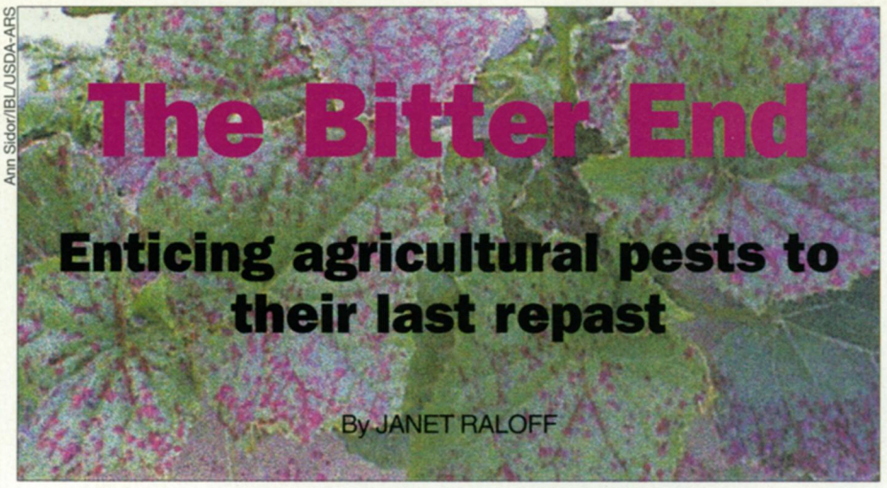

Ann Sidor/IBL/USDA-ARS

The Bitter End

Enticing agricultural pests to their last repast

By JANET RALOFF

Cucumber leaves speckled with dye-laced melon juice.

Though it looks like any ordinary watermelon—and smells deliciously sweet—this mutant is no picnic treat. Its juicy red fruit is overwhelmingly bitter. Even a small nibble provokes an intense gagging reflex and imparts an aftertaste that lingers for close to an hour—unless you're an adult corn rootworm, also known as a cucumber beetle.

The juice of this mutant melon "tastes like a hot-fudge sundae to rootworms," explains Albert DeMilo, a chemist at the U.S. Department of Agriculture's Beltsville (Md.) Agricultural Research Center (BARC).

A student of this insect's taste preferences, DeMilo is helping concoct tempting flavorings for pesticides that smite the rootworm, which costs U.S. farmers up to $1 billion annually.

Growers currently fight this scourge by lacing the soil with as much as 30 million pounds of poisons a year. Corn rootworm larvae are the target for roughly half of all insecticides applied to U.S. crops grown in rows. Though using some of the most toxic compounds in agriculture's arsenal, this chemical warfare has not routed the pest. In fact, rootworms have in many areas evolved a tolerance to some of these strong poisons.

Enter the BARC scientists, with their armloads of melons, gourds, and other natural products. Instead of targeting the larvae, which feed on the anchoring roots of corn and the rinds of melons, these researchers are developing a mean cuisine for the adults, beetles that feed on leaves and corn silk. The idea is to knock out most of the beetles before they can plant their eggs—and next year's blight—in the ground. If the researchers succeed, farmers won't have to continue spreading chemicals onto the soil, a practice that risks contaminating groundwater and killing off a host of beneficial insects and worms.

Under the direction of entomologist Robert F. Schroder at BARC's Insect Biocontrol Laboratory, the researchers have been cooking up poison-laced recipes for the beetle's discriminating palate. His team wants to make a smorgasbord of pesticide treats so deliriously irresistible that the beetles will gorge.

Judging by the results of preliminary taste tests, the insects indeed find the scientists' bitter cuisine to-die-for.

Like most other melons, squashes, cucumbers, and gourds, the watermelon that Schroder and his colleagues have enlisted in their war contains a chemical called cucurbitacin. Compared with grocery store watermelons, the mutant melon that they use has dramatically more of this compound, which belongs to a family of perhaps 15 bitter chemicals known as steroid terpenes. These compounds, which many insects and vertebrates find unpalatable, evolved as natural pesticides.

The rootworm's unusual appetite for cucurbitacin apparently developed as a canny evolutionary ploy to appropriate the plants' defense. A bird needs to taste only one of these bitter insects—and promptly vomit it up—to learn an indelible lesson. With such an incentive, rootworms are passionate for the bitter chemical. Once entomologists realized this, they began investigating cucurbitacin-rich flavorings for rootworm poisons.

In 1993, the Environmental Protection Agency approved the first bitter mixture for crop spraying. Carbaryl, a carbamate pesticide, is flavored with cucurbitacin-rich buffalo-gourd powder. Marketed under the trade names Slam, primarily for corn, and Adios, for other crops, it remains the only embittered rootworm pesticide that is commercially available.

When blended with water and dispersed from a plane, the pesticide forms small droplets that dot the leaves of plants, beckoning beetles to their last meal. Aerial application of the cucurbitacin-baited pesticide allows farmers to reserve the poison for use only after the pest has invaded.

Today, however, most farmers apply unflavored carbaryl or other toxic pesticides to the soil without first determining whether rootworm larvae are present. Explains Larry Chandler of USDA's Northern Grain Insects Research Laboratory in Brookings, S.D., roughly half of the soil insecticides applied to combat rootworms probably are unnecessary. "The farmer uses them as insurance," he says, and as a preemptive strike.

Applying soil insecticides at planting—literally, as the tractor is laying down seed—adds no more than $10 per acre, says Chandler. Aerial application of Slam, by contrast, costs about $15 per treated acre—and another $3 to $7 per acre for the services of a beetle scout, who periodically surveys fields for signs of rootworms.

Farmers find it unnerving to leave newly planted fields untreated, says Chandler. So selling them on Slam has been difficult. Far fewer than half of corn growers in his region have been willing to adopt this strategy—despite some potential advantages.

For instance, in some years the scout doesn't find many beetles on plants, so spraying isn't needed. When it is required, about 5 percent as much Slam on the leaves can achieve the same kill rate as poisons applied to the soil. Furthermore, the embittered poison threatens little collateral damage to friendly insects—from ladybugs to parasitic wasps—that help growers by naturally attacking many pests.

Chandler has commissioned studies to pin down the precise cost differences between use of soil pesticides and aerial


Purdue University, Dept. of Entomology


USDA-ARS

Soil-dwelling larval rootworms (center of inset) eat the roots of corn, eventually causing damage called goosenecking. Robbed of their anchoring roots, severely affected corn will simply fall down.

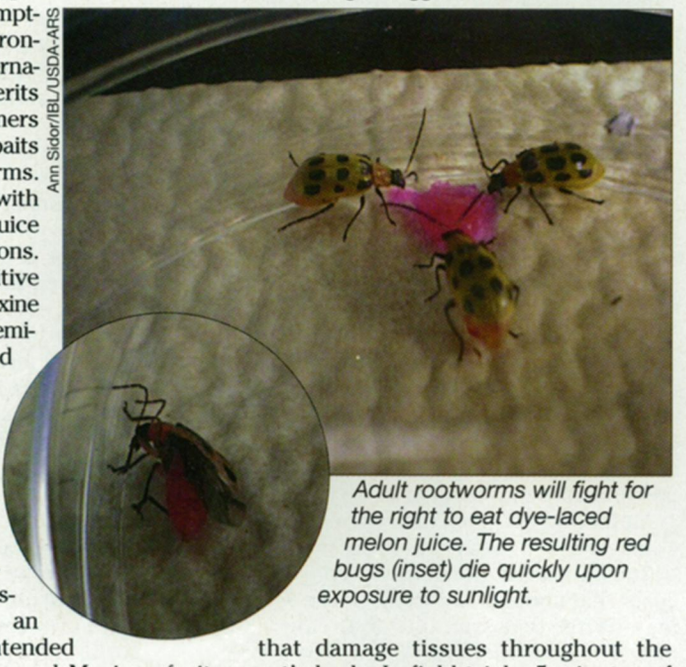
spraying with Slam. They will examine regional factors that affect the economics of farming. "Economics is going to drive many of the decisions that determine whether this is ever going to fly big-time," he predicts.

Schroder's group thinks it has an even more tempting and environmentally friendly alternative—one whose merits may sway more farmers to try cucurbitacin baits for adult rootworms. Their recipe starts with the beetle-pleasing juice of the mutant melons. The poison additive they've picked is phloxine B, a photoactive chemical also known as red dye #28.

This commercial colorant tints a number of cosmetics, such as lipsticks, and drugs, such as Pepto Bismal. It also has provided some of the pesticidal wallop in an experimental brew intended to kill Mediterranean and Mexican fruit flies (SN: 4/15/95, p. 237).

Dispersed from a plane, the dye-laced melon juice stains crop leaves with tiny carmine dots. When the rootworm beetle encounters them, it stops to feed on a treat considerably more enticing than the plant it had intended to eat. As it gorges on dot after dot, the bug's body acquires a deepening blush.

Exposure to sunlight unleashes toxic chemical reactions in the now crimson bug. "We're not sure what happens," Schroder acknowledges. His best guess is that the light triggers oxidation reactions that damage tissues throughout the pest's body. In field trials, 5 minutes of sunlight killed red-dyed beetles.



Ann Sidor/IBL/USDA-ARS

Adult rootworms will fight for the right to eat dye-laced melon juice. The resulting red bugs (inset) die quickly upon exposure to sunlight.

As with Slam, Schroder notes, "only the targeted rootworms should be tempted to eat the pesticide." Beneficial insects, which avoid the bitter taste, can visit sprayed fields with impunity. The dyed juice should prove no risk to people's health, he adds. The additive already colors products humans ingest, and the cucurbitacin concentrations are extremely low—less than 1 gram per acre.

Since early spring, USDA has had a group of farmers ready to try the baited dye on their fields, but they must wait for EPA approval. Schroder says, "We've got the juice, the planes are ready—even the sprayers are lined up."

What's the holdup? EPA has required toxicity data to determine any potential danger for workers who handle and spray the photoactive dye in sunlight. The USDA had hoped to use data submitted by the company that is trying to commercialize the red dye to kill fruit flies. However, those data have turned out to be inadequate, acknowledges Phyllis A. Martin, a microbiologist working at BARC.

"There were deficiencies in the [dye's] registration application," agrees EPA spokeswoman Ellen Kramer, "and they have not been addressed yet."

If the dye-toxicity studies must be repeated, field trials with the melon juice may have to wait a season or be conducted using a more conventional pesticide, such as carbaryl, as the poison.

Meanwhile, cucumber growers in North Carolina are anxious to try the experimental red-dyed melon concentrate, asserts entomologist Bill Jester of the North Carolina State University Cooperative Extension Service in Kinston. Their motivation, he says, is concern for honey bees. With parasite infections having killed so many bee colonies in recent

Rootworms: A U.S. export?

Until 1992, corn rootworms were a distinctly American phenomenon. Then, the scourge took a Balkan vacation—and found the venue so hospitable that it stayed.

Because the first beetles outside the Americas were sighted in corn fields just outside an airport in Belgrade, Yugoslavia, it appears that the insect hitched a jet ride, notes entomologist C. Richard Edwards of Purdue University in West Lafayette, Ind. It probably began its air travel in the Midwest. Indeed, the rootworm infesting Belgrade fields is identical to the pest, known as the western corn rootworm, plaguing crops in Iowa, Illinois, and Indiana. This variety bears the name *Diabrotica virgifera virgifera*. Elsewhere in the United States, related *Diabrotica* species often dominate.

Shortly after the initial Belgrade sighting, Yugoslav officials put out an international call for help. Neither the United States nor United Nations came through with assistance, Edwards notes, owing to their sanctions against the nation for its actions in Bosnia. As coordinator of the regional rootworm-management program for Illinois and Indiana, Edwards unofficially offered his expertise.

For the past 4 years, he has been mapping the insect's advance. By 1996, it had spread to Hungary, Romania, and Croatia. Since then, scouts have spied it in Bulgaria, Bosnia-Herzegovina, Montenegro, and Italy. The insect currently stands poised to invade Spain, France, Germany, and Portugal, Edwards says.

Tom Hlavaty USDA-ARS

When half-inch-long adult beetles can't find a bitter meal, they will dine on corn silk, shown here, or other crops.

Rootworm infestations have become severe in only 8 percent of the affected area—all of it in Yugoslavia. There, corn yields have fallen by at least 20 percent, typically 36 bushels per acre, which is similar to what farmers in the U.S. corn belt experience. Unlike their U.S. counterparts, many of the Yugoslav farmers cannot afford to fight the blight, he says.

On sabbatical last year with the U.N. Food and Agriculture Organization, Edwards helped launch a permanent European monitoring program for the insect. He also initiated a model aerial-control program using Slam, the only commercial bitter-baited insecticide.

In many ways, Edwards says, the bitter bait is well suited for these small farmers. A single plane can hit many fields at once, ensuring areawide control of the bug.

Having already dispersed over almost 46,000 square miles, an area the size of Pennsylvania, this blight represents "the most important introduction of an agricultural-crop pest into Europe since the Colorado potato beetle's arrival there in 1876," says Edwards. —*J.R.*

years (SN: 6/29/96, p. 406), growers have become very protective of those pollinators that remain and are keen to test insecticides that would minimize ancillary damage to honey bees, he says.

Farmers need a broad arsenal of weapons so they can tailor the attacks on rootworms according to the crop, conditions, and the insects' resistance to pesticides.

Both Slam and Adios rely on carbaryl to kill adult rootworms. "We know that we probably need to develop some alternative active ingredients," says Morris Gaskins of Micro Flo Co., the products' Memphis-based manufacturer. Moreover, Gaskins notes that the company is seeking alternatives to buffalo-gourd root as its source of cucurbitacin. "We have found several varieties of cucumbers that have extremely high concentrations of these compounds and are much easier to grow," he says.

Schroder's group is also investigating an alternative source of cucurbitacin: the root of a wild Brazilian plant called taiuia. Schroder and USDA ecologist Guillermo Cabrera Walsh, based in Buenos Aires, independently encountered South American corn growers who were extolling taiuia's ability to lure rootworm beetles away from their crops. Local farmers sliced the cassava-like root, soaked it overnight in insecticide, then set it out in the fields as bait.

Cabrera Walsh's experiments with taiuia indicate that this plant actually "draws cucumber beetles away from the corn—often from quite a distance." He even sprays extracts of it on cloth as a bait to collect live beetles for study. In contrast, insects have to contact the cucurbitacin in buffalo gourd and the bitter melon before they feed on it.

"In theory, [all] the cucurbitacin molecules are too heavy to become airborne," Cabrera Walsh says. This suggests that some other agent in the root may be the airborne lure that rings a dinner bell for the pest. "So, we are trying to investigate that—because an attractant, if it were a different substance [than the bitter compound]—could be important" as an adjunct to any future pesticides.

Indeed, if it worked well enough, a bait in traps between crop rows might obviate the need to actually treat plants directly.

The important thing to remember, Chandler cautions, is that no matter how well it works, no insecticide is likely to eradicate a pest. "The best we can hope for is to control it" at a cost that doesn't prove prohibitive, he says.

For corn and other crops, the bitter medicines under development offer not only a partial cure to their rootworm ills, but one having a minimum of environmental side effects. □

Different pest, similar tactic

Lopez/ARS

A corn earworm moth feeds on the nectar of a Gaura plant, a night-blooming relative of evening primrose. This insect costs U.S. farmers $2 billion annually. USDA scientists in College Station, Texas, are working to harness chemicals responsible for this flower's perfumed scent to attract the earworm—also known as the cotton bollworm, tomato fruit worm, and sorghum head worm—to pesticides. As with the lethal treats being designed for rootworms, trace quantities of the earworm poisons would be dissolved in a liquid tailored to the pest's palate. That will probably be sugars, explains Juan Lopez Jr., an entomologist who's been working on the project for 8 years. —J.R.

Biology

From Lewisburg, Pa., at the annual meeting of the Animal Behavior Society

Damselfly nightlife has its own traditions

Damselflies may not have holiday barbecues, but they do have traditional roosting places, according to a new study of their nighttime gathering spots.

The twigs, grass blades, or other perches look like miniature versions of the trees or bridges where flocks of starlings or cowbirds spend the night, note Paul V. Switzer of Eastern Illinois University in Charleston and Gregory F. Grether of the University of California, Santa Barbara.

Switzer

A rubyspot damselfly roosts near fake insects.

By day, male rubyspot damselflies in California lead a macho life. They defend empires of a square meter or so from intruding males and chase whatever females flit by. As night falls, however, the action shuts down. Groups of up to 75 males and females return to a roosting place and show no inclination to mate or fight. "A male could be a quarter of an inch away from some male he was beating up on during the day," Grether remarks.

He and Switzer wondered whether the nightspots represent some kind of tradition, selected primarily because insects had used them the previous evening. Alternatively, the gathering places could represent the only good choices for spending the night.

At unused spots, the researchers set fake damselflies made of paperclips and clay and observed that real insects settled down next to them for the night. After a week, researchers removed the fake insects and found that damselflies continued to cluster at the new roosts. This willingness to accept a new site led Switzer and Grether to argue that damselflies have tradition. Switzer even goes so far as to say, "It is culture." —*S.M.*

What color is your carnivore?

The splotches, rings, and stripes on a carnivore's face reveal the fingerprints of evolutionary forces in its past, argues Alessia Ortolani of the University of California, Davis. She is trying to crack the code.

Ortolani pieced together a huge family tree showing the evolutionary relationships of 200 terrestrial carnivores. Its twigs bristle with dogs, cats, hyenas, and weasels, as well as lesser-known species such as somewhat catlike African genets. Then, Ortolani focused on particular facial markings, looking for patterns in the histories of the animals that bear them.

Natural white eyeliner turns up often in nocturnal carnivores.

In her analysis, white markings around the eyes, like the crescents under a tiger's eyes, often appear in lineages of nocturnal predators that prowled dense forests. The white marks could have aided communication among creatures sorting out friends and foes by their facial expressions in the gloom, Ortolani speculates.

In lineages of grassland species, like African wild dogs, that roam open spaces, Ortolani found many dark muzzles. In daylight, these features stand out, suggesting they might serve as a conspicuous signal for diurnal animals. —*S.M.*