AGRICULTURE

CORNBOY VS. THE BILLION-DOLLAR BUG

Technology to defeat the corn rootworm, scientists worry, will work only briefly against an inventive foe

By Hannah Nordhaus
August of 2013, a man named Joseph Spencer, who studies farm insects, was looking for a farmer named Scott Wyllie.

In good growing years, crop corn around Piper City and elsewhere is as standardized and predictable as a widget rolling off an assembly line: the plants have the same spacing, the same height. Wyllie’s corn, however, had developed a personality: the stalks had twisted back on themselves like the neck of a goose. Spencer could pull one from the ground with a flick of his wrist; the once white roots underneath were gnawed and brown, like teeth gone rotten. Some plants had tipped over from their own weight and the air was teeming with grain-stained, yellow-and-black striped beetles. They clambered on leaves, matting, defecating and munching on corn silk. Spencer had to close his mouth to keep the insects out.

Wyllie, who farms 1,000 acres, told Spencer he had done everything the experts recommended to fight the insects. The latest attempt, from Monsanto, involves em- ploying rootworm behavior at the Illinois Natural History Survey at the University of Illinois at Urbana-Champaign. And he knew that the beetles were laying eggs in soy the next, feed exclusively on corn and lay their eggs there, farmers had been able to control the beetles simply by swapping corn and soy fields every year, when the larvae emerged in soy the next spring, there was nothing for them to eat. Levine drove up to Piper City to look for another explanation. There wasn’t one. “The beetles were laying eggs in soy,” he says.

It was only with the advent of efficient center-pivot irrigation in the 1950s, which allowed continuous mass production of corn, that rootworms spread east from Colorado and Kansas across prairie lands that had been converted to cornfields. By this decade, farmers and scientists were pinning their hopes on a new modification—a corn laced with special genetic molecules that work within a rootworm cell nucleus to shut down crucial genes. The new technology should arrive in fields by the end of this decade. But environmentalists are concerned gene alterations may harm helpful insects such as ladybugs. And scientists and farmers alike know it is only a matter of time until the rootworm evades to resist the new corn. “You can’t stop resistance,” Spencer says. “You can only slow it down.”

His calling was born of calamity. In 1987 an entomologist with the Natural History Survey named Eli Levine got a call from a Piper City grain-elevator agronomist who was seeing damage in corn that had been rotated with soy. Scientists believed this to be impossible.Because Western corn rootworms feed exclusively on corn and lay their eggs there, farmers had been able to control the beetles simply by swapping corn and soy fields every year—when the larvae emerged in soy the next spring, there was nothing for them to eat. Levine drove up to Piper City to look for another explanation. There wasn’t one. “The beetles were laying eggs in soy,” he says.

This wasn’t the first time the rootworm had changed its behavior. When entomologist John Lawrence LeConte first wrote about the beetle in Kansas in 1868, it was a harmless chewing insect from Central America found in low populations on the Western Great Plains. The adults emerged from the ground in early summer, fed on maize, squash and prairie grasses, mated, laid eggs in crevices in the soil, and died before the first frost. In good growing years, crop corn around Piper City and elsewhere is as standardized and predictable as a widget rolling off an assembly line: the plants have the same spacing, the same height. Wyllie’s corn, however, had developed a personality: the stalks had twisted back on themselves like the neck of a goose. Spencer could pull one from the ground with a flick of his wrist; the once white roots underneath were gnawed and brown, like teeth gone rotten. Some plants had tipped over from their own weight and the air was teeming with grain-stained, yellow-and-black striped beetles. They clambered on leaves, matting, defecating and munching on corn silk. Spencer had to close his mouth to keep the insects out.

The beetles are Western corn rootworms, and it had been their wormlike larvae that gnawed Wyllie’s corn roots to de-struction. Wyllie, who farms 1,000 acres, told Spencer he had done everything the experts recommended to fight the insects. He rotated his corn crop with soy every other year to interrupt the rootworm food supply. He planted corn seeds that were genetically engineered to release a toxic protein that kills the hungry larvae. But in the field that day, Spencer could see that those approaches—the most successful and widely used strategies to fight the pest—had failed. “I got a chill down my back,” Spencer remembers. “I thought, ‘This is it. The worst-case sce-nario.’” Spencer has spent most of his career studying rootworm behavior at the Illinois Natural History Survey at the University of Illinois at Urbana-Champaign. And he knew that the insects swirling around him meant trouble not only for Wyllie’s crop but for the entire Midwestern corn belt.

The rootworm—Diabrotica virgifera—this is the most expensive and consequential pest in American agriculture. It is known as the “billion-dollar bug”—although in fact it probably costs the U.S. closer to $2 billion every year. The beetle spends its life cycle on corn, and corn is the nation’s largest crop by far. It frequently covers 80 million acres and sometimes more. The crop brings in $60 billion in annual sales. Farmers spend hundreds of millions in chemicals, seeds and labor fighting it. Agriculture companies spend hundreds of millions developing products to help them do so.

The result is an evolutionary arms race: the beetle damages farmers’ crops; seed companies create a product to kill it; the beetle evolves to resist the product; the crop gets infested again. And then, “just in time, the good guys in the white hats ride into town,” Spencer says, with a new beetle-killing weap-on. For the past decade the weapon of choice has been famous-ly controversial genetically modified corn plants that make chemicals to kill rootworm larvae. But Spencer saw in Wyllie’s fields that rootworms were winning.

Today farmers and scientists are pinning their hopes on a new modification—a corn laced with special genetic molecules that work within a rootworm cell nucleus to shut down crucial genes. The new technology should arrive in fields by the end of this decade. But environmentalists are concerned gene altera-tions may harm helpful insects such as ladybugs. And scientists and farmers alike know it is only a matter of time until the rootworm evades to resist the new corn. “You can’t stop resistance,” Spencer says. “You can only slow it down.”

BEHAVIOR CHANGE

Spencer’s office at the Illinois Natural History Survey is lit-tered with corn paraphernalia: corn-themed signs, mugs, bo-

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tant females did something they had never done before: a nest-
less few flew into a field of soy and found that their guts could
tolerate soybean foliage long enough to lay eggs there. The next
year their progeny emerged to a feast of corn. It was an im-
mensely advantageous adaptation. The beetles had found a
way to resist not only modern pesticides but also modern farm-
ing practices.

In 1996, after growers in Illinois and Indiana suffered mas-
sive losses to these new rootworms—the infestation was so bad
that window washers on Chicago's Sears Tower reported masses
of wind-borne beetles mobbing their platforms—the survey
hired Spencer to study the rootworm's troubling new behavior.
Spencer had done his graduate work on onion flies, and his
talks on the obscure insects attracted only a couple of hundred
people. When he gave his first lecture on rootworms, how-
ever, more than 1,500 farmers and researchers attended. The
crowd was dead-silent, capt. "I thought, 'Wow, this is a cool
insect. People care about it,'" he says.

TARGETED INSECTICIDE

AN INTENSIVE BEETLE population continued to spread from
Illinois to Iowa, Michigan, Missouri, Ohio, Ontario,
and Wisconsin, farmers found themselves in a
blind. Their livelihoods depended on healthy corn,
and they felt they had little choice but to
douse acre after acre of their seeds with high lev-
els of toxic, broad-spectrum insecticides. No-
body—not farmers, not entomologists, and es-
specially not the Environmental Protection Agen-
cy—was happy about it.

Which is why, in 2003, when the agribusiness
behemoth Monsanto came out with a hybrid
corn engineered to produce a protein that killed
rootworms, farmers rushed to get it into their
fields. The company (which funds some of Spen-
ner's research) had already produced a hybrid
corn plant with an added gene from a soil bacte-
rium, Bacillus thuringiensis (Bt), that was toxic
to a moth called the European corn borer. The
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To a monthly insecticide tag, called CrySBbl, which bound to
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For about five years farmers who planted the new root-
worm-killing seed achieved the same happy results they had seen with the rootworm borer. But in 2006 some growers began see-
ning damage again, and it soon became clear that some root-
worm populations had developed resistance. The beetles in

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"LOOKING FOR A WEAKNESS: In a greenhouse, Spencer grows
corn that releases a beetle-killing toxin. (1) Spencer examines
rootworm larvae under a microscope (2). In a research laboratory,
scientists care for rootworm eggs for five months until the larvae
hatch (3). After hatching, the larvae are driven off roots by heat
lamps and collected at the bottom of funnels (4).

another that towers above a crosshatched confusis of soy. Oth-
er students move to spots on the ground in strips between
fields. "Everybody turn on their walkie," Spencer says. He's the
greek explorer: Tilley hat, khaki bandanna, slip-off pants, stop-
watch, reading glasses, multiple pens in his pocket. He waves
his net high in the air. "In 40 seconds we're going to start the
haul," he announces.

The team plans to conduct eight collection periods of 10
minutes apiece, during which they will catch as many root-
worms as possible. By doing so, Spencer hopes to better under-
stand "the populations that leave and the ones that don't"—
and whether beetles that resist Bt corn and crop rotation are more
likely to leave their host fields. Some rootworms are talented
long-distance travelers. Once the insects rise above the layer of
turbulent air below the scaffolds, they say, "they're going to go a
long way. They could have a 1,000-mile flight range in those
convective updrafts of thunderstorms. Spencer has old pho-
tographs of billions of rootworms piling two to three inches deep
along the edge of Lake Michigan after one such storm.

From above, the corn looks like a very large marching band,
tassed hats crowded impossibly close—"the massed multi-
tural," Spencer says. When he first arrived in Illinois, he some-
times caught up to 15 beetles a minute. "Snowed rootworms." But
beetle populations have been low in the post-Bt years, and
floods in spring of 2015, which drowned many beetles in the
ground, suppressed populations even further. That summer he
cought nine beetles all season. He calculates that the effort cost
his lab about $89,400 per rootworm ounce, with labor and
material costs. That is more than 80 times the price of gold.

(More every spring he offers his students a prize: 10 gold dollars
if they catch the first adult rootworm of the season. Then Spen-
er eats the insect. "They're not delicious or anything," he says.
The wing casings get caught in his teeth.

The sun drops lower over the jungle of corn. Spencer sees
something off in the middle distance. He races across the
soil, leaps far out over the guard rail, and rushes his net up
and out. "Woohoo! I caught a rootworm!" He examines the bee-
tles in the net. "My heart's racing!"—then opens the cooler
and flash-freezes it. "Put her in a vial, blink! Awesome." It is
one of nine beetles the team will catch that night.

The next day he and his team dissect the insects in the lab,
grinding each one into a vial of "beetle gemish" and testing
their gut contents. The fields around the scaffolds are planted
with two types of corn, each engineered with a different Bt
drip. Doping gene check sticks—they look like pregnancy
tests—in the bag smoothie, Spencer "interrogates the beetles'
digestive systems" to determine which proteins are in their
guts and thus where the beetles feed during the previous 24
hours. If an insect tests positive for a trait not present in his
own fields or for two different traits, he knows that beetle is a
"mover." The team also sets up tents within cornfields, slurping
the beetles up with "bugsuckers," modified shop vacuums that
look like Ghostbusters proton packs. If those beetles come from
fields planted with rootworm-killing Bt, he knows they have
developed resistance.

Spencer puts on magnifying "nerd goggles" and places a lar-
va under a microscope—it's a tiny, groping "neonate," between
two and three millimeters long, white and newly hatched. It is in
this life stage that the rootworm finds the corn roots on which it
lives and the bit of its billion-dollar damage. "This little thing," he
says, "is the worm that roars." Next he places six yellow-and-
black adults under the microscope; they run up and down the
side of the larvae, leaving a thin layer of fluid every two and
three millimeters. Then Spencer puts on the "bugsuckers," and
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The RNAi trait has received initial regulatory approval from the U.S. Department of Agriculture and the Environmental Protection Agency, and Monsanto hopes that the final Bt-RNAi corn seed will win EPA approval by the end of this decade. If it does, however, Monsanto is seeking regulatory approval for a corn seed that would integrate two older Bt toxins with a new technology called RNA interference, or RNAi. The technology involves a naturally occurring molecule that the bacteria produce to kill the insects they feed on by shutting down specific genes in their bodies. The RNAi trait, which has been tested extensively in the lab, was found to be as effective as the existing Bt toxins at killing rootworm larvae. Furthermore, RNAi offers a new way to introduce resistance to the insects, as it could be used to target new genes that have not been previously used in the Bt technology.