

Precise Inputs for a Cleaner Environment

When the sandhill cranes pass over the Platte River Valley in Nebraska this spring on their annual flight north, they'll fly over a cleaner environment.

A decade has passed since the U.S. Department of Agriculture began a major clean water effort in the Corn Belt from the Platte River to the Des Moines River to the Mississippi River to the Great Lakes.

In 1990, USDA began five comprehensive research and demonstration projects to evaluate and develop farming methods that safeguard water resources. Known as the Management Systems Evaluation Areas (MSEA), the sites are in Iowa, Kansas, Minnesota, Missouri, Nebraska, the Dakotas, Ohio, and Wisconsin. MSEA, led by USDA's Agricultural Research Service; Cooperative State Research, Education, and Extension Service; and university colleagues, involves close cooperation with federal, state, and local agencies.

MSEA's cornerstone is the close integration of research and education activities. This water quality program merged in 1996 with a broader USDA program called ASEQ, for Agricultural Systems for Environmental Quality. With this merger, the joint program expanded to Mississippi and North Carolina.

The work initially emphasized reducing the amount of pesticides reaching groundwater, says Dale A. Bucks, ARS national program leader for water quality management. But the emphasis soon expanded to include nitrates in surface water and groundwater and pesticides in surface water.

"Now the program also emphasizes phosphorus and collects data on air quality, soil management, off-site impacts, and newer farm practices," Bucks says.

Pesticide levels in groundwaters were far less than originally anticipated. Iowa results were typical: The common herbicide atrazine showed up in well water at

levels above the U.S. Environmental Protection Agency's standard for drinking water only once in 8 years of intensive sampling. Bucks warns, however, that more research is needed on newer pesticides and other synthetic chemicals, such as hormones and antibiotics, in runoff from fields, farms, and watersheds.

SCOTT BAUER (K8701-1)



Soil scientist Jim Schepers measures canopy reflectance from several plants using real-time sensors being developed for mobile applications. Selected colors monitored by this inexpensive sensor are compared with more extensive data collected by costly spectroradiometers.

Why the emphasis on nutrients? Because they have generally been a problem at the study areas, Bucks says. Annual "dead zones" off the Gulf Coast and fish kills from *Pfiesteria* on the East Coast also pushed nitrogen and phosphorus into the limelight. These nutrients can feed harmful algal blooms associated with these problems.

The Midwest part of the joint program is still going strong, changing the landscape of American farming, often far beyond the Corn Belt.

In Nebraska—Groundwater Quality Is Improving

James S. Schepers, an ARS soil nitrogen expert at Lincoln, Nebraska, says that groundwater in the Platte River Valley has less nitrate and pesticides in it today because of the program. Nitrate-nitrogen levels in the groundwater have been reduced from 30 parts per million (ppm) to 10 to 15 ppm. EPA's standards for drinking water call for a maximum of 10 ppm.

"The techniques that led to these reductions are being adopted across the country," says Schepers. "Basically, they center on the burgeoning field of precision agriculture and split applications of nitrogen fertilizer." Schepers serves on a committee promoting solutions like this nationwide.

Farmers traditionally apply nitrogen fertilizer in the fall based on the results of a soil test. They often add "insurance fertilizer," the rate of which is based on a guess about how much more fertilizer might be needed by spring planting time. Fertilizer has been cheap enough that farmers would rather overapply it than risk having an anemic corn crop, says Schepers.

The Midwest program came up with an alternative: Apply nitrogen in two or more applications—beginning with a starter dose in spring—and monitor for nitrogen deficiency before applying more.

The Nebraska scientists developed several ways to monitor, including the use of a portable chlorophyll meter to instantly test plants for nitrogen deficiency. Farmers could combine the meter with a special soil test at planting time and another when the corn is 18 inches tall.

Applications Become More Precise

MSEA scientists have documented that crop yields and nitrogen needs within a field vary tremendously. So one of their main priorities was to develop equipment that can apply nitrogen at a variable rate.

The Nebraska scientists designed sensors to pinpoint nitrogen needs based on sunlight reflected from crop leaves. Mounted on a high-clearance sprayer, the sensors look like small headlights. One stares skyward so it can measure daylight intensity. Another points toward the plants and measures light reflected

for water and environmental quality.

In precision agriculture, farmers apply only the type and amount of inputs—water, pesticides, or fertilizer—that plants need for optimal yields. To do this, they rely on sensors that collect data on plant and soil conditions as the tractor moves across the field. GPS (Global Po-

manure applied as fertilizer can also be a water quality concern. So ARS soil scientist Brian J. Wienhold, also at Lincoln, is testing manure from swine raised on a new corn variety bio-engineered to reduce phosphorus excretion. Wienhold is assessing the potential this low-phosphorus manure has for reducing runoff losses of phosphorus.

JAMES SCHEPERS (K8696-19)



Mounted on a high-clearance sprayer, crop canopy sensors monitor plant greenness, which is translated into a signal by an onboard computer that controls the application rate of nitrogen fertilizer to the soil.

from the crop to detect how much nitrogen the plants have in their leaves. Farmers can drive through the cornfield—no matter how tall the crop is—and automatically add nitrogen where needed.

ARS scientists in Nebraska developed the sensors through a cooperative research and development agreement with a private company. Now they are working on second-generation sensors, says Schepers. Similar reflectance techniques are being tested on airplanes and satellites.

Variable-rate equipment is key to the precision agriculture revolution currently brewing in the agricultural equipment industry, fueled in part by the program

sitioning System) receivers locate the tractor in the field, and computers onboard the tractor calculate the best possible yield and the soil's capacity to hold chemicals. The results of the calculations are used by the computer to adjust the application rate of each chemical as the tractor moves along. The onboard computers can also use data from stored maps or aerial photographs instead of sensor data.

But Schepers says the first line of defense against nitrate leaching is wisely managing irrigation and drainage water. "It's excess water that carries nitrate to groundwater," he says.

Excess phosphorus from animal

In Missouri—Soil Type Does Matter

As in Nebraska, scientists working at the Missouri site rely on sensors to achieve the best use of fertilizer nitrogen within each field. "Our tactics are different, based on different soil conditions," says Eugene Alberts, "but the goal is the same: to not over- or under-apply nitrogen fertilizer." Alberts leads the ARS Cropping Systems and Water Quality Research Unit in Columbia, Missouri.

To set variable rates for nitrogen, the Missouri scientists experimented with sensors for estimating claypan topsoil depth. These relied on measuring the soil's electrical conductivity. The lower the conductivity, the deeper the topsoil. As it deepens, crops are higher yielding, justifying more nitrogen fertilizer.

"There's no sense in fertilizing for a yield of 200 bushels of corn an acre on soil that could never yield even 100 bushels," says Alberts.

The research focuses on the claypan soil region in north-central and northeastern Missouri. The region is representative of more than 7 million acres of Midwest cropland. Newell R. Kitchen, an ARS soil nitrogen management expert who works with Alberts, says, "A claypan layer restricts roots and lowers crop yields. The claypan also causes surface runoff that has high herbicide levels in spring and early summer."

The main study area in Missouri is the 28-square-mile Goodwater Creek watershed, with 50- to 90-acre commercial

cornfields and 1-acre study plots. One-fourth of the wells in the watershed exceed the drinking water standard for nitrate. Most drinking water comes from municipal reservoirs, but people in isolated areas get their drinking water from wells.

Kitchen says, “we need to find a way to fine-tune farming methods to avoid loading the groundwater with nitrate. Ken Sudduth, an ARS agricultural engineer, and I are field-testing several innovative strategies for applying nitrogen at a variable rate.

“Over the last 4 years, the Missouri program has expanded to include most of the northern and some of the central parts of the state.”

In Iowa—Less Is Better

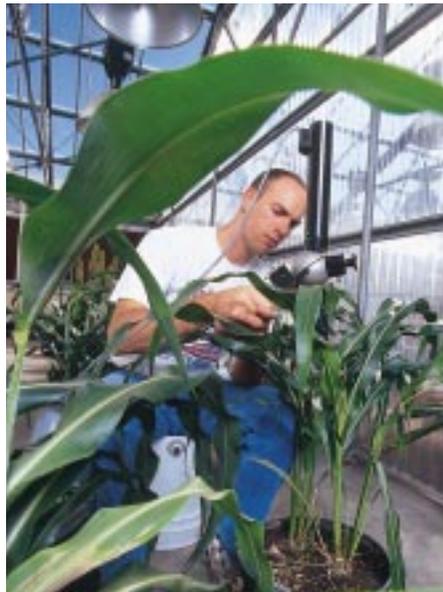
In one Iowa watershed, farmers used MSEA findings to lower nitrogen fertilizer use by 50 pounds per acre over 20 percent of the watershed.

ARS scientists in Ames, Iowa, credit the reduction to split nitrogen applications and a technique they developed to reduce nitrate leaching. In the Corn Belt states—the nation’s heaviest users of nitrogen fertilizer—most nitrogen fertilizer is injected into the soil as a pressurized gas called anhydrous ammonia. Knifelike blades cut a slot in the soil into which the gas is dispensed through a hose alongside the blade.

The scientists at the National Soil Tilth Research Laboratory worked with Iowa State University colleagues to install a disk behind each “knife” to mound soil on both sides of the slit. This prevents the slot from funneling rainwater that could carry nitrate toward groundwater.

Jerry L. Hatfield, head of the Soil Tilth Laboratory in Ames, says he and his colleagues are starting to test newer herbicides that are highly selective and applied at doses a fraction of those of conventional herbicides. The new herbicides also break down in the soil in a few days.

SCOTT BAUER (K8700-1)



Spectroradiometers can be used to measure and record the spectral signature of reflectance from an individual leaf. Here, technician Jim Tringe uses the device to identify special wave bands or colors unique to a given crop stress, such as nitrogen deficiency.

SCOTT BAUER (K8697-1)



Technician Andrew Pond uses an iron oxide test strip to measure the amount of phosphorus present in a runoff sample.

“Part of the natural evolution of this water and environmental quality program is a response to changes in pesticide technology as well as farm practices,” Hatfield says.

The Iowa site has high nitrate levels in water drained off fields by underground pipes. This water pours directly into streams. Hatfield says 40 percent of the Midwest has poorly drained soils that require similar pipes. The pipes have perforations so some drained water can leak back into the soil as it flows the length of the pipe into a stream.

The researchers are testing various solutions. One is installing the pipes in a bed of woodchips and planting deep-rooting alfalfa over the top. The woodchips are a carbon source to feed microbes that break down the nitrate into harmless components as it leaches from the pipes. Any nitrate that manages to leach below the woodchips will be caught by the alfalfa roots.

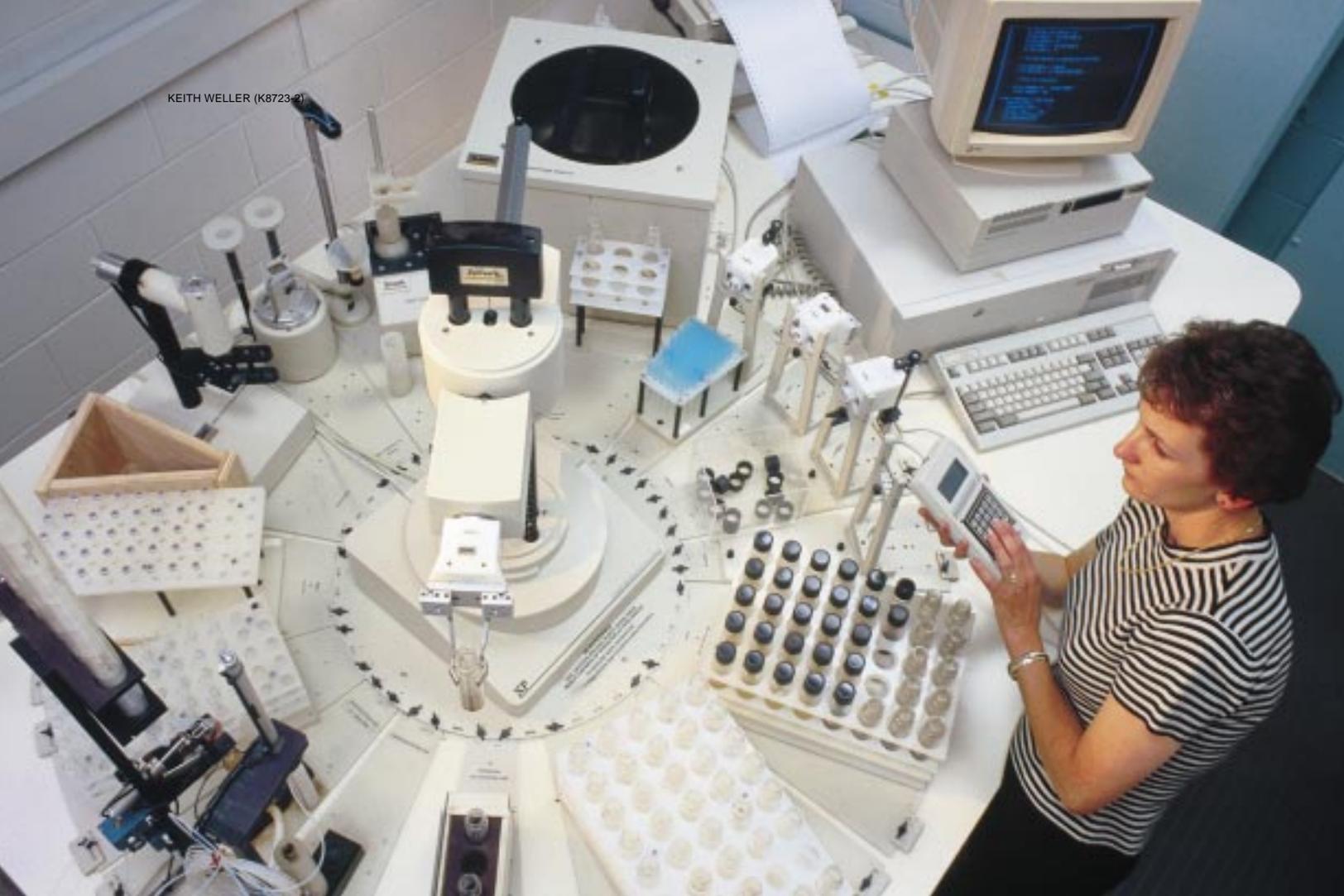
Again in line with program findings, the Des Moines water treatment plant reported record levels of nitrate this year from the Des Moines and Raccoon Rivers, but no problem with herbicides.

Hatfield says the researchers’ goal is to design farming systems that mesh practices for better use of water with those for better use of nutrients.

“We’ve been developing practices that lower subsurface drainage nitrate content and improve yields at the same time,” Hatfield says. These concepts are being applied to the Lake Springfield watershed in Illinois to help improve water quality in the lake.

In Ohio—Handling Drainage Water

Researchers in Ohio are focusing their efforts on the effects of drainage on surface water quality. They are studying poorly drained areas of Ohio as part of the ASEQ program. The main concerns are nitrates and pesticides reaching surface water after leaving underground drainage pipes.



Amy Morrow, a chemist in Ames, Iowa, inspects the operation of the soil extraction robot that is used to remove herbicides from soil samples. This unit has processed soil samples throughout the life of the MSEA program.

They have built a highly successful system for poorly drained soils. This system, which uses uniformly spaced drainage lines, was designed by scientists at ARS' Soil Drainage Research Laboratory in Columbus, Ohio, working with researchers at Ohio State University.

The system supplies irrigation water that goes into the drainage pipes during the summer, says Norman R. Fausey, who heads the Columbus lab. The plants get a uniform water supply, thus promoting nutrient use and maximum yields. Almost no nitrates or pesticides leach below the pipes, and the amount of nitrates and pesticides leaving the field through the drains in the fall, winter, and spring is greatly reduced.

Recently, the Ohio researchers began testing the treating, storing, and reusing of drainage and surface runoff water to irrigate. The water is routed to a wetland

constructed for that purpose. The wetland removes sediment and nutrients before the water is stored in a reservoir. The system has the potential to produce zero discharge to streams—helping to improve water quality and reduce peak flows downstream.

In Minnesota—Ridge Tillage

Scientists in Minnesota are looking at how ridge tillage affects pesticide leaching. Robert H. Dowdy, of ARS' Soil and Water Management Research Unit at St. Paul, Minnesota, says that rotating crops with the ridge tillage system caused an 85-percent reduction in the amount of atrazine herbicide used over an 8-year period, compared to continuous corn grown conventionally.

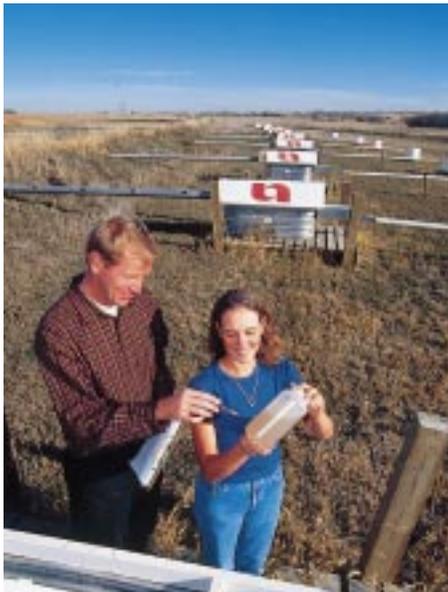
"We reduced atrazine by using it only every other year when corn was grown

and by applying it in bands over the row. This allowed us to use two-thirds less on each application," Dowdy says. "Ninety-eight percent of the atrazine is gone by the end of the corn season."

Dowdy's team evaluated the ability of an ARS-developed Root Zone Water Quality Model to predict leaching of herbicides in soil. "We found that it accurately predicted pesticide levels in the top 6 inches of soil," Dowdy says. "It overestimated leaching below that depth because of flaws in the lab technique used to provide the model with leaching information. We have since developed a new technique that corrects the problem."

The Northern Sand Plain scientists also found a way to irrigate crops more precisely by a weekly check of soil moisture with a portable time domain reflectometry (TDR) unit.

SCOTT BAUER (K8699-1)



Soil scientist Brian Wienhold and technician Julie Paschold examine a runoff sample collected from plots on which nitrogen and phosphorus losses are studied. The plots received swine manure differing in phosphorous content.

“While the MSEA program has used new technology like the TDR unit and the chlorophyll meter, many of the practices in the successful ridge tillage system are not new. What is new about this program is that it packages practices together into systems that work, protecting water quality and growing crops,” Dowdy says.

The same is true for all the sites in the environmental quality program.—By **Don Comis**, ARS.

This research is part of Water Quality and Management (#201) and Soil Resource Management (#202), ARS National Programs described on the World Wide Web at <http://www.nps.ars.usda.gov/programs/nrsas.htm>.

Scientists mentioned in this story can be contacted through Don Comis, 5601 Sunnyside Ave., Beltsville, MD 20705-5129; phone (301) 504-1625, fax (301) 504-1641, e-mail dcomis@asrr.arsusda.gov. ◆

Corn Seed Pretreatment Reduces Fusarium

Finding kinder, gentler microbial friends for corn plants has led to a strategy for controlling a fungal toxin—even before the crop is planted.

The fungus, *Fusarium moniliforme*, is especially dangerous if it gets into corn fed to horses or swine, says ARS microbiologist Charles W. Bacon. While contamination with the fumonisin toxin produced by *F. moniliforme* is rare in the United States, the Food and Drug Administration established tolerance—or maximum allowable—levels as a precaution in early 1999.

Bacon heads the Toxicology and Mycotoxin Research Unit in Athens, Georgia. He and fellow microbiologist Dorothy M. Hinton found a safe, convenient way to prevent corn contamination from the moment the seedlings come up. They began working on the project in 1996.

Now a company is developing a seed treatment with a harmless natural bacterium that suppresses *F. moniliforme*. Farmers may have access to the treatment in a year or two, pending final field tests.

Fusarium thrives inside corn plants, dwelling in spaces between the cells. And one obstacle to removing it has been that many isolates actually benefit the plants.

“While the fungus is bad news for mammals, we found that most strains of it seem to help improve corn root growth,” says Bacon. “This better enables the plant to survive dry conditions and related stress. What we’ve done is substitute a bacterium that is harmless to both plants and animals.”

Last year, Bacon and Hinton found that a strain of *Bacillus subtilis* fills up corn’s intercellular spaces before *F. moniliforme* gets the opportunity. Scientists call this competitive exclusion.

And the *B. subtilis* wants the plant all to itself. In petri dishes, it actually repelled *F. moniliforme* and may do more for plants’ roots than *Fusarium* does. The helpful *B. subtilis* has shown promise not only in the lab but also in greenhouses and small-scale field plots in Georgia and Iowa.

Bacon and Hinton filed a patent on the technology, which caught the eye of Donald S. Kenney, director of technology for Gustafson LLC, a seed treatment company in Plano, Texas.

“To control fungal toxins in an ear of corn through a seed treatment is especially interesting to us,” says Kenney. “You’re protecting the harvest by doing something far upstream, before the farmer even buys the seed.”

Scientists have found other strains of *B. subtilis* that prevent corn from being contaminated with *Fusarium*. But the growing plants would have to be “vaccinated” with the microorganism through sprays or other treatments. And that’s impractical for farmers.

However, seed treatments are very practical. “We use a fermentation process to stabilize the bacteria and increase concentrations,” says Gustafson plant pathologist Philip Brannen. “Seed companies would buy the product from us in a liquid or dried form.”

Another benefit is the product’s stability. Corn seed sellers get about 10 percent of their product returned from retailers each year, says Kenney. Pretreated seed may have to be stored a year before it can be resold. The treatment seems to last at least 2 years, which is plenty of time for resale.—By **Jill Lee**, formerly with ARS.

This research is part of Food Safety, an ARS National Program (#108) described on the World Wide Web at <http://www.nps.ars.usda.gov/programs/appvs.htm>.

Charles Bacon is in the USDA-ARS Toxicology and Mycotoxin Research Unit, Richard B. Russell Research Center, 934 College Station Rd., Athens, GA 30605; phone (706) 546-3158, fax (706) 546-3116, e-mail mewborns@ars.usda.gov. ◆