MINNESOTA Science
Agricultural Experiment Station
UNIVERSITY OF MINNESOTA
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Old Microbes Defeat Potato Diseases

Streptomyces scabies *and* Verticillium *wilt are rare in fields planted to potatoes for many years continuously. Duplicating that disease suppression elsewhere is a goal of researchers Neil Anderson (center) and Linda Kinkel (right). Their field harvesting team includes graduate student Tsitsi Ndowora (left).*

Potatoes, Minnesota's most important vegetable crop, are attacked every year by *Streptomyces scabies* and *Verticillium* wilt. They can cause heavy economic losses. But a new biological control is being tested by experiment station researchers.

Biochemist Janet Schottel and plant pathologists Neil Anderson and Linda Kinkel are evaluating antibiotic producing soil microbes in potato fields. "It was interesting to find that these microbes are closely related to the *Streptomyces* bacterium they work against," Schottel says.

Anderson was first alerted to the antibiotic effect because he knew disease was absent from experiment station fields which had been planted continuously to potatoes for many years. Antibiotic producing microbes are abundant in such suppressive fields, says Schottel. Applying the antibiotic producing microbes to potatoes has provided significant disease control over four years of field studies.

"More than 90 strains of *Streptomyces* have been identified that produce antibiotics effective against scab," says Anderson. "Six of these inhibit both the scab-causing and wilt organisms. These strains also show promise as controls for other pathogens."

"We're really excited about being able to use these suppressive organisims for disease control instead of using harmful chemicals," says Kinkel. Growers currently rely on resistant cultivars, altering soil acidity, or soil fumigation, an inadequate control that also risks contaminating soil and water.

The research team is currently comparing the levels of disease control achieved by individual strains and by different combinations of them. They are especially interested in finding combinations that inhibit the pathogenic bacteria and fungi but not each other.

Additional work in progress is looking at the influence of suppressive strains on rotation crops such as corn and soybeans, and on the ability of these beneficial microbes to survive and thrive in the soil and on plant roots over time. Research to purify and characterize the antibiotics is also on their current agenda.

The antibiotic producing organisms are grown in oatmeal agar—a gel on which microorganisms grow well. They are applied by dipping tubers before planting. Additional control comes from an in-furrow application at planting time.

Trials will continue seeking the combination of antibiotics that most effectively inhibits scab and *Verticillium* wilt.

The project is an example of research connected with the Plant Molecular Genetics Institute: basic research leading to practical applications.

Grants from the Legislative Commission on Minnesota Resources and the U.S. Department of Agriculture have helped support field, greenhouse and laboratory tests, as well as the development of commercial applications.

—David Hansen

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Tiny Tethers Wire Insects to Tracking Device

In a couple of St. Paul campus labs, the bugs are really wired—but not from too much caffeine. These insects are tethered to electrical recording devices by minute strands of gold filament. The electrical tethers allow researchers to get a micro-glimpse at their feeding behavior.

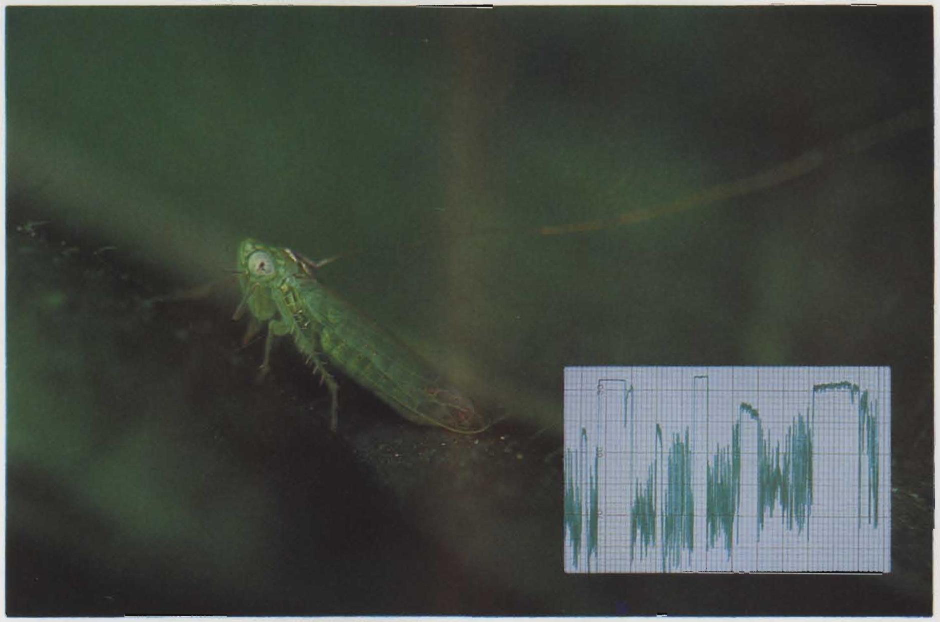
Experiment station plant physiologist Will Koukkari and entomologist Ted Radcliffe are applying their expertise to a problem affecting both their specializations—oscillations in plants' response to stress and insect damage to plants. Their subject of study is the potato leafhopper, nemesis of midwestern farmers who grow alfalfa or other legumes.

In the field, the leafhopper wreaks havoc with crops, reducing yields and soaking up time and money of farmers

It is helping to dig its own grave by providing insights into how it feeds and how it might be controlled.

forced to apply control measures. In the laboratory, it is helping to dig its own grave by providing insights into how it feeds and how it might be controlled with minimum economic and environmental cost.

The researchers' technically challenging approach is conceptually as simple as dropping batteries into a flashlight. A thread-like wire is glued to the leafhopper's back, then attached to a recording device. The leafhopper is placed on a



A nearly microscopic gold filament wire is glued to a leafhopper. It transmits the insect's head movements to a polygraph-like recording device that graphs the insect's various episodes of feeding, non-feeding and rapid probing behaviors.

siege by leafhoppers would be in double trouble if they faced drought at the same time. Radcliffe and Al-Dawood found that water stress not only changes the condition of the plant but also alters the insect's feeding behavior to what they believe is a less destructive pattern.

The results could influence how treatment thresholds—predefined levels of insect infestation that farmers use to decide whether spraying is worth the cost—are set. "The assumptions were that the threshold would have to be [lowered] under stress," Radcliffe explains. "We have found that, if anything, the thresholds would be higher when the leafhopper infestation is accompanied by water stress."

leafhopper feeding intertwine.

"Biologists are used to dealing with the structural organization of life—molecules, cells, tissues, and so forth—but there is also the temporal organization—when certain things happen and when they do not. The previous studies were two-hour experiments. Now we are looking at the feeding behavior for 25 to 50 hour stretches to see how things change with time," he says.

In addition to studying the interactions of time, water stress and feeding, the researchers are also throwing variables such as boron deficiency and plant sucrose levels into the feeding-behavior ring.

"The tendency in any one discipline

'Applied' Molecular Genetics is Institute Goal

"Molecular genetics is the basis for understanding plant improvement. It focuses on how genes work and what traits they control," says genetics researcher Burle Gengenbach, who just finished three years as director of the university's Plant Molecular Genetics Institute.

The institute, formally chartered in 1985 when the experiment station provided funding, has 20 faculty members, representing more than 100 graduate and research positions spread across six departments, in two colleges.

"One of the very positive aspects of our organization is the ability to interact without walls (of departments), it's a tradition here. It flourishes," says Ronald Phillips, current institute director.

"The institute isn't in competition with departments. It strengthens them," says Irwin Rubenstein, head of the Department of Plant Biology and the institute's first director. "It brings molecular biology into traditional departments."

"We want research that can be used in an applied sense and new technology and methods that can be applied, for instance, in breeding programs," says Gengenbach.

Examples are plentiful. Plant biologists in the College of Biological Sciences are investigating corn pollen's molecular response to high temperatures to

Genetics *continues on page 3*

Water, Energy, Health Care and

ond wire.

When the insect pierces the plant, the electric circuit is completed, and a surge is inked out on a strip chart. Using this method, the researchers are able to observe and record different types of feeding behavior—repeated poking versus steady sucking, for instance—as well as periods of inactivity.

Before they began working with Koukkari, Radcliffe and graduate student Abdulrahman Al-Dawood had been using the bug-on-a-rope technique to study how leafhopper feeding behavior is altered by water stress in plants. Many crop experts had previously assumed that plants under

their studies. A widely recognized expert in biological rhythms of plants, he is investigating how natural rhythms in plant growth and movement and in

effects," Koukkari says. "We now have to deal with the interactions of the different effects."

—*Mary Hoff*

Heat Shock: Molecular Key to Corn Improvement

Shock is a universal response to excessive heat in plants, insects and even humans. It's also the focus of experiment station research by plant biologists Nora Plesofsky-Vig, Robert Brambl and Norbert Hopf. More specifically, they are studying corn's heat shock response.

"Heat shock is a living organism's response to abnormally high temperatures. It attempts to protect itself, its cells actually, against damage from potentially lethal temperatures," Plesofsky-Vig says.

It does this at the molecular level, by creating protective heat shock proteins in different parts of the plant. It happens in a matter of minutes.

Imagine a Minnesota cornfield on a scorching afternoon, with the temperature climbing past 100 degrees. "Growers have long known that high field temperatures during pollination can depress yields," Brambl says. "Apparently pollen germination and growth are inhibited and fertilization of the silks is reduced."

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Students Research, Learn and Earn

"Students should make the most of all opportunities. There are lots of them," says Gertrude Greene, a summer research apprentice in a program sponsored by the College of Biological Sciences. She and 114 other undergraduate students worked side by side with university researchers this past summer.

College and high school students have many university research doors open to them if they are interested.

Undergraduate research apprentices like Gertrude Greene work in labs assisting university faculty with research projects.

Signe Betsinger, assistant director of the Minnesota Agricultural Experiment Station, is a firm supporter of research apprenticeships. "We hope that participants become excited about science and move into it. We're concerned that across the country—and here in the experiment station—we need to develop a diverse pool of scientists to meet our future needs."

Participants are often matched with faculty working on experiment station projects, from labs in food science to wild rice plots in northern Minnesota. Greene spent a summer analyzing blood from dairy cows, measuring feed and weighing the animals. She worked at the Rosemount Experiment Station and in the laboratory with dairy scientist Brian Crooker, looking at ways to improve economic return from cull dairy cows.

Sally Jorgenson, associate dean of the College of Biological Sciences and coordinator of the largest undergraduate research program at the university, says students are involved in four types of research activities. "Most important, they do their own research project. In addition, they are part of a research team and assist a faculty member with research, participate in seminars, and prepare and present a summary of their project."

Ten weeks of rigorous academic work is complemented by evening workshops, weekend recreational activities and noon seminars. Program administrators say students do a good job of meeting the scholastic challenges.

"Our undergraduate program had 600 applications for 120 openings," says Paul Magee, dean of the College of Biological Sciences. "Seventy percent of those accepted had GPAs over 3.5."

Most internship programs are aimed at students already in college, but several high school programs are also going strong. The programs create awareness of career possibilities. They help participants decide if a science career is within their interests. "They also get a sense of

Students *continues on back cover*

Competitiveness Challenge Minnesota

"Water quality, energy conservation, improved health care, and economic competitiveness are the major challenges confronting Minnesota," says Paul Magee, dean of the College of Biological Sciences. He is determined that research will contribute to improvements in all four.

Paul Magee

"Basic research provides the foundation for many advances in agriculture," Magee says. "The boundary between basic and applied research is becoming very blurred—if it exists at all. Much of what we do is directly transferable to agriculture, medicine or other fields. For example: genetically engineered fish; toxins produced by plant pathogens; and increased knowledge of how biological systems work—to help us make plants with better yields or better properties."

Projects that benefit Minnesotans range from studies of human fungal pathogens to innovative uses for corn syrup, such as for producing less damaging road salt through microbial action.

Better known programs include the Bell Museum of Natural History spearheading the reintroduction of peregrine falcons in Minnesota.

Evaluating effects of global climate change also falls partly within the College. Under way is a project analyzing forest migration over the last 10,000 years, in cooperation with the Remote Sensing Laboratory in the College of Natural Resources. Other projects rely on the electron microscope facilities, also funded by the experiment station.

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Will Altered Fish Alter Environment?

Injecting rainbow trout with growth hormone genes of another fish species presents intriguing possibilities. Anglers, fisheries managers and aquaculturalists might gain larger, faster-growing fish. But the idea also raises far-reaching questions concerning the impact of transgenic, genetically altered fish on delicate freshwater ecosystems.

The concerns are shared by Anne Kapuscinski, a fisheries researcher for the experiment station and Minnesota Sea Grant. She is quick to point out that some genetically altered fish are likely to create no environmental threats, but she nonetheless advocates a thorough, ration-al appraisal of that potential.

Kapuscinski is helping the U.S. Department of Agriculture establish safety standards for transgenic fish research. Working with Eric Hallerman at Virginia Polytechnic Institute and State University, she also educates fisheries scientists and managers about the potential environmental impacts of genetic engineering. "My role as a scientist is to be as objective as possible. My responsibility is to society at large," she says.

Ecosystems are so complex that any change can result in unanticipated consequences.

At least 13 species of transgenic fish have been created from salmon, catfish,

transgenic fish on freshwater systems depends in part on the type of environment into which they are released. Releases into less controlled environments pose greater potential for upsetting ecosystems.

Natural ecosystems are so complex that any change can result in unanticipated consequences that become evident only after significant periods of time, Kapuscinski says. Transgenic predatory fish that depend on different food resources through their life cycle provide a hypothetical example. Altered feeding habits resulting from changed growth rates could eventually destabilize predator-prey population ratios. The changes could ripple through an entire aquatic ecosystem.

Whether these changes would lead to new ecological balances or result in irreversibly altered ecosystems are the kinds of questions Kapuscinski says we need to consider. In large enough numbers, even sterile transgenic fish unable to spread their novel genetic traits might cause major ecosystem damage. Risks could be acute for smaller, less ecologically stable lakes and aquatic environments that support depleted or endangered species.

Kapuscinski says unacceptable risks can be identified. She says interdisciplinary teams of scientists with broad-ranging perspectives are needed to develop risk-assessment strategies.

The variety of altered traits and behaviors from gene transfer experiments needs to be thoroughly evaluated for environmental consequences, she says. Sterilization techniques and screening to confirm sterility need to be improved. Finally, better risk-assessment procedures are needed to enable more accurate pre-

At an experiment station field day, Sister Esther Nickel explains to farmers how she videotapes in the ground. Long clear plastic tubes like the one she is holding are inserted in the soil next to corn and soybean plants very soon after planting. A video sensor is attached to a long pole with a light at the bottom, and lowered down each tube every week during the growing season to record root growth in place. Her presentations include an explanation of how her research on rotation effect may someday affect a farmer's production.

Underground Television Goes to the Root of Research

When an agricultural mystery is hidden in the soil, research must go underground. The mystery? The well-known "rotation effect" that boosts yield when the same crop is not planted in a field year after year. Unravelling the reasons for that boost may help keep agricultural practice in sync with nature.

Research to develop sustainable agriculture practices is important to a unique university agronomy graduate student, Sister Esther Nickel. She works with experiment station agronomist Kent Crookston, and when not working toward her PhD, she manages a farm

Phythium, *Rhizoctonia* and *Fusarium*. She says she is finding "more pathogens and nematodes in both continuous corn and soybean, compared to first year crops."

A medical analogy makes sense to Nickels. "If roots are diseased, if they are infected early in the season, if they show slower growth—then the plant has less root surface area for water and nutrient uptake. Thus the plant will not have as much leaf growth, will not be able to accomplish as much photosynthesis, and that would cause a yield decline. It is like the human respiratory system—you don't rainbow trout. In one area of research, extra growth hormone genes, usually from other fish species, injected into newly fertilized eggs have produced individual fish that grow twice as fast as normal. However, host fish may also develop other new characteristics, some of which raise ecological concerns.

Transgenic fish have not yet been released into natural waterways. The consequences of doing so remain hypothetical, but Kapuscinski is concerned disruptions could occur in at least three ways. First, faster growing transgenic fish may consume more than their usual share of food resources. Second, the tolerance of transgenic fish may be altered to environmental factors like water temperature, acidity or salinity. Third, there could be changes in transgenic fish territoriality, seasonal migrations and selection of habitats, mates and prey. Changes in enough individuals could alter the species' traditional ecological niche.

Potential environmental impacts of aquatic genetic technology.

—John Shepard

Society needs to be concerned about possible environmental consequences of releasing genetically altered fish into our lakes and waterways, says experiment station fisheries researcher Anne Kapuscinski.

Mercy.

Crookston's 12 years of corn and soybean studies show annual rotations increase yield by 8 to 10 percent. Nickel says the effect is actually less of a "yield boost" than an avoidance of yield decline.

The effect is more pronounced when plants are stressed, such as from drought. Previous research by Philip Copeland suggested that crops in rotation can take up water better, indicating a healthier root system may be part of the equation.

Nickel's challenge was to measure root growth in the field. "If you pull the plants up to measure their roots, you've lost your chance to document root development throughout the season," she says. Her solution was to adapt medical video technology. Nickel had experience with this technology in her former career as a respiratory therapist.

Comparing visual records of first and fourth year corn showed healthier corn roots in the first year crop. Results were less clear with soybeans. As soil compaction, water percolating up the tube and other field research hazards complicate results, this year Nickel increased the number of tubes in the field from 24 to 32.

Nickel is also looking at three types of fungi in other plots of first year and fourth year corn and soybeans. She is taking root samples from those plants three times each during the growing season, looking for the presence of three fungi—lungs."

"What we typically do as agronomists is cut off the plant at the top of the soil, and study that. But we're missing a big part if we don't take a look at the other part of the plant," Nickel says.

This holistic approach reflects Nickel's commitment to sustainable agriculture. Her community's 115 acre farm in Jackson County is a working sustainable agriculture laboratory as well as a teaching farm. Nickel has already worked with Minnesota Extension Service agronomist Jeff Gunsolas on a farm project testing alternative weed control strategies with corn. She hopes to develop a long-term collaboration with university researchers on projects giving farmers real field data about sustainable practices.

—Jennifer Obst

Plant roots are clearly visible with Nickel's medical type television system.

Challenge *continued from page 2*

Such technological facilities are resources that contribute to interdisciplinary efforts. This issue of *Minnesota Science* reports several Minnesota Agricultural Experiment Station projects underway in the college and in cooperation with other units of the university.

The Plant Molecular Genetics Institute, for example, promotes basic research fostering concrete applications. "It reaches across department and college boundaries, yet doesn't isolate researchers from their peers. It is a remarkably successful strategy for intercollege cooperation and has established a nationwide reputation.

The college also combines research with teaching to stimulate interest in science education among nontraditional audiences. Internship programs accept both high school and college students.

There is an undergraduate research program for a more traditional science educational audience. "It is an enormous success. The kids work in labs throughout the university. In biology, biochemistry, agriculture, medicine and veterinary medicine," Magee says. "Our country gets talented people that are encouraged to study science. The participants benefit from the intellectual experience and they get a head start in school."

Magee says research and teaching programs also promote relationships outside the university. A council of advisors includes members from the state Board of Education, small companies, and large corporations such as Cargill, 3M, Ecolab and DuPont.

Magee has been Assistant Director of the Agricultural Experiment Station for five years. Previously he was head of the Department of Microbiology and director of the Biotechnology Research Center at Michigan State University.

—David Hansen

Genetics *continued from page 2*

improve the plant via genetic engineering.

Agronomists and plant biologists are improving our understanding of nodulation on alfalfa roots, the process responsible for that plant's remarkable ability, in symbiosis with nitrogen fixing bacteria, to draw nitrogen out of the air and make it available to plants in the soil.

The approach works. "Much of the institute's research at some point has a direct connection with an applied problem," Gengenbach says. "This is recognized as our strength around the country." The institute also has an education role. It sponsors seminars, symposia and discussions and funds several graduate student research positions.

The institute includes biological sciences and agriculture faculty in the departments of Agronomy and Plant Genetics, Biochemistry, Genetics and Cell Biology, Horticultural Science, Plant Biology and Plant Pathology.

—David Hansen

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Timber Bridges Get New Life

Innovative renewal may cut replacement costs by about 75 percent for more than 1,000 rural Minnesota bridges. Renovation rather than replacement is a new strategy being looked at for timber bridges.

As a bonus, forest products researcher Robert Seavey says, "We may also be able to improve the load rating at the same time, which would be helpful since many bridges were not made for today's loads."

The renovation concept originated with Gene Isakson, director of public works for Sibley County. He sought an alternative to replacing structurally sound bridges whose only faults were being slightly narrow and underrated. His idea has been tested on a 1950 vintage bridge south of Winthrop.

The bridge's asphalt surface was removed to expose the original planks, which run the same direction as traffic. An additional layer of treated planks was added crossing the original layer. Then, grout was pumped into cavities between the old and new planks to fill voids, and a new asphalt surface applied.

"After we added new rails, it looked like a whole new bridge to the traveling public," Isakson says. The bridge was 24 feet wide. "Now it's 28 feet with new, safer bridge rails. Plus, we think we're increasing the strength and load carrying capacity by 30 to 40 percent."

Roberto Leon, a structural engineer in the Institute of Technology, is testing the performance of the structure.

"We put a premium on safety," Leon says, "and this is an economical way of improving it." The Minnesota Department of Transportation (MN DOT) must approve any increase in weight limit.

In the tests that were run, drivers of two fully loaded dump trucks cruised side by side across the new bridge at 60 miles-per-hour. The drivers hardly knew when they were on the bridge. "We're seeing a stiffer bridge and a better distribution of the load, less deflection," Leon observed.

"Since the new layer goes across the roadway and at a right angle to the bottom layer, it spreads the stress in a transverse direction," Seavey says.

Replacing the 48 foot bridge would have cost over $100,000. "We did this for 25 percent," Isakson says. "And the amount of time we had the road closed was minimal, days versus weeks."

Leon agrees. "If you can upgrade while keeping the road open, it's a big advantage. On secondary roads there are thousands of these bridges, built in the 40s, 50s and 60s. Just think of the savings in time and money."

The Local Road Research Board, Sibley County and Wheeler Consolidated, Inc. are funding the project along with the university's Center for Transportation Studies.

—David Hansen

Lambert soybean is the first Phytophthora *resistant release from the experiment station.*

New Soybeans Resist Nematode

There's good news for Minnesota soybean growers losing yield to soybean cyst nematode. The Minnesota Agricultural Experiment Station has released Alpha, its first resistant variety.

It has also released three new higher yielding soybean varieties—Agassiz, Lambert and Parker.

Soybeans account for 14.3 percent (over $1 billion) of Minnesota farm cash receipts. Soybeans and soybean products also annually account for about $430 million of Minnesota's $1.8 billion in agricultural exports.

"Alpha is the earliest soybean cyst nematode resistant variety now available, giving farmers in central Minnesota, where the nematode has recently been found, a resistant variety to grow. It can also be grown in southern Minnesota as an earlier variety than Bell, the other publicly developed resistant variety that can be grown in Minnesota," says University plant breeder James Orf.

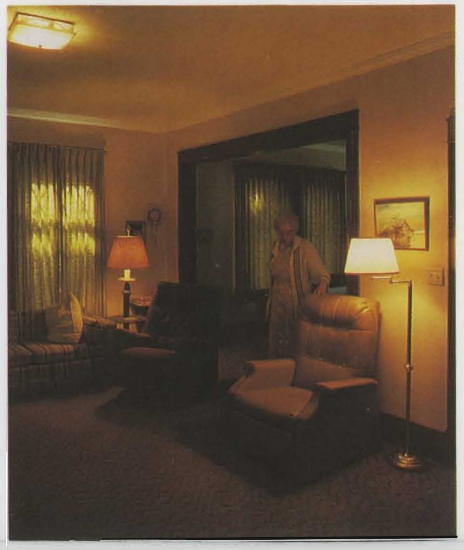
Lighting Needs Differ for the Elderly

As we get older, our eyes age also. Lighting adequate for sharp-eyed youth may no longer be adequate for a middle-aged or elderly person. So says University of Minnesota lighting specialist Dee Ginthner, who has done research for the experiment station, on the lighting needs of the elderly.

Ginthner says older eyes are less able to focus on close-up tasks, slower to adapt to sudden changes in light intensity and more sensitive to glare.

"The increased opacity of the lens, which starts at about age 40, means that older eyes need more illumination," says Ginthner. "Most older persons need at least three times as much light as a younger person does to read or sew or see the fine print in a phone book."

Inability to tolerate glare is why some older people complain about oncoming headlights when they drive at night. And, slower adaptation to sudden



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this university as a good place to go for their education," Magee says.

The programs motivate women and students of color to go to graduate school and into science careers. Laura Gammill, a 1989 undergraduate participant who is now in a PhD program at MIT, says the program was one of the best opportunities she ever had to do research.

"It definitely gave me the confidence I needed to pursue more projects, such as my thesis," she says.

Opportunities include summer American Indian apprenticeships at the Cloquet Forestry Center, and year-round programs in the colleges of Agriculture, Natural Resources and Human Ecology.

"The pool of scientists we'll have in the next century will be dramatically different from now," Betsinger says. "The U.S. population is changing and it's important for us to reflect that change."

—David Hansen

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EDITOR
David L. Hansen
PRODUCTION AND COPY EDITOR
Larry A. Etkin
DESIGNER
Nancy H. Teufert
PHOTO EDITOR
David L. Hansen
PHOTO CREDITS
Transgenic Fish by Nancy Johnson; Summercrisp Pear by Don Breneman; others by David L. Hansen.

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Address all correspondence and requests to the Editor, *Minnesota Science*, Educational Development System, 405 Coffey Hall, 1420 Eckles Avenue, University of Minnesota, St. Paul, MN 55108-6068.

Minnesota Agricultural Experiment Station
University of Minnesota
220 Coffey Hall
1420 Eckles Avenue
St. Paul, Minnesota 55108-1030

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