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Controlling nitrogen runoff with on-farm BIOREAC

By Madeline Fisher, Crops & Soils magazine contributing writer; sciencewriter@sciencesocieties.org
Midwest farmers looking to control nitrogen runoff from their fields now have another option to consider. In places such as Iowa, Illinois, and Minnesota, denitrifying bioreactors are gaining ground as tools for removing nitrate from agricultural drainage before it reaches streams and rivers.

While the term “bioreactor” conjures up something high tech, these systems are simply buried trenches filled with wood chips, and they remove nitrate through the natural microbial process of denitrification. Studies by scientists worldwide have found that bioreactors can remove 50% or more of the nitrate that would ordinarily escape from farm fields. And because these systems don’t take land out of production and are easy to install and maintain, they’re also finding favor with landowners.

“There is good interest from farmers to put these systems on their fields … and early adopters who are willing to try these systems out,” says Alok Bhandari, an associate professor of agricultural and biosystems engineering at Iowa State University. At the same time, Bhandari points out that bioreactors need more study. “I think we still don’t understand these systems completely, so there are a lot of research questions that we’re continuing to have,” he says.

The need for bioreactors is especially acute in the U.S. Corn Belt, where a vast network of underground pipes collects excess water from the soil and discharges it into nearby streams. Known as drainage tiles, these pipes are one of the great successes of modern agriculture, having made farming possible on more than 50 million acres of land that would otherwise be too wet for crops.

But the tile system also has a downside. As excess water drains from fields and empties into local waterways, it carries with it soluble and potentially harmful pesticides and fertilizers, including nitrate. The Raccoon River in Iowa, for example, has the highest average nitrate
concentration among the 42 largest tributaries in the Mississippi River Basin, according to the city of Des Moines Water Works, which draws the city’s drinking water supplies from the river. As a result, the agency recently had to build a nitrate removal facility—the largest of its kind in the world—to keep nitrate-nitrogen levels below 10 ppm, the USEPA’s limit for safe drinking water.

Moreover, fertilizers from the Midwest travel down the Mississippi River and into the Gulf of Mexico, where they help fuel the development each summer of a lifeless, oxygen-depleted area of water known as the “dead zone.” The problem has grown so massive that in 2007, a USEPA science advisory board on hypoxia called for a 45% reduction in the amount of nitrogen and phosphorus entering the Gulf of Mexico from the Mississippi and Ohio River watersheds.

Bioreactors could definitely play a role in addressing these problems. But they shouldn’t be seen as the ultimate solution, cautions Dan Jaynes, a research soil scientist with the USDA’s National Laboratory for Agriculture and the Environment in Ames, IA.

“We see bioreactors as one of the tools in the toolkit,” says Kult, who has helped construct a number of bioreactor demonstration projects around Iowa. “The bioreactor needs to be paired with a comprehensive nutrient management plan and other best management practices.”

How they work

Although bioreactors vary in design, they all operate in basically the same way: Drainage water is routed through an underground trench of wood chips (or some other carbon source), where soil microorganisms convert the nitrate into nitrogen gas and release it harmlessly into the atmosphere.

In Iowa, bioreactors are placed at the edge of a field, under grass buffers, but they can also be designed so that farmers can drive equipment right over the top of them. Denitrifying wetlands, in contrast, require farmers to give up some cropland, making them “a little harder to sell,” Kult says. Wetlands also can’t be created on certain landscapes, he adds, and so bioreactors are an attractive alternative.

Denitrification occurs naturally in soils anyway; thus, bioreactors aim to raise the rate of denitrification above normal, background rates. This means, first of all, providing denitrifying bacteria with an ample supply of readily available carbon. They also need an appropriate habitat and enough time to perform denitrification.

Bioreactors are relatively simple to construct. A trench is dug and lined with a filter, then filled with wood chips, and finally covered over with a compacted soil layer. The trench is usually placed in grass buffer strips or other areas of the landscape that don’t contribute to surface runoff.

Although bioreactors vary in design, they all operate in basically the same way: Drainage water is routed through an underground trench of wood chips (or some other carbon source), where soil microorganisms convert the nitrate into nitrogen gas and release it harmlessly into the atmosphere. Illustration by Dr. Alok Bhandari. Reprinted with permission from the Leopold Center of Iowa State University.
degradable carbon on which to grow. Although corn cobs and other carbon sources have been tested, Bhandari believes wood chips are probably the best filler material to use. “They are a slow-release, solid carbon source, and they give the reactor a structural integrity,” he says.

The other important condition for denitrification is a water-saturated environment depleted in dissolved oxygen gas. Bhandari explains that in the presence of oxygen, denitrifying microbes switch to using oxygen to break down carbon rather than nitrate. In this case, the wood chips simply degrade without the benefit of nitrate treatment.

Wastewater treatment plants have used similar concepts to maximize denitrification for decades. Still, it wasn’t clear if the same ideas would apply in farm fields when Jaynes started studying bioreactors more than a decade ago. “We got into this early enough that we really just wanted to make sure it worked or not,” he says.

That basic question has now been answered: Bioreactors can be “very effective” at removing nitrate, Jaynes says. In the experimental plots his group studies, two 6-ft-deep trenches were dug parallel to a tile line, one on either side. The trenches were then filled with 4 ft of wood chips and finally layered over with 2 ft of topsoil. Subsurface water in the root zone must therefore pass through these wood chip “curtains” before reaching the tile and leaving the field. As it does, the bioreactors remove approximately 65% of the nitrate compared with the control plots. In other words, while the control plots typically release 20 to 25 ppm nitrate-nitrogen, Jaynes says, the bioreactor plots only discharge 6 to 8 ppm.

**Design considerations**

The bioreactors Bhandari studies are somewhat different. For one, although he has installed long, channel-like reactors similar to those of Jaynes’ group, the design giving the best results right now is a broad bed of wood chips, about 25 ft wide, 50 ft long, and 4 ft deep.

Secondly, instead of having subsurface water flow through the reactor on its way to the tile, these designs actually divert water from a tile—usually a tile main—through the reactor, returning the treated water to the tile right before it empties into a stream.

To achieve this, a small section of tile at the top of the bioreactor is replaced with a control box containing stop logs. The stop logs essentially act as a dam, blocking water from entering the tile and diverting it into the reactor for treatment.

But after a big storm—when flow rates are high and the reactor is running full—water easily washes over the stop logs and into the tile, bypassing the reactor completely. This feature is key, because the possibility of water backing up inside the reactor and onto fields is the number one concern of most landowners, Kult says.

During periods of high flow, preventing water from rushing through the reactor too quickly is also critical; otherwise, the low oxygen concentrations needed for denitrification won’t develop, and little nitrate will be removed. To control the reactor’s hydraulic retention time, Bhandari thus recommends installing a second set of stop logs at the reactor’s downstream end. Turning up these stop logs holds water in the reactor longer, boosting denitrification rates.

“What we’ve observed is that a hydraulic retention time inside the reactor of about four to eight hours will

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“We see bioreactors as one of the tools in the toolkit. The bioreactor needs to be paired with a comprehensive nutrient management plan and other best management practices.”

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Placing the upper control structure, which diverts water from the existing field tile into the bioreactor. Photo courtesy of Keegan Kult, Iowa Soybean Association.
provide an annual 40 to 50% reduction in nitrate,” Bhandari says.

Although managing the stop logs sounds like work, “we think the farmer would have to adjust the flow maybe just twice a year,” Bhandari says. During the spring rainy season when water is flowing quickly, for example, the downstream stop logs can be turned up to increase the retention time. Once the rains are over, these stop logs can be dropped again to prevent water from sitting too long inside the reactor, Bhandari says.

Bioreactor placement

With money from Agriculture’s Clean Water Alliance (ACWA), a group of 13 Iowa agricultural cooperatives and retailers, and Wisconsin’s Sand County Foundation, the Iowa Soybean Association (ISA) has now installed six bioreactors in the Des Moines and Raccoon River watersheds, including ones being studied by Bhandari. After completing one more reactor this year, ISA then plans to construct dozens more in partnership with the USDA-NRCS Mississippi River Basin Initiative, which offers additional Environmental Quality Incentives Program cost-share money to farmers in select watersheds. Thus, a large part of Kult’s job now involves determining where bioreactors should go on the landscape and finding landowners who are willing to host them.

How does ISA decide where to build these systems? As far as tile lines go, Kult works with farmers to identify those with the most consistent flow, so that as much water as possible is treated. He avoids tiles with many surface inlets due to the risk of water-borne sediments clogging the reactor. So far, ISA has also installed demonstration bioreactors mainly on tiles of 6 to 10 inches in diameter, for an average cost of $8,000. Building bioreactors on tiles much larger than this can become prohibitively expensive.

But by far ISAs most important criterion for situating bioreactors has to do with nitrate levels. A decade’s worth of ACWA-sponsored nitrate monitoring in the Raccoon and Des Moines River watersheds has revealed certain sub-watersheds to be nitrate hot spots, Kult says. The ISA is now focusing its efforts in these problem areas rather than just building bioreactors everywhere. Kult thus recommends landowners and agencies do at least some nitrate monitoring ahead of time to ensure the practice has maximal impact.

Jaynes, too, favors a targeted approach. He also thinks that individuals, organizations, and government agencies need to consider carefully what they hope to achieve in building these systems. Is the goal simply to put a dent in the total mass of nitrate flowing down to the Gulf? Or is it to meet a certain water quality standard, or protect a small parcel of sensitive habitat? These are very different goals, Jaynes says, and each will have its own implications for bioreactor size, location, and design.

“We’ve answered the question, do bioreactors work or not?” he says. “Now the question is: How would you design one to meet a certain criterion for performance?”

The future

As bioreactors slowly spread across the landscape, a number of additional uncertainties remain, including questions about the impacts of these systems on the larger environment. In particular, Jaynes says, “One worry about bioreactors is that we’re trading a water quality problem for an air quality problem.”

He explains that because nitrate isn’t converted into nitrogen gas all in one step, the potential exists for substantial production of nitrous oxide, an intermediate in the denitrification process—and a potent greenhouse gas. Preliminary laboratory and field measurements by Jaynes, Bhandari, and others suggest the amount of nitrous oxide released by bioreactors is
likely no more than that produced by natural denitrification in streams and soil. But more study is needed to fully assess the risk.

Another concern is the possibility of producing methylmercury, a dangerous neurotoxin that accumulates in fish and in people. Little is known about the potential for producing this chemical inside bioreactors, but Bhandari thinks proper management of hydraulic retention time could help reduce the chances. Because conditions become ripe for methylmercury production when nitrate is completely consumed, “we try to ensure that all of the nitrate is not removed, but that nitrate (still) falls below the 10 ppm standard,” he explains.

He adds that the same bacteria that generate methylmercury also release hydrogen sulfide—notorious for its rotten-egg smell—which means that producers should monitor periodically for sulfide odor.

Perhaps the biggest unknown of all right now is just how long bioreactors will last. The bioreactors that Jaynes studies appear to be just as effective at removing nitrate today as when they first were constructed 10 years ago, suggesting their total lifespan could be 15 to 20 years. But a more precise number will be needed eventually.

Otherwise it’s impossible to calculate the bioreactor’s true cost-effectiveness and compare it against cover crops, drainage water management, and other nitrogen management practices on a “dollar per pound of nitrate removed” basis, Jaynes says.

Still, a preliminary cost analysis by Jaynes and his colleagues suggests that bioreactors might fare reasonably well in the competition for precious conservation dollars—with a cost right now that’s higher than denitrifying wetlands, but significantly lower than cover crops.

Bioreactors also have something else going for them in the cost–benefit equation: Unlike cover crops and certain other nitrogen management practices, they’re virtually management-free.

“Once you put them in, they run,” Jaynes says. “The farmer doesn’t have to do anything, which is a real plus when you’re talking about conservation practices.”

“Once you put them in, they run. The farmer doesn’t have to do anything, which is a real plus when you’re talking about conservation practices.”
Meet the professional: Fred Vocasek

When Fred Vocasek was asked to join the Kansas CCA board in its inaugural year, he thought he would help launch the group, stay for maybe 12 months, and then move on to other things. “That was 1992,” he recalls with a laugh. Now, he jokes that his colleagues can’t get rid of him. They’re not complaining. Earlier this year, the board voted unanimously to nominate Vocasek for the International CCA of the Year Award, calling him a “model CCA” and acknowledging his “selfless volunteering” for the Kansas CCA program, innovative ideas, and vision. A 27-year employee of Servi-Tech, the nation’s largest crop-consulting firm, Vocasek received the award in Long Beach, CA in early November at the Annual Meetings of the American Society of Agronomy (ASA), Crop Science Society of America, and Soil Science Society of America.

In addition to serving on the Kansas CCA board since its inception, Vocasek has held several positions on the International CCA board, most recently as its representative to the ASA board. But while he may joke about his involvement, Vocasek values the CCA program deeply, especially for its ability to reach people through continuing education. “To me, that’s the strength of the program,” he says. “By educating and working with the CCAs, you’re not just working with the 25 people in the room. You’re working with the 25 people in the room who will then work with their 20 or 25 people outside. So, those efforts are multiplied.”

Vocasek’s own reach has been just as long at Servi-Tech, according to CCA Orvin Bontrager, the company’s education director. As a laboratory agronomist and technical services representative in Dodge City, KS, Vocasek has helped hundreds of customers interpret soil and water analysis results, use water and fertilizer more efficiently, comply with environmental regulations, manage manure and wastewater, and more. Because of his expertise and teaching skills, he’s also frequently tapped to train Servi-Tech’s crop consultants and agronomists in soil fertility management.

In these company trainings, Vocasek brings the same passion for teaching and career-long learning that he shows in the CCA program. He always bases his soil fertility

[continued on page 18]
Solving problems, bringing people together

Both Davis and Kemp agree that his knowledge of soil chemistry was simply superb, and when trying to solve a vexing problem, he left no stone unturned. Kemp recalls, for example, how Franklin attacked the state's perennial problem with manganese deficiency in soybeans. Convinced that the amount of manganese farmers were applying to the crop was sufficient, Franklin searched tirelessly for other answers. He encouraged Kemp to try a liquid fertilizer application. He explored the possibility that glyphosate was immobilizing the nutrient or that new soybean varieties weren't as manganese efficient. Although the problem continues today, Kemp says the experience taught him a lot about thinking outside the box and viewing a problem from multiple perspectives.

Franklin was also skilled at getting people to see each other's perspectives. In the CCA program's early years, for instance, extension agents and fertilizer salespeople were pretty suspicious of one another, relates Davis. But the barriers quickly broke down once CCA classes got everyone in the same room together—especially with Franklin up at the front openly acknowledging people's differences and asking them to work through them.

"He would say, 'Let's discuss this and see if we can't come to some agreement about what the numbers mean,'" Davis says. "Ralph had a way of challenging everybody to step back and take a look at the big picture," rather than sticking to their own narrow viewpoints.

He loved to have his viewpoint challenged, as well. Few things seemed to delight him more, in fact, than arguing over a meaty soils problem. Kemp remembers many a lively debate with Franklin that ended up leading both of them to a deeper understanding of an issue. Questioning and argument were also among Franklin's most important teaching tools, because he knew that in order to defend a position, students really had to know what they were talking about.

"He loved knowledge," Kemp says. "He was the kind of person who wanted you to learn. And he wanted you to teach him."

With Franklin gone, the South Carolina CCA program is trying now to regroup. Trainings are still going on, and the program's long-time leaders are committed to keeping things going. But so far, no one has stepped up to take charge with quite the same passion and energy as Franklin.

"He has definitely been sorely missed," Davis says. "[If there] were a clone of him that we could get our hands on, it would sure make all of us feel better."

They also just miss their friend. Says Kemp, "I wish he was still here to argue with me."

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New options in forage sorghum

By James Giese, Director of Science Communications; jgiese@sciencesocieties.org or 608-268-3976

Sorghum is a hardy warm-season grass that can be grown as a forage or grain crop. Because it is drought resistant, there has been some renewed interest in the crop during seasons of high temperatures and drought and in areas beyond its present range. There is also some potential in using sorghum as a biomass energy crop because it is a rapid-growing annual that can fit into a traditional crop rotation on a short-term basis.

Sudangrasses and sorghum-sudangrass hybrids can be grazed by livestock or fed as green chop or hay. Forage sorghum usually produces as much silage per acre as corn. However, sorghum silage contains less grain and is higher in fiber than corn silage.

Forage sorghum can be more economical to produce than corn and may be a good choice for silage where there is little rainfall or where the climate is too hot. It grows best in sustained elevated temperatures from 75 to 80°F. Sorghums require one-third to one-half less water than corn. An additional benefit is that forage sorghums can be grown on more marginal crop land than corn.

Currently, sorghum production is concentrated in areas where corn production is limited because rainfall is insufficient and the temperatures are too high. So, most of the U.S. sorghum acreage is in the southern Great Plains states; with Kansas, Nebraska, and Texas as the leading producers.

In the U.S. Midwest, forage sorghum production has been limited because the crop matures late and, except in drought-prone areas, does not produce as much total digestible nutrients per acre as well-adapted, high-yielding corn hybrids.

However, the introduction of several new traits has lead to the expanded production of new hybrids that match corn silage in nutritive quality.

“The acreage planted to forage sorghum is increasing,” says Brent Bean, professor and extension agronomist at the Texas AgriLife Research and Extension Center in Amarillo. “Forage sorghum uses less water than corn. Corn makes a great forage but requires about 30% more water for maximum production compared with forage sorghum. With the development of brown midrib (BMR) forage sorghums, the quality of forage sorghum has been improved. Some forage sorghum hybrids, both BMR and non-BMR, can produce quality silage equal to that of corn. Also, the cost of producing sorghum is significantly cheaper than corn.”

The primary sorghums used for forage can be grouped as forage sorghum, sudangrass, and sorghum-sudan hybrids. According to the Forage Sorghum Silage Production Guide—Western Production (offered by the United Sorghum Checkoff Program) by Bean and Mark Marsalis, each of these types has a different growth characteristic that influences how they should be used. Even within a type, considerable differences can exist between varieties. Typically, forage sorghums, which grow to 6 to 12 ft tall, are used for silage or for a single-cutting hay crop. Sudangrass is most often used for grazing, multiple hay cuttings, or occasionally green chop. Sorghum-sudangrass hybrids...
are best used for single or multiple hay cuttings and grazing.

**Growth, yields, and pest management**

Sorghums are coarse, fast-growing, warm-weather grasses that can provide feed in mid-summer when many other types of forage are slower to develop. Stems are erect and solid and reach from 2 to 12 ft in height.

Buds that form near the crown develop into grain-producing tillers. Sorghums are best suited to warm, fertile soils; cool, wet soils limit their growth. The crop tolerates drought fairly well though adequate fertility and soil moisture maximize yields. Sorghum becomes dormant in the absence of adequate water, but it does not wilt readily. Growth resumes when moisture conditions improve.

Soil fertility requirements are somewhat similar to those of
corn at the same yield goals; although sorghums are usually more efficient in their use of phosphorus and potassium.

Following are some recommended uses based on the *Forage Sorghum Silage Production Guide*—Western Production by Marsalis and Bean:

Forage sorghums are best harvested as silage. Forage sorghums can range anywhere from 6 to 14 ft in height. The feed value of sorghum silage per acre is about 90% that of corn silage. On more productive soils, with favorable moisture and fertility, corn is a better silage crop, producing comparable yields and higher feed value than forage sorghums and sorghum-sudangrass hybrids.

Grain sorghum hybrids were developed for grain production and tend to make good quality silage; however, silage yield will be less than what can be obtained with forage sorghums. In some cases, producers of dairy silage will sometimes prefer a high-grain hybrid rather than taller types with higher stover content.

Sorghum-sudangrass hybrids are a cross between sorghum and sudangrass and are characterized by relatively small-diameter stems, high tillering capacity, rapid re-growth potential, and low grain yield. Sorghum-sudangrass hybrids can produce good quality silage, but are best suited for grazing or hay production.

New developments

The introduction of some new traits in the past few years is expanding the use of forage sorghums. These new developments include the introductions of brown midrib forage sorghums, photoperiod-sensitive sorghums, and brachytic dwarf sorghums.

**Brown midrib sorghums**

The brown midrib gene is linked to a reduction of lignin content in the plant. Lignin is a non-digestible component of the cell walls that limits forage fiber digestion. New brown midrib hybrids have shown an 18.9% average increase in feed value compared with conventional types.

“Before the release of the brown midribs, sorghums have been known for their good heat tolerance, water efficiency, and ability to produce good volumes of forage in a short period of time,” says Ricky Rice, forage sorghum specialist with Advanta US. “They were used extensively in the southern United States, but as you moved north, they were basically used as a rescue crop. The reason was because the forage quality could not match that provided by corn silage, alfalfa hay, or cool-season grasses.

“However, with the introduction of the brown midribs that all changed. This trait dramatically lowered the lignin content and improved the nutritional quality.”

The trait provides a premium summer annual hybrid with the same agronomic characteristics that are found in a conventional sorghum-sudangrasses hybrid such as good hay quality, heavy pasturing, superior drought tolerance, and adaptability.

**Photoperiod-sensitive sorghums**

Delaying flowering in sorghums and sorghum-sudangrasses will also delay the decline in quality of the vegetative portion of the plant.
Selected maturity genes have been used to produce hybrid forages that are extremely photoperiod sensitive and do not flower until very late in the growing season. Some of these photoperiod-sensitive varieties, including forage sorghums and sorghum-sudangrass hybrids, are commercially available. The delayed flowering slows the decline in forage quality associated with floral initiation and provides flexibility in harvest management for producers.

The addition of the photoperiod-sensitive trait has really helped in the agronomic management of sorghums and sorghum-sudangrass hybrids,” Rice says. “The plant no longer is dependent on how many days it has been growing or how many heat units it has acquired. It will change from vegetative to reproductive when the day length gets to a certain period.

“So what that did was, especially in sudangrass hybrids, give growers a wide window when the crop can be harvested and still maintain quality over a long period of time.”

Varieties with the photoperiod-sensitive trait combined with the brown midrib trait were introduced around 2001, so this allowed the combination of improved nutrition quality with more versatility in agronomic practices, according to Rice.

**Brachytic dwarf sorghums**

Brachytic dwarf genes in sorghum control height and produce a type of dwarfism known as “brachytic dwarfism,” which reduces the length of the internodes without affecting other agronomic plant characteristics, such as leaf number, leaf size, maturity, or yield/biomass production.

The brachytic dwarf sorghums produce comparable tonnage to taller hybrids by producing more leaves and more tillers. Sorghums with this trait have very high leaf-to-stalk ratios, prolific tillering, superior standability, and comparable tonnage to normal-height sorghums.

“Brachytic dwarf hybrids have shortened internodes,” Rice explains. “The height of the plant is greatly reduced, but the same number of nodes exists as in normal hybrids. This helps with problems associated with lodging, and also the shorter internodes are not harvested too low, allowing good regrowth after grazing or cutting.”

**Herbicide resistance**

According to Rice, herbicide-resistant grain sorghums could be available by 2012 or 2013. Heavy weed infestations can reduce grain sorghum yields by up to 50%.

“Kansas State researchers have developed a herbicide-resistant grain sorghum line that is tolerant to acetolactate synthase–inhibitor herbicides,” Rice says. “This trait will give growers another management technique to help control weeds and increase yield.”

Kansas State is working with several seed companies in developing the acetolactate synthase (ALS)–resistant sorghum. The researchers are also working with the USEPA’s Minor Use Pesticides program to register the use of Steadfast herbicide (DuPont) on ALS-resistant sorghum.

In addition to herbicide resistance, a variety of improved biotech and conventional forage sorghum traits are being developed.
These include:
- cold tolerance: a conventional trait that could lower sorghum’s tolerance to cold soils by 10°F or more. This means sorghum can be planted earlier, in 50°F soils, and the range of grain sorghum can be expanded throughout the Corn Belt;
- salt tolerance: this trait will expand the range of lands available for crop production and reduce requirements for fresh water;
- nitrogen use efficiency: although sorghum already requires less nitrogen than corn, an increase in its nitrogen use efficiency will increase its usefulness; and
- drought tolerance: although sorghum is already a drought-tolerant crop, this trait will provide additional drought tolerance beyond the current 30 to 50% less water that sorghum currently requires compared with corn and other crops.

**Pest management**

Sorghums are hardy plants but can be attacked by several pests and currently lack good weed control methods beyond cultivation. Sudangrass and sorghum-sudangrass hybrids planted in a well-prepared, warm seedbed germinate and grow rapidly and can compete well with most annual weeds. Weeds can be controlled with cultivation if the crop is planted in rows 20 inches or more wide.

Forage sorghums are attacked by wireworms, seed beetles, cutworms, aphids, sorghum midge, chinch bugs, spider mites, armyworms, and earworms. Some of these pests can be controlled with insecticide seed treatments in the planter box. However, most of these insects do not normally occur in sufficient populations to warrant control in the Midwest.

**Toxicity**

According to the *Forage Sorghum Silage Production Guide—Western Production* by Marsalis and Bean, sorghums have the potential to be very toxic to animals. Two concerns that producers should be aware of are hydrocyanic/prussic acid poisoning and nitrate toxicity. Sorghum plants, particularly young plants, contain an alkaloid that releases hydrocyanic, or prussic, acid when hydrolyzed. This can be toxic to livestock. Young plants, branches in the leaf axils of injured plants, and new shoots from the crown at the soil surface contain more than twice as much acid as the mature leaves of normal plants. When the crop is cut and field-cured or is ensiled, and the hydrocyanic acid degrades (two to three weeks after ensiling), the danger is greatly reduced. Sudangrasses contain less than half as much hydrocyanic acid as most sorghums.

In addition, during periods of plant stress such as drought, sorghums tend to accumulate nitrates, which can poison livestock. If retarded crop growth is observed, analyze the forage for excessive nitrates before feeding it. In the case of high nitrate levels, the storage should be ensiled or combined with other feeds low in nitrate to reduce overall daily nitrate intake.

Another concern is that ensiling forage sorghum with a high nitrate concentration can produce nitrogen dioxide (NO₂), which is toxic to humans and animals. For this reason, care should be taken when a silage pit or bag is first opened when high nitrate levels are suspected. If nitrate concentration in forage sorghum is an issue, add 8 lb of sodium metabisulfite per ton of fresh material to reduce the risk of NO₂ formation.

Forage sorghums can be a better option than corn in some environments. The drought hardness of forage sorghums and their greatly reduced use of water compared with corn make them an excellent forage or silage plant in semi-arid production areas. Recent developments such as the brown midrib and brachytic dwarf traits and others coming in the seed pipeline are expanding and improving the production possibilities for forage sorghums.

The information in this article was based on Forage Sorghum Silage Production Guide—Western Production, by Mark A. Marsalis, extension agronomist, New Mexico State University Agricultural Science Center at Clovis, and Brent Bean, extension agronomist, Texas AgriLife Research and Extension Center at Amarillo. Available online at www.sorghumcheckoff.com/userfiles/WesternForageGuide_FINAL.pdf. The Sorghum Checkoff Program offers a variety of production guides based on region. For more information, see www.sorghumcheckoff.com.
Certification update

By Luther Smith, Director of Certification Programs; lsmith@sciencesocieties.org or 608-268-4977

We are coming to the end of another year, and that means CEUs are due for about half of you reading this magazine. Every certified professional with ASA and SSSA has a two-year CEU cycle with 40 total CEUs required to be earned by the end of December. You can check when your cycle ends and how many CEUs have been reported 24/7 via the websites (www.agronomy.org/certifications or www.soils.org/certifications).

There’s still time if you need more CEUs. You have several options. For professional meetings, look at the online calendar (www.agronomy.org/meetings/calendar) to determine what is available in your area. Self-study CEUs are published in the magazine, but better yet, go to the website and search more than 40 titles. You can take the quiz online and save $5. You also have the option to self-report CEUs. If an educational event that you attended met the CEU standards but was not board approved, you can still self-report it. Just use the online form.

Now is the time to let your certification expire due to a lapse in CEU reporting. Use the tools found on the websites and update your records before the end of the year.

Now is not the time to let your certification expire due to a lapse in CEU reporting. Use the tools found on the website and update your records before the end of the year.

The next CCA and CPAg exam date is February 4, 2011 with a registration deadline of December 10. The next CPSS/C exam date is April 15, 2011 with a registration deadline of March 4. Get started towards professional certification, and register for the appropriate exam.

Already certified? Encourage a colleague to become certified. If every certified professional (14,000+) would tell one person to become certified, we could double our numbers overnight and drastically expand the professionalism in agronomy and soils.

Back to the future—regulations

I was in Washington, DC recently talking with commodity groups, government agencies, and agriculturally focused membership organizations. I came away from those discussions feeling like we were back in the early 1990s when the CCA program was started. Back then, there was discussion around implementing regulations that would not allow an individual to provide both agricultural inputs (fertilizer, crop protection products, etc.) and advice. So industry, academia, and government representatives along with the American Society of Agronomy got together and developed the CCA Program. The goal was to establish standards by testing and improve professionalism through continuing education requirements.

We were successful—the CCA Program was born, and the specific regulation discussions diminished.

Fast forward to 2010. There are about 13,000 CCAs throughout the U.S., Canada, and India with continuing expansion plans for Argentina, Mexico, and South Asia. There are another 1,000 plus certified professionals in agronomy and soils. Recently, the regulatory discussions in the U.S. have escalated around water quality issues. There is increased talk about what types of regulations are needed to improve nutrient management and minimize off-site movement into water resources. This is not completely new, but the pressure for measurable results has greatly increased.

There are many good things happening on the farm related to implementation of conservation practices and better utilization of inputs that many of you are directly involved in, but the story may not be getting through to policymakers in DC. There’s a great opportunity for farmers to be working with certified professionals. As professionals, you can help them adopt the best practices for their operation, improving environmental conditions while minimizing or even avoiding undue regulations.

Becoming certified is a rigorous process, but think about what is required through the continuing education process and what that represents. Farmers tell us that they view the continuing education requirements as one of the key benefits to working with a certified professional. It shows them that you are keeping up on the latest information, which in turn keeps them up to date. You conduct 40 hours of learning every two years, so you can expand your knowledge and skills. We process more than 8,500 CEU course applications annually representing more than 23,000 CEUs. When you consider 14,000 certified professionals earning on average at least 20 hours per year, that equals 280,000 hours in learning. Who is better qualified to help farmers optimize their production while protecting the environment than you as a certified professional?

Your clients will judge you more on how you perform than on the initials after your name—we all understand that. Those initials, though, are becoming increasingly important to the regulatory community. Just saying that you know what you are doing will not be enough; you will be asked to prove it, and being certified helps you do that and also helps your customers.
Brown midrib sorghums

Advanta US offers a variety of forage sorghums. Much of the company’s research efforts have focused on developing brown midrib 6 (bmr-6) hybrids. The brown midrib gene in sorghums reduces the lignin content in the plant. Lignin is the component of the cell walls that can limit forage fiber digestion. The brown midrib trait was discovered in corn at Purdue University in 1926. In 1978, the mutant was identified in sorghum. Research indicated the trait reduced lignin in sorghum comparably to corn and sparked interest for utilization in sorghum forage production. Currently, three genes—bmr-6, bmr-12, and bmr-18—are used in the sorghum industry to produce primarily brown midrib hybrids. Forage analysis and feeding trials have demonstrated improved digestibility from brown midrib forage. Dry matter yields have been comparable to conventional sorghum forages and competitive with corn silage.

According to Advanta US, brown midrib forage sorghum and sorghum-sudangrass can deliver forage quality and animal performance comparable to alfalfa and corn. Compared with corn, the brown midrib forages require one-third less water and less fertilizer for similar yields. Currently, the company is centering its new development efforts on sorghums with herbicide tolerance, cold tolerance, increased sugar yield, and higher total biomass for ethanol or fuel production.

For more information, call 800-333-9048 or visit www.advantaus.com.

Nematode samplers

A new line of nematode samplers is said to be the first collection of products made to improve the efficiency of sampling for parasitic nematodes.

Fred Vocasek | From Page 10

advice on the very latest findings from university studies and other independent research, Bontrager says. At the same time, he excels at making the information understandable and applicable to a wide range of professionals, including crop consultants, fertilizer dealers, and growers.

“He’s just a very good educator from the standpoint of promoting good soil fertility management,” Bontrager says. “And making sure, as advisers, that we’re making the most economically and environmentally sound recommendations.”

Emphasis on the environment

A mounting emphasis on the environment is probably the biggest change Vocasek has seen over his life and career in agriculture. Growing up on a small farm in Nebraska—where there was “work for two and income for one”—Vocasek spent countless days toiling with a pitchfork and a manure spreader, mucking out barns. Not surprisingly then, he got hooked by the modern promise of agronomy while attending the University of Nebraska in the mid-1970s.

“When I graduated, I felt that our job as agronomists was to use science and technology to put a plate of healthy, nutritious food in front of every person on the planet,” he says.

Over time, however, concerns about farming’s environmental impacts have overshadowed the benefits that technology-based agriculture brings, he says. Many are now calling for a return to smaller, less industrial agricultural systems—a trend Vocasek admits he finds puzzling, given his own experiences on his family’s small farm and the love he has for many other things that modern technology provides, from cell phones and i-Pads to fresh fruit 365 days a year. Still, he has adapted to this change.

“I think the way we do it is by emphasizing efficient production,” he says. “Working every drop of water as hard as we can, so to speak,” or helping growers be as sparing as possible with fertilizer.

Thirty years ago, for example, many fields in southeastern Kansas were flood-irrigated, meaning that farmers might use 30 to 35 inches of water to produce each acre of corn, Vocasek says. But today, growers produce double the amount of corn on just 16 to 18 inches, thanks to improvements in technology and Servi-Tech’s work with crop consultants on efficient water usage.

Bontrager adds that Vocasek is extremely good at identifying the environmental issues and regulations that could affect Servi-Tech’s clients and then educating the company’s consultants on these issues; for example, the regulations governing the handling of manure, fertilizers, and pesticides at concentrated animal feeding operations (CAFOs).

“I know he has worked with many advisers on helping their clients meet the regulations that are needed to continue their livestock and crop production businesses,” Bontrager says.

The common denominator in all this work is Vocasek’s belief that CCAs can’t rest on their laurels and expect to be effective—they must keep learning and growing. Now that he has won the International CCA of the Year Award, no one expects Vocasek to rest on his laurels either.

“Individuals with careers as long and successful as Fred’s could become stagnant,” wrote the Kansas CCA Board in its nomination letter. “Fred is quite the opposite. He is consistently thinking about the future of the industry and how professionals like him can play a role.”

Vocasek is also an enthusiastic supporter of Crops & Soils magazine, serving as chair of the ad hoc advisory board.
The AMS Nematode Sampler TR-5 comes standard with five wheels and is extendable up to seven wheels. According to AMS, it is a cost-effective and efficient way to get samples from larger fields. The TR-5 connects to any tractor equipped with a Category 2 style three-point hitch and auxiliary hydraulic hook-ups. The nematode samplers are currently being used in Idaho, Montana, Minnesota, North Dakota, Washington, and Canada. For more information, call 800-635-7330 or visit www.ams-samplers.com.

Soil moisture sensor

A soil moisture sensor, the EC-5 by Decagon Devices, may be used to measure soil moisture and volumetric water content for greenhouse management, hydrology, irrigation scheduling, plant ecology, watershed characterization, and wireless sensor networks. The unit measures water content in any soil or soil-less media with minimal salinity and textural interactions. The sensor allows the user to characterize a site at multiple depths and locations. It determines volumetric water content by measuring the dielectric constant of the media using capacitance/frequency domain technology. The sensor uses a 70 MHz frequency, which minimizes salinity and textural effects, making it accurate in almost any soil or soil-less media. Factory calibrations are included for mineral soils, potting soils, rockwool, and perlite. The unit’s small size is said to make it easy to install—handy in field installations and good for nursery pots. In addition, the design makes it easy to push directly into undisturbed soil to ensure good accuracy.

For more information, call 800-755-2751 or visit www.decagon.com.

The EC-5 soil moisture sensor from Decagon Devices.

The TR-5 nematode sampler from AMS.
The Next Generation Agronomy Management System

ADVISOR is a comprehensive web-based agronomy management system providing decision support for agronomic best practices, GIS based field activity, and connectivity between all participants in the food production continuum.

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- Crop Protection, Soil Performance, and Crop Production
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CDMS 800.237.2367 | sales@cdms.net | www.cdmsadvisor.com
Soybean cyst nematode (SCN) is the most yield-limiting disease of soybean in Ontario and the northern United States. Unfortunately, many soybean growers continue to lose yield to the disease, and although effective and practical management tools are available, many growers still are not properly managing SCN or are unaware of the problem. Many researchers believe the stagnant soybean yields in certain parts of the province and the U.S. North Central region are partly due to insects and diseases, particularly SCN.

An international multi-year project was established with the following research objectives:
1. Reduce losses and improve SCN management in Ontario and the U.S. North Central states;
2. Demonstrate the effects of different SCN resistance sources on SCN field populations in a single cropping season; and
3. Produce annual fact sheets summarizing the results of this effort across all collaborating states and Ontario.

**Methods**

On-farm strip trials were established in the following states/provinces, with 28 total sites: Illinois (2), Nebraska (2), Iowa (3), Ohio (2), Minnesota (3), Missouri (2), North Dakota (2), Wisconsin (2), Kansas (2), Michigan (3), South Dakota (2), and Ontario (2). All locations utilized large plots with the exception of North Dakota where only small areas of a small number of fields are known to have SCN at this time. At most of the locations, there were multiple varieties, which represent the main resistance genes for SCN management.

Replicated strip plots were established with a minimum of four replications at each site. Each location has a minimum of four soybean varieties, which represent an SCN-susceptible variety, and varieties with SCN resistance from PI 88788 and PI 548402 (‘Peking’). In some locations in the U.S., another resistance source, PI 437654, was used where available. These are the most commonly used sources of resistance to SCN in northern soybean production areas. Regionally adapted varieties with similar yield potentials were used at each location.

Soil cores were collected at planting and at harvest from each strip plot at both locations in 2008 and SCN egg densities determined from each plot. A modified HG SCN type test is being done on both the spring and fall samples to characterize the SCN population at planting for the entire area as well as in individual plots at the end of the season. All HG typing is being conducted through Dr. Terry Niblack’s lab at the University of Illinois, and we have obtained the necessary permits from the USDA to facilitate the movement of soil to Dr. Niblack’s nematode lab in Illinois.

**Ontario results and summary**

In Ontario, two locations with known SCN infestations (Chatham/Kent, Essex) were established for large in-field demonstration purposes in both 2008 and 2009. The SCN-resistant varieties outyielded the susceptible varieties by 48.9% in Field 1 (Chatham/Kent) and 45.1% in Field 2 (Essex) in 2008 (Fig. 1 and 2).
North Central
Wisconsin CCA news

Congratulations to Carl Nachreiner, an agronomist with Landmark Services Cooperative, for being named the 2010 Wisconsin CCA of the Year! Nachreiner has more than 30 years of crop-advising experience and was part of the first class of Wisconsin CCAs. His primary job responsibilities are crop production, soil fertility, pest management, farm nutrient management, and conservation planning. However, as the farmer-nominator implied, Nachreiner’s job responsibilities can be summed up simply as “looking out for our best interests.”

As part of his responsibilities, Nachreiner has implemented several field demonstration plots that assist his clients with variety, fertility, and pest management decisions. He also participates in several educational field days as well as regional research projects including an Aphanomyces root rot monitoring program and beta testing of WEEDsoft, a computer software weed management program. Nachreiner also contributes to his client’s needs by authoring an electronic newsletter, which features his local observations as well as those from the University of Wisconsin and other regional industry partners. He also served as a mentor to several CCAs.

Nachreiner has also given back to the agricultural community by serving as a member of the technical advisory committee for University of Wisconsin’s Nutrient and Pest Management Program, two terms on the Wisconsin CCA board, and as a member of several other agricultural production, environmental, and industry committees. In his “spare time,” Nachreiner is an active member of his church, providing support to his local parish, regional diocese, and other religious-based nonprofit groups as well as missionaries both stateside and abroad.

2011 nominations requested

The Wisconsin CCA board is currently accepting nominations for the 2011 Wisconsin CCA of the Year Award. The deadline for applications is March 1, 2011. Electronic applications are preferred; however, applications may be faxed or mailed. Unsuccessful applications will not automatically be reconsidered the following year. For more information or to nominate a CCA, contact Bryan Jensen, Department of Entomology, 1630 Linden Dr., Madison, WI 53706 (fax: 608-262-3322 or email: bmjensen1@facstaff.wisc.edu).

The award will be given at the CCA luncheon prior to the start of the Wisconsin Crop Management Conference. The winner of this award is automatically nominated by the Wisconsin CCA board for the International CCA of the Year Award, which is given at the Annual Meeting of the American Society of Agronomy each fall. The official nomination form consists of five questions and must be completed in full for the committee to review. Two letters of reference are also required. An individual may only receive the award once.

As a nominator (especially as a successful nominator), you will get something that money cannot buy. You’ll have that special feeling knowing you took the time to nominate a friend and colleague for a job well done. You will also send the message that his/her job performance is recognized and appreciated. Please make it a priority to nominate a deserving CCA. After all, if you don’t do it, then who will?

Wisconsin CCA luncheon

The Wisconsin CCA board would like to invite all CCAs to a free luncheon during the Wisconsin Crop Management Conference on Tuesday, January 11, 2011. Lunch will start at 11:00 am and will be held in the Lakes Room on the second floor of the Alliant Energy Center, 1919 Alliant Energy Center Way, Madison, WI. There will be a short program (to be determined) that will conclude at 12:30 pm. More information will follow.
Editor’s note: We’re still looking for tales from others. Please share a story about your experience as a soil scientist with Crops & Soils readers. Email dferris@sciencesocieties.org.

I have had several conversations with people regarding ethics this month, so I thought perhaps an ethics tale might be in order. This particular tale goes back to a golf course/housing development that I worked on. My role on the project was to delineate the wetlands, write the environmental review document, and then secure any permits needed for the project. If you have any experience with these types of projects, you know that they are expensive and the developer is always trying to fast-track everything. In some cases, as with this project, the natural resource professionals tend to be looked upon by the developer as the people that hold up the project and the ones that add extraneous costs to the budget. I always thought this was an unfair assessment because the engineers can also hold up projects and are typically the bulk of the budget, but they are also viewed as a necessity. Don’t get me wrong, the overwhelming majority of my clients were honest, wanted to make sure that they were doing the right thing(s) for the environment, and appreciated the work we did, but this story isn’t about them.

This particular project was being constructed on a beautiful piece of property that was primarily wooded, but also had several wetlands across the landscape. The firm I worked for was hired to perform the Phase I environmental assessment as well as the environmental/natural resources work. I was the natural resources manager and put together a team for the project. Environmental review documents, which require information on many different aspects of the proposed project including items such as soil, surface and groundwater, aesthetics, socio-economics, traffic, and endangered/threatened species, to name just a few, can be complex and require attention to detail. This tale focuses on the endangered/threatened species and ecology aspects of the environmental review.

We had completed the wetland delineation and in the process noted that a few of the wetlands were of high quality, as were the areas of vegetation on the watersheds surrounding them. It was the wrong time of year to see flowering plants, and many of the endangered species that may have been present in this high-quality habitat would only be present in the spring of the year. One of the people I relied on when doing this type of work was the botanist we had on staff. I sent the botanist out to take a look at the areas because we had a few hits on the Natural Heritage Data-
I now had a client that appeared to be heading towards unethical practice and trying to hide the fact that there was likely a high-quality ecosystem on the parcel of land being developed.

and informed me that the client wanted to know what these plants looked like and where they were so that the client could “take care of them.”

An ethical dilemma

At this point, I had been in consulting long enough to have established a good reputation with the agencies for doing technically good and ethical work. I now had a client that appeared to be heading towards unethical practice and trying to hide the fact that there was likely a high-quality ecosystem on the parcel of land being developed. This also became an ethical dilemma for me in that this particular project meant a lot of income for the company that I worked for and some prestige to the people that could get the job done successfully. Given that there is a consultant/client confidentiality that needs to be considered, the consultant (me) just couldn’t run to the agencies to let them know what was going on. A call to the client convinced me that there was no changing the client’s minds because the client wanted to get the project approved and start construction due to financial considerations.

So you tell me. What would you do?

I don’t think this is a highly unusual situation for consultants to be in. This is just one of many experiences that I have had involving some ethics decision on my part. It gets especially difficult when you have a big project for a big client where financial considerations aren’t only significant for the current project, but also in looking at future work with that client.

The decision of how to handle the situation becomes more complicated when it is not totally your own. In the case of the telltale ginseng, I had to convince the owner of the company that what the client was asking us to condone and have knowledge of was not in the company’s long-term best interests. Why? Because we did a lot of work with the agencies across all sectors of our company’s services, so we had a lot of interactions across a lot of agencies, and the agency world is a small population. If word gets out that someone is unethical or trying to get around regulations, the company’s reputation is damaged on many fronts. This would subsequently hurt our ability to work for the rest of our clients because the trust we had built with the agency personnel would be compromised. Trust is hard to earn, but very easily lost.

In the end, the owner of the company agreed that this was not a situation that we wanted to be a part of, and by close of business that day, we were no longer consulting on that project. We handed over the work we had been paid for and moved on.

(We had this option spelled out in our contract language; an important clause for situations such as this.) Another firm picked up the projects, and whether they knew what happened or got involved with the ginseng cover-up, I will never know. I also don’t know if the developer ever made good on the threat to take care of the ginseng. I will say that there were additional issues that came up on the project (the consulting world is small too), and an agency employee commended us on getting out.

Your conduct is noticed

This told me that people do notice, and being the ethical party pays off in the end. It is also nice when clients start noticing that your reports and permit applications, while thoroughly reviewed, aren’t scrutinized to death like other consultants due to the agencies trusting that they are getting a straight-forward assessment. The client equates this to savings, and for us, that equated to more project work.

I gave an ethics talk to the Association of Ohio Pedologists this month and ended up having some very good discussion on decision making and personal codes of conduct as it relates to the soil science profession. If you haven’t looked at or read the ethics statement that you signed upon becoming licensed or certified in a while, take some time to do so. We make decisions every day, and many have an ethical component that needs to be considered. Unethical practice hurts all of us: the public, other professionals, and the future of our profession. If you see or have first-hand knowledge of someone in violation of the ethics statement, please report it. If you have questions or would like additional information, please feel free to contact me at dferris@sciencesocieties.org.
Natural resource conservation: The hidden agronomic practice

As a landowner, producer, and CCA in Southwest Louisiana, I witness firsthand how soil and water conservation practices are incorporated into farming operations. The dominant crops produced in my area are rice, soybeans, crawfish, and sugarcane. Naturally, the ultimate goal for producers and landowners is to achieve high crop yields and profitability. In doing so, they not only have to evaluate their direct crop input costs, but also their farming practices and infrastructure needs for efficiency.

Today’s landowner and producer consider conservation practices and best management practices an integral part of their operation. In Southwest Louisiana rice country, a producer would be hesitant to add a new farm into his operation if he could not implement conservation practices such as irrigation land leveling, irrigation water management, an underground irrigation water conveyance pipeline, and erosion control structures. These conservation practices are considered absolutely necessary for efficiency and profitability.

In addition to improving producer profitability, these practices better utilize crop nutrients, thus reducing nutrient loss into surface and subsurface water supplies. Conservation practices also allow producers to better manage invasive weed species and implement integrated pest management plans. The management of the farm infrastructure also involves several conservation practices such as access roads, channel-bank vegetation, buffer strips, filters strips, and grassed waterways.

Conservation work in the U.S. on the national level began in the 1930s with the formation of the Civilian Conservation Corps under the direction of the Department of Interior’s Soil Erosion Service. In 1935, this was followed by the congressional establishment of the USDA Soil Conservation Service (SCS), which later became the Natural Resource Conservation Service (NRCS). Early on, the leadership of the SCS saw the implementation of conservation on privately owned lands as a challenge. With guidance provided by the USDA, states began to adopt laws that formed conservation districts throughout the U.S. and its territories. This process, which is in place today, encourages locally led conservation efforts on privately owned lands.

A voice for natural resource conservation

The National Association of Conservation Districts (NACD) was formed in 1946 with a vision of being America’s voice for natural resource conservation. NACD is non-profit organization representing more than 3,000 conservation districts throughout the U.S. and its territories. It partners with other national agencies and organizations to promote natural resource conservation for private landowners. Presently serving as NACD’s second vice president, I chair the Legislative Foundation Committee, which coordinates all national legislative activities pertaining to natural resource conservation.

The basis of the NACD conservation effort is grassroots driven and locally led. Each state has passed legislation spelling out its local conservation program. The state conservation agency and local soil and water conservation districts are the workhorses of this effort. They are the local organizations with “boots on the ground” to deliver conservation practices and provide local leadership to determine conservation needs. It is their knowledge and effort that drives NACD to become America’s voice for natural resource conservation. This grassroots delivery system makes the U.S. a world leader in natural resource conservation.

Working with landowners and producers as an American Society of Agronomy CCA gives me an opportunity to fully integrate natural resource conservation into producers’ management plans. Today’s producers clearly understand that it’s their responsibility to protect the natural resources that will provide a bountiful supply of food and fiber for future generations.

I would encourage other agronomy or soil science professionals working in the conservation field to explore professional certification offered by the American Society of Agronomy and Soil Science Society of America. Certification provides a number of valuable benefits, including continuing education and professional networking opportunities. For information on how to apply, visit: www.agronomy.org/certifications.
Are current soil test–based phosphorus and potassium fertilizer recommendations adequate?

By Dale Leikam, Fluid Fertilizer Foundation, Manhattan, KS; Gyles Randall, University of Minnesota, Waseca; and Antonio Mallarino, Iowa State University, Ames

Profitable crop production requires adequate crop nutrition, and there are few fields that do not require the addition of supplemental crop nutrients. As a result, there has been much investment in time, expertise, and money devoted to developing reliable soil tests that are well correlated to crop nutrient uptake and crop yield response. Once a reliable soil test is developed, it is then calibrated to estimate the nutrient application rate required for optimum crop growth at various soil test levels.

Historically, the soil test value and crop to be grown have been the main, and often only, factors used in making nutrient rate recommendations—although there are sometimes adjustments made for factors such as expected crop yield, soil type, and/or soil association. However, there are many other factors that affect crop growth, nutrient availability, nutrient uptake, and crop production efficiency that need to be taken into consideration in order to arrive at a nutrient management program that best fits a specific field. The cultural and tillage system used, planting dates, soil/environmental conditions, equipment availability, an individual farmer’s long-term approach to managing risk and land investment, crop/fertilizer prices, and other factors are not estimated by soil testing, but they generally influence crop nutrient rate decisions.

While plant-available nitrate and/or ammonium N soil testing have historically been used for N recommendations in lower-rainfall areas such as the Great Plains and other western states, N soil testing has generally not been used in more humid regions such as the Corn Belt and southeastern states. Higher rainfall in these areas causes much more weather-induced variability in inorganic soil N supplies and much less reliability in assessing available N supply to the growing crop. As a result, the focus of this discussion will be on phosphorus (P) and potassium (K).

Interpretation of P and K soil tests and fertilization guidelines

As cropping systems change with the increased adoption of reduced- and no-tillage systems, it is possible that nutrient recommendations may also need to change. Additionally, as crop yields continue to increase year after year, the overall amounts of crop nutrients required and the rate of crop nutrient uptake is also increasing. As yields continue to climb, farmers need to consider the total amount of nutrients required by these higher-yielding crops as well as the daily nutrient requirements, especially at critical stages of crop development. Table 1 (next page) presents the very large total nutrient uptake and daily nutrient requirements of high-yielding corn and soybeans in a Rutgers University study. Since most P and K moves to the root surface across only very short distances by diffusion, questions sometimes arise about the adequacy of many current crop nutrient recommendations developed at much lower yield levels than those currently obtained by top producers.

Soil tests for P and K do not directly tell how much of a nutrient is “available” to a crop, nor do they accurately predict precisely how much of a nutrient to apply in a specific field/situation. Instead, what soil tests do much better is estimate the soil’s relative ability to supply a nutrient to a growing crop. They provide an index value of potential nutrient availability—not a quantitative amount. Through correlation and calibration research, these soil test index values provide the probability of obtaining a crop response to applied P and K and also estimate the long-term average relative yield if no P or K is applied compared with crop yield if fully adequate amounts of the nutrients are applied (sufficiency).

There are two widely used general approaches for interpreting P and K soil test values and developing rate recommendations—nutrient sufficiency and build-maintenance. Various universities and individuals have adopted one of these approaches or an approach that falls somewhere in between and combines certain aspects of both.

The goal of nutrient sufficiency–based recommendations is to, on the average, apply just enough P and/or K to maximize profitability in the year of application with no consideration of future soil test values or required fertility programs. The objective of this approach certainly makes sense from an economical standpoint. In general, nutrient sufficiency recommendations will, on the average, provide about 90–95% of maximum yield. However, since there is always uncertainty in the amount of a crop nutrient actually required to maximize profitability for a specific field in a given year, more or less P and/or K is typically...
recommended than is actually needed. While there is no concern for future P and K soil test values with the nutrient sufficiency approach, over the long term, soil test values will eventually stabilize in the crop responsive range somewhat below the critical soil test value. The critical soil test value is usually defined as the soil test level at which there is a relatively low probability of obtaining a yield response to added crop nutrients and about 90–95% of maximum yield will be obtained if crop nutrients are not applied. Recommended rates go to zero at the established critical soil test value for this approach.

Because of the long-term positive residual benefits of P and K applications to soils, coupled with the cost of annual soil testing and the uncertainty of being able to accurately predict the optimum application rate required for a specific field in an individual year, taking a longer-term view of P and K management is certainly appropriate. The objective of build-maintenance fertility programs is to manage soil test levels rather than trying to predict precisely how much P and/or K would be required for optimum crop production in a given year for a particular situation. At low soil test values, build-maintenance programs are designed to increase soil test levels to a desired soil test value (e.g., the critical value) over a specified time frame and then maintain soil test levels within a targeted maintenance range. The identified maintenance range generally lies just above the critical soil test value. No fertilizer is suggested at soil test values greater than the maintenance range. In general, crop yields will be about 100% of maximum yield, and the risk of yield loss due to insufficient fertility is minimized with this approach.

The nutrient sufficiency approach generally suggests lower P and/or K application rates in the early years of adoption (if soil test values are low initially) and will eventually approach crop removal as soil tests equilibrate in the crop responsive range. Build-maintenance rates will

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**308 bu/ac corn nutrient uptake**

**101 bu/ac soybean nutrient uptake**
generally be higher in the initial years (if soil test values are low initially) until soil test values are increased to the desired soil test value when crop removal application rates maintain soil test values in the desired soil test range. Some states slowly build soil tests to a soil test value near (but below) the critical value and then maintain them with crop removal maintenance rates. Other states may have a different variation with portions adapted from both the nutrient sufficiency and build-maintenance approaches.

Why do different institutions/people adopt different approaches to P and K fertilization? Is it because crops respond differently in different geographic regions, making one approach better than others for a given region? Not really. Actually, soil test correlation research conducted across wide geographic areas provides very similar results if the soil-sampling depth is the same. For a specific P or K soil test procedure that is appropriate for a given geographic area, similar long-term average relative yields at various soil test values have been found. Figure 1 uses P correlation data from Iowa State University and Kansas State University to illustrate this point. While there are significant differences in soils and climate between these two states, the resulting crop response research data are very similar. The general interpretation of Bray P1 soil test values in the heart of the Iowa Corn Belt is the same as on the Great Plains of Kansas. Similar conclusions result for other comparisons across the U.S. and Canada if the same soil test extractions/procedures are used. The science is essentially the same—it is the interpretation of the science that often varies.

While the established P critical value for Iowa State and Kansas State has been set at 20 ppm Bray P1 (Fig. 1), others have generally set the critical values anywhere between 15 and 25 ppm Bray P1. These differences may result from the specific mathematical model used to describe the relationship between soil test and relative crop yield and other subjective factors such as an allowance made recognizing that fields exhibit spatial and temporal variability in soil test values. And although not explicitly recognized, those developing soil test-based fertilizer recommendations introduce their own bias concerning the best approach for interpreting response data and managing P and K fertility programs. It is not so much a difference in research data that causes differences in approaches to P and K fertility programs by different institutions/individuals; rather it is often a difference in “philosophy,” a particular approach to risk management, and/or past experience among those developing fertility recommendation programs.

Which interpretation approach is correct?

This is a relevant question, but there is not a simple, clear-cut answer. There are many nutrient management programs that vary between a strict sufficiency approach and a strict build-maintenance approach. The advantages of P and K management programs that are closer to a nutrient sufficiency approach include the minimization of P and K applications at soil test values less than the established critical value as well as the minimization (but not elimination) of the risk of not obtaining a profitable response to the last increment of applied P and/or K in the year of application.

Situations where the sufficiency approach makes the most sense include: (a) limited resources available to invest in a particular year, (b) expected short land tenure situations, and (c) soils with a very high capacity to quickly convert relatively soluble/exchangeable forms of fertilizer P and K to forms that are largely unavailable for crop uptake in a given year. Disadvantages of this approach include: (a) the requirement of frequent, precise, and accurate soil testing, (b) the requirement of very good knowledge of optimum application rates each year, and (c) the risk of P or K limiting crop growth and long-term crop productivity and profitability.

The advantages of programs closer to a strict build-maintenance approach include: (a) greatly reduced risk that P or K will limit crop growth and long-term productivity and...
profitability, (b) reduced need for frequent soil testing, (c) allowance for timely planting and management of fertilization over time, and (d) increase in the future flexibility of the overall fertility program. However, this increased flexibility and risk reduction may require a greater investment in fertilizer initially to build soil test values to the maintenance range. In the long term, however, both nutrient sufficiency and build-maintenance rates eventually tend to stabilize at rates equal to the amounts of P and K removed in the harvested portions of the crop.

Both of these nutrient recommendation approaches and the management strategies specific to each approach are appropriate for individual farmers, individual fields, and specific conditions in any given year. Regardless of what state a farmer operates in, consideration of an individual producer’s attitude concerning risk, viewpoint in making long-term investments in soil fertility, expected land tenure, and other objectives should be used to develop individualized P and K fertility management programs. In the past, the risk and benefits of various approaches have generally not been well communicated to farmers and crop advisers. Any of the discussed approaches may be “right” or “wrong” for a given situation.

**Will applied fertilizer fully substitute for soil fertility?**

One of the assumptions that most P and/or K recommendations are based on is the premise that fresh fertilizer applications to low-testing soils will fully substitute for the fertility provided by high-testing soils. In other words, it is generally assumed that maximum yields can be obtained either by building up soil test P and K levels to “high” values or by applying enough nutrients to soils testing “low.” Research has shown that this may not always be the case. For example, several Canadian studies with small grains (Read et al., 1977; Wager et al., 1986) clearly demonstrated that annual applications of row-applied P to low-testing soils never did equal the yields of wheat and barley grown on high-testing soils. Long-term studies at the Rothamsted Experiment Station in the United Kingdom also found that P-fertilized crops on low-testing soils did not equal those on high-testing soils (Johnston and Poulton, 1993).

Recently, studies with corn and soybeans have shown similar results. Table 2 presents the summarized results of a three-year University of Minnesota research study that included both low- (6–9 ppm Bray P) and high-testing soils (20–27 ppm Bray P). In this study, fertilizer P was applied only to the corn crop in the corn–soybean rotation. On the high-testing soil, corn yields averaged 192 bu/ac over the three years with no response to freshly applied P fertilizer. On the low-testing soil, which had been mined by 10 years of either corn for grain, corn silage, or soybeans with no fertilizer P added, there was a modest response to applied P, but yields only averaged 167 bu/ac, even at the higher 50 lb P2O5/ac rate. For soybeans, there was a small response to residual P applications to corn measured on the low-P soil with no response on the high-P soil, but yields averaged 49 bu/ac on the high-testing soil and only 37 bu/ac on the low-testing soils. Clearly there was an advantage to both corn and soybeans for having a high P soil test compared with a low test. The yield advantage across all eight treatments averaged 30 bu/ac (18%) for corn and 12 bu/ac (32%) for soybeans. Moreover, the economic penalty associated with the low P–testing field was severe even when fertilizer P was applied at nutrient sufficiency rates recommended by the university.

The results from this and other studies do raise some interesting researchable questions: Under what conditions would applied fertilizer be expected to fully substitute for low soil fertility? How does subsoil P and K fertility enter into this discussion? How is the effectiveness of fertilizer applications vs. soil fertility affected by the interaction of soil/environmental conditions (e.g., temperature, moisture, etc.)? Are current university nutrient recommendations based on data from older, lower-yielding sites appropriate for very high-yielding production systems where daily nutrient demand and annual nutrient drawdown from the rooting profile can be substantial? The previously discussed research suggests that current soil test–based fertilizer recommendations are not always adequate for obtaining very high yields. These and other questions identify numerous and valuable opportunities for additional research to continue improving crop production efficiencies and achieving the very high yield potential of current high-yielding hybrids/varieties and future genetic advances.

**Summary**

There are several logical and appropriate approaches to managing P and K fertility. Within the bounds of environmental stewardship, it should be up to individual producers to determine the appropriate fertility approach suitable for their production system. Nutrient sufficiency programs generally minimize fertilizer inputs in the early years but have an increased risk of P or K limiting crop growth and long-term profitability. Build-maintenance programs may cost more in the initial years if soil tests must be built up, but they generally provide for maximum yield and long-term profitability while increasing fertilizer management flexibility in the coming years. In addition, an individual producer’s attitude toward managing risk, long-term viewpoint in making investments in soil fertility, expected land tenure, and other goals and objectives should be incorporated into the decision-making process for determining the P and K fertility management program that best suits the individual producer’s needs.

We should also keep in mind that an individual farmer’s approach to risk management may not remain the same in the future. The adoption of new technologies and practices by producers has resulted in U.S. corn yields increasing from about 100 bu/ac in 1980 to about 160 bu/ac in 2009—with many producers currently growing in excess.
Table 2. Effect of Bray P soil test on corn and soybean yield response to fertilization. (Source: Gyles Randall, University of Minnesota).

### Three-year average corn yield

<table>
<thead>
<tr>
<th>Application method</th>
<th>P rate †</th>
<th>Low-P soil</th>
<th>High-P soil</th>
<th>High-P advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>lb P₂O₅/ac</td>
<td>bu/ac</td>
<td>bu/ac</td>
<td>%</td>
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<td>158.1</td>
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<tr>
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<td>196.4</td>
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</tr>
<tr>
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<td>166.4</td>
<td>196.2</td>
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<td>Deep band + pop-up</td>
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<td>189.0</td>
<td>17.5</td>
</tr>
<tr>
<td>Pop-up</td>
<td>50/40</td>
<td>165.7</td>
<td>194.5</td>
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<td>Deep band</td>
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<tr>
<td>Broadcast</td>
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<td>167.0</td>
<td>190.2</td>
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</table>

*p > f* <0.001 0.39 - - - - - -

LSD (0.05) 10.5 NS - - - - - -

Average 162.6 192.1 29.6 18

Bray P₁ soil test 6–9 ppm 20–27 ppm

### Three-year average soybean yield

<table>
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<tr>
<th>Application method</th>
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<th>Low-P soil</th>
<th>High-P soil</th>
<th>High-P advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>lb P₂O₅/ac</td>
<td>bu/ac</td>
<td>bu/ac</td>
<td>%</td>
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</tr>
<tr>
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<tr>
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<td>48.4</td>
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</table>

*p > f* 0.01 0.84 - - - - - -

LSD (0.05) 3.5 NS - - - - - -

Average 37.1 49.1 12.0 32

Bray P₁ soil test 6–9 ppm 20–27 ppm

† Rates are for low-test site/high-test sites.
‡ Residual rates are for previous corn crop low-test site/high-test sites.
of 200 bu/ac corn. Continued increases in the yield potential of modern agricultural production systems leads some producers to question whether the substantially increased total nutrient demand/uptake and associated increased daily nutrient demand during certain critical growth stages can be met with a fertility approach that attempts to minimize P and K additions in any one year. Risk of yield loss is an increasingly important concern facing producers. The possibility that future yield may be lost in the field due to inadequate P and/or K availability or supply is unthinkable for many producers. Future fertility programs must address these types of producer concerns.

Likewise, in order to continue to increase crop yields in the future, it is important to note that research has shown that annual fertilizer applications may not fully substitute for high P and K soil fertility. Highest crop yields are often associated with soil tests greater than the established critical value. There may be a severe economic penalty associated with low P or K soil tests even when fertilizer is applied—especially in years/situations with high yield potential.

References


This quiz is worth 1.5 CEUs in Nutrient Management. A score of 70% or higher will earn CEU credit. The International CCA program has approved self-study CEUs for 20 of the 40 CEUs required in the two-year cycle. An electronic version of this test is also available at www.agronomy.org/certifications/self-study.

Directions
1. After carefully reading the article, answer each question by clearly marking an “X” in the box next to the best answer.

2. Complete the self-study quiz registration form and evaluation form on page 34.

3. Clip out pages 32–34, place in an envelope with a $30 check made out to the American Society of Agronomy (or provide your credit card information on the form), and mail to: ASA c/o CCA Self-Study Quiz, 5585 Guilford Road, Madison, WI 53711. Or you can save $5 by completing the quiz online at www.agronomy.org/certifications/self-study.

3. Soil test values for P and K
   a. provide the probability of obtaining a crop response to applied P and K.
   b. estimate the long-term average relative yield if P or K is applied compared with crop yield if inadequate amounts of the nutrients are applied.
   c. estimate the short-term average relative yield if P or K is not applied compared with crop yield if fully adequate amounts of the nutrients are applied.
   d. provide the probability of obtaining a crop response if P and K are not applied.

November–December 2010 Self-Study Quiz
Are current soil test–based phosphorus and potassium fertilizer recommendations adequate? (no. SS 04098)

1. The two widely used general approaches for interpreting P and K soil test values and developing rate recommendations are
   a. nutrient sufficiency and build-maintenance.
   b. nutrient maintenance and build-sufficiency.
   c. critical sufficiency and fertility maintenance.
   d. Bray P1 and potash maintenance.

2. What is the critical soil test value?
   a. The minimum soil test level below which there is a 90–95% chance that yields will fall below maximum yield.
   b. The soil test level at which there is a relatively high probability of obtaining a yield response to added crop nutrients and about 90–95% of maximum yield will be obtained if crop nutrients are applied.
   c. The soil test level at which there is a relatively low probability of obtaining a yield response to added crop nutrients and about 90–95% of maximum yield will be obtained if crop nutrients are not applied.
   d. The soil test level at which there is a 90–95% chance of obtaining a yield response to added nutrients and a relatively low probability of nutrient losses through runoff or leaching.
4. The goal of nutrient sufficiency–based recommendations is to
   - a. manage soil test levels rather than trying to predict precisely how much P and/or K would be required for optimum crop production.
   - b. consider future soil test values or required fertility programs.
   - c. apply P and/or K above recommended rates to maximize yields in the year of application.
   - d. apply just enough P and/or K to maximize profitability in the year of application.

5. Which of the following is NOT true about the nutrient sufficiency approach?
   - a. More or less P and/or K is typically recommended than is actually needed.
   - b. Soil test values will eventually stabilize in the crop responsive range above the critical soil test value.
   - c. In general, nutrient sufficiency recommendations will, on the average, provide about 90–95% of maximum yield.
   - d. Recommended rates go to zero at the established critical soil test value for this approach.

6. Which of the following is true?
   - a. If soil test values are low initially, nutrient sufficiency P and/or K application rates will generally be lower in the early years of adoption.
   - b. If soil test values are low initially, build-maintenance P and/or K application rates will generally be lower in the initial years.
   - c. If soil test values are high initially, nutrient sufficiency P and/or K application rates will generally be higher in the early years of adoption.
   - d. If soil test values are high initially, build-maintenance P and/or K application rates will generally be lower in the initial years.

7. Which reason is NOT given in the article as to why different institutions/people adopt different approaches to P and K fertilization?
   - a. Different risk management approaches.
   - b. Different crop responses in different geographic regions.
   - c. Different fertilization philosophy.
   - d. Different past experiences.

8. Highest crop yields are often associated with
   - a. soil tests greater than the established critical value.
   - b. low-testing soils.
   - c. minimal year-to-year variability in test levels.
   - d. fertility programs that minimize P and K additions in any one year.

9. One advantage of P and K management programs that are closer to a nutrient sufficiency approach is the
   - a. elimination of P and K applications at soil test values less than the established critical value.
   - b. elimination of the risk of not obtaining a profitable response to the last increment of applied P and/or K in the year of application.
   - c. maximization of P and K applications at soil test values less than the established critical value.
   - d. minimization of the risk of not obtaining a profitable response to the last increment of applied P and/or K in the year of application.

10. In which of the following situations would the sufficiency approach make the most sense?
    - b. Limited resources available to invest in a particular year.
    - c. Soils with a very high capacity to quickly convert forms of fertilizer P and K that are largely unavailable for crop uptake to relatively soluble/exchangeable forms.
    - d. When knowledge of optimum application rates is lacking.

11. One advantage of a program closer to a strict build-maintenance approach is
    - a. increase in the future flexibility of the overall fertility program.
    - b. frequent, precise, and accurate soil testing.
    - c. good knowledge of optimum application rates each year.
    - d. immediate boosts in productivity and profitability.

12. Which of the following is true regarding applied fertilizer applications and soil fertility?
    - a. Fresh fertilizer applications to low-testing soils will fully substitute for the fertility provided by high-testing soils.
    - b. Current soil test–based fertilizer recommendations are not always adequate for obtaining very high yields.
    - c. The economic penalty associated with high-testing soils is usually severe.
    - d. Maximum yields can be obtained either by building up soil test P and K levels to “high” values or by applying enough nutrients to soils testing “low.”
13. Which is NOT mentioned in the article as something unique to an individual producer that should be incorporated into the decision-making process for determining the P and K fertility management program?  
- a. Attitude toward managing risk.  
- b. Long-term viewpoint in making investments in soil fertility.  
- c. Expected land tenure.  
- d. Geographic location.

14. Soil tests for P and K  
- a. accurately predict precisely how much of a nutrient to apply in a specific field/situation.  
- b. estimate the soil’s relative ability to supply a nutrient to a growing crop.  
- c. directly tell how much of a nutrient is “available” to a crop.  
- d. provide a quantitative value of nutrient availability.

15. Which is true regarding the cost of a build-maintenance program vs. a nutrient sufficiency program?  
- a. Nutrient sufficiency programs may cost more in the later years.  
- b. Nutrient sufficiency programs may cost more in the initial years.  
- c. Build-maintenance programs may cost more overall.  
- d. Build-maintenance programs may cost more in the initial years.

SELF-STUDY QUIZ REGISTRATION FORM

Name: ____________________________________________
Address: ____________________________________________ City: __________________________
State/province: __________________ Zip: ________________ CCA certification no.: ____________

☐ $30 check payable to the American Society of Agronomy enclosed.  
☐ Please charge my credit card (see below)
Credit card no.: __________________________ Name on card: __________________________
Type of card: ☐ Mastercard ☐ Visa ☐ Discover ☐ Am. Express Expiration date: ____________

Signature as it appears on the Code of Ethics: ____________________________________________

I certify that I alone completed this CEU quiz and recognize that an ethics violation may revoke my CCA status.

This quiz issued November 2010 expires November 2013

SELF-STUDY QUIZ EVALUATION FORM

Rating Scale: 1 = Poor  5 = Excellent

Information presented will be useful in my daily crop-advising activities: 1 2 3 4 5
Information was organized and logical: 1 2 3 4 5
Graphics/tables (if applicable) were appropriate and enhanced my learning: 1 2 3 4 5
I was stimulated to think how to use and apply the information presented: 1 2 3 4 5
This article addressed the stated competency area and performance objective(s): 1 2 3 4 5
Briefly explain any “1” ratings: ___________________________________________________
Topics you would like to see addressed in future self-study materials: ___________________
Nitrogen fertilizer and urease inhibitor effects on canola emergence and yield in a one-pass seeding and fertilizing system

Canola uses large amounts of crop nutrients, including N. Nitrogen deficiencies limit canola yield, so N fertilization is essential to maximize canola production. When no-till systems are used, in-soil banding via injection prevents volatilization losses and immobilization in surface residues, if placed below the crop residue. Banding can reduce volatilization losses when soil has a high sorptive capacity because the soil cover reduces the risk of ammonia loss. Banding N fertilizer can slow the conversion of ammonium to nitrate N, reducing the risk of denitrification and leaching losses. Weed competition can be reduced when N fertilizer is banded beneath the soil surface instead of broadcasting fertilizer.

In-soil banding of N is widely adopted on the Canadian prairies, with fertilizer commonly applied during the seeding operation. Seeding and fertilizing in a single operation reduces time, fuel, and labor costs and can help to decrease seedbed disturbance and retain soil moisture. Equipment costs are lower if the seed and fertilizer can be placed in a single band, using only one opener, but this can lead to seedling damage at high N rates.

Fertilizer toxicity to seedlings

Canola is sensitive to seedling damage. The rates of N required to optimize crop yield are usually too high to be safely placed with the seed. Separating the fertilizer from the seed, by placing it in a separate band from the seed row, reduces risk of seedling damage and increases the amount of N that can safely be applied near the seed row at the time of seeding. Nitrogen and P fertilizers are commonly placed together in a single band, and placement of P near the seed row is important to ensure that the plant can access the P early in the season. Some seeders can side-band both N and P fertilizer near the seed to allow early access of the roots to the fertilizer while reducing the risk of seedling damage.

Because canola is sensitive to fertilizer damage, a recommended separation considered safe varies from about an inch to the side and an inch below the seed row to 2 to 2.8 inches to the side and below the seed row, depending on the province. Most of the seeders being used commercially target a separation of an inch to the side and an inch below, meeting the Saskatchewan provincial recommendations, but none of the side-banding seeders that are currently widely available on the northern Great Plains target a separation that meets the provincial recommendations from Manitoba. Effective separation is likely to vary with factors such as ground speed, fan speed, equipment wear, field topography, fertilizer volume, and soil conditions, and may be less than targeted.

Urea ammonium nitrate (UAN), a liquid blend of urea and ammonium nitrate, and urea are both common forms of N fertilizer. The urea molecule is not directly damaging to seedlings, but when urea is applied to the soil, it rapidly hydrolyzes to ammonium (NH$_4^+$) in a reaction catalyzed by the enzyme urease. The more rapidly the urea hydrolyzes, the higher the concentration of NH$_4^+$ and NH$_3$ present in the soil solution, which increases the risk of damage. Ammonium is in equilibrium with NH$_3$, so seedling damage can occur both through a “salt effect,” where increased osmotic potential of the soil solution desiccates the plant, and through direct ammonium toxicity. In contrast, nitrate only causes damage through the salt effect. Therefore, toxicity to cereal seedlings is believed to increase in the order of ammonium nitrate < UAN < urea. For canola, ammonium nitrate is considered as toxic to seedlings as urea, but there is not much information comparing the relative toxicity of urea and UAN when used on canola.

Urea toxicity can be reduced in many crops by applying the urease inhibitor NBPT to the fertilizer granule or the UAN solution. The urease inhibitor slows the conversion of urea to ammonium, allowing more time for rainfall to occur to dilute the fertilizer and for the intact urea molecule to move away from the seed row, thus reducing the concentration of NH$_4^+$ and NH$_3$ in contact with the seedling. Since NBPT delays rather than eliminates urea hydrolysis, its effectiveness on reducing seedling damage depends on the diffusion characteristics of urea in the soil and on urease activity as well as the moisture level of the soil.

Experimental objective, methods

In the July–August 2010 issue of Agronomy Journal, researchers reported on a study in which they evaluated the effects of increasing rates of side-banded UAN and urea, with and without NBPT, on seeding emergence, biomass production, and seed yield of canola, with varying amounts of weed competition depending on the presence or...
absence of herbicide application, on sites with different soil textures.

The experiment was a split plot with whole plots arranged in a randomized complete block design, with four replications. Fertilizer treatments were the main plots, and herbicide treatments were the subplots. Statistical analysis was conducted with contrast analysis using Proc Mixed. Contrast analysis was used to determine the effects of the fertilizer rates, sources, and use of urease inhibitor. Differences or regression factors were considered significant at $p < 0.05$. Linear, quadratic, and cubic contrasts were assessed for each fertilizer source. Regression equations were calculated using Excel only if the liner or quadratic contrasts determined using Proc Mixed were statistically significant. The correlation between stand density and seed chlorophyll concentration was determined using Proc Corr, and regression equations were calculated only if the correlation was statistically significant.

Analyses were conducted separately by site and year because seedling damage is a sporadic occurrence that is strongly affected by soil characteristics and environmental conditions occurring immediately after seedling. Responses to fertilizers differed substantially with year and location, so assessment by site and year is a more meaningful evaluation of the effect than combining the data across sites and/or years. In no case was there a significant interaction between herbicide application and any treatment, so data were combined over herbicide application treatments.

**Stand density**

Stand counts were taken before herbicide application, so herbicide treatment had no effect on stand density. Stand density at two weeks after seeding was consistently decreased by application of side-banded urea or UAN on the clay loam soil, indicating that the fertilizer caused seedling damage, reducing germination and crop emergence. On fine sandy loam soil, stand density was reduced by urea or UAN only in 2001. Seedling damage from fertilizer applications is expected to be greater on lighter- than heavier-textured soils. In 1999 and 2000, between 1 and 2 cm of rain fell between seeding and crop emergence, while in 2001, less than 1 cm rainfall occurred in this period. The rainfall that occurred in 1999 and 2000 may have been sufficient to move the fertilizer away from the seed row in the fine sandy loam soil but may have been too little to be effective in the clay loam soil, due to the higher moisture-holding capacity of the clay loam compared with the fine sandy loam soil. Alternately, diffusion of the ammonia away from the seed row may have been more restricted on the clay loam soil than on the fine sandy loam soil, increasing ammonia toxicity.

Average seedling survival rate is 50%, but can vary from 25 to 75%, so optimal seeding rate will vary considerably depending on field conditions and seedling vigor. The stand density in the absence of fertilizer application in this study ranged from 30 to 58 plants per foot, indicating that the seeding rate was close to optimal. In spite of the significant level of seedling toxicity resulting from fertilizer application in the absence of a urease inhibitor, stand density remained within the broad range considered acceptable. Due to high seed costs of hybrid canola, there is a trend toward reducing seeding rates at the low range of, or even below, recommended levels even though higher seeding rates may be economically beneficial. Use of low seeding rates would increase the risk of lower-than-acceptable stands if seedling damage were to occur.

**Crop biomass yield at flowering**

Crop biomass yield at flowering was significantly increased by herbicide application on the fine sandy loam in 1999. In 2001, however, weed population was exceedingly high, and the plots without herbicide application could not be harvested. Herbicide application had a large effect, although it was not statistically evaluated. At the other site, biomass yield was generally numerically higher with herbicide application, but the effects were not statistically significant. Glyphosate efficacy was not reduced at lower N rates as has been seen in previous studies probably because the recommended glyphosate rate used in the current study was high enough to allow control even at the lower N rate. There was no interaction between herbicide application and treatment in any site year, so data were combined over herbicide treatments for analysis of fertilizer effects.

The canola in this study may have been able to recover from seedling damage because stand density was acceptable even where significant seedling damage occurred and growing conditions were not extreme. Seed prices for canola have increased substantially with the introduction of genetically modified and hybrid canola types. Many producers have responded to the higher seed costs by reducing their seeding rate to near or below the lower values of the recommended seeding range to decrease input costs. Reduced seeding rates and adverse growing conditions would increase the risk of inadequate stand density and reduced yield.

**Seed yield**

Seed yield was higher with than without herbicide application in four of the six site-years, with the increase ranging from 7 to 18% (data not presented). On the fine sandy loam in 2001, weed populations without herbicide applications were so high that the crop could not be harvested, so herbicide application had a major influence although it was not determined statistically. Herbicide application failed to increase seed yield only on the clay loam soil in 1999. There was no interaction between herbicide application and treatment in any site-year, so data were combined over herbicide treatments for analysis of fertilizer effects. Seed yield increased with N application in five of the six site-years, although the magnitude and pattern of N response varied with N source and environment.
Conclusions

Seedling damage occurred in canola with increasing rates of urea or UAN fertilizer applied as a side-band with target placement of about an inch to the side and an inch below the seed row at the time of seeding. Decrease in stand density with UAN was similar to that resulting from urea application. The urease inhibitor NBPT was effective at reducing seedling damage in canola from both urea and UAN fertilizer in all site-years of the study.

Dry matter yield at flowering was not generally affected by seedling damage, but NBPT increased canola seed yield at high rates of N application in three of six site-years and decreased seed yield in one site-year. The reason for the decreased seed yield was not apparent. The reduced stand density did not consistently result in decreased biomass yield or seed yield because canola has a great ability to compensate for reduced stand by increased branching. However, seeding damage and reduced stand density led to delayed maturity and increased chlorophyll content in four of six site-years.

This study was conducted using the full recommended rate of seeding and resulted in an adequate crop stand even where significant seedling damage occurred. Where seeding rates are used that are at the low end of, or below, the recommended range, reductions in stand density could have a greater effect on seed yield, maturity, and chlorophyll concentration than the authors noted in this study. Therefore, caution should be used to ensure that seed and fertilizer separation is adequate and safe rates of N application are not exceeded near the seed row. Use of NBPT can reduce the risk of seedling damage and increase the amount of urea or UAN that can safely be side-banded in a one-pass seeding and fertilizing operation.


November–December 2010 Self-Study Quiz

Nitrogen fertilizer and urease inhibitor effects on canola emergence and yield in a one-pass seeding and fertilizing system (no. SS 04099)

1. When no-till systems are used in canola crops, in-soil banding via injection prevents
   a. volatilization losses and immobilization in surface residues.
   b. runoff into neighboring streams.
   c. burning of seed.
   d. desiccation of seeds and sprouts because of osmotic pressure.

2. Weed competition can be reduced when
   a. N fertilizer is banded beneath the soil surface.
   b. N fertilizer is broadcast.
   c. N fertilizer is combined with glyphosate.
   d. N fertilizer is banded in very moist soil.

3. The toxicity of UAN to canola as compared with the urea may indicate a greater
   a. sensitivity of canola to the osmotic effects of the fertilizer.
   b. solubility of UAN in small amounts of water.
   c. protective effect of ammonium nitrate on cell surfaces.
   d. salt effect on germinating plant tissues.

4. In this study, herbicide application failed to increase seed yield
   a. in four of the six site-years.
   b. only on the fine sandy loam soil in 1999.
   c. only on the clay loam soil in 1999.
   d. in all of the site-years.

5. The urea molecule is not directly damaging to seedlings, but when urea is applied to the soil,
   a. it can solubilize to ammonium nitrate.
   b. it rapidly hydrolyzes to ammonium.
   c. it can create pockets that the seed will not germinate in.
   d. it releases the enzyme urease, which can stunt seedling development.

Quiz continues next page
6. Use of NBPT can reduce the risk of seedling damage and increase the amount of
   a. urea or UAN that can safely be side-banded in a one-pass seeding and fertilizing operation.
   b. urease inhibitor that must be used in a one-pass seeding and fertilizing operation.
   c. ammonium that can be injected directly into the row in a one-pass seeding and fertilizing operation.
   d. soil water in a in a one-pass seeding and fertilizing operation.

7. In 2001, weed population was exceedingly high, and the plots without herbicide application
   a. had biomass yields that were generally numerically higher, but the effects were not statistically significant.
   b. had biomass yields that were generally numerically lower, but the effects were not statistically significant.
   c. had high insect pressure as well.
   d. could not be harvested.

8. NBPT increased canola seed yield at high rates of N application in
   a. three of six site-years.
   b. all sites-years except one.
   c. two site-years only.
   d. site-years with low rainfall.

9. Where seeding rates are used that are at the low end of, or below, the recommended range, reductions in stand density could have a greater effect on seed yield, maturity, and
   a. chlorophyll concentration.
   b. biomass and plant health.
   c. seed size.
   d. runoff of urea.

10. The reduced stand density did not consistently result in decreased biomass yield or seed yield because
    a. weeds were reduced or eliminated with herbicide application.
    b. canola has a great ability to compensate for reduced stand by increased branching.
    c. side-banding of UAN increased flowering intervals.
    d. side-banding of UAN increased chlorophyll levels.
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