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Howard Deer would like to clear up an important misconception about integrated pest management.

"Most farmers have been using integrated pest management since day one," says Deer, USU toxicologist and Extension pesticide specialist. And he says most still do, albeit not to the extent that farmers did before World War II when the only available pesticides were mostly natural compounds, such as lead, arsenic and strychnine (many of which were extremely toxic and nonselective).

Integrated pest management has renewed interest in cultivation, crop rotation and other tactics that farmers can employ to keep weeds, insects, and other pests at bay. While the exact meaning of integrated pest management is somewhat ambiguous—for example, some interpret it as an adjunct to organic farming while others see it as leading to more accurate and cost-effective use of pesticides in conventional agriculture—it is likely to be increasingly important in agricultural research and production.

It may also be the only effective method of allaying the public’s concern about pesticide residues in food, and perhaps in avoiding an outright ban on pesticide use.

**Increased Pesticide Use**

In the mid-1940s, farmers embraced the first synthetic organic pesticides available to agriculture, the pesticide DDT (now banned) and the herbicide 2,4-D. Pesticide use in the U.S. now approaches more than 1
GOALS

Agriculture depends on the environment. No farmer willingly desecrates the life-sustaining resources that are the foundation of his livelihood. We too are committed to a system of agricultural production consistent with environmental quality.

As food safety, pollution, water quality and health command more public attention, the Utah Agricultural Experiment Station will emphasize those natural and biological systems that protect environmental quality and that will allow agriculture to remain one of this Nation's most productive sectors. Other segments of society will not willingly accept a stable or decreasing income. We cannot expect farmers and ranchers to do so either.

Coupled with biotechnology, IPM programs can provide substitutes for those pest-control chemicals that are no longer available. Our research will provide growers with effective alternatives that not only allow us to provide Americans with an abundant supply of healthful food, but at a cost that allows us to compete in international markets.

H. Paul Rasmussen
Director
Utah Agricultural Experiment Station

billion pounds annually, nearly three-quarters of which are used in agriculture. (Pesticides include herbicides, insecticides, rodenticides, fungicides, bactericides, nematicides, as well as other agricultural chemicals such as growth regulators.) Use of agricultural pesticides tripled between 1965 and 1985.

The result of this chemical largesse is now the subject of a rancorous debate. The antagonists often disagree on the extent of the problem and, not surprisingly, on the solutions. The dispute has spilled into the political arena where agriculture often has less clout than consumer interests.

The outcome of the debate is likely to transform agriculture. "It's clear that more restrictions will be placed on pesticide use," Deer says.

Critics charge that pesticides are widely misused and that harmful residues taint much of our food and water. Defenders of pesticide use argue that the occasional examples of pesticide misuse shouldn't overshadow the fact that pesticides have fostered a remarkable growth in agricultural productivity. And the risks, they contend, are often far less than we take in, for example, crossing the street.

IPM At Center of Debate

Defenders and critics of pesticide use in agriculture both endorse IPM, even though their definitions of the term may differ sharply. Both sides have amassed evidence to support their cause and both realize that the outcome may well depend on how adroitly the issue is presented to garner media coverage. Defenders point to the recent "Alar scare," which they contend was a sophisticated campaign that employed Hollywood actresses, thinly disguised press agentry and dubious statistics to create a maelstrom of public doubt and uncertainty. Critics charge that the agricultural establishment simply refuses to acknowledge the risks involved in pesticide use.

Deer notes that IPM—which he defines as controlling pests when a pest population approaches the level at which control is necessary to prevent a
decline in net return—will probably play a key role in calming the debate. IPM involves the use of biological, mechanical and cultural controls whenever possible and chemical controls when necessary. Deer says IPM is not “anti-pesticide” (it can occasionally increase pesticide applications) but it usually means less pesticide is applied.

IPM could mean the difference between banning of pesticides and their continued use under closer supervision. Deer notes that atrazine, one of the most widely used herbicides in agriculture, was recently reclassified as a restricted use pesticide available only to certified applicators. That classification is likely to be applied to more pesticides.

Nor is IPM synonymous with sundry proposals for alternative agriculture, although it may incorporate some of those elements. And it will not augur a reversion to a simpler era of management. The opposite is true: IPM is a by-product of the information age in which research and intensive monitoring replace seat-of-the-pants judgement. Instead of simply treating a pest, farmers will learn how to intervene in an ecosystem involving complex interactions between pests, beneficial organisms, plants, tillage practices, and the weather.

It won’t be easy.

The recent discovery of trace levels of pesticides in 9 of 44 wells in Utah recently tested by the Utah Department of Agriculture and the U.S. Geological Survey has brought the issue closer to home. Deer

### A Projection

If all constraints on 100 grain beetles, including predators, parasites, disease and shortages of food and water are removed, there would be almost 1,000 beetles after 3 weeks, 300 million beetles in 20 weeks. After unrestrained growth for a year, there would be almost $9 \times 10^{18}$ beetles. After 82 weeks, there would be more than $60 \times 10^{27}$ beetles weighing more than the Earth itself.


### Importance of conventional pesticide expenditures to U.S. farmers, 1988 estimates.

<table>
<thead>
<tr>
<th></th>
<th>($ billion)</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm pesticide expenditures$^1$</td>
<td>5.1</td>
<td>3.9</td>
</tr>
<tr>
<td>Total farm production expenditures$^2$</td>
<td>132.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

$^1$Excludes wood preservatives, disinfectants, and sulfur.

$^2$USDA,1989.

Source: USDA and EPA staff estimates.
The Situation in Utah

Areas of high groundwater contamination potential*

*Selection was based on soil permeability, distance of water table from the ground surface, and use of irrigation. Areas were identified by USU Extension groundwater specialist Richard Peralta and Howard Deer using the computer program DRASTIC.

<table>
<thead>
<tr>
<th>County</th>
<th>Uses</th>
<th>Pesticide</th>
<th>Concentration (ug/l)</th>
<th>EPA HA limit (ug/l)</th>
<th>Detection limit (ug/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sevier</td>
<td>Irrigation</td>
<td>Chlorpyrifos</td>
<td>0.05</td>
<td>NA</td>
<td>0.01</td>
</tr>
<tr>
<td>Washington</td>
<td>Irrigation</td>
<td>Atrazine</td>
<td>0.20</td>
<td>3.0</td>
<td>0.10</td>
</tr>
<tr>
<td>Duchesne</td>
<td>Stock</td>
<td>Dicamba</td>
<td>0.12</td>
<td>200.0</td>
<td>0.10</td>
</tr>
<tr>
<td>Morgan</td>
<td>Domestic</td>
<td>Atrazine</td>
<td>0.10</td>
<td>3.0</td>
<td>0.10</td>
</tr>
<tr>
<td>Morgan</td>
<td>Municipal</td>
<td>Atrazine</td>
<td>0.20</td>
<td>3.0</td>
<td>0.10</td>
</tr>
<tr>
<td>Sevier</td>
<td>Not Used</td>
<td>Cyanazine</td>
<td>0.10</td>
<td>10.0</td>
<td>0.10</td>
</tr>
<tr>
<td>Beaver</td>
<td>Irrigation</td>
<td>Atrazine</td>
<td>0.20</td>
<td>3.0</td>
<td>0.10</td>
</tr>
<tr>
<td>Utah</td>
<td>Dom, Irr, Stk</td>
<td>Prometon</td>
<td>0.20</td>
<td>100.0</td>
<td>0.10</td>
</tr>
<tr>
<td>Sevier</td>
<td>Atrazine</td>
<td></td>
<td>0.20</td>
<td>3.0</td>
<td>0.10</td>
</tr>
</tbody>
</table>

1Forty-four wells were tested by the Utah Department of Agriculture in cooperation with the U.S. Geological Survey. The table concerns the nine wells containing traces of pesticides.

2Value based on EPA Lifetime Health Advisory.
Deer couches the debate in more general terms. “Most Americans have acknowledged that we want a certain standard of living, and that we have to tolerate some types of ‘environmental insults’ to achieve it, which include such things as allowing car exhausts and some smoke to escape from factories. The public is now being asked to accept a similar phenomenon in food—low levels of pesticide residues.

“We can probably produce food with no chemical residues, but we cannot produce as much or the same variety of foods as inexpensively as we do now,” Deer says.

A ban on pesticides would also probably mean bug-infested grain, wormy and deformed fruits and vegetables—and considerably higher prices. Some estimate that world production of food would fall by 30 percent without pesticides. Critics say these are overblown threats.

Deer notes that the natural toxins produced by plants experiencing higher levels of stress, such as those attacked by insects, may be more dangerous than low levels of pesticides. Many scientists think that microbiological hazards, pathogenic microorganisms such as viruses, bacteria and bacterial toxins, pose a far greater threat to health than pesticides.

Deer says farmers who apply pesticides according to directions do not significantly increase health risks to consumers, although the consumers appear to be increasingly apprehensive of any pesticide-related risk. “Admittedly, some farmers did place an overreliance on chemicals as a quick-fix, which increased pest resistance to pesticides,” Deer says.

Assessing Health Risks

The potential health risks associated with pesticides range from immediate reactions, usually from a single, relatively large exposure, to chronic health effects, often resulting from exposure to low levels of pesticides over a long
period of time. The effects differ in combination with other substances, which are difficult to assess.

About half of the 600 active ingredients of pesticides registered for use with the Environmental Protection Agency (EPA) can legally be used on food. One of the most controversial areas concerns the tolerances established for a pesticide, which may differ for raw or processed foods and animal feed. EPA bases tolerance on risk assessment. The agency considers the risk of one additional cancer case per 1,000,000 people over a lifetime of exposure as insignificant and, if warranted by the benefits of pesticide use, may accept the risk of one additional cancer case per 100,000 people over a lifetime of exposure.

The acceptable daily intake (ADI) for a pesticide, as determined by the EPA, is usually at least 100 times lower than the level at which no health effects can be observed in animals exposed to the pesticide. The ADI represents the level of a pesticide residue which can be safely ingested by an average person every day over a 70-year lifetime.

The brouhaha surrounding pesticide residues has reverberated through all aspects of agriculture—critics question the relevance of animal studies to humans, the adequacy of government regulatory systems, the safety of genetically engineering plants or microorganisms to resist pests, and government and industry commitment to alternatives.

But there are a substantial number of people who equate all pesticide residues with "poison," and who firmly believe that their use has made our food supply less nutritious and healthful. They hold their views with the conviction of religious zealots. For them, pesticide use is a black and white issue.

Many scientists and farmers view the issue in different terms—as matters of degree, statistical procedures and research protocols, and practicality.

Apparently, the solutions that society adopts will depend on who finally manages to define the problem.

Rangeland Herbicide Doesn't Appear to Move Far

The herbicide tebuthiuron (Spike®) apparently does what it's supposed to—kill unwanted rangeland trees without moving into the groundwater.

During a recent study of the environmental fate of the herbicide, which is used on rangelands in the Intermountain Region to kill cedar and juniper trees, researchers found that tebuthiuron tended to remain in the upper region of soil, although slightly deeper than the manufacturer's data indicated. And although it sometimes persisted in the soil longer than the manufacturer indicated, "it was not at levels that would cause concern," says Howard Deer, USU toxicologist and Extension pesticide specialist.

Levels of the herbicide were tested at sites in Idaho, Wyoming, Colorado and Utah. "The herbicide is very effective, and only small amounts are required. Before it was available, other less effective herbicides had to be applied at higher amounts and more often, which increased the risk of soil and groundwater contamination," Deer says.

Tebuthiuron is a long-lasting chemical that kills trees 1-3 years after it has been applied and prevents their regrowth. Cedars and junipers release allelopathic chemicals that prevent growth of desirable grasses and forbs, markedly reducing forage production.

KG

This research was partially funded by the Western region of the USDA's National Agricultural Pesticide Impact Assessment Program (WR-NAPIAP)

Howard Deer 750-1602
Biocontrol may help USU researchers stamp out an aggressive weed before it acquires a larger foothold in Utah and neighboring states.

The weed is squarrose knapweed, a close relative of Russian, spotted, and diffuse knapweeds, and yellowstar thistle. All of these species are natives of the eastern Mediterranean region—and all pose serious threats to crops and rangelands in the Intermountain region.

So far, the only substantial (about 100,000 acres) infestation of squarrose knapweed in the country is confined to central Utah near Tintic. There are much smaller infestations in other western states.

“We can’t allow this weed to become as widespread as spotted knapweed, which now infests more than 2 million acres in Montana, and threatens wildlife habitat, recreational areas, and is crowding out desirable forages on rangelands for livestock,” says USU weed scientist Jack Evans.

USU researchers are determining if seed-destroying flies now being tested as a biocontrol agent against spotted knapweed will also be effective against squarrose knapweed.

The small flies lay eggs on the seed heads of knapweed. Once eggs hatch, larvae of the fly feed on and destroy the developing seeds.

“These flies have been quite effective against spotted knapweed, which is a perennial plant that depends on seed production for survival and distribution. We don’t know if it will be as successful against squarrose knapweed, which is also a perennial,” Evans says.

A major question concerns the effects of the region’s hot, dry summers and cold winters on the fly’s ability to survive. Researchers should know within a year whether the fly can slow the spread of squarrose knapweed. If it does, it might also be effective against Russian knapweed, which infests large areas in eastern Utah.

The only effective control measures now are cultivation and a few herbicides. The effectiveness of selected herbicides against squarrose knapweed is also being evaluated.

Almost 40 years ago, USU weed scientist Delmar Tinge found a small infestation of squarrose knapweed in the state, which he classified as a separate species. Many taxonomists originally questioned his classification but most now agree with his assessment.

The mature deciduous heads of squarrose knapweed stay closed and retain the seeds. Spines of the seeds cling to animal wool, hair or fur like a cocklebur. Historically, spread of the weed was associated with sheep. Seeds might have been introduced by sheep or in woolen products.

The research also involves weed scientist Steve Dewey, plant pathologist Sherm Thomson, and entomologist Ted Evans.

Howard Deer 750-1602
Steve Dewey 750-2256
Sherm Thomson 750-3406
Ted Evans 750-2552
Monitoring a Biological Nemesis of GRASSHOPPERS

A USU researcher is developing a faster, more efficient and less expensive technique to measure the effectiveness of a promising bioinsecticide now being tested against grasshoppers.

The bioinsecticide is a naturally occurring protozoan parasite, *Nosema locustae*, which can reduce grasshopper populations by 50 percent several weeks after it is applied, and may offer some residual protection for a year or more, says biologist Nabil Youssef. The U.S. Department of Agriculture is now conducting a 5-year test of the bioinsecticide.

*Nosema* infection is difficult to detect, however, which could hamper its acceptance. Current monitoring techniques now involve either time-consuming microscopic examination of dissected grass-

Spores of *Nosema locustae* and diseased grasshoppers.
hoppers to identify spores or elaborate staining techniques to detect the early stages of infection. Early detection is essential because *Nosema* requires 3-4 weeks to kill grasshoppers. If initial treatment was not effective, waiting that long would preclude effective retreatment or the use of alternative controls.

Youssef plans to develop monoclonal antibodies to *Nosema* and its spores, thus making it possible to use medical diagnostic equipment to detect infection and assess the quality of the bait used to treat grasshoppers.

Severe grasshopper infestations periodically cause substantial losses on rangelands in the western U.S. Some researchers estimate that grasshoppers destroyed 23 percent of the forage on 647 million acres of western rangelands during 1977, a typical treatment year. The destroyed forage was worth almost $400 million.

*KG*  
*Nabil Youssef 750-2513*

This research was partially funded by the Western Region of the USDA's National Agricultural Pesticide Impact Assessment Program (WR-NAPIAP)
IPM Results Convince
FRUIT GROWERS

The evidence is clear—integrated pest management pays off. Handsomely.

For seven years, the national and Utah Cooperative Extension Service have funded IPM research at USU for fruit growers. In 1989-90, it appears that 15 growers participating in the program will save about $500,000 by irrigating according to soil moisture levels and by scouting for pests, reducing or eliminating some routine pesticide applications.

These growers saved an estimated $300,000 during 1988-89 and almost $600,000 during 1987-88.

The results have convinced many erstwhile critics. Some growers were initially “somewhat skeptical” of the program, particularly because they thought there was too much risk involved in not automatically spraying at predetermined intervals, says Sherm Thomson, USU plant pathologist. Since then, however, word of success of the project has percolated among growers throughout the state. Although relatively few growers officially participate in the pilot IPM program, “we feel 75 to 80 percent of the growers use at least some IPM strategies during the year,” Thomson says.

It now appears that the goals of the IPM project—producing better quality fruit while using 30 percent fewer pesticides and 30 percent less irrigation water—are obtainable in most years.

“Results clearly show that high-quality fruit can be produced while reducing pesticide applications, conserving irrigation water, reducing the adverse environmental impact and improving profits for growers,” Thomson says.

Information is essential for IPM strategies. Climatic data from five representative fruit-growing regions around the state are analyzed to determine irrigation requirements and the risk of disease and insect outbreaks. The environmental information is used in computer models to forecast insect and disease outbreaks.

Here are some of the benefits growers chalked up during 1988-89 thanks to the IPM project: Pear and apple growers were advised to
Here are some of the benefits growers chalked up during 1988-89 thanks to the IPM project: Pear and apple growers were advised to apply bactericide in time to prevent the blossom blight phase of fire blight. (Growers who ignored the warnings sprayed at the wrong time and failed to control the outbreak.)

Two rainy spells prompted fear that apple scab might be a problem, but scouts found that spores had not been released, thus letting growers avoid 2-3 fungicide applications on about 1,400 acres, saving about $70,000. Information also let growers delay applying fungicide until powdery mildew lesions were detected, thus saving $45,000. And recommendations helped apple growers control mites with two fewer sprayings, thereby saving $84,000.

There’s more: Growers saved $35,000 by relying on natural parasites to control tentiform leafminers.

Integrated pest management doesn’t always reduce insecticide applications. A warning that a long growing season would result in a third generation of codling moths would require that growers apply a late season cover spray to protect fruit.

Growers are also irrigating more efficiently, thanks to a related program offered by the Soil Conservation Service (SCS). Information from neutron probe tubes indicates that 50 percent of the growers were irrigating correctly during 1988-89, up from 35 percent the year before.

SCS personnel, inspectors with the State Department of Agriculture and fruit growers conduct orchard surveys. Growers receive recommendations directly or via news-letters and telephone. The project

**PROGRESS**

For eight years, the findings of USU entomologists has significantly improved aspects of integrated pest management for orchards.

- They developed an easier method to estimate populations of harmful and beneficial mites: Instead of counting the tiny mites on leaves, scouts can simply determine whether the mites are present or absent on a certain number of leaves per acre.
- Predicting when the Western cherry fruit fly would emerge and develop, and the relation ship between insect development and fruit maturation has made it possible to tell growers when they should spray to control this insect pest.
- They determined that the codling moth, the most important insect pest of apples and pears in the state, had not developed significant resistance to Guthion®, the most widely used insecticide, thus reassuring growers that they need not use more expensive alternative insecticides.
The southern United States is about to acquire some really nasty residents—Africanized honey bees.

So, eventually, will Utah. What happens next is uncertain, but it probably won’t be as bad as some fear even though their arrival will make life more unpleasant, at least for a while.

Africanized honey bees are expected to cross into Texas from Mexico sometime late this year or early in 1991, says John D. Vandenberg, entomologist with the U.S. Department of Agriculture Bee Biology and Systematics Laboratory at Logan. He says humans may accidentally introduce them into Utah before they migrate on their own accord.

Their arrival in Utah is unlikely to have a major effect on agricultural crops and orchards but will make honey production a lot more expensive and labor intensive, Vandenberg says. Utahns will also have to be more cautious when they venture outside.

But the Africanized bees’ arrival might be a severe blow to the state’s rangelands and forests. Because they build nests in areas overlooked by European honey bees, they “may make it extremely tough on wild bees if they compete with native bees for pollen,” Vandenberg says. That could adversely affect pollination of native forest and range plants.

“We are in a good position in Utah as far as having alternative pollinators for the European honey bee,” Vandenberg says. The alfalfa leafcutting bee is now used in commercial alfalfa seed production in the Northwest, and in limited areas in Utah. Beekeepers could easily scale up production of the blue orchard bee, an alternative pollinator of orchards which is slowly gaining commercial acceptance.

The Africanized bees’ effects on pollination by wild bees is the biggest unknown. Fortunately, studies of the pollination of endangered plant species, prompted by concern over the effects of insecticide applications to control grasshoppers, will indicate the role of native bees on native flora and the consequence of any decline in pollination.
“Theoretically, Africanized bees can’t overwinter but all bets are off when they hybridize with European honey bees,” Vandenberg says. Interbreeding might improve their ability to store honey and preserve their nasty disposition, or it might make them gentler. “We won’t know until hybrids start forming,” he adds.

Africanized honey bees resulted when several African queens accidentally released in Brazil in 1957 interbred with gentle European honey bees. Their aggressive offspring have since spread steadily northward. The USDA implemented programs to slow their advance, which, in combination with severe frosts and drought, have apparently been successful. The nearest colonies of Africanized honey bees are now at Soto la Marina, Mexico, about 160 miles south of Brownsville, Texas.

The aggressive Africanized queens tend to take over the gentle European queens, and beekeepers must closely monitor queens and drones, the males which mate with queens, to determine when interbreeding has occurred. An international marking system has been developed to help beekeepers identify queens and facilitate selection for desirable qualities.

Vandenberg says interbreeding of Africanized and European honey bees will require several changes in beekeeping methods, including the posting of warning signs. Africanized bees are extremely sensitive to disturbances so colonies must be handled cautiously. Better methods of transportation will also be required.

Improved management strategies are the best defense against Africanization, he notes. This includes marking queens with a small dab of paint to differentiate them from unwanted (and unmarked) queens, replacing queens annually, and separating colonies to minimize disturbances to neighboring colonies while working. Beekeepers should also prevent swarming by removing honey frequently to ensure that colonies always have empty combs. Vandenberg also recommends saturating the area with desirable European drones when the queen flies and mates.

The Africanized bees are no more venomous than European bees, but they are about ten times more likely to sting. They attack in large numbers, sometimes by the thousands, and persist in their attack. They follow people and animals for as far as two miles from their colony. “Their tendency to swarm readily seems to be an adaptation to an uncertain environment in which there are no cold winters,” Vandenberg says. Rather than staying in one place to accumulate honey, they move on readily and allocate energy to reproduction.
It's not clear whether the North American winters will limit their spread. The strain was originally adapted to the tropics and may find it more difficult to compete against the European bee in the United States where winters are colder.

The Africanized honey bees are expected to spread across the southern United States by 1995. "The first onslaught might be the worst," Vandenberg says.

Vandenberg says states could theoretically prevent the introduction of Africanized bees by intensively monitoring and controlling the movement of bee colonies. This is impractical, however. Hundreds of thousands of bee colonies are moved annually in a symbiotic relationship in which beekeepers reap honey and producers improve pollination of their crops.

About $200 million in honey is produced annually in the United States, but bees' major value is as pollinators of crops worth about $20 billion annually.

**BEE CAREFUL**

Utahns will have to be a bit more wary following the arrival of Africanized bees, but they won't have to cower indoors. There will be more risk. A single bee sting can kill someone allergic to bee venom, but the accumulated poison from several hundred or more stings could kill anyone. Multiple stings break down blood cells and muscle tissues, and cause kidney stress.

USDA scientists studying the Africanized bee offer the following advice:

- Those allergic to bee stings should carry and know how to use prescription sting kits.
- Bees tend not to sting while gathering nectar and pollen from flowers. However, assume that all nests are dangerous. Never approach an occupied nest and do not disturb swarms.
- Be aware of the honey bee threat just as you are aware of the threat of poisonous snakes. Don't disturb trees, stumps, logs or rocks without first checking for bees.
- Keep an escape route in mind. Although bees will pursue some distance, you can run and gradually leave them behind. Most serious injuries to people and livestock occur when victims are confined.
- Don't slap at the bees or take cover. The bees tend to sting at your head, so throw protection over your head as you run.
- If you are with someone who is attacked, encourage them to run with you. If they fall or get trapped, try to protect them and yourself from further stings by covering with clothes or blankets.
- Bees leave their stingers behind. Don't remove them with tweezers or fingers; you might squeeze in more venom. Instead, scrape them off with your fingernails.
- Allergic persons should seek medical attention even after the emergency use of sting kits. Anyone stung 15 or more times should seek medical attention.
Targeting Herbicides to
CONTROL BRUSH

Researchers are studying effective and environmentally sound methods of controlling brush species on foothill rangelands used for spring and fall grazing.

The major culprit is rabbitbrush, which resprouts and often becomes dominant following the control of big sagebrush. Big sagebrush and rabbitbrush tend to crowd out more palatable grasses and forbs.

Although 2,4-D can effectively control rabbitbrush, there is only a narrow "window" when it is effective. It must be applied when there is adequate soil moisture, enough actively-growing foliage to translocate herbicides and moderate temperatures.

"Herbicide control has been particularly difficult during the past three years due to drought conditions," says range scientist Chris Call. "Last year, it appeared as if we had fairly good control but there was regrowth of rabbitbrush from the crowns."

Different herbicides and application methods and schedules may offer better control. Chris Call, Roger Banner, Extension range specialist, and Jack Evans, weed scientist, have begun a 3-year study of four herbicides (2,4-D, pictoram, triclopyr, and glyphosate) applied at approximately 2-3 week intervals and at different rates. Herbicides will be radiolabeled to determine sites and rates of herbicide translocation. Residues in soil and the economic feasibility of control will also be assessed.

Broadcast spraying is often used to apply herbicides on rangelands, but as little as 30 to 50 percent of the herbicide actually reaches target plants. Drift and residue can restrict use in some areas.

The researchers will compare the effectiveness of broadcast spray application with a carpeted roller applicator that deposits herbicide only on foliage, thus reducing the risk that herbicide will inadvertently be applied on soil and eventually contaminate water. The applicator also makes it possible to selectively apply a nonselective herbicide such as glyphosate to avoid harming grasses and forbs in the understory.

KG
Chris Call 750-2477
Roger Banner 750-2472
Jack Evans 750-2242

This research was partially funded by the Western Region of the USDA's National Agricultural Pesticide Impact Assessment Program (WR-NAPIAP)
tidy orchard (at least on the ground) may not necessarily be the most profitable orchard. Entomologist Diane Alston, a specialist in fruit tree insect pests, is studying how different ground covers (including bare soil and weeds) affect insects in apples and tart cherries.

Growers often try to eliminate or carefully control vegetation between fruit trees. In orchards in the East and Midwest, the predatory mites and other beneficial insects that overwinter in weeds help control some pests. Alston is determining whether it pays to provide similar havens in Utah orchards for natural enemies (predators, parasites and pathogens) of pests such as mites.

There are several factors to consider.

Ground covers have several benefits—they control erosion, increase water penetration, hinder the establishment of harmful weeds and reduce soil compaction. Mowing or using selective herbicides may be less costly and require less management than repeated cultivation.

However, ground covers compete with orchard trees for water and nutrients and may harbor harmful insects, diseases, nematodes and rodents. And in peach orchards, insects that cause "cat-facing" (scarring) of fruit may lurk in certain weeds.

The success of biological control, an integral aspect of IPM, depends on the synchrony between predators and their prey, Alston says. Providing a good overwintering habitat might mean an increase in the number of beneficial mites and insects early in the season just when the populations of plant-feeding insects start to surge.

"The codling moth and the Western cherry fruit fly are the primary pests that we worry about. But by applying pesticides to control them we may also destroy beneficials such as the predatory mites and parasitic wasps that take care of the secondary pests," Alston says.

Alston says an IPM regime that includes cultural practices may not appreciably improve production until the third or fourth year. Growers usually must accept more damage when they apply less insecticides and acaricides in order to give the natural control organisms time to make a comeback.

The economic consequences may be difficult for growers to accept. While decreasing the amount of pesticides that are applied is beneficial, especially with the current consumer interest in food safety, growers must initially forgo income in order to reach this goal, Alston says.

JC

Diane Alston 750-2516

It might pay to provide havens for predators, parasites and pathogens that prey on pests such as mites.
Researchers Improving INDIAN RICEGRASS

Indian ricegrass, recently named the state grass of Utah, will become increasingly important for range reseeding in the Intermountain West as researchers overcome problems associated with seed shattering and seed dormancy.

“Native stands of Indian ricegrass now provide forage for cattle, especially winter forage,” said Tom Jones, a plant geneticist with the USDA Agricultural Research Service. “However, it’s difficult for growers to raise a seed crop because of seed losses—the glumes, which hold the seed, open and the seeds ‘shatter’ or drop.”

Low germination rates are another obstacle to widespread use.

Jones collected ricegrass seed or plants from more than 100 sites throughout the species’ range, which extends from Nevada to Colorado, and from the Columbia River Basin to northern New Mexico. A population from Billings, Montana, holds rather than shatters its seeds.

He is also trying to identify the seed production conditions that will minimize seed dormancy, thus improving germination. Under some conditions, germination rates have exceeded 85 percent. Germination rate of fresh seed is often less than 5 percent.

The scientific name for Indian ricegrass, Oryzopsis hymenoides, means rice-like and papery. The feathery flower stalks of the self-pollinating plant superficially resemble rice. Paiute Indians in the Humboldt Basin reportedly used ricegrass seed as a reserve food.

Jones said that the potential value of Indian ricegrass as forage has been recognized for a long time.

“It’s been studied off and on for more than 50 years. The first research thesis on the plant is dated 1934. Previous researchers have tried to break seed dormancy. We’re trying to keep it from occurring in the first place.”

Tom Jones 750-3082

SUMMER 1990 71
Synthetic peptides (small proteins) appear to be effective against an organism that causes a previously untreatable and potentially fatal form of diarrhea.

The protozoa, Cryptosporidium parvum, a single-celled parasite, causes mild diarrhea in adults, but can make children seriously ill. Patients afflicted with AIDS or other ailments that weaken the immune system may develop chronic, life-threatening diarrhea following infection. Until now, doctors were unable to control the parasite and only treated the symptoms of infection.

Lytic peptides lyse (break open) cells. The synthetic peptides tested are similar to those which Swedish researchers originally found in the giant silk moth.

More than 90 percent of the protozoa were killed after a 30-minute exposure to a solution containing the peptide, say USU veterinary scientists Michael Arrowood and Mark Healey.

The peptides were synthesized and supplied by Jesse Jaynes at Louisiana State University. Jaynes has found that the peptides have potent antibacterial, antiprotozoal and antitumor activities.

Lytic peptides have also been found in the skin of frogs and the intestines of pigs, which indicates that these anti-disease agents may be widespread in nature, Arrowood says.

The USU researchers tested three types of lytic peptides, one of which was significantly more effective against the protozoa. The tests involved incubating the infective stage of the parasite at body temperature and adding various concentrations of the peptides. Additional tests are planned to determine if the peptides are effective in laboratory animals.

KG

Michael Arrowood 750-1897
Mark Healey 750-1901
Automated surface irrigation systems are being developed that will link fields to farms, farms to canal systems and canal systems to rivers.

In addition to saving time, the system will make more efficient use of water.

USU irrigation engineers have developed prototypes for parts of the system. The computerized systems—one for surface irrigation of fields and another for canals—will mimic the on-the-spot decisions made by farmers and canal managers. A commercial prototype for canals should be available in 2 or 3 years. A comparable system for fields will take longer to develop.

Conditions affecting irrigation or the flow of water through canals change so rapidly that information a few hours old may not be accurate, says irrigation engineer Wynn R. Walker. For example, infiltration rates near the head of a field may be substantially different from those at the end of a field. Mounding and discharge rates in canals also change quickly. Farmers and canal managers have learned how to adjust for these conditions.

It now appears that computers can do the same.

To continuously funnel information to computers that control water flow, “feedback loops” electronically transmit information from sensors in fields or canals (via a satellite or radio system) to computers. This information is processed by a new generation of computer software to determine the state of the irrigation system. Conventional “straight” software forecasts irrigation parameters based on data such as infiltration rates. The “inverted” software required for the automated systems does the opposite—it uses the behavior of systems to calculate the appropriate characteristics, such as infiltration rates, that affect efficiency.

A prototype system for canals will be tested on the Experiment Station Drainage Research Farm this summer.

“Our eventual goal is to produce a totally automatic irrigation system that senses and makes all decisions, just like a center pivot system in which a farmer just has to push a button. This is a logical continuation of our surge flow research,” Walker says. Surge flow irrigation, which was developed at USU, is the only surface irrigation system in which the discharge rate can be changed to improve efficiency.

Walker says USU irrigation engineers are developing the technology that will be used 10 or 15 years in the future when inexpensive computers are in widespread use on farms. Automating surface irrigation will give farmers more time for management, marketing and planning, activities that can markedly improve profitability.

KG

Wynn Walker 750-2785
Resuscitating
RURAL ECONOMIES

There's no simple formula for buoying economic growth in rural areas. Traditional resource uses such as grazing and mining may offer the highest payoff in some areas, while recreation might fuel the most economic development elsewhere. A lot depends on the type of recreation, however.

Production industries such as agriculture have a much larger impact on a local economy than service industries, says USU economist Bruce Godfrey. However, as a local economy contracts, it becomes increasingly difficult for a rural area to collar employment or income from any economic sector.

One problem stems from the fact that while recreational expenditures may be high, a relatively small proportion of the revenue generated in a rural area is actually "captured" to fuel additional economic growth in the area. For example, most of the money spent on gasoline in rural areas goes to the refiner, transportation companies and other non-local enterprises.

Godfrey is identifying enterprises likely to have the greatest economic benefit for rural areas.

One of the key issues he has addressed is the economic impact of designating an area as a wilderness. There have been widely divergent estimates of the economic impact of wilderness areas, ranging from assertions that wilderness designation revitalizes rural areas to criticism that wilderness areas actually siphon revenue from local areas. "The economic impact of wilderness areas is not nearly as big as some adherents suggest nor nearly as negative as some critics claim," he says.

However, as a general rule, the fewer the restrictions placed on recreational uses, the greater the economic benefits for nearby rural areas.

Godfrey's assessment of the economic impact of wilderness areas is based on a national survey on the characteristics of wilderness users conducted by the U.S. Forest Service. Survey results indicate that more than 80 percent of the visitors are from the state in which the area is located; most are from urban areas. Godfrey says this indicates that wilderness areas may attract users that might have visited wilderness areas in other states or engaged in other recreational activities, but do not seem to draw a large proportion of out-of-state visitors. As a result, wilderness areas probably have only a slight effect on the state's overall economic growth—and an even smaller effect on the local economy.

Most visits to wilderness areas also consist of day hikes or weekend jaunts. "These types of visitors just don't spend that much money in rural areas," Godfrey notes. Most purchases for equipment and other major items are made in urban centers. As a result, designating an area as a wilderness often means that local communities are harmed and non-local interests reap most of the benefits.

KG
Bruce Godfrey 750-2294
or eight years, the federal Cooperative Extension Service has funded IPM programs in the state. One program involves fire blight, a potentially devastating bacterial disease of peaches, apples and other pome fruits that kills buds, and can eventually afflict branches and entire trees. If unchecked, the disease can wipe out entire orchards.

It’s not understood exactly how the bacteria that cause fire blight, *Erwinia amylovora*, become pathogenic, but researchers do know which conditions are likely to foster damaging infections. Extension plant pathologist Sherm Thomson can predict whether the risk of infection is negligible, low, moderate or high by analyzing rainfall, humidity and temperature data from eight sites around the state. Control requires spraying with streptomycin or a copper solution. He also assesses disease risk by monitoring the number of bacteria in flowers. Pollinating insects can spread the bacteria and conditions often favor spread of the pathogen when fruit trees are in bloom.

The IPM program is no panacea for fire blight, but it’s much better than some of the things that growers have tried to protect orchards from the disease, which included “driving rusty iron nails into the trees and hanging horse shoes among the branches,” according to a 1925 report.

*KG*

**Forecasting Fire Blight**

Flowers colonized by insects and rain

Bacteria multiply on stigma

Bacteria move into flowers, leaves and stems through natural openings and wounds

Bacterial strands spread by insects, mites, spiders, rain, wind, etc.

Bacteria overwinter in cankers and other areas, latent infections become active in the spring

Infected flowers darken, shrivel and exude bacteria, bacteria move into twigs and limbs forming cankers
Field Test Monitors
Changes in
INSECTICIDE RESISTANCE

The quick and inexpensive field test that a USU entomologist uses to monitor insecticide resistance may eventually be the nearest thing to curbside service to improve insecticide use.

The test, which is now extensively used in research, could be widely used in IPM programs to improve insect control and cut insecticide use, says entomologist Bill Brindley. Similar tests can determine the type of resistance and the potential effectiveness of alternative insecticides.

Monitoring insects' reactions to insecticides is essential if farmers hope to avoid a potentially devastating increase in resistance, Brindley says. Scientists estimate that insecticide resistance has already occurred in more than 400 pest-insecticide combinations.

Much of Brindley's research concerns lygus bugs, plant-sucking pests that feed on more than 100 plant species including alfalfa. These insects are a thorny problem in alfalfa seed production in the Northwest in part because insecticides effective against lygus bugs often harm bees that pollinate alfalfa. Resistant lygus bugs have become more common in recent years, Brindley says.

Brindley tests for resistance by placing insects in plastic bags carefully treated with varying concentrations of an insecticide. The insects and bags are kept in a portable cooler at a constant temperature. After a short "incubation," insect mortality is recorded and used to calculate the LC50 (the lethal concentration needed to kill 50 percent of the insects).

The technique is far less expensive and about as accurate as laboratory bioassays, Brindley says. It works with many species of insects, including beneficial insects.

Brindley says monitoring changes in the LC50, which sometimes varies between adjacent fields due to different patterns of insecticide use, alerts farmers when to switch to a more effective insecticide before resistance becomes troublesome. With accurate spraying records, it's possible to determine whether an insect resistant to one insecticide will also be resistant to other insecticides.

Tests can be modified to determine which defenses an insect is employing against an insecticide. The procedure is as follows: A synergist, a chemical which blocks certain enzymes known to degrade pesticides, is used before adding insects to the insecticide-treated plastic bag. A decrease in the LC50 after the synergist is added indicates that these enzymes are involved in resistance to the insecticide.

"There have been some surprising findings concerning the relationship between resistance to insecti-
cides,” Brindley says. Some insecticides that supposedly fostered the same type of resistance turn out to trigger unrelated defenses. And, conversely, researchers learned of differences between other insecticides thought to induce similar mechanisms of resistance.

It also appears that levels of a certain enzyme are related to an increase in resistance as lygus bugs prepare for overwintering, perhaps in response to photoperiod or the type of plant hosts. Learning what underlies this increase could make it possible to manipulate resistance by biotechnological means, perhaps increasing resistance in beneficial insects and reducing resistance in insect pests.

KG  Bill Brindley 750-2551

*This research was partially funded by the Western Region of the USDA's National Agricultural Pesticide Impact Assessment Program (WR-NAPIAP)*
Researchers such as Chris Heck study the emergence and health of sugarbeet seedlings. People who spend a lot of time with their pets often tend to imbue them with human qualities. Anne Anderson spends a lot of time with plants. She thinks they talk.

The plant pathologist has overheard some curious exchanges, most of them involving an injured plant’s self-defense. The fragmentary conversations she has deciphered so far indicate how a plant’s molecular “language” changes in response to attacks by harmful microbes.

So far, Anderson has heard the start and end of a few of these “conversations.” Transcription of the complete dialogue will make it easier to genetically engineer disease-resistant plants.

There are uncanny similarities in the defense mechanisms of plants and animals. “It’s interesting that all cells in insects, animals and plants are not that much different in the methods they employ to try to defend themselves,” she says.

Translating A PLANT'S SELF-DEFENSE Vocabulary

Plants lack the immune system and specialized defense cells of higher animals but intricate molecular gambits let them “reprogram” each cell to resist a pathogen or injury, a process which often involves changes in enzymes or products normally used for other purposes.

In situ hybridization with messenger RNA (mRNA) lets Anderson monitor how messages slip through both the crystalline cellulose wall and membranes surrounding the cell and into the nucleus to change DNA and enhance resistance. Some of the bean cultivars she studies are resistant to races of the fungal pathogen *Colletotrichum lindemuthianum.* Comparing responses of resistant and nonresistant cultivars (and responses to different races of the fungus) differentiates between changes associated with resistance and those that are part of the normal molecular dialogue.
It takes a while for cells to let each other know what’s going on in what Anderson says are “interesting and delicate mechanisms to achieve differential gene expression,” but there are perceptible shifts in cell metabolism.

For example, 6 hours after a bean plant has been exposed to a pathogen product called an elicitor, plant cells 20 layers from the infected cells respond with molecular messages associated with defense. Moreover, in intact tissues, Anderson has found that the mRNA for enzymes associated with defense compounds accumulate in a wave-like pattern, perhaps because cells wait for messages from the cells that react first.

The plant starts to muster its molecular defenses when it recognizes elicitors, which are one of several types of surface structures on the fungus or fragments of plant cell walls. For some reason, perhaps because some plants and bacteria evolved simultaneously in symbiotic relationships, far more elicitors can be extracted from the surface of fungi than from bacteria.

One of the first resistance responses of a plant is a sharp increase in the production of hydrogen peroxide, an oxygen-rich compound that can kill invading microbes. “Hydrogen peroxide is also a messenger that signals cells to change their metabolism to produce protective proteins and other products,” Anderson says.

Little else is known about the biochemical processes triggered by an elicitor except that it is recognized by a receptor, which then initiates the changes in secondary messenger systems that alter cell metabolism. One result of these changes is the production of phytoalexins, plant antimicrobial compounds whose synthesis requires more energy and entails “extra housekeeping” to initiate new metabolic pathways. Her research centers on two key enzymes required to synthesize phytoalexins, chalcone synthase and phenylalanine ammonia-lyase. Other responses include the synthesis of enzymes such as chitinase, which degrades the cell walls of fungi, and perhaps those of bacteria.

These responses are involved in a dramatic resistance response called hypersensitivity, a localized response to microbes in which the plant prevents further growth and spread of the pathogen. Other resistance mechanisms of plants are systemic (where a challenge at one site triggers resistance at another, distant site), and immunity (in which the microorganisms survive but with diminished symptoms).

Some resistance mechanisms involve physical defenses. For example, the plant can form compounds that strengthen the cell wall or make it more difficult for pathogenic enzymes. The plant also invokes chemical defenses. An injured plant tends to produce more antimicrobial compounds, bacteria-killing chemicals such as hydrogen peroxide or phytoalexins and a variety of defensive proteins, some of which degrade fungal cell walls. Other, as of yet uncharacterized, proteins are produced in response to viruses and other stresses.

“For these changes to occur, messages must be triggered by contact with the microbial challenge. Some occur where the cell encounters the microbial challenge while other messages tell neighboring cells to prepare their resistance arsenal,” Anderson says.

Scientists’ ability to eavesdrop on these messages will eventually help plants improve their defense arsenal.

Anne Anderson 750-3497

Plants can reprogram cells to resist a pathogen or to counter the effects of an injury.
Nematodes. We can’t get rid of them so we’re learning to live with these parasitic round worms of plants and are developing better IPM programs to keep them at bay.

The ubiquitous worms are a problem for farmers throughout the world, who rely on crop rotation, cultivation and chemical nematicides to limit damage, says USDA nematologist Gerald D. Griffin. He studies nematodes in vegetable crops, alfalfa and range grasses.

The best way to keep populations in check on annual crops is to rotate host with nonhost plants, if possible. Unlike bacterial and fungal populations, which may rapidly “explode,” nematode populations increase more slowly and may be stymied when a non-host crop is planted. Control is necessary if the nematodes reach an “economic threshold,” a point where substantial economic losses exceed the cost of treatment. Unfortunately, economic threshold levels, which depend on cultural practices and environmental conditions, are not known for all nematodes.

“Ideally, crops should be rotated before nematodes become a problem,” he says. In perennial crops where crop rotation is not possible, treatment with nematicides before planting may be advisable. Nematicides approved for use in certain crops include 1,3-dichloropropene (Telone II®), a volatile fumigant, and aldicarb (Temik®), a systemic insecticide.

“One hundred percent control is not possible,” Griffin says. “And ironically, the greater the plant yield, the greater the nematode population.”

NEMATODES:
Suppressed but Never Vanquished

80 UTAH SCIENCE
Nematodes are found everywhere—in soils, oceans and mountains. “N. A. Cobb, the father of modern nematology, said that if the land masses were swept away, the world would still be dimly recognizable as a film of nematodes,” Griffin says. There are probably more kinds of nematodes than insects. Their small size (0.2 to 2.0 mm) and similar appearances often mean that only nematologists can tell them apart, although species differ in their hosts and lifestyles.

The science of nematology is still young, although knowledge of certain parasitic nematodes is as old as human history. The “fiery serpents” of the Bible were probably large nematode worms that parasitize human extremities. Hookworms, pinworms and trichina worms continue to threaten human health, particularly in underdeveloped countries.

Not all nematodes are parasitic and those species that parasitize plants pose no threat to human health. “If the plant-parasitic nematodes had an adverse affect on humans, we would have been dead a long time ago,” Griffin quips.

Nematodes that affect Utah crops are the alfalfa stem nematode that reduces shoot growth and thrives after heavy spring rains and irrigation, and the northern root-knot nematode that feeds on alfalfa roots and creates conditions favorable for infection by bacteria and fungi, which decrease root growth and can kill young alfalfa plants.

Cultural practices affect nematode damage of alfalfa. Nematodes reduce the amount of nonstructural carbohydrates that alfalfa plants store in their roots and crowns, and rely on to survive during the winter and during drought. Yields will decline and plants are even more likely to be damaged if stress on alfalfa plants is increased by harvesting too often.

The Columbia root-knot nematode causes abnormal growth of potato tubers, making them unsuitable for market. Damage varies with location and environmental conditions. Crop rotation won’t take care of the problem entirely.

“If we get a long hot season, we will have more nematode generations resulting in more damage than from a shorter cool season. By monitoring soil temperatures, we can predict the type of damage we’ll see in potatoes,” Griffin says.

Field and greenhouse studies indicate that nematodes may significantly reduce productivity in certain rangeland grasses, including the crested wheatgrasses. Chemical control on rangelands is impractical from both economic and environmental standpoints. The best option is to screen rangeland grass populations for tolerance to nematodes, a nematode-control method that is utilized in other susceptible crops.

JC

Gerald Griffin 750-3073
Farmers Should Benefit as IMMIGRANT LADYBEETLES Join Native Species

Ifalfa fields often teem with beneficial insects, all of which blithely ignore property lines. Many wander off in search of prey in other crops.

Farmers who don’t raise alfalfa have a stake in limiting pesticide applications on alfalfa fields, which are often “nurseries” for beneficial insects, says USU entomologist Ted Evans. He is studying ladybeetles, which are popularly (but incorrectly) known as ladybugs, some of the most valuable inhabitants of these verdant breeding grounds.

There are many native species of ladybeetles, but another species, the European native *Coccinella septempunctata*, is also moving into the state.

Evans is studying the rate at which this new species is becoming established in alfalfa fields and other crops in Utah and is determining whether this species will compete with native species.

Results of his laboratory studies indicate that the larvae of the new immigrant won’t unduly interfere with the foraging by native ladybeetle larvae. It also appears that *C. septempunctata* will help existing ladybeetles control aphids in crops and gardens.

Immature ladybeetles, ungainly grub-like larvae that blindly crawl about on alfalfa plants until they
contact and devour prey, have a voracious appetite for the larvae of alfalfa aphids and other insect pests, including the occasional alfalfa weevil larva. After molting several times, larvae of *C. septempunctata* pupate and emerge with seven black spots on a round, red back. Medieval Europeans associated these spots with the seven sorrows of the Virgin Mary, the origin of the name ladybird.

In England, millions of these ladybeetles can inhabit an acre of aphid-infested grain field. When the number of aphids decline, ladybeetles stream from fields to other areas, including the coast where they carpet and force the closure of beaches.

Ladybeetles can be equally conspicuous in the United States, and their predation helps keep a lid on the number of aphids, probably the second most damaging insect pest of alfalfa in Utah (next to alfalfa weevils). While entomologists have not quantified the value of ladybeetle predation, farmers must often contend with the prolificacy of aphids, which Evans says have a “tremendous reproductive capacity and can complete a dozen or more generations during a single growing season, leading to an astronomical increase in population.”

*The more insecticide farmers apply to control alfalfa weevils, the more they harm ladybeetles and other predators of alfalfa aphids.*

Ladybird beetle larva
Aphids aren't a greater problem due in large part to ladybeetles and other aphid-eating insects, including parasitic wasps, lacewings, big-eyed bugs and hover flies, most of which are also very susceptible to the insecticides used to control serious infestations of weevils.

“We are pretty well convinced that if we didn’t have to pray for weevils, we wouldn’t have to pray as much to control aphids,” Evans says. Because ladybeetles are so mobile, farmers raising other crops may have a larger stake than they realize in programs to reduce insecticide use on alfalfa fields.

Ladybeetles have long been a favorite weapon of entomologists. More than a century ago, entomologists introduced the Vedalia beetle, a species of ladybeetle from Australia, to southern California, where it proceeded to wipe out cottony cushion scale that threatened the state’s young citrus industry. Since then, entomologists have tried to duplicate this feat by introducing other species of ladybeetles, generally with limited success.

Entomologists with the U.S. Department of Agriculture are again introducing C. septempunctata after several previous unsuccessful attempts. Twenty years ago, however, entomologists discovered an established colony in New Jersey of unknown origin that was spreading on its own accord. Entomologists decided to aid the sweep of this species across the country, which has now been purposely introduced to states surrounding Utah. A few have migrated into Utah on their own. Their numbers are expected to increase throughout the state, Evans says.

KG
Ted Evans 750-2552

Seed Coat Proteins May Improve Disease Resistance

Molecular biologist Elizabeth Hood and co-workers have isolated a protein from the seed coat of corn that may help the plant resist disease-causing microbes.

“We know that certain proteins in the seed coats of dicotyledons—beans, for instance—are involved in disease resistance, but this has yet to be demonstrated for the monocotyledons,” she says.

The proteins are embedded in the nonliving cellulose cell walls of the seeds. “Cell walls were formerly thought to be—well, boring,” Hood says. “Now we’re finding that they go through a number of changes. They loosen to allow expansion, and their components change throughout development.”

They may also affect resistance or susceptibility to disease. Tough cell walls may be impermeable to pathogens, or may inhibit bacteria and fungi.

Hood identified an hydroxyproline-rich glycoprotein in the seed coats of corn that consists of about 430 amino acids. Its concentration is greatest 20-40 days after pollination.

Popcorn seeds, whose coats are thicker and watertight, contain about three times as much of the glycoprotein as sweet corn seeds. Popcorn pops when heated and the water inside the kernel expands and bursts the seed coat.

“We’re now ready to isolate the genes coding for the corn cell wall protein,” she says. The procedure involves isolating the messenger RNA, constructing its DNA complement and inserting the DNA complement into a bacterium. If the right genes have been transferred, the bacterium will produce the protein.

If the protein is involved in disease resistance in corn, it should be possible to genetically engineer plants with more disease-resistant seed coats.

JC
Elizabeth Hood 750-3711
Models Track

CHEMICAL MOVEMENT

Through Soils

SU researchers are developing models to predict what happens to pesticides and other chemicals as they travel through soils.

"Not much is known about what happens to many of the agricultural chemicals after they are applied to soil," says physical chemist David Marshall. The ability to predict the movement of chemicals in soil will make better use of pesticides as well as reduce the risk of runoff and groundwater contamination.

Marshall is developing a model based on the rapidity and strength of chemical binding. Compounds vary in their affinities for different soil components.

Marshall says the model he is developing with Karl Topper, a graduate student in soil science, will apply to radioactive isotopes, ions and metals, as well as agricultural chemicals.

"The usual models are too simple," Marshall says. "We'd like to predict the persistence of chemicals, how they move, how fast they move, and the potential for groundwater contamination. The rate of a chemical's movement depends on its attachment to materials it encounters.

"The problem is that we know so little about the fundamental interactions of chemicals with soil particles," Marshall says.

In a separate study, Joan McLean and William Doucette, chemists with the Utah Water Research Laboratory, are investigating the sorption affinity of various pesticides for different soil components, information required by existing models of soil transport.

McLean notes that many of the models now used to predict the movement of organic contaminants such as pesticides often assume that a soil's organic carbon content is the most important factor governing the sorption of chemicals to soil. This approach isn't very accurate in many western soils that contain relatively little organic matter. Moreover, most studies of this type have emphasized petroleum-based chemicals, which tend to be more non-polar than pesticides.

McLean and Doucette will determine how other soil components, such as clay and sand, and the chemical structure of various pesticides affect movement.

JC/KG

William Doucette 750-3178
David Marshall 750-1628
Joan McLean 750-3199

This research was partially funded by the Western Region of the USDA's National Agricultural Pesticide Impact Assessment Program (WR-NAPIAP)

Pesticide movement through soil depends on chemical binding and other soil characteristics such as the proportion of clay and sand.
Foresters were among the first to rely on integrated pest management. They had little choice. Their relatively low-value "crop" covers millions of acres. Stands may not generate any income for decades. While farmers might spend tens or even hundreds of dollars an acre to fend off an insect or disease (and at least have a chance of recovering their costs), foresters usually have had to find some way to accommodate natural forces and processes to garner any profits.

"Foresters have used integrated pest management longer than integrated pest management has been around," says USU forest pathologist Fred Baker. Even though insecticides, pesticides and herbicides are used sparingly, the role of IPM in forestry is not widely acknowledged.

Baker says the goal is to manage forests as naturally as possible. Some losses are inevitable, but native trees and their pests, which have co-existed for thousands of years, have reached a balance that can be changed by a shift in management. The shift may favor the tree—or the pathogen.

There are gains and risks in introducing exotic species of trees. These species may flourish in the new environment where pests from their native environment are lacking. However, they often succumb to a pest that has little effect on native species, Baker says.

The possibility of introducing exotic pests on imported plant materials is an even greater concern. Dutch elm disease, chestnut blight and white pine blister rust, which devastated forests in the United States, are examples. Dutch elm disease alone is estimated to have cost the timber industry billions of dollars in the United States alone.

There is a perception among many foresters that IPM will not work in their region. They believe IPM is best suited for warm, humid climates and theSoutheast, for example. But Baker says that while temperature and humidity are important, IPM can be successful in any region.

"IPM is not a single approach," Baker says. "It’s a management philosophy that involves understanding the ecology of pest outbreaks and using a combination of tactics to manage pests.
States, were introduced from other continents.

Baker's research concerns the relationship between management practices and the vulnerability of forests to parasitic organisms that either stunt or kill trees. More intensive management or interference with the "natural" forces in a forest system can dramatically affect the productive capacity of a forest, Baker says. For example, fire control has changed the species composition of trees and the types of pests. Intense fires that cleaned forest stands also killed dwarf mistletoes. An unwelcome byproduct of fire prevention has been an increase in dwarf mistletoe.

A tree's response to aboveground insect pests sometimes depends on what happens underground, as illustrated by Baker's studies of two fungal root diseases.

The stress induced by a pathogen apparently weakens a tree's defense systems and makes it more susceptible to other pathogens and forest insects. Lodgepole pines infected with the fungus *Armillaria ostoyae*, which attacks roots, are more prone to attack by the mountain pine beetle.

"There can be a tremendous amount of root disease present with no aboveground symptoms," Baker says, which makes it difficult to predict the chance of a mountain pine beetle infestation.

Conventional sampling for the fungus involved digging up roots, a grueling task that hampered sampling. Baker and graduate student Stefen Zeglen have developed easier and more accurate sampling methods that involve digging a few small pits.

It was once thought that mountain pine beetle infestations were cyclical, and occurred only in dense stands of large trees. A stand was supposedly "safe" from attack for several years following an infestation. "It now appears that there are some sites infected with the fungus where mountain pine beetle seems to persist, but we really don't understand why," Baker says. Root disease may play a role.

Tomentosus root disease, which is caused by the fungus *Inonotus tomentosus*, attacks blue and Engelman spruces growing at high elevations. Foresters attached little significance to the presence of the fungus until several persistent outbreaks of spruce beetles indicated that stress from the root disease made trees more susceptible to these pests.

The relatively inhospitable environment at high elevations—intense ultraviolet radiation, thin soils,
How MISTLETOE Chokes Forests or the Kiss of Death

A few of the more than 1,500 types of mistletoes are Christmas traditions, but not the dwarf mistletoe Arceuthobium americanum.

Like all mistletoes, A. americanum contains some chlorophyll, which lets it synthesize some carbohydrates. However, it appropriates most of its water and nutrients from host trees. This usually doesn’t appreciably slow growth rate until the mistletoe parasitizes the upper half of the crown. As mistletoe demands more nutrients, an infected branch can become several times larger than nearby uninfected branches. Infected branches eventually outcompete and kill adjacent uninfected branches. Over time, photosynthesis by the few remaining uninfected branches is reduced so much that the tree dies.

These aerial parasites expel their seeds at a speed of about 90 feet per second and as far as 50 feet. Not much is known about the long-distance dispersal of A. americanum seed. Dwarf mistletoe spreads farther than can be accounted for by exploding seeds, which indicates some seeds are probably carried by birds and other wildlife.

The viscous coat of the seed sticks to needles, usually until the first rain when seeds slide down the needles. Some become attached to the twigs, where they germinate and infect the tree. A. americanum is unusual among the dwarf mistletoes in that it can become established on older branches.

The penetrating edge of the mistletoe enters the cortex, and sends a rootlike system throughout the bark, some of which become embedded in layers of xylem. It usually requires an incubation period of 2 to 5 years for a newly established plant to form aerial shoots, and at least 6 years to start producing seeds.

and extreme temperatures—make it difficult to reestablish seedlings. Regeneration has usually involved leaving a few mature trees to shade seedlings, but Baker says it may be necessary to remove all spruces on tomentosus-infected sites to avoid infecting seedlings. The fungus persists in roots for at least 25 years, which means that planting of susceptible seedlings must be delayed at least that long.

Bulldozing stumps to expose roots to air accelerates demise of the fungus, but is usually prohibitively expensive, about $300 per acre. Another alternative is to let aspens naturally colonize infected sites that have been logged. After 25 or 30 years, spruce will naturally reinvade the site.

Baker is also studying the spread and control of dwarf mistletoe (Arceuthobium americanum), which can damage and eventually kill lodgepole pine, the most widely distributed conifer in western North America, and jack pine, which is a valuable timber species in Canada. Recent surveys indicate that about 60 percent of the lodgepole stands in the Intermountain Region and almost 25 percent of the timber-growing area in Manitoba are infected.

When the parasite infects a branch, it causes a proliferation of branches called a witches’ broom. Witches’ brooms can be so thick that it may be difficult to get close enough to the trunk to fell infected trees.

Baker is participating in a 5-year study to evaluate the effectiveness of various management techniques. Results are also incorporated in a model to predict rate of spread of the parasite. It now appears that severely infested trees should be removed, but lightly infested trees can remain without significantly reducing timber production.

KG  
Fred Baker 750-2550
The Chemical Changes that Transform a BACTERIA from Friend to Foe

These microbes may be the Dr. Jekyll and Mr. Hyde of the plant world. They protect healthy plants from fungi but mercilessly attack cells in diseased or injured plants.

A USU researcher is determining how this transformation occurs.

The bacteria are *Pseudomonas syringae* pv. *syringae*, a widespread microbe which colonizes the surfaces of most plants and a culprit in many plant diseases. Scientists have recently recognized that the low levels of the toxin syringomycin that these bacteria produce on healthy plants "may be Nature's way of controlling fungi," says molecular biologist Jon Takemoto.

But on an injured or diseased plant, numbers of this opportunistic pathogen multiply and syringomycin levels increase astronomically "perhaps in response to signals produced by the plant itself," Takemoto says. He found that syringomycin opens up a channel in the cell membrane that allows calcium to rush into the cell, triggering harmful changes in enzyme activities, and in cell structure and development.

Last year, he and his co-workers identified the structure of the toxin as a lipopeptide, a type of molecule known to interact with membranes. The next step is to identify where the toxin binds with the cell membrane, which may also be the site where calcium enters the cell.

Researchers recently discovered several other strains of *P. syringae* that produce toxins with slightly different structures. "We may have just scratched the surface concerning these toxins, and for that matter, the lipopeptides produced by these types of pathogens," he says.

Yeast is extremely sensitive to the toxin and its genes are relatively easy to identify and isolate. Takemoto uses it as a model system to determine enzymatic changes precipitated by this toxin. "So far, the physiological events appear to be similar in yeasts and plants," he says.

Takemoto's research is supported by the National Science Foundation, the Utah Agricultural Experiment Station and the USU Biotechnology Center.

*KG*
For the
UTAH APPLE MAGGOT,
a Name Change Might be in Order

S

ometimes laws supersede knowledge, and integrated pest management takes it on the chin. That happened recently with the infamous apple maggot, a pest that apple producers in Utah were forced to "control" even though it has posed little threat to apples in this state.

Some California laws governing the importation of apples didn't accommodate what researchers learned about the insect pest, whose larvae can burrow through and ruin fruit, says USU entomologist Diane Alston. When apple maggots are found within 1/2 mile of an orchard, Utah growers are forced to spray with an insecticide every two weeks to meet quarantine requirements imposed by California, even though USU researchers discovered that apple maggots posed a negligible threat to apples.

In Utah, entomologists learned that apple cultivars usually ripen too late for the apple maggot (Rhagoletis pomonella), but cherries are susceptible to attack. The main (and native) host of the pest is wild black hawthorn, plants in the same family as apples but of no economic consequence to growers.

In the eastern United States, the apple maggot switched to apples about a hundred years ago, a prospect that alarmed fruit growers in Utah.

Researchers say the life history of the insect and its synchronization with host plants indicate that switching is less likely to occur here. "The apple maggot has been here for decades, and it's abundant in the state on hawthorns, which grow in riparian areas of the northern mountains," says entomologist Frank Messina. "But, despite the insect's name, it doesn't attack apples. Only a few uncommon early varieties that are grown as backyard trees appear vulnerable, but even these have been spared."

The difference in hosts between the Utah and eastern apple maggots probably reflects the relative timing of fly emergence, and may also reflect genetic differences.

The time of fruit maturation influenced a fruit's susceptibility to attack. In the early 1980s, the apple maggot was discovered in sour cherries. "The sour cherries were quite ripe, but apparently they were still suitable as a host for the apple maggot," Messina says. Now, however, surveys indicate that the apple maggot population did not sustain itself.

Why not? That's difficult to answer, and may reflect several factors, including developmental and behavioral considerations.

In laboratory studies with natural and artificial fruits, Messina and his co-workers found female flies are attuned to color, odors, and the curvature of the substrate. Egg-laden females preferred hawthorns and cherries far more than apples.
Messina used a “penetrometer” to measure the puncture resistance of fruits when the flies were ready to lay eggs. Apples’ high resistance indicate that mechanical factors are also involved in the flies’ avoidance of this fruit. Messina continues to examine other factors that affect the egg-laying behavior of apple maggots and other insects, including seed beetles.

Alston attributes some of the decline to the removal of abandoned orchards and hawthorn trees near productive orchards. Although apple maggots are widely dispersed in the state, the only areas where they are found near to apple orchards is in areas of Utah County.

In studies of the western cherry fruit fly, Messina found that the even, uniform dispersion of eggs indicates that females mark fruit when they lay eggs so other females can avoid this fruit. That benefits these insects, but distributes the damage more widely.

The bottom line is that learning how to implement an integrated pest management program isn’t always enough. Sometimes economic realities have more clout.

“We have tried to convince California that apple maggots will not infest our apples, but they want to be sure and haven’t lifted the quarantine. Spraying for apple maggots is hard on beneficial insects,” Alston says.

JC

Diane Alston 750-2516
Frank Messina 750-2528
Good Guys or Bad Guys?
PLANT/MICROBE RECOGNITION

It’s an underground movement that includes chemical warfare.
And it crops up all over.
The subterranean players in this drama are soil microbes, some bad, some good. A USU researcher studying how plants distinguish between beneficial and pathological microbes says findings could have widespread application in biotechnology.

Mycorrhizal fungi are beneficial microbes that, among other functions, help plants procure otherwise unavailable nutrients and water. Some mycorrhizae colonize the interior of roots, while others stay on the outer surface.

The mechanisms these fungi employ to reduce a plant’s resistance so they can colonize roots involve modification of a plant’s expression of disease-resistance genes. This attribute might have several applications in biological control, says molecular biologist Anne Anderson.

“For instance, we might insert a gene into the fungus to make it antagonistic toward disease-causing microbes, which would enhance its beneficial effects.”

Learning more about the defenses plants employ against harmful microbes might also enhance a plant’s resistance to pathogens.

“It’s chemical warfare,” she says. “Some plants produce enzymes that digest or break down the invaders. Some plant chemicals are phenols that create a barrier similar to the ultraviolet barrier created by melanin in human skin. Some barriers are species of oxygen that are very destructive, and some are antibiotics.”

Mycorrhizae are found in all kinds of plants from trees to agricultural crops, and are useful in reforestation and in the revegetation of mine spoils, as well as fostering crops in suboptimal soils.

“We know that plants are growing with fungi, but we don’t appreciate the interactions. Some microbes inhibit the growth of other microbes. There are bacteria that suppress pathogen growth in the soil, for instance. These microbes might be used in natural control,” Anderson says, thus improving the productivity and quality of agricultural production.

Anderson’s research is supported by the U.S. Environmental Protection Agency, the National Science Foundation, the USU Biotechnology Center and the Utah Agricultural Experiment Station.

JC

Anne Anderson 750-3497