Forensic Botanists Find the Lethal Weapon of a Killer Weed

By CAROL KAESUK YOON

For over a century, spotted knapweed has been a growing scourge on the North American landscape, spreading across millions of acres of prairies, hillsides, roadsides and rangeland - pretty much anywhere it can get a root in the dirt. Everywhere it spreads, it replaces native grasses and other plant species to the consternation of conservationists as well as ranchers, whose cows refuse to eat it.

The weed, which sprouts pink and purple flowers and can grow a spindly three feet tall, is a European import, thought to have been introduced in North America as a contaminant in crop seeds or in dirt used as ship's ballast and then dumped. But scientists have long been baffled by the plant's appalling effectiveness at driving out other plants.

Now in the current issue of the journal Science, researchers say they have found spotted knapweed's deadly secret: a potent and previously unknown poison that releases through its roots into the soil to kill off neighboring plants. By eliminating its neighbors, the weed can appropriate all the water and nutrients that the other plants would have taken, and it has plenty of new space to spread out in.

Dr. Jorge M. Vivanco, a plant biologist at Colorado State University and an author of the study, says the toxin acts so quickly that within 10 seconds of contact the neighboring plants' roots begin producing chemicals that set off a cascade of events that will ultimately kill their own cells.

"In one hour the roots die," he said. "The whole plant dies in a matter of days." The substance is such an effective herbicide that, Dr. Vivanco said, his university had already taken out a patent on it.

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The pervasive spotted knapweed sprouts pink and purple flowers and can grow to three feet.

Scientists often assume that invasive exotic species are able to thrive in new environments because they have escaped from their predators and other enemies at home. But scientists say the new study suggests that such troublesome imports may also succeed by using potent but unrecognized methods, like chemical warfare.

"This is a really nice demonstration that other factors come into play," said Dr. Sarah Reichard, an invasion biologist at the University of Washington. "This paper shows that the interactions can be very subtle, things happening below ground that we really haven't had any knowledge about."

The notion that plants use poisons to suppress or kill their neighbors - a phenomenon known as allelopathy - has been around for decades. But until now, few scientists have had much use for it.

"People have been rather dismissive of the whole subject," said Dr. Alastair Fitter, an ecologist at the University of York who was not involved in the study.

Part of the problem was that much of the earliest work was poorly done, he said in a telephone interview. But as Dr. Fitter wrote in an accompanying commentary in Science, he believes the new study is so convincing that it will "now place allelopathy firmly back on center stage."

The researchers found that the roots of the spotted knapweed released two forms of a chemical known as catechin (pronounced KAT-uh-kin) identical in all respects except that their molecular structures were mirror images of each other.

One form, known as +catechin, is also found in green tea and was already known as an antioxidant, able to neutralize the harmful molecules called reactive oxygen species that are thought to speed the aging process.

The toxin turned out to be the second form, -catechin, which had essentially the opposite effect of its mirror image. It induced the production of harmful reactive oxygen species in neighboring plant roots, setting off the process that led to cell death.

The finding helps explain the failure of many efforts to fight the onslaught of spotted knapweed by burning it and then seeding the area with desired plants.

"What they've seen is that 99 percent of the seeds died, and now we know why," said Dr. Vivanco. With -catechin soaked into the soil, he said, susceptible seeds have no chance of making it.

But even though the poison is very powerful, it remained unknown to researchers because everything was happening below ground.

"One plant arrives in a field where there are a lot of native plants," Dr. Vivanco said. "The next year you see not one, but actually a patch of spotted knapweed where the natives were. And if there are still native plants near it, they don't look so healthy."

Around Missoula, Mont., home of the University of Montana, for example, a diversity of native species once bloomed.

Now after several decades of this subtle underground warfare, the hills have become a vast monoculture of spotted knapweed, Dr. Vivanco said, as have millions of acres in that particularly hard-hit state.

The scientists found that the grasses that grow alongside spotted knapweed in Europe are much better able to resist its toxins than native North American grasses. Scientists say this suggests that the European grasses have evolved a resistance to this potent toxin, one that North American grasses lack.

Spotted knapweed will be getting a dose of its own medicine.

Since spotted knapweed landed in North America, a century or so ago, it has spread to nearly every state and has caused a variety of problems.

Eric Lane, the state weed coordinator for Colorado, said the loss of native plant species curtailed the food supply not only for cattle but for wild species like elk, many birds and insects. In some states, he said, the spread of spotted knapweed is so severe that elk herds have altered migration pathways to avoid vast inedible swaths of it.

The weed has also led to erosion because it does not hold soil as well as native grasses.

In the search for solutions to this green plague, researchers were excited to discover that the plant Arabidopsis thaliana, whose entire genome has already been sequenced, is susceptible to -catechin. As a result, they can see in detail how a plant's genome reacts when its roots are hit with the toxin.

The scientists found 10 genes that appear to shift into high gear immediately. Scientists say they hope that by identifying what those genes are doing, presumably mounting the beginnings of a defense, they can genetically engineer plants that can more effectively resist the spotted knapweed's attacks.

Researchers are also testing to see what native plants are resistant to the -catechin. They hope to develop a list of species that can be used to revegetate an area after spotted knapweed has been burned.

So far, the researchers have found no native plants that can withstand the poison.