U.S. Department of Agriculture Agricultural Research Service

June 1991

Agricultural Research

Weeds We Can Live Without

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Nightmare on Weed Street

Imagine this: A creeping, burrowing menace invades your property. You frantically attack it with whatever sharp-edged tools are at hand—hoe, shovel, even an axe. But instead of dying, each amputated segment becomes a new living enemy, relentless in its spread.

Or perhaps the invader spews thousands of seeds across the land, each seed capable of lurking in the soil for half a century before bursting to life. Maybe it was once considered friendly, but has turned out to be too competitive or even poisonous under the right conditions.

Welcome to the wonderful world of weeds.

Actually, a fledgling Hollywood director could do worse than turn to weeds for horror film themes. With agricultural yield losses and control costs of $15.2 billion annually, weeds are certainly enough to give farmers—and gardeners—nightmares galore.

About 1 out of every 10 species of plants on the face of the Earth is a weed—some 30,000 weed species in all. Eighteen hundred of those 30,000 cause serious economic losses in production of one crop or another, and about 300 weed species plague cultivated crops throughout the world. The United States has become home to 70 percent of the worst weeds in the world.

U.S. farmers spend an estimated $2.1 billion annually for herbicides, plus another $938 million in application costs. Herbicides—chemicals designed specifically to fight weeds—account for more than 65 percent of all pesticide sales in the United States.

Without this effort, it is estimated, we would lose 20 percent of our wheat crop, 25 percent of the corn, 27 percent of the soybeans, 68 percent of the rice, 72 percent of the cotton, and half of the fruit and vegetables.

This month's feature, "Ten Weeds We Could Live Without," indicates that battle strategies are still evolving. One major breakthrough is the development of postemergence herbicides. After the first wave of phenoxy herbicides in the 1940's, essentially no new postemergence herbicides came on the scene until the mid-1970's.

But with these newcomers, farmers at last have in hand herbicides that allow treatment of the actual growing weed after it emerges from the soil, rather than treating the soil in advance and trying to second-guess nature on what types and numbers of weeds might eventually emerge.

Postemergence treatment is as much a boon for the environment as it is a bane for weeds. Researchers say the new postemergence chemicals, such as fluazifop and bentazon, are generally deactivated in the soil, broken down by microbes or bound to soil particles, and don't linger as other chemicals might.

But scientists aren't satisfied to know that a chemical will somehow kill a weed; they want to understand why. The answers can turn into exciting new research directions.

For example, ARS scientists in Mississippi have found that diphenyl ether herbicides are effective against weeds because they disrupt the weed's production of chlorophyll. In learning just how diphenyl ether herbicides work, the researchers also gained important insights on how plants in general make chlorophyll—information that could be useful in someday manipulating crop plants' responses to stress.

Nature, the source of humankind's weed woes, also offers ways to counter these pest plants, though scientists must look carefully for clues. Sometimes they stumble on such clues, as happened in Mississippi with a natural pathogen that appears capable of beating back a whole host of leguminous weeds: Researchers had intended to test a different pathogen against sicklepod, a serious weed in soybeans and cotton in the South and Southeast. They'd planted their sicklepod, but before they could unleash their test pathogen, the weeds had already fallen victim to a mysterious new pathogen.

Long-time participants in the battle against weeds say nothing is ever completely eradicated, be it a weed or an insect. But every new discovery, whether on the workings of a chemical or the effectiveness of a biocontrol measure, brings us closer to a more perfect balance between the good of nature and our goal of an abundant, economical food supply for the world.

Sandy Miller Hays
ARS Information Staff

Agricultural Research

Cover: Mature velvetleaf weeds dominate a soybean field. © Grant Heilman, Inc.

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Vol. 39, No. 6
June 1991

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Agricultural Research is published monthly by the Agricultural Research Service, U.S. Department of Agriculture, Washington, DC 20250-2350.

The Secretary of Agriculture has determined that publication of this periodical is necessary in the transaction of public business required by law.

Subscription requests should be placed with the Superintendent of Documents, Government Printing Office, Washington, DC 20402. Please see back cover for order form.

Address magazine inquiries or comments to: The Editor, Information Staff, Room 316, Bldg. 005, 10300 Baltimore Ave., Beltsville Agricultural Research Center-West, Beltsville, MD 20705. Phone (301) 344-3280. When writing to request address changes or deletions, please include a recent address label.

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Ten Weeds We Could Live Without

They're the bane of farmers and backyard gardeners, the scourge of the plant world. One word says it all: weeds.

In this unsavory kingdom, some are hated more than others. A recent survey of weed specialists across the country fingered some of the foulest of the leafy invaders nationwide. What follows are profiles from the specialists' "weeds hit list," and how scientists with USDA's Agricultural Research Service are fighting back.

One of the most notorious weeds is field bindweed, described by one researcher as "an out-of-control morningglory."

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Bindweed

"Someone started digging field bindweed's roots one time and found they went down more than 6 1/2 feet," says Paul E. Boldt at ARS' Grassland, Soil, and Water Research Laboratory at Temple, Texas. "The seeds can lie in the soil for 30 years and still germinate."

Grain and forage yields are reduced by 20 to 80 percent because of competition from this creeping, crawling vine. Yield loss estimates for California alone run at least $25 million per year.

Hopes are pinned on a defender so tiny that it cannot be seen with the naked eye.

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A costly crop pest, tall morningglory winds around these corn plants competing for sunlight and moisture.

Discovered by ARS scientists in Greece, the microscopic Mediterranean mite *Aceria malherbae* attacks field bindweed, gnawing its leaves. Thousands of the mites released in 1989 at sites near Bushland, Texas, and in New Jersey have survived and reproduced at both locations, although their impact against bindweed has as yet been minimal.

Aceria malherbae alone probably cannot whip the bindweed monster. But it can be an important team player in a biological control strategy against this weed, Boldt says.

"The mite feeds on the leaves, and I think we're going to have to find something that attacks the roots as well," he notes. "If its crown, roots, and leaves all are attacked, it surely won't survive."

Happily, there are candidates for the other assignments. These insects—a flea beetle that attacks the crown and a second beetle whose larvae feed on bindweed's roots—are found in Europe.

"If we could get these three together, this would give us a good start on controlling field bindweed," Boldt says.

Annual morningglories, also on the weeds hit list, are notorious for their ability to spread. But for all its wandering, morningglory may find one of its worst threats at its very roots, in the soil. ARS microbiologist Robert J. Kremer has identified several strains of root-dwelling bacteria called rhizobacteria that will attack a variety of weeds, including morningglory.

Kremer's weed-fighters come primarily from the rhizobacteria genera *Bacillus, Erwinia, Pseudomonas,* and *Flavobacterium*. These bacteria break down the weed's root cell walls or deliver toxins to its leaves, disrupting production of needed chlorophyll.

Tests indicate these natural weapons could get an extra boost from commercial products such as the herbicide butylate and the insecticide carbofuran.

These commercial compounds stimulate the weeds to germinate, explains Kremer. In the process of germination, the weed seed releases nutrients that attract and nourish the attacking rhizobacteria. In addition, the germinating weed's roots begin developing and offering a resting place for the aggressive bacteria.

Kremer's microbes also work against another noxious weed, this one with the picturesque name of velvetleaf.

In greenhouse tests with this common pest of row crops, one rhizobacterium slashed top growth of 14-day-old velvetleaf seedlings by 88 percent, compared with uninfected plants.

Taproots of the microbe-infected seedlings were less than half the length of uninfected seedlings, and lateral root growth was also reduced. Shorter roots mean less nutrients and water and greater susceptibility to stresses such as herbicides.

If left unhindered, a single healthy velvetleaf plant can set up to 8,000 seeds, and those seeds are capable of remaining viable after half a century in the soil. But the seeds could also help lead to the weed's undoing, according to Kremer. That's because an insect that resembles the boxelder bug has a voracious appetite for velvetleaf seeds.

The insect, *Niesthrea louisianica*, uses its sharp sucking mouthparts to pierce the seed's coat and drain the contents. And there's more bad news for velvetleaf: Fungi that hitch rides on the bug's stomach, back, and legs then move in to infect the weakened seed. Only about 5 percent of seeds attacked can survive and germinate, Kremer notes.

10 OF OUR WORST WEEDS

Annual morningglories
Ipomoea species
Introduced from tropical areas in South America
Kissing cousin to field bindweed, it grows to as much as 16 feet depending on the species. Various members of this family infest an estimated 174 million acres in the United States.

Canada thistle
Cirsium arvense
Introduced from Eurasia (rather than Canada)
A perennial weed ranging from a foot and a half to 4 feet tall. It is very difficult to control because of its deep root system; breaking up the roots by plowing only serves to increase the number of plants. Researchers say it takes only two Canada thistles per square yard to reduce grain yields up to 15 percent.

Common cocklebur
Xanthium strumarium
Introduced from Eurasia and Central America. Also native to Mississippi Valley
Farmers spend at least $100 million annually to combat this tall, bushy weed with the prickly seeds. But over the years it has spread across the entire United States, causing serious economic losses from the East Coast to Colorado and from South Dakota to the Gulf of Mexico.

Common lambsquarters
Chenopodium album
Introduced from Eurasia
This weed is found all across the United States but takes its heaviest economic toll east of a line drawn from Montana to Texas. It grows from a foot to 6 feet tall, with the seedling leaves uniformly distinct, sporting a frosty coating with a purple sheen on the underside.

Common ragweed
Ambrosia artemisiifolia
Native to North America
Found nationwide, most commonly in the eastern and north-central states, ragweed infests pastures and roadsides, sometimes growing to 8 feet in height. It also releases a potent pollen that causes hay fever in about 35 million people in the United States.

10 OF OUR WORST WEEDS

Field bindweed
Convolvulus arvensis
Introduced to United States from Eurasia
Ranked among the dozen worst weeds in the world. In the United States, it infests 47 of the 48 contiguous states; only Florida has escaped the deadly embrace of its 3 to 10 foot vines.

Pigweed
Amaranthus species
Thought to be native to the Great Plains
Now infesting most of the corn and soybean acreage in the United States, as well as many other crops, this weed has been tagged by weed control specialists as one of the most troublesome. It grows to about 5 feet tall.

Purple nutsedge
Cyperus rotundus
Introduced from Eurasia
Nutsedge is a perennial grass that grows up to about 3 feet tall. It infests primarily the Southeast and Southwest. It spreads by seeds and creeping tendrils.

Velvetleaf
Abutilon theophrasti
Introduced from India
Growing up to 7 feet tall, it is found throughout the United States except Montana, Idaho, Wyoming, and portions of North and South Dakota. The weed takes its name from the short, velvety hairs on its many branched stems. Velvetleaf hits hard at row crops, particularly soybeans, corn, and cotton. Farmers treat 38 million acres of corn and soybeans annually to control it and spend about $350 million to fight the weed in all crops.

Wild oats
Avena fatua
Introduced from Europe
Growing 1 to 3 feet tall, this weed can cut spring wheat yields by 30 percent or more in the Northern Plains states.

DRAWINGS BY REGINA O. HUGHES

The hitchhiking fungi are mostly from the genera *Fusarium* and *Alternaria*. Studies are now focusing on finding other fungi that might wreak even more damage than the ones already in place.

Also targeted by ARS researchers is purple nutsedge. Farmers spend millions of dollars annually combatting this weed. But thanks to ARS research, those amounts may someday be trimmed. Agency scientists have found that adding inorganic salts such as ammonium chloride to the herbicide boosted control by 30 to 50 percent.

The herbicides MSMA (monosodium methanearsenate) and glyphosate, currently used on the weed, are unreliable and expensive, according to Chester G. McWhorter, a plant physiologist at ARS' Southern Weed Science Laboratory at Stoneville, Mississippi.

Another weed that's unfortunately no stranger to soybean farmers is common cocklebur, an invader that has run rampant across the entire United States. But studying this plant's notable aggressiveness could lead to clues on hindering its progress, according to ARS scientist Edward W. Stoller.

A plant physiologist at ARS' Crop Protection Research Unit at Urbana, Illinois, Stoller says that the 4-foot-tall weed towers over soybeans, pushing its leaves both into and above the soybean leaf canopy. The weed competes with the crop for light; Stoller and fellow scientists have shown this shading can cut bean yields by more than 15 percent.

The researchers' expanded knowledge about the weed's biology will lead to improved means of control, according to Stoller. "By understanding how the weed grows, we may be able to reduce herbicide use and also find alternative methods to fight it," he says.

Another all-too-familiar weed in row crop fields is pigweed, an annual broadleaf that has harassed U.S. corn and soybean farmers for years. The good news is that for all its ability to spread and thrive, pigweed appears vulnerable to natural chemicals put out from the roots of such common plants as sunflowers and sorghum. Laboratory tests by ARS scientists have shown, for example, that populations of pigweed decline sharply when planted alongside germinating sorghum.

The secret, says ARS scientist Donald D. Bills, is allelopathic chemicals released by the nonweed plants. Further research on these allelopathic substances, which include a broad class of compounds called phenolics, could lead to breeding other crops with built-in weed resistance.

Pigweed

Researchers might also successfully synthesize these compounds to produce herbicides that are easy on the environment, says Bills.

Such natural weapons can pop up in surprising places. For example, researchers at ARS' U.S. Vegetable Laboratory at Charleston, South Carolina, tested extracts from the skin of a sweetpotato bred to resist insects. The sweetpotato extracts proved very effective at blocking germination not only of pigweed, but velvetleaf and morningglory as well.

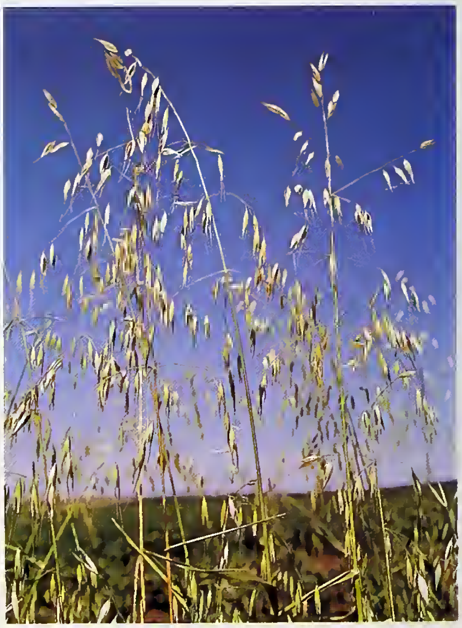
Another notorious name on the "weeds hit list" is common lambsquarters. The sight of its distinctive purplish leaves pushing up means crops face a tough struggle against this highly competitive weed.

Fortunately, the scales are being tipped in favor of the crops by ARS scientists in Washington and Illinois. They've found that slow release of herbicides may boost weed kill of lambsquarters.

In lab tests, a starch-encapsulated herbicide that kills lambsquarters and a number of other weeds remained in the top half-inch to inch of soil when water was added to simulate irrigation. Non-encapsulated herbicides leached downward 5 to 6 inches, the scientists found.

Lambsquarters

When herbicides are held closer to the soil surface, they're more likely to come in contact with—and work against—weed roots and seeds, according to ARS research chemist Robert E. Wing, who worked on the study at the National Center for Agricultural Utilization Research at Peoria, Illinois.



Wild oats.

Herbicide sensitivity in wheat poses a problem in combating wild oats, another of the worst weeds in America. Battle plans have been complicated by the fact that a herbicide widely used to control the weed also injured some wheat varieties.

But ARS scientists have discovered that tolerance to the herbicide, called difenzoquat, is inherited and can easily be bred into new wheat varieties.

Difenzoquat won't reduce yields of tolerant wheat, says Robert H. Busch, a geneticist in ARS Plant Science Research at St. Paul, Minnesota. "Breeding wheat for herbicidal tolerance could give farmers more choices in fighting wild oats," Busch says.

Northern Plains farmers face still another "worst weed" in Canada thistle. In North Dakota alone, this weed reduces yields of spring wheat by millions of bushels each year.

But there's new hope in the form of a sequence of herbicide treatments developed by ARS scientists.

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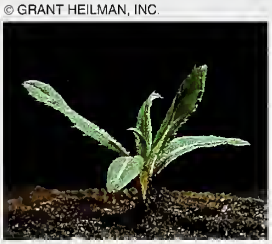

Canada thistle

In a 3-year study, the scientists applied glyphosate to thick stands of thistles in the fall, followed by bromoxynil plus MCPA in the spring. By the third fall, reports ARS agronomist William W. Donald, thistle numbers were down from about 30 per square yard to only 1. All three herbicides are approved by the Environmental Protection Agency, Donald notes.

ARS scientists are still considering strategies to counter common ragweed, a native of North America. By comparison, it's a relative newcomer to Europe and the Soviet Union. But it's settled into the Soviet Union to such a degree that last year Oleg Kovalev, an insect hunter from Leningrad, came to this country to look for insects to devour it. Kovalev works at the Zoological Institute of the USSR's Academy of Sciences.

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Common ragweed

Kovalev was joined on one leg of his 5-week, 10-state search by ARS entomologist Stephen D. Hight. Hight is based at ARS' Insect Biocontrol Laboratory at Beltsville, Maryland. Kovalev's bug hunt was historic as the first by a Soviet scientist under some five-year research agreements reached in 1989 with ARS.

While some scientists are sharing beneficial insects globally, others have begun to think regionally, says Hight.

"There are different species of insects in different parts of the United States that feed on ragweed," he notes. "The thought is that you might bring the eastern insects to the West and the western insects to the East. But first, of course, we'd need considerable studies to ensure the insects won't harm nontarget plants. This would be a small-scale version of what Kovalev's done."—By **Sandy Miller Hays,** ARS

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On the Woad Again

A 3-foot-tall biennial sporting yellow flowers, a rosette of flat leaves, and the improbable name of dyer's woad, has staked out thousands of western acres by waging chemical war.

To eliminate nearby plants, this crafty weed drops killer seed pods that exude toxins as they decay. Thus dyer's woad makes short work of competitors, including valuable western range grasses.

The tactic works all too well. "Dyer's Woad Wages Chemical War in West," a 1988 story in *Agricultural Research* noted, "entire hillsides are virtually covered with dyer's woad." These hills turn from bright yellow in the spring, when the plant sets seed, to deep indigo or black around June 15, when the plant dies off.

"At that time, areas infested with the weed look as if they'd been charred by fire," says ARS range scientist James A. Young of the Renewable Resource Center in Reno, Nevada, who has studied dyer's woad for more than a quarter of a century. He credits *Agricultural Research* with upping the weed's scientific profile; after the original story was published, he received inquiries about the weed from colleagues around the world.

When we last reported on dyer's woad, reporter Howard Sherman noted that the toxin-producing weed has gradually infested parts of the American West. Since then, it has stepped up its poisonous romp through Utah, where it now poses a very serious weed problem.

Intrigued by the article, plant physiologist Steven F. Vaughn and research associate Anita M. Brinker at ARS' National Center for Agricultural Utilization Research in Peoria, Illinois, have begun a study of how woad eliminates its competitors, a process known as allelopathy. Brinker is currently performing bioassays to isolate its herbicidal agents.

In Europe, dyer's woad was cultivated by itinerant dyemakers for thousands of years as a dyestuff that produced an indigo blue. After the fields were abandoned, farmers found they would "woad" for years.—By **Regina Wiggen,** ARS.

Mothproofing Walnut Trees of the Future

Tomorrow's walnut trees may be armed with a new weapon that better equips them to battle insect enemies.

Genetic engineers have given experimental walnut trees a mothproofing gene borrowed from the soil-dwelling bacterium *Bacillus thuringiensis,* or Bt. The gene may enable trees to manufacture a powerful Bt protein that kills many destructive insects when they are in their caterpillar stage.

The protein, however, is harmless to humans and other mammals, as well as to birds, fish, many insects, and other forms of life.

The gene might protect walnuts against attack by pests that chomp on leaves or ruin nut kernels. These insects include codling moth (also a major pest of apples), navel orangeworm, and Indianmeal moth, says Patrick V. Vail, an ARS research entomologist at Fresno, California.

At the Horticultural Crops Research Laboratory, and in the small experimental orchard about 200 yards from the back door of his laboratory, Vail plans to test trees that contain the new gene.

Vail says his experiments, planned for 1992, will reveal whether the present version of the Bt gene is powerful enough to knock out walnut's persistent pests. If it isn't, biotechnologists can rework the gene so that it packs more of a punch. The genetic engineers can modify the gene, for example, by attaching different promoters—segments of genes that turn its activity on or off, much like a light switch.

Vail's tests with leaves from the young orchard and, in about 3 years, the first nuts of the transgenic trees, will tell biotechnologists how well the gene is working and what parts of the trees contain the special protein.

That's important, Vail says, because right now scientists don't know where the protein ends up in a tree and how much of it the tree produces.

> Genetic engineers have given experimental walnut trees a mothproofing gene borrowed from a soil-dwelling bacterium.

For the Bt-based strategy to work, trees must produce large enough amounts of the protein in nut kernels or perhaps in the hull—the thick outer layer that protects the familiar nutshell—to stop the voracious insects.

To start an experimental orchard of transgenic walnut trees at Fresno, Vail will rely on budwood cut from genetically engineered trees now growing in an orchard at the University of California at Davis. The first of its kind, the Davis orchard—now 2 years old—is the work of two UC Davis researchers—Abhaya M. Dandekar and former ARS scientist Gale H. McGranahan.

According to Vail, Bt has been widely used for about 30 years in spray formulas to kill caterpillars that attack home gardens, farm crops, and forest trees. The Bt protein targets caterpillars stomachs and plays such havoc with their digestion that insects simply stop eating and eventually starve to death.

By putting the Bt gene into walnut's genetic makeup, UC Davis genetic engineers may have sidestepped the need for some chemical sprays currently used in walnut orchards. Further, the team may have cut back the need for chemicals that today protect stored walnuts from insect attack in the warehouse, supermarket storeroom, or home pantry.

The idea of giving plants a Bt gene isn't new: Scientists elsewhere have already moved it into cotton and tomatoes, for example.

To transfer the gene to walnut, the Davis scientists bathed tiny walnut embryos in a solution that contained the gene. In the laboratory, some, but not all, of the laboratory embryos took up the gene. The scientists nurtured offspring of those embryos into seedlings. Later, they grafted shoots from the seedlings onto rootstocks in the campus orchard.

The trio of walnut pests that the Bt protein might fend off causes at least $9 million in losses each year to the U.S. walnut industry. That's in spite of using the most effective chemicals

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English walnut trees.

available. California growers produce 99 percent of this country's walnut crop, worth about $191 million each year.

The codling moth's cream-colored caterpillar, about five-eighths of an inch long, sneaks into walnuts through a soft, narrow passageway in the pointed tip of the developing walnut. This natural route allows the hungry caterpillar to reach the center of the nut.

Navel orangeworm's similarly sized, yellowish-white caterpillar may attack next. This caterpillar enters walnuts once the hull splits open. That happens naturally as the nut matures.

Unlike the codling moth and navel orangeworm, which typically attack walnuts still in the orchard, the Indianmeal moth becomes a nuisance once nuts are harvested and moved indoors. The moth's caterpillar, whitish and about a quarter inch long, wriggles into damaged walnuts. The worm can also crawl into poorly sealed bags of nutmeats.

If the 1992 Fresno tests show that Bt protects walnuts from these insect culprits, the scientists will have trimmed years off a conventional walnut breeding program. "Genetic engineering allows you to insert the gene of your choice directly into walnut," says Gary L. Obenauf of California's Walnut Marketing Board, cosponsor of the research. "And in the case of Bt, you're inserting a gene that you probably couldn't even get into walnut through traditional breeding."—By **Marcia Wood,** ARS.

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Conserving Cropland for the Future

Rich brown soil blankets the hilly farmland of eastern Washington's Palouse region. But during the long, cold winter, drizzling rains—lasting for weeks on end—sweep away that precious soil.

That topsoil has helped make the Palouse famous for its bountiful wheat harvests—and infamous for its severe erosion problems. An average of 10 to 12 tons of soil per acre wash away from Palouse farmland each year. Much moves to the bottom of the sloping fields, eventually working its sediment-clogging way into streams.

For every inch of topsoil lost, wheat yields drop by 2 to 3 bushels per acre.

Researchers and farmers know how to slow this erosion—by changing the way plowing and sowing are done. The practice known as conservation tillage uses tilling and planting implements that leave residues—wheat stubble, barley straw, or pea vines—from last season's crop on the soil surface. These residues cover and protect fields during the cold, rainy months and help retain the topsoil. And conservation tillage, also known as reduced or minimum tillage, typically involves fewer passes over the field with farm implements.

One major problem, however, has stalled widespread use of this tactic—weeds. With less tillage, weeds thrive. Crop residues left on the soil help keep the ground moist and give weed seedlings a better environment in which to emerge and grow. Deep tillage, on the other hand, helps kill weeds by burying their seeds and disrupting their roots.

But farmers may be able to save their soil and their money, as well as keeping weeds at bay, says Frank L. Young, a weed scientist at the ARS Weed Research Unit in Pullman, Washington. Young heads a comprehensive, large-scale integrated pest management project in the Palouse that is now in its sixth and final year.

The project involved seven ARS and five Washington State University and University of Idaho scientists from varied disciplines: soil and weed scientists, economists, engineers, entomologists, and plant pathologists.

They compared two different tillage systems (conventional and conservation), two different crop rotations (2 years of winter wheat followed by spring wheat: and winter wheat, spring barley, and spring peas), and three weed management levels ranging from minimum to maximum.

Each of the 12 different combinations was replicated on four different plots. The plots covered 80 acres and were farmed using field-scale tractors and equipment.

The best systems produced substantially higher profits per acre compared to the others. What's more, the same best-paying methods also meet federal requirements for soil-saving techniques that farmers need to stay in business. The key? Control weeds, plant different crops each year, and practice conservation tillage.

WES TAYLOR

This no-till drill can penetrate residues from previous crops to plant wheat and other small grains.

To achieve the same yields with conservation tillage, the researchers had to boost levels of herbicides for a period of time. Although such a tradeoff—substituting herbicides for tillage—was previously known, it had not been documented in the small grain-growing region of the Pacific Northwest.

In most test plots, especially those under conservation tillage, moderate or maximum herbicide levels were economically warranted, but that could change over the long-term, says project leader Young.

"Farmers will be able to reduce the chemical inputs once they get a handle on the existing weed populations with intense treatments for a few years," he says.

The researchers determined their weed treatment levels based on field surveys of the existing weeds, which varied from year to year. Generally, says Young, the moderate herbicide level was close to the standard recommendations from extension specialists, who advise growers on farming tactics.

The maximum rates used in the study never exceeded the recommended rates on herbicide labels. Moderate and minimum rates were usually equivalent to 80 and 60 percent, respectively, of the maximum level.

In addition to eventually allowing farmers to scale down chemical use, future studies will be on herbicides that don't persist in the environment and have low toxicity to birds and mammals, says study collaborator Alex G. Ogg. He is the research leader of the Weed Management Research Unit in Pullman.

Young's future work will also look at nonchemical methods of weed control. These include cultural practices, such as choosing more competitive varieties—a tall, sturdy wheat with an extensive root system, for instance—that can more effectively compete with weed species. Another method is to examine different crop-planting patterns, such as paired rows. Paired rows with banded fertilizer provide rapid plant growth, which shades weeds and slows their growth. However, weeds must be controlled in the open space between pairs of rows.

With the years of data gleaned from this study, Young, with economists and extension specialists, hopes to develop a computer model to predict the best weed management strategy for a farmer. As an example, he'll use a similar model developed for weed

Palouse region of eastern Washington. (K-1021-15) control in corn by ARS scientist Edward E. Schweizer at Fort Collins, Colorado. After fine-tuning the specific details of the model, using data from research plots, Young anticipates testing it on actual farms in 3 to 4 years.

"A farmer in the Palouse might one day be able to take a laptop computer out to the field, survey the weeds and input that information," says Young. "Then the computer would give the farmer the most economic strategy, based on the expected yield and price of the crop."

Rotating or alternating crops from year to year reduces soilborne pathogens, like the devastating fungus take-all that builds up when wheat is grown year after year. Rotation also helps control weeds naturally. Planting peas or barley in the spring breaks the growing cycle of winter annual grassy weeds such as downy brome and jointed goat grass.

Weeds are a particularly bad problem in peas, the worst culprits being wild oats, lambsquarters, mayweed chamomile, and mustards.

Yet some of the most encouraging results occurred in the pea plots. "We were able to grow peas with equal or greater yields in conservation tillage, compared to conventional tillage," says Young.

For farm profits, the top-ranked system was the wheat-barley-pea rotation using conservation tillage and optimum safe doses of herbicides. The least profitable was the wheat-only system grown under conventional tillage, according to Douglas L. Young, a Washington State University agricultural economist. He documented the financial aspects of the study.

The economic benefits could pay off even more in the long run. The 1985 Farm Bill requires farmers to have farming practices, such as conservation tillage, in place to save

FRANK YOUNG

Winter wheat shown in photos on this page was grown in adjacent plots under conservation-tillage practices, but with maximum (above) and minimum (below) weed control methods.

FRANK YOUNG

their soil by 1995. If farmers don't comply, they aren't eligible for certain government assistance programs and deficiency payments. These payments make up the difference between the target price set by Congress and the market price farmers receive.

While individual farms will require different practices to control erosion, USDA's Soil Conservation Service criteria for conservation tillage is a minimum of 30 percent residue cover after seeding. All the plots with conservation tillage met the requirements, while none of the conventionally tilled plots did, says agricultural engineer Donald K. McCool, who is with the ARS Land Management and Water Conservation Research Unit.

The principal difference between the two tillage systems was the type of tillage used after harvest. Conventional tillage uses a moldboard plow, which inverts the soil and buries about 90 percent of the residues, leaving a mere 10 percent to cover and protect the soil.

Conservation tillage is done with a chisel plow, which breaks up the soil without turning it over, leaving 50 to 60 percent of the residues on the surface. In some instances during the study, they also used a no-till drill, which leaves even more of the crop residues on the surface. That was feasible after the spring pea harvest, for example, since peas leave fewer residues than grains. Some no-till drills can't always penetrate a heavy residue cover of wheat stubble for a suitable crop stand, so some tillage is needed.

While standing on stepladders, McCool and his technicians took color slides of each field plot before and after each tillage operation. They projected the slides onto a screen with a grid, enabling them to determine the percentage of field that was residue-covered.

Conservation tillage helps save water as well as soil. And many studies have shown that more available water means higher crop yields, says hydrologist Keith E. Saxton, another project participant.

Saxton, who is also at the Land Management and Water Conservation Research Unit, found that the conventionally tilled plots had 1 to 3 inches less water available for crops compared to the minimum-till plots.

The reason, he says, is the lessened snow catch and increased evaporation and runoff from the plowed ground. Residues on the surface catch and trap more snowfall than the smooth, tilled surfaces. "Each inch of water not available to the crop translates to a loss of 7 to 8 bushels of wheat," says Saxton.

Residues might also help stave off insects, like the English grain aphid, a major pest of wheat and barley. WSU graduate student Erin Borden found higher numbers of the aphids on the conventionally tilled plots than on those under conservation tillage. That may be because the higher residue levels repel the aphids, says Borden. A related study in the Midwest showed that mulches seemed to keep aphids from landing on crops.

Borden is also looking at whether certain weed species tend to harbor different pests of beneficial insects.—By **Julie Corliss,** ARS.

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FRANK YOUNG

On left, chisel-plowed area retains a layer of straw on the surface that conserves moisture and prevents erosion.

Just the Fibers, Please

If the useful part of a cotton plant is the cotton fiber, why not grow just the fiber—in a laboratory dish?

Growing them in the lab instead of in the field offers researchers an opportunity to understand the mysterious cellular and biochemical factory that makes cotton fibers.

That's what ARS scientists Robert W. Seagull and Barbara A. Triplett at the Southern Regional Research Center in New Orleans began working on 5 years ago.

"Fibers grown in the lab provide us with a good model for studying the biological mechanisms that regulate important economic traits such as fiber length and strength without the complications of having to examine the rest of the plant," says cell biologist Seagull.

Their aim and expectation is not to produce commercial quantities of fiber. Seagull says, "But once we understand what biochemical signals from what structures in the cells direct specific traits, we may be able to achieve higher quality fibers by either classical breeding or molecular genetic manipulation."

In cellular terms, cotton fiber cells are unusual giants, easily reaching several centimeters in length; most plant cells grow no larger than a few hundred micrometers.

"Yet if fiber cells can grow that long, why can't they grow longer? What shuts off the lengthening process? These are basic questions we are just beginning to answer," says Seagull.

To unravel the mystery of length, he is studying how the cells become fibers by looking at how and where cell wall is laid down.

It has been believed that elongating cotton cells grow primarily from the end of the cell protruding out from the seed thus creating a growth tip.

"On the contrary, while a somewhat higher percentage of growth may take place at the fiber tip, I've found significant amounts of growth taking place along the whole length of the fiber," says Seagull.

In order to directly examine the fiber and pin down exactly where growth takes place, Seagull had to devise a new way to prepare cells to be studied under the electron microscope.

In his method, fibers are plunged into liquid propane at minus 196°C, which freezes cells in microseconds. This fast-freeze causes cells to solidify before the water in them can form ice crystals. Crystallizing water disrupts delicate cell structures.

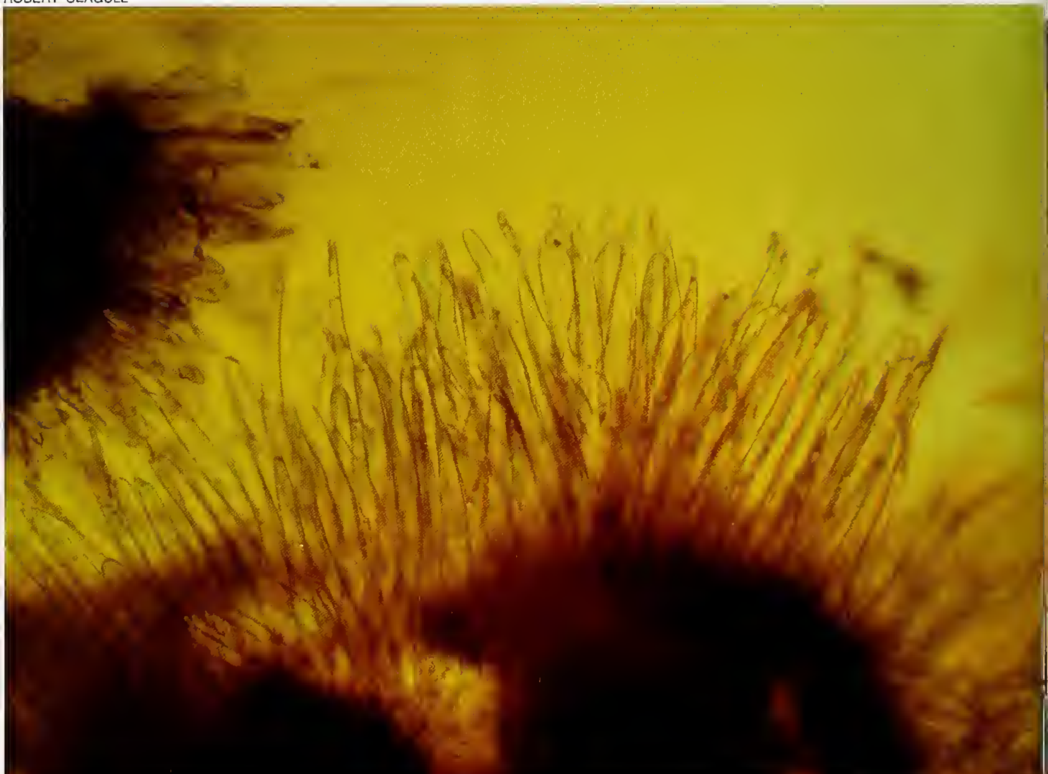
The frozen cells are gradually warmed to minus 80°C, and the cell's water is replaced with an acetone-osmium mixture, which preserves the cell's ultrastructure.

"This technique has given us images of a cotton fiber that are more lifelike than any we've seen before. Using relatively high magnifications of 50,000 times, I can directly find the sites of primary cell growth," Seagull explains.

Cell structures called secretory vesicles have been found all along the length of the fiber in the process of fusing to the cell membrane. Secretory vesicles supply new membrane to accommodate cell lengthening and bring the building blocks for cell wall formation from inside the cell to the membrane. Growth takes place where vesicles fuse in the cell.

Length is not the only trait of interest. Seagull's improved preserva-

ROBERT SEAGULL



Cotton fibers growing in ovule culture. Magnified about 170 times.

tion technique was also used to confirm when cuticle, the waxy outer coating of a fiber, appears. The cuticle is responsible for much of the way cotton reacts to dyes and other chemical finishings during textile processing.

Previous thought was that cuticle is synthesized late in the cell's life around 21 days after the flower blooms and after secondary wall is laid down in the fiber.

But molecular biologist Triplett found evidence that cuticle appears very early in fiber formation, as early as 10 days after flowering.

"Bob was able to confirm what I had found biochemically by finding a cuticle structure," says Triplett. "Cuticle in its early stages is there even before the fibers are long enough for me to pluck them from the seed with tweezers to examine the composition biochemically."

This early cuticle production could change some thinking on how to go about altering cuticle's response to chemical finishings like permanent press and dyeing, Triplett explains.

"It means researchers are probably going to have to look much earlier in the fiber growth process to make any real changes in how cotton responds to chemical finishing processes," she says.

Seagull and Triplett are also looking at many other pieces of the cellular manufacturing process such as the layering of microfibrils in the cell wall. Microfibrils are filaments of cellulose responsible for much of a cotton fiber's strength.

"Throughout much of the fiber elongation phase, microfibrils are deposited like bands around a barrel circling through the primary wall," says Seagull. "As the elongation slows toward the end of growth, microfibrils of the secondary wall are deposited in helixes and ultimately in parallel, longitudinal lines. This multilayered wall improves the strength of the mature fiber.

"We are examining a set of structural elements in the cell cytoplasm involved in controlling the deposition and organization of the microfibrils. These elements, called microtubules, control the patterns of the micro-fibrils."

Now the researchers are looking for biochemical signals that direct this multilayered wall through an analysis of the protein components of the microtubules.

"We haven't isolated any proteins with identified functions yet, but we expect to," Seagull says.

The combination of ultrastructure and biochemical analysis is bringing new information into focus all the time.

Recently, they've begun to pinpoint where messenger RNA localizes for production of proteins specified by particular genes.

"This information will bridge the gap from biochemistry to cell biology," Triplett says. "Knowing when and where pivotal developmental points are will help us identify genes that control specific important processes or the signals that turn the gene off or on at a particular time. Some day we may be able to tell a breeder you need to select for cotton that turns on a specific set of genes at a particular time or at a different level to improve the quality of cotton fiber.—By **J. Kim Kaplan,** ARS.

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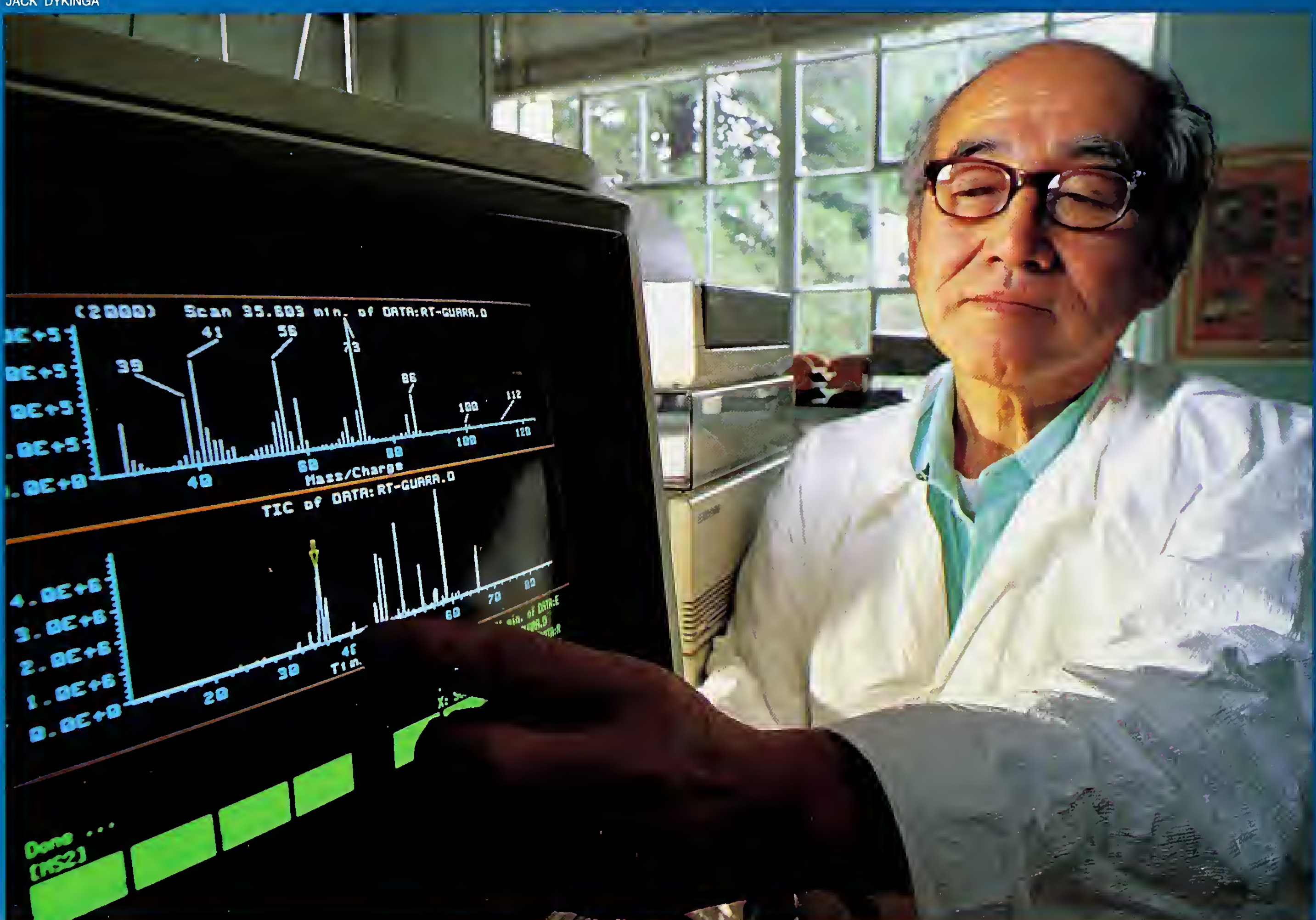
Floral Lures May Doom Corn Earworm

For part of its life, the corn earworm, *Helicoverpa zea,* is a night-flying moth that sips the nectar of weed flowers, such as the gaura. Drawn by the alluring fragrance of blossoms, virgin female moths choose food before sex: All newly emerged females spend their first night feeding and wait until their second night to mate.

JACK DYKINGA



Chemist Roy Teranishi analyzes the volatile chemicals from night-blooming flowers that attract the corn earworm moth. (K-4052-1)

This peculiar preference is the key to a strategy ARS researchers are devising to kill a most troublesome insect.

In the caterpillar stage that follows the moth form, *H. zea*—variously known as the corn earworm, tomato fruitworm, and cotton bollworm—costs growers about $1.5 billion in damage and control measures each year.

The brown, pink, or red *H. zea* (formerly *Heliothis zea*), about 1.25 inches long and nearly as thick as a pencil, also plagues backyard gardeners around the country. "Most home gardeners who grow tomatoes or sweet corn know this worm," says ARS entomologist Peter D. Lingren at College Station, Texas.

Lingren, along with entomologist Jimmy R. Raulston at Weslaco, Texas, and their co-researchers, hope to concoct a deadly brew: an insecticide mixed with perhaps honey or sugar, to stimulate moths' feeding, plus chemicals that mimic the tantalizing natural scents emitted from petals of weed flowers.

"If we can use the floral essences to entice newly emerging moths to eat bait laced with insecticide," Lingren explains, "we should be able to kill them before they get a chance to mate."

In nature, night breezes carry floral aromas from petals to hungry young moths. The aromas signal nectar—fast-food for the foraging insects. "The moths' appetite for the nectar," says Lingren, "may be a crack in their armor. Using floral aromas as a lure may be a way for us to get at them, without destroying nature's equilibrium."

If unchecked, female moths will flit from the weeds over to nearby corn plants or other crops the night after mating to lay their eggs. The eggs develop into caterpillars that burrow into the corn ear, tomato fruit, or cotton boll and feed on it. "Caterpillars are extremely difficult to control once they get inside the ear, fruit, or boll because insecticides can't get at them," says Lingren.

The floral-lure approach should reduce the amount of insecticide now used to keep the caterpillars in check. That's because adult insects such as moths are typically around 10 to 100 times easier to kill with insecticides than are caterpillars.

Further, the attractants may prove less costly than insecticides. Growers may spend less money to kill female moths than to destroy offspring that hatch from the eggs. A mated female moth typically lays about 1,000 eggs; on average, at least 500 will hatch into crop-damaging caterpillars.

EDWARD MCCAIN

Corn earworm moth feeding on gaura, a night-blooming weed. (K-4054-14)

The scheme, in addition, might replace spraying of insecticides directly onto crops. A floral attractant, a feeding stimulant, and an insecticide might be impregnated in the kind of twist tie used to close garbage bags, for example. When twisted around a cornstalk or tomato vine, the tie need never touch an ear of corn or ripening tomato.

The lures won't threaten honey bees. "The extracts we're looking at," says Lingren, "don't attract them."

Finally, the floral essences would lure both males and females, an important advantage over single-sex lures such as today's sex pheromones.

Lingren and colleague Raulston have spent years night-stalking the moths each March through November to discover clues to the secret lives of the insects. The scientists' nocturnal forays have revealed that moths' favorite nectar-bearing plants in the South and Southwest include the night-blooming species *Gaura drummondii, G. longiflora,* and *G. suffulta.*

These species are roadside weeds, growing from 1 to 15 feet high. They produce honeysuckle-like blossoms of pink, white, or reddish-pink. In bloom, a single bush of *G. longiflora* may boast as many as 1,000 flowers.

Each gaura flower puts out an impressive food bribe for moths—about 5 to 10 milligrams of nectar. "That's a tremendous amount for a single flower," says Lingren.

Gaura has no economic use, although Indians in Mexico once made a poultice from it to treat arthritis.

To mimic the floral essences that tantalize moths, scientists must first identify the chemicals that make these aroma-imparting compounds. That's the job of ARS chemists such as Ted Shaver at College Station and Roy Teranishi at Albany, California.

Teranishi has, for example, already pinpointed about a dozen key chemicals from *G. drummondii* flowers. The blooms were among the 450,000 gaura flowers that Lingren, Raulston, and others painstakingly collected last year.

Using gas chromatography and other approaches, Teranishi and colleagues at Albany pinpointed about a dozen major compounds from the floral extracts.

Although no one knows exactly what *G. drummondii* flowers smell like to a moth, Teranishi says our noses perceive the fragrance as sweet, very floral, and much stronger than the perfume of day-blooming weeds. "Flowers that bloom only at night have to kick out a lot of aroma so that they'll stand a good chance of being found and pollinated by night-flying moths," he explains.

One of the chemicals gives off what we would pick up as a "pleasant, greeny aroma," he says. Another compound is common in roses. Cinnamon and wintergreen scents are also part of the weed's bouquet.

The experiments at Albany are the first to identify the aromatic compounds of *G. drummondii.* Luckily, most of the newly identified substances can be synthesized using chemicals right off the shelf.

Now the challenge is to discover if these chemicals are indeed the ones that tempt moth appetites, and—if so—what blend of these compounds will make the most potent lure.

To find out, the Texas entomologists test the candidate chemicals in different blends. Outdoors, they monitor traps containing cotton wicks saturated with floral chemicals. Indoors, they fan scented and unscented air past the moths, then watch to see which breeze attracts the insects.

There are thousands of possible mixtures, so it may take at least a year to discover the ideal recipe.

The floral lure strategy may tomorrow protect individual crop fields and backyard gardens. The technique may offer even broader protection if it snares moths before they have a chance to migrate. Such control would be significant, because moths can travel 300 miles or more in a single night when the wind is right.

In southern Texas, for example, moths abandon maturing cornfields, unsuitable for egg-laying, and migrate north to vast cottonfields. "We want to stop the moth at its source before it has a chance to spread from one crop to the next," says James Coppedge, an ARS national adviser on insect research. If the lures turn out the way researchers hope, growers and gardeners alike will have a new, safe, and powerful weapon for fighting the versatile moth.—By **Marcia Wood,** ARS.

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Roy Teranishi is with USDA-ARS Plant Protection Research Unit, Western Regional Research Center, 800 Buchanan St., Albany, CA 94710. Phone (415) 559-5659. ◆

Hunting Moths by the Dark of Night

At sunset from March to November, ARS entomologist Jimmy R. Raulston can often be found setting up camp along the Rio Grande, preparing to spend the hours until dawn peering through night vision goggles.

But he is not interested in tracking human traffic crossing the river near Weslaco, Texas. Raulston wants to know what moths are doing.

Raulston, who is with the Subtropical Cotton Insects Research Laboratory in Weslaco, Texas, watches what plants attract the nocturnal corn earworm moth—one of the most destructive and costly insect pests in U.S. agriculture. His work is part of a study to find a chemical lure that could be used to control the moths before they lay eggs in crop fields or possibly to lure them into traps.

What the moths are most attracted to is the aroma of the night-blooming weed gaura.

"I've watched corn earworm moths fly from upwind across a gaura patch at 15 feet high without a pause. But when they get downwind of the flowers they'll make a U-turn and head right back for a flower," says Raulston. "That's how we know it is the smell of the flower that counts."

The gaura is so attractive that Raulston has been able to count as many as 87 moths per hour in a 4-square-meter (about 43 square feet) area of the flowers.

In a cornfield near the observation patch, 42 percent of the moths carried gaura pollen, a sure sign that they had also visited the flowers, according to Raulston.

Corn earworm moths are not the only insects drawn by the gaura flowers. Raulston has noted many other nocturnal moths in the observation patch, including the cabbage looper, black cutworm, and true armyworm—all insects that damage crops.

To give chemists back at the labs enough fragrance to analyze, Raulston and other team members gathered as many as 15,000-20,000 flowers a night. Each gaura bloom lasts only a single night, then shrinks up and falls off the next day.—By **J. Kim Kaplan,** ARS.

EDWARD MCCAIN

Entomologist Jimmy Raulston prepares to observe the corn earworm moth's feeding patterns with night-vision goggles. Gaura blooms only in darkness. (K-4054-1)

RICHARD NOWITZ

Plant pathologist James Locke displays neem seeds and neem seed oil, a source of natural insecticide and fungicide. (K-4053-1)

Another Natural From Neem

Finding it in a greenhouse, you could easily mistake the young plant for a graceful ornamental fern, but it will mature into a full-sized tree. Its nut resembles a shelled peanut or a large citrus seed. Although not much to look at, neem seed has some extraordinary characteristics.

"ARS scientists have been working with neem since 1975," says James C. Locke. "Our current focus is to develop natural products from the plant that can reduce our dependency on synthetic pesticides."

And that's what they're doing at the ARS Florist and Nursery Crops Laboratory in Beltsville, Maryland.

Locke, a plant pathologist, entomologist Hiram E. Larew (formerly with ARS, now with the Agency for International Development), and James F. Walter, an engineer from W.R. Grace & Company, have teamed up to discover a new use for neem seed oil. They've found it can harmlessly control rust on beans and snapdragons and powdery mildew on numerous ornamentals without harming the plants.

Although neem seed extracts are being used as a botanical insecticide, this is the first time the seed's oil has been used successfully against fungal plant pathogens.

Locke says they emulsified extracted neem seed oil in water and used it as a full coverage spray, then subjected the plants to powdery mildew or rust. "We had success with applications containing as little as 0.25 percent oil," Locke says.

"We've been working on this project for about 2 years now. We've actually been using a byproduct from the production of the neem insecticide that the firm of W.R. Grace is marketing," Locke says. "The most exceptional characteristic of this oil is its ability to exhibit both insecticidal and fungicidal properties."

"We don't really know how the oil-water mixture works since the neem oil doesn't contain azadirachtin, the insecticidal compound found in the seed," Locke says.

But work it does. J. Rennie Stavely, of ARS' Microbiology and Plant Pathology Laboratory, reports the compound was nearly 100 percent effective against bean rust in greenhouse tests. Although its performance was not quite as dramatic in the field, the spray worked well enough to be economically feasible.

And when compared with commercially available petroleum-based horticultural oils, the neem-derived fungicide was more effective against both bean and snapdragon rusts.—By **Doris Stanley,** ARS.

James C. Locke is at the USDA-ARS Florist and Nursery Crops Laboratory, 10300 Baltimore Ave., Beltsville, MD 20705-2350. Phone (301) 344-2413. ◆

Less Waste Sugar, Better Soybeans

Soybeans, already the nation's prime source of food oils and high-protein meal for feeds, could become even more valuable if researchers can change the way the beans themselves use energy.

The problem is that soybean plants don't concentrate solely on cranking out valuable oil and protein. They spend some of their energy making three unnecessary sugars that have practically no nutritional benefit, according to Tsung Min Kuo, a chemist at ARS' National Center for Agricultural Utilization Research.

These three waste sugars—raffinose, stachyose, and verbascose—account for up to 6 percent of the weight of the soybeans, says Kuo.

His research team hopes to help molecular biologists and plant breeders develop soybeans that will convert the natural ingredients that now go into making the sugars into nutrients for animals instead.

The search for a way to stop the unwanted sugars has reached far beyond soybeans. The Peoria scientists have studied the differences and similarities in accumulation of the sugars in a wide variety of seeds, including those of cotton, peanuts, pumpkins, and sunflowers.

Working with zucchini leaves, ARS chemist Patrick T. Smith has found a way to purify a key enzyme, galactinol synthase, that's used by zucchini plants in making raffinose sugars.

As researchers learn more about this enzyme from zucchini, their discoveries might help them work with different forms of the enzyme in soybeans.

"Eventually we might find some way to turn this enzyme off in soybeans or inactivate much of it during seed development," Smith says.

Kuo and Smith are trying to learn the sequence of amino acids that make up the enzyme. This effort lays the groundwork for finding the sequence of nucleic acids—gene building blocks—that determine which amino acid sequences occur.—By **Ben Hardin,** ARS.

Patrick T. Smith and Tsung Min Kuo are at the USDA-ARS National Center for Agricultural Utilization Research, 1815 N. University St., Peoria, IL 61604. Phone (309) 685-4011. ◆

Test for Toxin-Producing Molds

Not every mold is a dangerous microorganism, though the ones that produce mycotoxins assuredly are.

Kerry O'Donnell and fellow microbiologist Stephen W. Peterson are helping to keep our food free of toxin-producing molds; the ARS scientists have identified the DNA sequences of some molds that commonly produce mycotoxins in field crops.

"Molds can look very similar, even under a microscope. But we know that each species has unique DNA sequences. Through "fingerprinting" these molecular codes, we can identify specific molds and distinguish them from one another," says Peterson.

Once their fingerprints are known, researchers can design DNA probes that will quickly and accurately identify molds that produce food contaminants. He and O'Donnell are currently developing a field test that can be used by farmers and agricultural commodity graders in the field to detect *Aspergillus flavus*, the mold that produces aflatoxin. It is hoped this test could be ready for commercial development in a year or two.

One to two percent of the U.S. corn crop, which is valued at $20 billion annually, is lost to aflatoxin.

"With a DNA probe, a farmer could easily detect the presence of fungi that are likely to contaminate crops with aflatoxin before a large-scale problem occurs," Peterson says.

Were a probe available, farmers could decide to harvest earlier or thoroughly dry their corn right after harvest to about 12- to 14-percent moisture. "Such a practice could prevent growth of the fungi."

Current ways of checking for *Aspergillus flavus* are culturing methods that take up to a week to detect the mold. In contrast, a DNA probe could identify fungi in less than 24 hours. "This method is so sensitive, it can detect as few as one to three cells of the fungus," says Peterson.

Probes can also be designed for other fungi. "Most foods and feeds are susceptible to invasion by molds during some stage of production, processing, transportation, or storage," says Peterson. And some are even part of the curing (or aging) process. One such mold, *Penicillium verrucosum*, is used in some European cured sausages.

"It's a good fungus that helps flavor the meat. But it looks just like *Penicillium veridicatum*—a bad one that makes a toxic substance called ochratoxin A, associated with kidney disease," says Peterson. Another lookalike mold is *Penicillium chrysogenum*, which produces penicillin.

While these *Penicillia* molds look similar, the chemical compounds that make up their DNA are quite different. We can sequence them like letters in the alphabet to reveal their differences.—By **Linda Cooke,** ARS.

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RANGETEK, a Rancher's Best Friend

Protecting rangelands from overgrazing by cattle may become easier, thanks to a new computer program called RANGETEK. The user-friendly program helps ranchers determine the optimum number of cattle to graze on a specific range.

Many factors influence range stocking rates. For instance, the types and amounts of forage grasses, like bluebunch wheatgrass or Idaho fescue, affect the rate, as does how much it rained before the growing season, says J. Ross Wight, one of the program's designers. Wight, a range scientist, works at the ARS Watershed Management Research Unit in Boise, Idaho.

"Based on past weather records, the program can tell you how much forage will likely be available during the upcoming season in a specific region. That information helps determine the number of cattle that can safely graze there," says Wight.

Grazing too few cattle when there's plenty of forage cuts into a rancher's income, but grazing too many, too long, can wipe out the best forage species. Overgrazed land is also more susceptible to erosion, he adds.

RANGETEK prompts users for information about soil type, the predominant plant species, and the length of the growing season on the range in question—information all resource managers have. Armed with long-term weather records available from weather stations, along with the soil moisture status at the beginning of the growing season, the program can forecast the likelihood of having a good, bad, or average year, in terms of plant growth.

Soil moisture and weather data files are currently being developed for range sites in Idaho, specifically for RANGETEK. However, the program can be used wherever the data can be measured.

Another option is entering actual values for temperature and rainfall every week during the season, which gives a real-time simulation of soil water content as plants grow. The resource manager could then keep tabs on the current range conditions, without having to actually measure the soil moisture content.

The program would give resource managers enough advance information so that they could move cattle from a pasture in time to prevent damage due to overgrazing.

The Department of Interior's Bureau of Land Management and the USDA's Forest Service, which controls most of the publicly owned land suitable for grazing, will likely find the new technology beneficial, says Wight.

This spring, Wight, along with scientists from USDA's Soil Conservation Service and state extension personnel, will use RANGETEK to forecast forage yields in key range sites across Idaho. The results should help refine the program's accuracy and provide detailed information on the impact of a potential drought in Idaho's rangelands.—By **Julie Corliss,** ARS.

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Flash Drying Saves Seeds

Seeds from most major crops grown in temperate areas contain right amount of moisture to keep them viable until needed for the next growing season but not too much to promote mold and rot.

Over the past 40 years, scientists have developed the best storage techniques for these seeds so they can be kept not only for the next growing season, but for many years.

"We're fairly confident we can store seeds such as wheat in liquid nitrogen, which is minus 322°F, for more than 100 years," says Christina W. Vertucci, of the Agricultural Research Service. "Unfortunately, we have yet to learn how to safely preserve recalcitrant seeds." Many tropical plant species produce hard-to-store seeds that have high moisture levels and can't survive dehydration like most seeds from temperate areas.

"Flash drying may solve the problem. We cut out the embryonic axis, or growing portion of the seed and blow compressed air over it to remove a certain seed moisture up to 100 times faster than normal drying. After 30 minutes of this drying, we store the embryos in freezers that are minus 112°F. So far the embryos have survived for 6 months," says Vertucci.

While longer storage periods are needed to ensure that the technique actually works, she remains optimistic they will succeed.

Vertucci, a plant physiologist at ARS' Plant Germplasm Research Unit, National Seed Storage Laboratory, in Fort Collins, Colorado, says that the secret to long-term storage may be getting rid of the nonvital water but retaining the water that is essential for the survival of the seed.

Vertucci is working with Norman W. Pammenter and Patricia Berjak, plant physiologists visiting her laboratory from the University of Natal, Durban, South Africa. They had experimented with the flash drying technique on recalcitrant seeds of *Landolphia kirkii*. A viny shrub in its native Africa, *L. kirkii* sets seeds twice a year, making it readily available for research.—By **Dennis Senft,** ARS.

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KEITH WELLER

Christina Vertucci, a plant physiologist at the National Seed Storage Laboratory in Fort Collins, Colorado, prepares a recalcitrant seed for storage using a new flash drying technique. (K-4051-3)

Broken Rice Tied to Nitrogen

Neatness counts—especially when it comes to rice farming.

That's the news from plant geneticist Robert H. Dilday at ARS' Rice Production and Weed Control Research Unit at Stuttgart, Arkansas. Dilday says the results of a 3-year study show that hit-or-miss application of nitrogen fertilizer on rice can land farmers a failing grade where it hurts the most—in payments at the mill.

"With varieties of rice that take a lot of nitrogen fertilizer such as the semidwarfs, we saw twice as many broken kernels—called brokens—when the rice wasn't fertilized," Dilday notes. "Rice millers pay only half as much for rice that contains a lot of brokens.

"This means that when you aerially apply your nitrogen, you have to be sure you get an even distribution and don't miss strips in the field. If you do miss strips, you could be shooting yourself in the foot twice: once in lost production, and again in lower prices paid for the rice at the mill."

In Dilday's experiments, nitrogen was applied to test plots of Lemont and Newbonnet rice in several ways: all the nitrogen at once, before flooding of the rice field; half at preflood and the rest in two equal doses later in the growing season; and a six-way split. Other plots received no nitrogen at all.

In 1987, Lemont rice that received all its nitrogen fertilizer preflood had only 14.2 percent brokens, Dilday recalls. That same year, his Lemont rice that received no fertilizer had 33.3 percent brokens.

Lemont is one of the semidwarf varieties favored by farmers. Among the attributes of semidwarf varieties is a resistance to lodging—a condition where the rice stalk breaks, dumping the head onto the ground.

But rice doesn't have to be a semidwarf variety to show the harmful effects of sloppy nitrogen application. Newbonnet also suffered from the absence of nitrogen in Dilday's tests, although percentages of brokens weren't as great: 15.6 percent brokens in 1987 with no nitrogen, compared with 11.9 percent brokens when all the nitrogen was applied preflood.

Nor is nitrogen application the only pitfall awaiting rice producers. Dilday says other studies at Stuttgart have shown that poor timing of field drainage before harvest can hurt rice quality, too.

"A lot of times, farmers like to drain the field early because if they leave the water on too long, they have a really muddy field and a devil of a time moving around with their harvest equipment," Dilday explains.

"We've tried draining at different times and actually harvesting the rice with the water still on the field. Our studies show the longer you leave the water on the field, the lower your percentage of brokens."—By **Sandy Miller Hays,** ARS.

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