourescens* (Pf) bacteria by inserting genetic material from Bt bacteria that codes for production of the Bt toxin. When caterpillar insects such as cabbage loopers or cotton bollworms consume the Bt toxin in the Pf bacteria, the insects die.

Light resistant. The toxin produced by the Pf bacteria isn't damaged by sunlight, says Andrew F. Barnes, operations manager for Mycogen. The Pf cells are treated with heat and chemicals in a patented process that further preserves Pf cell walls. The process protects Bt toxin from the field environment. The man-made Pf bacteria remain poisonous in the field long enough to provide some full season protection against caterpillar insects. The product could be offered for sale in 1989. The U.S. Environmental Protection Agency has allowed Mycogen scientists to test the man-made bacteria's toxic effects in the field. According to Barnes, all the bacteria have been killed before leaving the lab, so there's been no chance of their getting loose in the environment and reproducing.

Monsanto Co. scientists are using a slightly different variation of this approach. They're transferring the genetics for Bt-toxin production into *Pseudomonas* bacteria that are normally associated with the roots of corn plants. The idea would be to apply live bacteria as a seed coating at planting time. Theoretically, the toxin-producing bacteria would grow along with the roots and would be effective in controlling corn rootworms.

Calgene's Holly Hauptli says a third approach to improving Bt-toxin technology is to endow living plant cells with the ability to produce the toxin. In theory, for instance, corn plants with the Bt-toxin gene would be able to resist feeding by corn borers. If such plants could be developed, they could be used in conventional breeding programs to produce commercial corn hybrids with corn-borer resistance.

This third approach is more difficult than either of the first two. It's not easy to manipulate the genetic material of complex plant or animal organisms. However, Hauptli points out that scientists are having some success with this kind of genetic engineering. For example, researchers have recently transferred the genetic material for Roundup herbicide resistance from bacteria into plants. Now plant breeders are trying to make this trait commercially useful.

Even more familiar to most farmers than Bt bacteria is the rhizobia family, which lives in nodules on the roots of legume plants and fixes nitrogen.

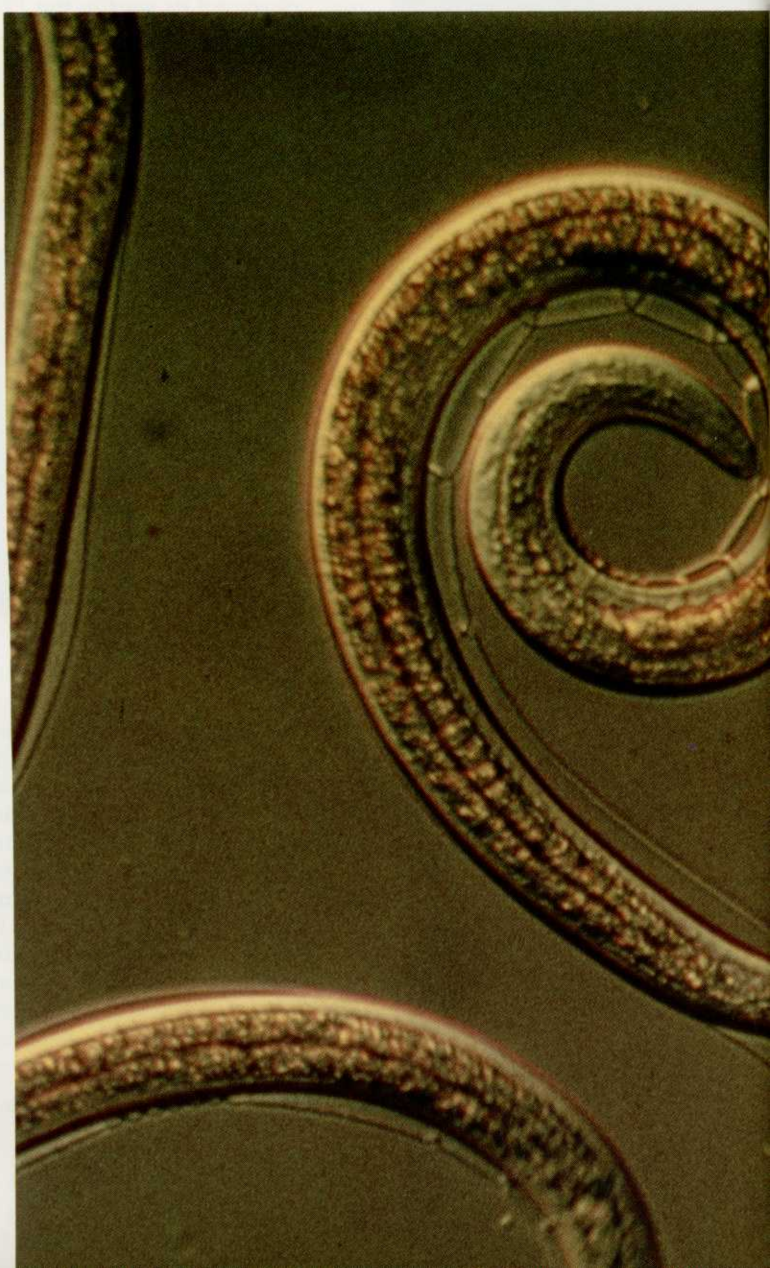
Tsuneo Kaneshiro, a scientist at USDA's Northern Regional Research Center, Peoria, Ill., has recently demonstrated that certain rhizobia can also provide other benefits for growing plants. Kaneshiro is studying bacteria treated in the laboratory to encourage genetic variation. One rhizobia variant, in addition to fixing nitrogen, also produces an enzyme that helps convert tryptophan into a growth regulator called indoleacetic acid. The acid stimulates plant growth over and above that which can be attributed to nitrogen fixation.

Other scientists are working with rhizobia strains that already exist in nature. For example, David Hume and his colleagues at the University of Guelph in Ontario recently tested a newly discovered naturally occurring strain. Soybeans treated with this strain yielded 9 percent more than soybeans treated with commercially available strains.

The Guelph scientists are also field testing naturally occurring bacteria that show a remarkable ability to protect crops from fungus diseases. "The bacteria protect the plants because they tie up iron in the root zone," Hume says. "Pathogens don't multiply as readily because they can't get enough iron. These bacteria help protect crops from take-all, pythium, fusarium, and rhizoctonia."

Special delivery. It's not enough, of course, to come up with microbes that are beneficial to plants. Scientists also have to come up with ways to get the microbes in the right place at the right time. Trevor Suslow, a researcher with Advanced Genetic Sciences, Oakland, Calif., has recently discovered naturally occurring strains of

Trevor Suslow applied bacteria to transplants in the left tray to protect the plants from some diseases.



Pseudomonas bacteria that attack the organisms responsible for certain plant diseases. In addition, he has gotten around the delivery problem. He injects a water solution containing the bacteria into the growing medium used in the greenhouse to produce transplants. "The same environment that keeps transplants alive is great for microbes," Suslow says.

Advanced Genetic Sciences has tested the treatment in cooperation with Growers Transplants, Salinas, Calif. Suslow says the treatment helps control pythium and fusarium. Treated transplants grow faster in the greenhouse and have higher survival rates when set out in the field. Treated transplants also grow faster in the field. In fact, treated lettuce and celery have been ready for harvest two and a half to three weeks earlier than untreated plants.

Harnessing fungus organisms for crop production is another aspect of ag microbiology's new era. Researchers are working with fungus strains that help protect crops from drought, salinity, and poor soil fertility. These organisms aid plants by enhancing uptake of moisture and nutrients. They are already being used commercially, for instance, to increase survival and speed growth of tree transplants on poor soils, according to D.H. Marx, a USDA plant pathologist at the University of Georgia.

In the future, farmers might be able to take advantage of other fungus strains, like the ones Richard Thomas and Robert Ames are studying at USDA's Western Regional Research Center, Albany, Calif. These fungi, which grow in association with plant roots, improve soil structure and might someday be used to help control soil erosion.

Friendly nematodes. Many farmers are accustomed to protecting crops from nematodes. However, certain strains of these organisms do no harm to crops but do attack spiders, insects, and other crop pests, says Harry Kaya, an entomologist and nematologist at the University of California, Davis.

According to Kaya, scientists have only recently begun to study how nematodes attack insects. *Steinernema* and *Heterorhabditis* nematodes are known to carry insect-killing bacteria in their bodies. The nematodes enter insects through natural body openings, then release the bacteria. While inside the nematodes, the bacteria are inactive. But they become active in insect tissue and can kill an insect within 48 hours.

One of the first private firms to offer nematodes for insect control is Biosis Company, Palo Alto, Calif. Art Kushner, marketing manager for the company, says Biosis plans to sell nematodes to control insect pests of artichokes this year. The company has found a way to mass-produce nematodes and keep them alive during shipment. The nematodes are applied so they accumulate at the base of leaves, where life-giving moisture collects.

In research done in cooperation with Biosis by Jan Jackson, a USDA entomologist at Brookings, S.D., nematodes were effective in controlling corn rootworms. But it took 5 billion nematodes per acre to do the job.

Biosis is also working on ways to use nematodes for controlling navel-orange worms in almonds, wireworms in sugarbeets, gypsy moths in forests, and household pests such as cockroaches. Another promising opportunity exists in lawn care. Biosis has an agreement with CHEMLAWN to develop nematodes for controlling white grubs, mole crickets, and cutworms in grass sod. This control would reduce the need to apply conventional pesticides where people and pets play.

Ag microbiologists are active on other fronts, too. Some are working with microbes that make better hay and silage. Some are concentrating on microbes used in manufacturing cheese and wine, as well as other foods and beverages. Then there are the growing number of uses for microbes in livestock production. (That's a whole other story.) In addition, scientists will probably find some uses for microbes that can't even be imagined today. It's easy to see why experts are claiming that the new era of ag microbiology is just beginning.

***Steinernema* nematodes control several insect pests, including black vine weevils in horticultural crops.**

Fungus organisms growing on onion sets in these chambers are able to improve soil structure.