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If you were going to design a biocontrol, you couldn't do better than this fungus. It's cheap (free, actually), persistent, and does exactly what it's supposed to—attack a particularly troublesome weed—and no more.

Its selectivity—a powerful attribute in biocontrol—is also part of the problem. Because it affects only dyers woad, whose distribution is relatively limited, there are few economic incentives to develop a commercial product from the fungus. (Registration of a new pesticide, which is how the fungus would be classified by the Environmental Protection Agency, costs millions of dollars.) Of course, the fact that the fungus is free also dampens the commercial possibilities.

Nonetheless, the fungus has earned a special place in the hearts of weed-haters, who can spread the fungus on their own. At USU, the researchers and extension specialists who plumb the practical applications and scientific anomalies of the fungus refer to it in respectful, admiring terms, as if it were a long-lost friend. In some respects, it is.

After it infects dyers woad, the fungus keeps the weed in check without herbicides or repeated inoculations, a
“green” solution to a weed that previously seemed to have no enemies. Dyers woad was spreading in inaccessible and wilderness areas, where herbicide applications were either impractical or illegal.

A REDUCTION IN SEEDS

“It’s important that people understand that an effective biocontrol agent can greatly reduce weed density and may slow the spread of a weed, but it can’t contain or completely eradicate a weed population. Mechanical, chemical, cultural, and biological control methods will be required to stop the spread of the weed,” said Extension weed specialist Steve Dewey.

The fungus prevents or reduces seed production in infected plants, and may also affect the survival of seedlings, rosettes, and overwintering plants, Dewey said. Due to fewer seeds, the primary method by which dyers woad spreads and reproduces, infestations of the weed may be thinned substantially within a few years. In some areas once choked with dyers woad, the fungus has returned the landscape to near-normal diversity.

“We know other factors may be involved in the reduction of woad infestations, but the fungus appears to be the primary factor at many locations,” Dewey said.

The fungus is a type known as a rust. “There are rusts that attack virtually every plant species, but most require two different hosts,” said Extension plant pathologist.
Sherman Thomson. The woad rust may have once required an alternate host but has retrogressed and—fortunately—can complete its life cycle solely on dyers woad. Such microcyclic rusts are very useful in biocontrol because the elimination of an alternate host markedly increases its ability to spread.

Another plus—the woad rust is a systemic fungus that affects the physiology, metabolism, and morphology of the host, delivering a powerful and debilitating blow to the plant. Most rusts target only a small portion of the host plant, and may cause small spots on leaves, leaving the plant virtually unscathed.

The rust was discovered by a weed supervisor near Niter, Idaho, in 1978. Dewey, who was then Extension weed specialist at the University of Idaho, began monitoring it as a potential biocontrol agent in 1982. He continued these studies at USU and introduced the rust into Utah in 1987.

**Woad “Shakes” and Powders**

Although initially identified as *Puccinia thlaspeos*, the fungus appears to be a distinct but closely related species. Until more is learned about its identity, it is known simply as “the woad fungus.”

Anyone can emulate the inoculation techniques of the USU researchers, who collect infected plants in the spring, strip off leaves to reduce the bulk, and either dry and grind them, or macerate them with water to create a “woad shake.” A household blender should be adequate to produce a woad shake if a mill for grinding dry material isn’t readily available.

The rust inoculum is then scattered near or sprayed on young (rosette) plants. In two studies, there were no differences in the infectivity of dry or wet inoculum. Symptoms usually don’t appear until the following spring. Infection rates usually exceed 50 percent. On some sites, 90 percent of plants have been infected, not total eradication but much better than a thicket of woad plants, especially since the rust keeps on working year after year at no cost.
The rust has several intriguing features, said USU plant pathologist Brad Kropp, who employs the polymerase chain reaction, a molecular technique, to develop an "early detection" method so researchers don't have to wait 6 - 9 months until symptoms appear to determine if a plant has been infected.

Compounds (glucosinolates) produced by dyers woad inhibit the germination of seeds of other plants, and may partially explain the woad's competitiveness. Australian researchers are interested in transferring the gene(s) controlling the production of these germination inhibitors to crops such as canola, thereby improving crops' ability to compete with weeds. (Dyers woad and canola are both members of the genus *Brassica*.)

**Uncertain Origin and Action**

Kropp also studies how the rust enters and colonizes plants, and where it resides in plants. "We have found it in some surprising locations, such as the roots," Kropp said. Plants can be infected by inoculating leaves, although there may be other modes of infection. Kropp speculated that the rust enters through leaves, migrates to the meristems where it lurks until the stem bolts and forms new leaves.

Preliminary analyses of DNA sequences revealed that the rust may differ from *P. tibiaspeos*, although it is probably closely related. The rust is of uncertain origin, and researchers hope to determine whether it arrived in North America with the weed (it hasn’t been reported on woad plants in Europe, however, where woad originated) or hopped from native plants.

"It's safe to say that we don't know exactly what species it is," Kropp said. Dewey agrees. "We have made significant progress in some areas, but in some respects we don't know much more about the rust than when we started."

Extension plant disease diagnostician Karen Flint is determining the optimum time to inoculate plants and the conditions that favor spread of the rust, as well as the best methods to prepare and store inoculum. Plants have been successfully inoculated using rust that has been frozen and stored for a year.

The rust is an obligate parasite and can be cultured only on living dyers woad plants. If the demand for rust ever outstrips the natural supply, it might be necessary to plant dyers woad on "rust farms."

That could be an ironic twist in the history of weed control—growing a weed in order to get rid of it. KG/John Devilbiss

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*An idyllic mountain scene except for the presence of dyers woad. A plant infected with the "woad fungus" is visible on the right.*
Promising Biocontrol of Wheat Disease

There are promising results in the search for a biocontrol agent of dwarf bunt disease in wheat. USU researchers have isolated a strain of bacteria from wheat that produces a potent antifungal agent. They are now determining whether the bacterium wards off the dwarf bunt fungus in the field.

Dwarf bunt, which can infest winter wheat in the Pacific Northwest and Northern Utah, replaces wheat kernels with a black smut. Resistant varieties confer protection against the fungus, but new sources of resistance and additional control options are required as races of the fungus evolve.

The bacterium, a strain of *Pseudomonas syringae*, was isolated from wheat grown in Cache County. The strain M1, named after the Manning variety of wheat on which it was detected, produces syringomycin, a peptide with known antifungal activity. Laboratory tests showed that the peptide was effective against the dwarf bunt fungus.

In greenhouse studies, small grain breeder David Hole and microbiologist Jon Takemoto found that spraying infected wheat plants with either the M1 strain or with syringomycin suppressed the dwarf bunt fungus.

Nearly a hundred different strains of *P. syringae* have been isolated from several plant species. Many strains are pathogenic, but some exist harmlessly on plants, Takemoto said.

Some researchers believe these bacteria are usually harmless until they encounter an injured or weakened plant, which they can then opportunistically invade. Some can form ice crystals at temperatures slightly above freezing, thereby injuring plants. The ability to form ice crystals helps bacteria survive cold weather, but it is not a desirable property in a biocontrol agent. USU researchers are now determining whether the strain M1 has this and other undesirable characteristics.
"I don't think M-1 is pathogenic, but rigorous testing will be required to confirm this," Takemoto said.

Field tests began in the winter of 1993, but conditions didn't favor the fungus, which requires moist, cool conditions with ample light and several months to germinate.

If the results of this year's field trials confirm M1's protective ability, there are several control options, one of which is inoculating seed with bacteria before planting. The M1 strain may have to be genetically engineered to remove genes associated with pathogenicity without altering its ability to produce syringomycin. Another option is to produce large quantities of antifungal syringomycin to treat infested plants.

Development of a commercial product is likely to require several more years of research, the scientists said. KG

**RECENT GRANTS AND CONTRACTS**

Noelle Cockett, Animal, Dairy & Veterinary Sciences Department, offers a research apprenticeship program for minority high school students with support from the Cooperative State Research, Education and Extension Service (USDA).

Jeffrey Broadbent and Bart Weimer, Nutrition & Food Sciences Department, study the causes and amelioration of bitterness in cheddar cheese. Their research is funded by the Office of International Cooperation and Development (USDA).

Esmail Malek, Plants, Soils & Biometeorology Department, evaluates evaporation, evapotranspiration, energy, and radiation components in a semi-arid environment with support from PacifiCorp.

Lynn Dudley, Plants, Soils & Biometeorology Department, studies the use of saline waste water from electrical power plants for irrigation. The research is funded by PacifiCorp.

The National Aeronautics and Space Administration funds research by Bruce Bugbee, Plants, Soils & Biometeorology Department, concerning the optimization of crop production using CO₂ gas-exchange.

Kay Asay, Plants, Soils & Biometeorology Department, develops and evaluates plant materials for roadsides for the Utah Department of Transportation.

The National Science Foundation funds research concerning stomatal responses in intact leaves by Keith Mott, Biology Department.
**ECONOMISTS HELP CHART COUNTY’S FUTURE**

What’s the economic prognosis for San Juan County?

Promising, but county residents will have a much better idea of the magnitude of growth—and more say in determining the type of development—following completion of a comprehensive inventory of the county’s economic resources.

The 400-page inventory by USU economists Donald Snyder and Chris Fawson compiles human, mineral, water, scenic, business, soil, and other resources in the county. It also assesses the infrastructure in the county, assets such as educational institutions, roads, and sewers.

“I was extremely impressed with the investments that the county made in infrastructure during the last few decades to facilitate economic growth,” Snyder said.

Questions remain about the type and consequences of economic growth in the southeastern Utah county, however. Monticello and Blanding, the two largest communities in the county (which has a total population of about 10,000) are already experiencing the effects of increased tourism from Moab. The county has also weathered a precipitous decline in mining.

Some of the decisions concerning economic growth may not be within the control of county officials, Snyder said, citing the decline in the mining and the increase in tourism. However, there are still ample opportunities to direct economic growth by protecting known resources, such as mineral deposits, and through zoning ordinances.

Other major decisions will involve trade-offs between enterprises, such as whether to encourage agriculture or tourism. County officials worry that the costs associated with tourism, such as trash collection, may largely offset the economic benefits of tourism.

Economists digitized maps of resources to facilitate comparisons of the location of various resources. The economists also compiled recent expenditures by the county, thus indicating where revenue had been allocated in the past.

“There is a tremendous amount of information available to counties, although most of it is difficult to compile and may not be readily accessible. This is unfortunate because many counties make decisions without a comprehensive knowledge of resources,” Snyder said.

The study was supported by state Mineral Lease funds. USU economists offer similar assistance to other counties. Private consulting firms also provide this assistance, although Snyder noted that, unlike a consultant, USU economists will continue to offer advice after the study is completed.

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WET WEATHER FAVORED "NEW" PLANT DISEASES

Last spring's prolonged wet weather favored the spread of several plant diseases seldom seen in Utah. These diseases probably won't persist if weather conditions revert to normal, according to USU plant pathologist Sherman Thomson.

However, control measures might be warranted if we experience another wet spring. Thomson recommends keeping a watchful eye on weather conditions.

The wet weather favored the spread of apple scab, which has now become relatively common in a few orchards in Utah County. Fortunately, USU plant pathologists were able to predict its spread and warned growers to apply fungicides. Those who followed the advice staved off serious problems. Those who didn't had a serious problem.

Barley stripe rust, an airborne fungus, surfaced in a few locations last year and gained a foothold in many barley fields in three counties this year. So far, it hasn't appeared to cause serious economic losses but it could if wet conditions persist, favoring its spread.

Many sycamores, oaks, mountain maples and other ornamental trees experienced severe defoliation due to fungi. The problem was also evident on trees in some canyons. Trees should recover from one year of defoliation, but might not survive several consecutive years of defoliation.

Thomson says producers and homeowners in areas that are normally wet expect diseases favored by damp conditions and incorporate the appropriate control measures into their management schemes. Not so in Utah, where spring rains and related diseases are usually intermittent.

The Utah Agricultural Experiment Station supports the plant disease survey, a program to continually monitor the presence and distribution of new diseases or outbreaks, and to study the origins and control of these new diseases. Almost 300 samples were processed by the USU Plant Pest Diagnostic Laboratory during the 1994 growing season. KG

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USU researchers are studying bacteria that may be a biocontrol agent against a group of fungi (*Ascosphaera aggregata*) that causes chalkbrood syndrome of bees.

For almost two decades, the alfalfa leafcutting bee (*Megachile rotundata*), the prime pollinator of alfalfa seed crop in the Pacific Northwest, has been afflicted by the disease chalkbrood, caused by the fungus *Ascosphaera aggregata*, which is the species of the fungus that is most pathogenic to the alfalfa leafcutting bee. (*A. apis* is the species that is most pathogenic to honeybees.) Chalkbrood often kills more than half the bee larvae in commercial operations and in feral populations.

Chalkbrood is now so pervasive in alfalfa fields that, for several decades, most growers have imported these bees from Canada instead of trying to propagate their own. Unfortunately, the disease has acquired a foothold in Canada, and chalkbrood threatens this source of bees—and also threatens the production of alfalfa seed in the United States, the source of 80 percent of the world’s supply.

**Antifungal Bacteria**

Entomologist Nabil Youssef and coworkers serendipitously discovered four species of antifungal bacteria (*Bacillus subtilis*, *B. macerans* (a), *B. macerans* (b), and *Pseudomonas cepacia*) several years ago in bee cadavers. Some of these bacteria appear to be more pathogenic to the fungus than others. All seem to attack the fungus via different mechanisms. “Some of the fungal cells lost turgidity and appear ‘wrinkled’ and others have broken cell walls. We never found any of the bacteria inside the fungus, which indicated the bacteria produce substances that interfere with the fungus,” Youssef said.

Youssef is now characterizing these antifungal substances, which could be antibiotics or toxins. If the biocontrol agent is effective against *A. apis* (the semi-pathogenic species of the fungus) it might be effective against *Ascosphaera* pathogens of other bees and against plant pathogens as well. It may also have applications in human medicine.
This summer, the USU researchers will introduce the bacteria into natural provisions in hives, along with fungal spores, and will monitor the outcome. The best (but somewhat unlikely) outcome would involve death of only the fungus. The worst outcome is that conditions in the gut of bees don’t favor growth of the bacteria, thereby failing to impede fungal growth.

The most likely outcome, Youssef said, is that the bacteria may not kill the fungus outright but will deter sporulation, thereby stemming spread of the disease.

**PATHOGENICITY IDENTIFIED**

Efforts to control the disease also involve identification of the source of the pathogenicity of the fungus. Many fungi that are pathogenic to plants contain plasmids, independent pieces of DNA found outside the nucleus. A plasmid was found in a strain of the semi-pathogenic *A. apis*. Another very pathogenic species of the fungus contained four plasmids, all of which appear to be unrelated.

The researchers are trying to produce a mutant strain that lacks these plasmids. These plasmid-free fungi will clarify the biological function of these plasmids and determine whether the plasmids are related to pathogenicity.

Research has been hampered by the difficulty of culturing the fungus. Most fungi multiply in several days. The sluggish *A. aggregata* must be cultured for four weeks before it replicates enough to be studied.

“Our work appears to be the first instance in which biocontrol is used to control a disease of beneficial insects,” Youssef said. “Usually, this type of research attempts to make insect diseases more virulent to control harmful insects.” KG

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Roots & Company: Underground Assistance for Crops

Talk about crowded: Millions of bacteria, fungi, protozoa, viruses and sundry other organisms lurk in a gram of dry soil.
It's a jungle down there. Fortunately, many of these microbes are benign. Some even promote plant growth. Still, there are certainly enough pathogens to debilitate or destroy plants. Soil-borne pathogens cause more than 3,300 root diseases worldwide—root rots, seedling blights, wilts, and crown and foot rots, and other diseases with similar unappealing but descriptive titles. Soil can be a nasty place for a tender root.

Even those close to the subject occasionally sound discouraged. "Of the maladies that affect roots there is seemingly no end," lamented plant pathologists in a textbook.

Plants aren't completely defenseless—many release substances to counter microbes, a process that scientists are examining in more detail—but these tactics are only partially effective.

A promising biological control (biocontrol) method involves increasing the number of beneficial microbes, including those antagonistic to pathogens, in the soil. It's an intuitively sensible approach, much like the notion that putting more police on the streets will reduce crime.

And it's just about as effective—or ineffective—as more police on streets. Criminals move and police can't be everywhere. The same type of impediments apply to beneficial microbes—for a variety of reasons, even the addition of billions might not make a dent in the incidence of disease.

The goal is to create a "suppressive soil," one inimical to pathogens. The problem is that it's difficult to alter the ecology of soil in more than a transitory fashion.
Of particular interest is the soil-root interface, the rhizosphere, which teems with several times as many microbes than the soil below because it is far richer in energy.

"Soils are enormously diverse and reach a dynamic equilibrium that is resistant to change," said USU plant pathologist Anne Anderson, who studies soil-borne pathogens, as well as several promising biocontrol agents.

There's a lot to consider about these underground allies. How many beneficial microbes are required? Can they survive when on sandy soil? Loam? When it's wet? Dry? Hot? Cold? With fertilizer? Without? On different crops? Against different diseases?

Of particular interest is the soil-root interface, the rhizosphere, which teems with several times as many microbes than the soil below because it is far richer in energy. Unfortunately, it's still largely unknown terrain. Finicky microbes also hamper research. For example, some won't grow without the appropriate plants. Results in the lab can be difficult to duplicate in field experiments, and the mechanisms that apply in field studies can be difficult to discern in the lab.

**Bacteria Provide Assistance**

The biocontrol of soil-borne plant diseases, including those studied by USU researchers, often involves pseudomonad bacteria. These bacteria are ubiquitous in soil and often attack disease-causing fungi. Several have proved their mettle as biocontrol agents.

Biocontrol has chalked up some successes in the control of soil-borne diseases. One example: In Australia, growers dip the roots of fruit trees into a nonpathogenic strain of agrobacterium that confers protection against crown gall caused by *Agrobacterium tumefaciens*.

Nonetheless, the use of microbes in biocontrol hasn't been as easy as, for example, inoculating soybeans with Rhizobium, an inexpensive measure that markedly increases the amount of nitrogen available to roots. "It's baffling why this inoculation should be so successful while similar approaches to biocontrol are so variable," Anderson said. This variability can be an asset in targeting control of a specific disease but it also explains why reliance on biocontrol against soil-borne pathogens is minuscule compared to the reliance on chemical controls.

"Industry research has declined because of the variability of biocontrol. A company generally wants to focus research on one major crop or on a biocontrol that offers protection against a wide variety of diseases. That probably won't be possible with biocontrol," Anderson said.
Biocontrol in Several Crops

The approach of Anderson and USU plant pathologist Brad Kropp differs from that of many researchers, who usually focus on one crop. They study biocontrol of soil-borne pathogens in sugarbeet and wheat, two crops often grown in rotation in the region.

Some forms of disease control are simple but effective. Anderson found that heating wheat seeds to 50°C for 30 minutes destroys the fungal pathogens *Acremonium* and *Cladosporium* carried within the seed. Beet seeds are similarly cleared of internal fungal pathogens by heating.

“All soils contain a high percentage of organisms with the potential to be antagonistic to harmful organisms,” Anderson said. Fungi are a common source of root diseases, whose most common antagonists are bacteria. “However, it appears to be difficult to find an organism with good activity in the greenhouse that is also capable of becoming established in the field,” Anderson said.

Kropp and Anderson study crown rot of wheat caused by the fungus *Fusarium culmorum*. The microbe colonizes the epidermal cells, which eventually fill with fungal spores that can infect other roots, and debilitates the plant by siphoning its energy-rich compounds (Figure 1, page 16).

Anderson and Kropp recently isolated two pseudomonads that produce antifungal compounds which inhibit *Fusarium culmorum* in the laboratory. Even better—seeds inoculated with one of the pseudomonads inhibited the fungus in the soil. The bacteria overwinter on wheat and survive on sugarbeet roots during the heat of summer. The same isolates that are beneficial on wheat also inhibit the growth of the sugarbeet fungal pathogens *Phoma betae* and *Rhizoctonia solani*.

Scientists believe that, among other mechanisms, pseudomonads may suppress pathogens by competing with them for iron or by producing growth-inhibiting chemicals such as hydrogen cyanide. However, the pseudomonads studied by Kropp and Anderson produced antibiotics and may also elicit an increase in the plant's defense against disease. These antibiotics cause the pseudomonads to become green or orange (Figure 2, page 16).

Applying New Techniques

Interest in the biocontrol of soil-borne pathogens was sparked almost 75 years ago when a plant pathologist introduced several types of saprophytic fungi and bacteria into sterilized soil, thereby reducing colonization by pathogenic microbes that attacked pine seedlings.

Genetic engineering has created new opportunities in the biocontrol of soil-borne pathogens, including the ability to alter microbes to increase the production of disease-thwarting substances, or to transfer antagonistic genes from microbes to plants.

Even high-tech biocontrol must be compatible with the complex ecology of soil microbes.

The USU researchers plan to bioengineer organisms that will be better at thwarting pathogens. One of their techniques involves insertion of a gene that makes bacteria emit light, which helps detect whether pseudomonads have colonized roots and how factors such as soil composition affect the survival of bacteria.

Using biocontrol to combat soil-borne pathogens could reduce crop losses, shave production costs and eliminate the environmental risks associated with chemicals. Perhaps the best (albeit aboveground) example of microbial biocontrol is the insecticide formed by the bacterium *Bacillus thuringiensis* (BT), which spawned a multimillion dollar industry. Unlike most soil microbes, however, BT has been studied since 1901.

The soil may harbor thousands of potential BTs. Unfortunately, much of what goes on underground is still terra incognita awaiting further exploration. KG
The USU researchers have obtained some remarkable close-up views of the fierce battles between soil microbes, including some of the common soil fungal species *Trichoderma*, which is coiled around the hyphal thread of another fungus (Figure 3). *Trichoderma* kills the fungus by puncturing holes in the fungal cell walls or by producing toxins that impair growth.

Views of beneficial relationships between plants and microbes are equally as striking.

For example, the hyphae of symbiotic mycorrhizal fungi invade the cortical cells of roots, forming delicately branched structures called arbuscules (Figures 1 & 4). These structures acquire phosphate and other minerals from small soil pores and donate them to the plant. In turn, the fungi utilize carbohydrates synthesized by plants.

The arbuscules formed by the fungus *Glomus intraradices* occur only in a defined layer of cells inside the cortex (Figures 1 & 4). Moreover, the presence of the arbuscules causes the plant cells to express genes involved in the plant’s defense responses.

There are often similarities in the defenses employed by plants and humans. However, Anderson said there doesn’t seem to be a response in humans that’s analogous to that of *G. intraradices*, i.e., a beneficial microbe that relies on the host as a source of nutrients and that also enhances the host’s resistance to pathogens.

Photos: Anne Anderson
BIOTECHNOLOGY PLAYS A KEY ROLE in biocontrol research at USU.

Biotechnology, the use of organisms to make a product or perform a process, is invaluable in the battle against harmful insects, weeds, and plant diseases. Many biocontrol techniques employ biotechnology to develop or modify one form of life (bacteria, fungi, nematodes, and parasitic insects) against another harmful life form.

These biocontrols are reducing our reliance on chemical herbicides, pesticides and fungicides in agriculture. One particularly promising area is the use of biocontrol agents to control pests resistant to synthetic chemicals.

One of the most widely known examples of biocontrol is the bacterium **Bacillus thuringiensis**, a common soil bacteria that releases the BT toxin harmful to insects. Insect larvae feeding on foliage ingest the bacteria and the toxin; those who do not feed on foliage are unharmed. Millions of dollars worth of BT are sold annually. Similar products await discovery.

As noted in this issue, biotechnology plays a key role in biocontrol research at USU: in the fungus that keeps dyers woad in check (e.g., the polymerase chain reaction), in the identification of a strain of bacteria that may be effective against dwarf bunt disease in wheat, in efforts to control chalkbrood syndrome of bees, and in the control of root diseases of crops.

There are innumerable other possible applications of biotechnological techniques in biocontrol.

The USU Biotechnology Center offers a variety of services to aid researchers in their search for effective biocontrols.

Many analysts think the next round of technological advances will result from an era of biological research. Biotechnology will ensure that agriculture continues to share in these gains.

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RESEARCHERS GET AT THE ROOT OF PLANT BEHAVIOR

Many of the important processes in a plant’s life are literally buried in secrecy.

When we think of plants, we think of the above-ground portions. Roots...well, roots seem about as exciting as freight delivery, a conduit for many of the raw materials that a plant requires for photosynthesis.

But roots aren’t as mundane as they seem and their role in plant growth is far more complex than once thought. Roots can be rather nimble. Gluttonous. Even combative.

USU range ecologist Martyn Caldwell, who is studying root behavior in a sagebrush-bluegrass ecosystem, said roots are surprisingly responsive to opportunity. Under the right conditions, root growth accelerates to exploit “patches” of soil laden with water and nutrients.

Water and nutrients tend to be available sporadically or in patches, Caldwell said. Those plants with the ability to capitalize on these resources have a powerful edge over their sluggish competitors.

The behavior of roots can explain a lot about the growth and competitiveness of plants. Although Caldwell studies root behavior in a sagebrush-bluegrass ecosystem, the findings should be applicable to many types of plants, including agricultural crops.

RAPID ROOT GROWTH

When conditions are favorable, roots of some plants can proliferate quickly, within a day or two, Caldwell said. This growth often coincides with changes in root membranes that enhance the rate of nutrient absorption.

Plants also recognize the roots from neighboring plants, and the presence of these adjacent roots also influences root growth. Plants synthesize an arsenal of chemical compounds, some of which deter roots from other species. The below-ground tussle may also involve actual root-to-root contact.
There is considerable communication among roots below-ground, and scientists are only beginning to decipher its nature and purpose. For example, sagebrush roots proliferate much more rapidly when they are adjacent to bluebunch wheatgrass than when they are next to crested wheatgrass.

“We don’t have a clue as to what’s mediating these events,” Caldwell said.

To monitor root development, USU researchers freeze a block of soil with liquid nitrogen. This frozen block is sawed into sections, which researchers examine to distinguish between grass and sagebrush roots, and to locate each fine root.

**FEAST OR FAMINE**

It appears that plants are adapted to a feast and famine regime of nutrients and water. In field studies, plants were grown in very large pits containing washed sand. Nitrogen was added to pits either in a pulse over a four-day period or was metered evenly over eight weeks. Surprisingly, graduate student Carol Bilbrough found that plant growth was much greater when plants received nitrogen in a concentrated pulse.

Radioisotopes of nitrogen will let researchers determine whether plants store these nutrients or use them immediately.

The findings could be used to improve a crop’s ability to capture a larger proportion of the nutrients from fertilizers.

Studies also involve mycorrhizae, the mycelium of a fungus that facilitates the acquisition of phosphate by roots. Of particular interest is whether mycorrhizae help plants “forage” for phosphate that occurs in patches.

**UPLIFTING BEHAVIOR**

Previously, Caldwell determined that plants engage in a process called hydraulic lift, in which deep roots take up water at night and deposit it in the upper layer of soil, thus letting plants acquire water even when stomates are closed during the evening. Plants then utilize the water deposited in the upper soil during the morning. Hydraulic lift may also help plants utilize nutrients available in pulses.

“Plants aren’t just sitting there with an ‘average’ root system. Some of these responses of roots are remarkable,” Caldwell said.

Caldwell’s research is funded by the National Science Foundation and the Utah Agricultural Experiment Station. KG
THE TYPE OF GROUND COVER promises to be an important component of biocontrol in orchards, especially of spider mites, a troublesome orchard pest in Utah, according to USU entomologist Diane Alston.

Spider mite adults overwinter in debris at the base of fruit trees and emerge in the spring to feed and reproduce on broadleaf weeds, such as field bindweed, knotweed, and prickly lettuce.

Spider mites pose no threat to fruit as long as they stick to weeds. However, when growers control weeds by mowing or with herbicides, spider mites seek sustenance in fruit trees, where their numbers can increase rapidly during warm weather.

Alston is determining which mowing and herbicide application regimes provide the best control of these weeds while limiting numbers of spider mites. Another promising control option is ground covers that compete with broadleaf weeds. Companion grass, a combination of perennial ryegrass and red fescue, which is often planted in orchards, appears to offer good control, as do alfalfa and some types of clover.

CONTROL, NOT ERADICATION

“We can tolerate a few mites in an orchard. Populations don’t appear to build up in these ground covers,” Alston said. Moreover, companion grass need not be mowed as often (some dwarf varieties of clover require no mowing), further shaving production costs.

It’s not necessary or desirable to eradicate all broadleaf weeds since a low density of weeds helps to harbor mites that prey on spider mites, keeping their populations in check. However, frequent mowing or application of contact herbicides tends to eliminate annual weeds and favors deep-rooted perennial broadleaf weeds that can harbor large populations of spider mites.

“The populations of spider and predatory mites can be kept in synchrony by good ground cover management practices, so it’s not necessary to spray. Several growers in the state have already demonstrated this,” Alston said.

TEMPERATURE AND GROUND COVER

The type of ground cover also promises to aid in the control of Western cherry fruit fly, whose larvae (i.e., maggots) burrow into cherries.

Alston said the threshold of control for commercial cherry producers is basically zero since processors reject an entire shipment if they find even a single maggot. Growers place traps in cherry orchards and base insecticide applications on air temperature, which affects the emergence of adult flies from the ground during the spring.
"The populations of spider and predatory mites can be kept in synchrony by good ground cover management practices so it’s not necessary to spray. Several growers in the state have already demonstrated this,” Alston said.

However, there’s a only a weak correlation between air temperature and ground temperature. Furthermore, ground temperatures vary with the type of ground cover.

During studies of the relationship between ground temperatures and the development of Western cherry fruit fly, information that could improve the timing of insecticide applications, Alston also found far fewer flies emerged from soil covered with a thick thatch than from bare soil.

“Ground cover could affect the survival as well as the emergence of Western cherry fruit flies,” Alston said. The type of ground cover won’t completely eliminate these insects and the need for insecticides in commercial orchards, but it could reduce the number of insecticide applications. Ground cover might be an effective control method for home orchards, where some level of damage is usually acceptable.
THE CLIMATE-AGRICULTURE RELATIONSHIP

Will more (or less) rain in Utah result in more wheat? Hay? Apples? What happens when temperatures change?

Agriculture changes in concert with the climate. The accommodation to long-term or dramatic shifts in climate, such as those associated with an ice age or prolonged drought, are readily apparent (albeit often in hindsight). However, we shouldn’t have to rely on history books to determine how land use is likely to be affected by subtler changes in the climate.

We won’t have to. USU researchers are determining how land use is affected by short-term climatic changes. When coupled with other climate change forecasts, the findings will be useful in formulating policies concerning crop production, water utilization, and range management.

The two-year study is prompted by concern over the possible change in global climate, especially the effects of winds associated with southern oscillations (SO) in El Niño (EN) which influence climate in the western United States. El Niño is a periodic shift in currents in the Pacific Ocean.

In some tropical regions forecasts of El Niño events are already used in agricultural planning.

USU economists Terry Glover and Chris Fawson, economist Keith Criddle at the University of Alaska, and Don Jensen, director of the Utah Climate Center, are analyzing agricultural production information and climate data from selected regions of Utah, California, Washington, and Oregon. A time-series model will let researchers distinguish between changes due to climate and those prompted by economic forces and technological advances.

The research is funded in part by the National Oceanic and Atmospheric Administration.

Utah is unique among the western states in that it is affected by ENSO in two ways, said Glover, who directs the study. One involves an east-west shift in weather patterns, the other a north-south shift.

The east-west shift or summer transition pattern is characterized by wet summers in the east and dry summers in the west; the pattern is usually reversed during the year after the ENSO event. “Some climatologists suggest that the ENSO event has become more protracted in recent years, and has lasted two or three seasons instead of one season,” Glover said. “Utah has been influenced by a weak ENSO event for the last three years, during which most of the state has experienced high moisture and fairly warm winters.”

A similar study of the relationship between climatic change associated with El Niño in the Midwest found that reductions in corn production in one area of the region were offset by increases in another area.

In Utah, Glover said climate-related change affected forage production on rangelands and was apparently involved in shifts in the production of specialty crops, such as a reduction in the acreage devoted to apricots and an increase in the acreage devoted to apples. KG

MORE INFO

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Heidi Leuszler wanted to couple field research with classroom and laboratory experience. She also wanted a graduate degree that combined ecology and genetics.

A tall order, but she found what she wanted at USU. Wildflowers, friendly ranchers, and a large slice of North Dakota were bonuses.

Leuszler works with entomologist Diane Alston in research concerning the integrated pest management of grasshoppers. Grasshopper control often involves applying broad-spectrum insecticides over large tracts of western range-land. Leuszler studied the effects of these insecticides on the bees that pollinate the purple coneflower, a common Great Plains wildflower.

The purple coneflower shares many attributes—including a reliance upon bees—with rare and endangered plants and numerous agricultural crops. As a result, monitoring what happens with purple coneflowers following the heavy use of insecticides could indicate what's likely to happen in similar systems.

Of particular concern was the effect of insecticides on the population genetics of the purple coneflower. Determining genotypes of plants and seeds by enzyme electrophoresis enabled Leuszler to ascertain the "mating distances" of purple coneflower, an indication of the genetic movement between plants.

One aspect involved a potential reduction in the number of bees in an area, which could reduce the distance bees travel between plants, thereby increasing the risk of inbreeding and eventually reducing the genetic diversity of the plant population. Rare plants and crop monocultures often lack genetic diversity, so any further reduction in diversity would be detrimental.

Leuszler is still analyzing the data, but preliminary results indicate that insecticide applications were associated with an unexpected increase in the distance bees traveled to pollinate plants, perhaps due to changes in the types or numbers of pollinators. This increase could be a mixed blessing—the purple coneflower populations appeared to remain genetically healthy, but the pollinators were forced to alter their foraging patterns.

These findings will be useful in developing comprehensive management schemes.

For two years from May to September, Leuszler gathered data at research sites in North Dakota located 10 to 60 miles from the nearest town. Fortunately, Leuszler relishes solitude and harbors an affinity for the plains. Another plus—meeting friendly ranchers and farmers, and the red-rich sunsets on the plains, accentuated by the dust boiling from country roads.

Leuszler leaves USU with solid experience and plenty of good memories. After completing her MS degree, she will teach biology in a community college in Illinois.
EDITOR’S NOTE

Forgive us. We couldn’t resist using the file photo on the front cover, even though it represents the antithesis of biocontrol.

But it wasn’t all that many years ago that home gardeners might have slathered plants with insecticides, guided by the dubious principle that if a little was good, more was better.

Me too. I was around when pesticides arrived on the scene, and treated them with the same cavalier attitude, sans respirator or protective clothing. Warning labels—naw. The risks seemed minor. Perhaps the level of trust was higher.

No longer. Some consumers rank the risk of Alar residues right up there with the Chernobyl disaster. Efforts to avoid all pesticide residues are de rigueur in some circles. "Chemicals" in food get blamed for a lot of our ailments, even though the fact that we eat too much probably poses a much greater threat to our health.

No one denies that pesticides pose a threat. Not too many people douse their gardens with insecticides. The use of pesticides in agriculture is severely circumscribed and carefully monitored. The system isn’t perfect, but on balance, we have made considerable progress. We are farming smarter and eating better.

Research helped get us there. It will get us even further.

ERRATUM

In the article in the previous issue concerning the economic effects of wilderness designation, respondents’ support for the wilderness proposal of the BLM (page 3) was misstated due to a clerical error. A slight majority of the respondents contacted supported the BLM proposal; almost two-thirds opposed the UWC proposal.

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