A vexing problem
Keeping farm-based phosphorus out of Lake Erie
Nitrogen Use Efficiency Conference
August 13–15 in Kansas City, MO

This summer, agronomists, crop and soil scientists, growers, extension agents, economists, and other agricultural experts will gather at an interactive conference in Kansas City, MO to discuss nutrient use efficiency (NUE) and the barriers and opportunities for improving it. The question at the root of the discussions will be: What are the economic and social impediments to adopting farming and livestock management practices that we know will improve NUE? Are there success stories for voluntary programs, regulatory approaches, and economic incentives?

Decades of research have yielded a wealth of knowledge to effectively manage nitrogen and other nutrients in agriculture. Small-scale studies have demonstrated that inadvertent nitrogen losses to the environment can be minimized without jeopardizing profitable crop yields. Despite great strides made in improving crop and livestock breeding, fertilizer products, feed management, and other technologies, nitrogen losses to the atmosphere, surface water, and groundwater are increasing at levels that pose serious environmental and human health concerns in many regions of the world.

This will be an interactive gathering, so that participants will have ample opportunities to discuss barriers and solutions and share ideas during poster sessions and beer and coffee breaks.

The workshop is sponsored by the Woods Hole Research Center, International Plant Nutrition Institute, and The Fertilizer Institute. Co-sponsors include the Soil Science Society of America, American Geophysical Union, and International Nitrogen Initiative.

For more information: www.soils.org/meetings/specialized/nitrogen-use-efficiency
Feature

Proper phosphorus fertilizer management is no longer just an issue for agriculture. On the heels of record-breaking blooms of algae in places like Lake Erie, the public has taken a keen interest in how farmers and their CCAs keep phosphorus on their fields. And conservation tillage practices like no-till may be at the heart of the pollution problem.


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Cover: Inset photos courtesy of (clockwise): Flickr/ChesBayProgram, NOAA, and Ohio State University. Cover design by Pat Scullion.
Proper phosphorus fertilizer management is no longer just an issue for agriculture. On the heels of record-breaking blooms of algae in places like Lake Erie, the public has taken a keen interest in how farmers and their CCAs keep phosphorus, or P, on their fields. And conservation tillage practices like no-till may be at the heart of the pollution problem.
Public attention on P fertilizer management reached a new high in 2011 when record rainfall in Ohio washed phosphorus from farmers’ fields into Lake Erie, feeding a toxic algal bloom that covered 1,930 square miles—the largest in the lake’s recorded history and more than twice the size as the previous largest bloom in 2008.

The following year, when farmers struggled with epic drought conditions, the size of the algal blooms shrank to 10% the size of the previous year. With phosphorus runoff from farm fields on the agenda, farming practices immediately became the topic of discussion.

The massive algal bloom that covered a fifth of Lake Erie in 2011 wasn’t the first episode of phosphorus feeding algae growth. Farmers faced a similar challenge in the 1970s when massive algal blooms raised the ire of the recreational and fishing industries, sparking an international movement to curb phosphorus fertilizer pollution.

The result was a resounding success of farmers, government, universities, and industry working together to solve the problem. Thanks to the widespread adoption of conservation tillage and no-till practices, the amount of sediment-bound phosphorus that left farmers’ fields and spilled into Lake Erie via soil erosion dropped off significantly, and the algae that fed on the phosphorus nearly disappeared.

But by the mid-1990s, a strange new phenomenon occurred. The algal blooms that were once thought of as a thing of the past began reappearing. And, they were becoming more frequent and toxic.

The blue-green algae blooms made of potentially toxic cyanobacteria began returning in the western basin of Lake Erie at an increased frequency through the 1990s and into the 2000s. But all the while, farmers were becoming more efficient with fertilizer use and were applying at significantly lower rates than they were in the 1970s.

The conundrum, says Gail Hesse, executive director of the Ohio Lake Erie Commission, was that less phosphorus fertilizer was going into the system while algal blooms were becoming bigger and more frequent.

“We don’t see this as an overapplication problem just based upon the phosphorus being supplied and what’s being removed,” explains CCA Robert Mullen, director of agronomy at Potash Corp. in Wooster, OH. “I would guess that the issue is the general rule of 80–20—that 80% of the problem comes from 20% of the production system. There are times when applications are made in less-than-ideal conditions that can result in a fairly large amount of phosphorus being transported. But, it doesn’t look as if all
farmers are the bad players, according to the data.”

Rising fertilizer prices, Mullen adds, have limited farmers’ ability to buy large quantities of phosphorus. Thanks to soil testing, precision technology, and improved information through CCAs and extension, farmers largely are applying fertilizer at only required rates. That’s in stark contrast to previous decades.

“When you look back historically during the 1960s and 1970s, we were probably oversupplying fertilizer phosphorus during that era,” Mullen says. “But in the last five years, at least in Ohio, we’ve actually been supplying less P than farmers are using with crop production.”

That’s often resulted in P deficiency on many farms today, he adds. Still, the algal blooms are back, and public attention is growing as other industries and the public bear the cost of algae-filled waters.

CCA Greg LaBarge, field specialist in agronomic systems at Ohio State University Extension, says tourism on Lake Erie is a $10 billion industry. The algal blooms, which can significantly reduce oxygen levels and threaten fish and other aquatic life, have caused tourists to cancel outings or not rebook for upcoming seasons. The toxic blue-green algae called microcystis (top middle) has become more common in Lake Erie and has caused numerous problems with pets. Photos by (clockwise): Ohio Department of Natural Resources, D. Schloesser (USGS Great Lakes Science Center), Tom Archer, and Susan Winsor/Corn & Soybean Digest.

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One toxic blue-green algae called microcystis, which produces the toxin microcystin, has become more common in Lake Erie and has a safety recommendation by the World Health Organization at 1 part per billion for drinking water and 20 parts per billion for recreational contact. In Lake Erie, this toxic algae has caused numerous problems with pets.

“We’ve had reported illnesses in pets in Ohio because dogs will swim in the water and drink the water, but they just don’t have the body mass to process the toxins out of their system,” Hesse says.

The Ohio Department of Natural Resources also has a monitoring system in place to warn the public of levels of exposure during algal blooms. Beaches at Lake Erie have even closed during severe algal blooms.

“The social cost of algal blooms isn’t just borne by beach goers and the tourism industry, though. Local

nuisance aspects from an aesthetic and recreational standpoint.”
public water supplies are also affected via higher treatment costs.

“The good news is that the treatment of the public water supplies is effective at removing the toxin,” Hesse says. “The city of Toledo has spent $3,000–$4,000 a day for additional treatment costs when there’s an algal bloom. So, in addition to the public health concern, there’s a broader public policy concern from our infrastructure cost. The costs get passed onto all of us as rate payers to our public water supplies.”

Dissolved P on the rise

Stumped by both the return of the algal blooms and their toxicity, government and industry leaders created the Ohio Lake Erie Phosphorus Management Task Force in 2007 to determine what had changed. The cause of toxic algal blooms, Hesse says, isn’t so simple. The return of the algae is a culmination of factors that have coalesced with time. Understanding the problem begins by distinguishing two different forms of phosphorus and their unique contribution to algal growth.

Phosphorus entering Lake Erie comes in two basic forms, according to the task force’s final report released in 2012: (1) dissolved phosphorus, which is P with sediment filtered from the water, and (2) particulate phosphorus that is bound to sediment particles. Together, these two forms comprise total phosphorus.

However, the difference between dissolved and particulate phosphorus is significant. While particulate phosphorus is chemically bound to sediment and is only about 30% bioavailable for algae growth, dissolved phosphorus is about 95% bioavailable. And, while particulate phosphorus that’s bound to sediment settles to the bottom of the lake, dissolved P remains suspended in the water column and supports the development of algal blooms, according to NCWQR.

Meanwhile, NCWQR researchers found that while the amount of particulate phosphorus bound to soil particles had been decreasing over the years, there was a dramatic increase in the concentration and load of dissolved phosphorus, starting in the mid-1990s. In recent years, dissolved phosphorus comprised of 26% of the total P but 52% of the bioavailable P moving into the western basin of Lake Erie from the Maumee River.

Why the increase in the more potent dissolved P and a decrease in particulate P?

NCWQR data revealed that only about 7% of the total P—comprising both dissolved and particulate P—entering the western basin of Lake Erie from the Maumee River can be attributed to municipal and industrial sources. That isn’t enough to account for the total increase, says Harold Watters, CCA and crops specialist at Ohio State University Extension.

“The task force knew that there were wastewater overflows out of Detroit, Toledo, and a number of other places mostly affecting the western basin of Lake Erie, but that still didn’t come up with enough phosphorus to indicate that’s the problem,” Watters explains. “They looked at homeowner lawns, storm sewers, on down the list and finally came to agriculture and determined from some information from the [NCWQR] that, yes, there was phosphorus going down those streams and rivers and into Lake Erie, and there’s probably phosphorus coming off the fields.”

With agriculture comprising the majority of land use in the Maumee River Basin, fertilizer for agricultural use is the largest contributor, Hesse adds. But something in the agricultural production system had changed.

Conservation tillage, tile drainage, and climate change

An increase in the amount of dissolved phosphorus coming from farms was invariably linked to the return of the algal blooms, the task force concluded. What wasn’t so
certain, though, was exactly how dissolved phosphorus was increasing and making it into the lake. Changing production practices in agriculture most likely accounted for the shift in less particulate P and more dissolved P moving through the system.

The answer may be hard for some farmers to swallow: The widespread adoption of reduced tillage and no-till may be at the center of the increase in dissolved P moving into Lake Erie.

By not incorporating fertilizer with tillage, fertilizer sits on top of the soil and remains vulnerable to rain or snowmelt, the task force concluded. And, by applying fertilizer in the fall and leaving it on top of hard, frozen soil through the spring, the phosphorus is allowed a long enough window to be washed into a river or stream.

“Typically, what farmers do is apply fertilizer to our soybean stubble in the fall ahead of corn,” Watters explains. “Unfortunately, we don’t necessarily incorporate it until the next spring shortly ahead of corn planting. It lays exposed out there from the first of November after soybean harvest until around April 1. And because it’s not incorporated, it’s subject to movement.”

More than 80% of Ohio’s soybeans are no-tilled, he says, while only about 20% of the corn is no-tilled. Even fields that are tilled, he notes, are in some form of reduced tillage.

Worm channels that develop in the soil may also be contributing to nutrient movement, Watters adds. In reduced-till or no-till systems, worm holes are allowed to develop in the soil, which create passageways for phosphorus to travel through the soil profile to drainage tile and then exit the field as dissolved P.

“When we plant corn, we don’t till it until we harvest the soybeans. So we’ve got a year-and-a-half to two years of opportunity for worms to start creating their little channels again,” Watters says. “And, it is believed that some of this phosphorus is going with water down these worm channels through the tile and then moving from the tile into the streams and on out into the lake. Again, this is all dissolved reactive phosphorus.”

Phosphorus exiting fields through drainage tile is no small issue in Ohio, which is comprised of heavy clay, poorly drained soils and where fields are commonly tilled. All northwestern Ohio and Indiana counties that are included in the Lake Erie watershed have between 60.1 and 100% of harvested land drained by subsurface tile, according to the last survey done by the USDA Natural Resources Conservation Service. That’s the most of all Midwestern states.

Major precipitation events are also deemed a concerning factor for P removal from farm fields, according to a recent article on the Lake Erie algal blooms published in Proceedings of the National Academy of Sciences of the United States of America (PNAS). In addition to conservation tillage and fall P application, extreme meteorological events associated with climate change—particularly regarding precipitation and temperature—are making conditions ripe for large and toxic algal blooms to form, the authors assert.

“Severe spring precipitation events, coupled with long-term trends in agricultural land use and practices, produced a pulse of remarkably high loading of highly bioavailable dissolved reactive phosphorus to the western basin of Lake Erie,” according to the academic...
team in reference to the remarkable algal bloom that resulted in 2011.

In addition, uncommonly warm and calm conditions in late spring and summer provided ideal incubation, seeding, and growth conditions for bloom development in the lake, the team concluded. And if current trends in climate continue, the authors warn, the remarkable events of 2011 will occur with increasing frequency if no action is taken to change the system.

Back to the basics with 4R nutrient management

The widespread adoption of reduced tillage and no-till (top left) may be at the center of the increase in dissolved P moving into Lake Erie. By not incorporating fertilizer with tillage, the fertilizer sits on top of the soil and remains vulnerable to rain or snowmelt. Also, worm holes (top middle) are allowed to develop in the soil, creating passageways for phosphorus to travel through the soil profile to drainage tile and then exit the field as dissolved P. Placing filters on drainage tiles (top right) or using some form of incorporation of the fertilizer when applied (right) could help reduce the amount of dissolved P entering waterways. Photos by (clockwise): Paige Buck (USDA-NRCS), North Appalachian Experimental Watershed of USDA-ARS, Josh McGrath, and the Department of Food, Agriculture, and Biological Engineering at Ohio State University.

small, Watters acknowledges. Making the necessary changes in agriculture must start by changing the way CCAs and their farmers think about P management and how to bring tillage back into systems where it was removed.

The hurdle, he warns, is that there is often times little economic incentive for the farmer to change practices when the loss of P costs the farmer less than a dollar per acre or if an investment in a new implement is required. Educating farmers of the larger consequences of phosphorus loss, he stresses, is where solving the problem of P loss begins.

“We’re starting with educating farmers and making them think about some incorporation with tillage or doing some banding with a planter,” Watters says. “And, it would help if we changed our tillage practices to incorporate fertilizer immediately after application rather than waiting for several months to go by.”

The critical discussion that CCAs must have with their farmer clients, adds LaBarge, ultimately comes down to the 4Rs of nutrient management: The right time, right rate, right source, right placement of fertilizer on the field. (Read more about the 4Rs of nutrient management in the September–October 2012 issue of Crops & Soils magazine.)

“We’re really looking at the adaptation of the 4R nutrient stewardship program,” LaBarge says. “In addition to that, we’re looking at a 4R certification program—a third party type of certification of practices that ag retailers can put in place as far as nutrient management. It’s a conscience effort on their part to bring better advice to their growers about what happens to that nutrient.”

Greater use of soil testing to limit overfertilization, the use of streamside buffers, and placing filters on drainage tiles have also been recommended as solutions that farmers implement to reduce the amount of P that makes its way into rivers and streams.

While more is still being learned about the problem, Mullen says action must be taken now at the farm level. Otherwise, he warns, it may become a government issue down the road if the problem persists.

“If no action is taken, there’s a greater likelihood of regulation from the state and federal level,” says Mullen. “Will they have the information to stop the problem? I’m not convinced.”

The widespread adoption of reduced tillage and no-till (top left) may be at the center of the increase in dissolved P moving into Lake Erie. By not incorporating fertilizer with tillage, the fertilizer sits on top of the soil and remains vulnerable to rain or snowmelt. Also, worm holes (top middle) are allowed to develop in the soil, creating passageways for phosphorus to travel through the soil profile to drainage tile and then exit the field as dissolved P. Placing filters on drainage tiles (top right) or using some form of incorporation of the fertilizer when applied (right) could help reduce the amount of dissolved P entering waterways. Photos by (clockwise): Paige Buck (USDA-NRCS), North Appalachian Experimental Watershed of USDA-ARS, Josh McGrath, and the Department of Food, Agriculture, and Biological Engineering at Ohio State University.
Potassium (K) is an important nutrient for soybean development. It is involved in most of the plant’s life-sustaining processes and is its most heavily absorbed nutrient after nitrogen. It is estimated that a 40 bu/ac soybean crop will uptake about 140 lb/ac potash (K₂O). About one-half this amount is stored in the soybean seed and is therefore removed from the field each year at harvest. Young soybean seedlings do not use a lot of potassium, but the uptake pattern during plant development is similar to that of nitrogen, and the rate of uptake peaks during the rapid vegetative growth period. Much of the potash taken up in the vegetative period is then transferred to the seed during pod fill.

Potassium deficiency can severely limit soybean yield potential; deficiencies can also lower disease resistance and impact nodule formation. Deficiency symptoms are most likely seen during the period from late flowering to early seed fill, and deficiency during the late vegetative stage to seed fill can affect seed fill. Deficiency symptoms can be accentuated when soil conditions are very dry because much of soil potash moves to roots by mass diffusion (i.e., area of high concentration to low concentration) although root interception is also important.

Project

A three-year on-farm project was established to assess if added liquid potash fertilizer could increase soybean yields and reduce deficiencies by providing an easily accessible source of potassium. The project also evaluated what soil types would have the greatest responses based on the existing soil test levels.

Methods

Data was collected at 15 sites over three years. Two trials were conducted in 2010, seven trials in 2011, and six in 2012. Trials included a minimum of two replications per location and were across a variety of locations, soil types, tillage systems, and soil test levels. Plots were planted with a Kearney 15-inch vacuum planter with John Deere 7000 planter units, and the fertilizer was applied in furrow. Plots were a minimum of 20 ft wide by 1,000 ft long. Some sites were planted by farmer co-operators using the same protocol.

doi:10.2134/cs2013-46-3-2

By Brian Hall, Edible Bean and Canola Specialist, Ontario Ministry of Agriculture, Food, and Rural Affairs; brian.hall@ontario.ca
Results

Soil test results for potash (Table 1) used the recommended ammonium acetate test for Ontario. Table 2 shows the average yield of the untreated check and the treatment of 3 gal/ac of 2–20–18 liquid fertilizer. The two treatments did not show a statistical difference over the three years of the trial.

Only one location (Lucan in 2010) showed a statistical response to the liquid fertilizer. The response does not appear to be tied to a “low” K soil test value as the soil test showed a value of 134 ppm K (LR). The response at this site was significant, at 5.5 bu/ac, and year had no effect.

Summary

The liquid fertilizer 2–20–18 was tested in soybeans at various locations, which had different soil types, geography, and soil test values. This study was conducted over three years at 15 locations. There was only one site that responded significantly to this fertilizer treatment. On average, there was no statistically significant response to the added expense of this fertilizer.

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U.S. North-Central

Nitrogen management trial on Iowa corn

By Dennis Holland, CCA, Dupont Pioneer, Alburnett, IA; dennis.holland@pioneer.com

Those of us making a living in agriculture have been enjoying relatively good economic times in recent years. And anytime we have high farm income, there is money left at the end of the year to invest into the operation. This situation creates an important question for many growers. “Where do I invest my money to get the best return on my investment?”

One area many growers are considering investing extra dollars in is nutrient management. Fertilizer costs have risen in the past few years and will undoubtedly keep rising. Government agencies are also scrutinizing fertilizer use in the Midwest from an environmental quality perspective. Nitrogen is one of the most costly fertilizer inputs for many Midwestern corn growers and is considered a pollutant when it winds up in streams and rivers. Improved management of nitrogen fertilizer will benefit growers financially and will help keep excess nitrogen out of our waterways.

There are many different ways to improve nitrogen management. The time of application, amount applied, placement, and the form of nitrogen used are all considerations to make when improving a nitrogen plan. One recent study I conducted with a grower in east-central Iowa demonstrates how different sources, timing, and placement of in-season nitrogen can affect corn grain yield.

This study was conducted in two long-term corn on corn fields with conventional tillage. The base nitrogen program across all acres in both fields was 140 units of urea ammonium-nitrate (UAN) banded pre-plant with a sidedress bar early in the spring. Then 40 units of UAN were broadcast with a sprayer pre-plant with an herbicide. One pass of vertical tillage incorporated the pre-plant nitrogen before planting. This study consisted of four different post-emerge nitrogen treatments focused on application timing, placement, and nitrogen source. Each treatment replicate was 60 ft wide (twenty-four 30-inch
rows) and 2,200 ft long. Treatments were replicated in both fields as indicated below.

**Treatment summary**

- **Untreated check**—Base nitrogen program only: 2 reps/location
- **SuperU**—50 units broadcast at V8 growth stage: 2 reps/location
- **Sidedress UAN**—50 units injected with a coulter at V4: 3 reps/location
- **Y Drop UAN**—50 units dribbled at the base of the plant at V12: 3 reps/location

The sidedress treatment was applied at the V4 growth stage with a 60-ft sidedress bar. Coulters at 30-inch spacing injected UAN approximately 4 inches deep between two corn rows. The SuperU treatment was applied with a high-clearance broadcast spreader pulled by a tractor at growth stage V8. The SuperU granules were simply broadcast over the crop canopy with most granules landing on the soil surface. The Y Drop treatment was applied at growth stage V12. The Y Drop attachments, which allow the UAN to be dribbled below the crop canopy at the base of the plants (see Fig. 1 below), were installed on a 60-ft high-clearance sprayer boom.

Yields of each treatment replicate were collected with a calibrated John Deere GS3 yield monitor and averaged for each treatment at each location. The lack of rainfall during the growing season reduced yields by roughly 30% in both fields, and yield variability was higher than normal. The observed data in both fields trended similarly among treatments, with the most dramatic yield improvement found in the Y Drop treatment (see Table 1).

So why did we see improved yields in the Y Drop treatment? Dry weather results in less movement of fertilizer in the soil. The Y Drop treatment placed the UAN right at the base of the plant near the roots, which allowed the nitrogen to be in the root zone where it can be most effective, relying less on root growth or fertilizer movement in the soil for plant uptake. Also, the Y Drop treatment was applied later in the growing season, immediately preceding the time when a corn plant’s growth rate is increasing and nitrogen uptake is greatest (Fig. 2). The later application of nitrogen right at the base of the plant where it can be more easily utilized is likely why the Y Drop treatment yielded more.

Improving fertility management plans has a lot of potential benefits. If growers increase yield levels by simply changing how or when they apply nutrients, while using the same or even less fertilizer, profits will go up and environmental losses will be reduced. I encourage everyone to review their fertility programs and consider trying something new on a few acres. Have a safe growing season, and see you in the fields! 😄

| Fig. 1. Y Drop attachments on a John Deere sprayer. |

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<th><strong>Table 1. Nitrogen treatments and yield results.</strong></th>
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**Fig. 2.** Corn N uptake throughout the growing season. (Source: Ritchie, S.W., J.J. Hanway, and G.O. Benson. 1993. How a corn plant develops. Iowa State Univ. Spec. Rep. 48. Iowa State Univ., Ames.)
In many places across the South, multiple generations of a producer family may long have raised extensive acreage of soybeans and corn. In addition to a vegetable garden, a row of tomatoes or patch of pecan trees often was tended near the family dwelling. These personal-use plantings will be there this year too, all across the South. However, in many areas, expansions of such plots are now being considered for possible use as economic mainstays for traditional producers and for new “sustainable” production units. These are the newest components of the American fresh produce system.

These fresh fruit and fresh produce enterprises are becoming the total enterprise for a new generation of southerners, many of whom are relatively new to agricultural enterprises. A common core of reasons seems to be driving this change from field crops to other crops. Among other reasons, the impetus to grow these new crops might spring from a desire to fill a perceived demand for locally produced fresh fruits and vegetables. Maybe last year’s venture into “community supported agriculture” proved profitable or very personally satisfying, and the grower wants to expand.

In very recent years, a driver for some who have not been traditional agronomists is hope that a fresh produce enterprise may replace a vanished “day job.” “Think how much I could make with a quarter acre” is a logical extrapolation for one who last year sold fruit from a dozen tomato plants at a roadside stand and experienced strong demand.

Local newspaper stories about “alternative agriculture” systems inspire new growers, too. Typical of such stories is one entitled “Study Shows Value of Buying Local,” in which more than half of customer dollars were shown to stay in the local community. The same article emphasized strong local demand for locally produced cut flowers, another emerging market (Campbell, 2013).

If your consulting work has earned you a good reputation and the trust of an experienced traditional client base, it is almost certain that someone will ask you for advice on growing fruit and vegetables this year. It is possible you may know as much about watermelon production as you do soybean production. Whether you do or not, you should realize different markets are sought for different crops and that market structures for fresh produce are very different from what you may be used to for row crops.

Also consider that what seems to be a request for technical advice may be a marketing inquiry in disguise. Because there is a relatively new national food safety system in place, you might also consider that you really are being asked how to grow a crop that can be sold in this new food safety system.

Expand your business and provide a service

Of course, you can learn fruit and vegetable production, but remember, in many southern states, there are specialized Cooperative Extension agents for EACH crop.

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doi:10.2134/cs2013-46-3-4

gronomy.org/certifications | soils.org/certifications

May–June 2013 | Crops & Soils magazine 13
Good agricultural practices

Ultimately its framework utilizes “Good Agricultural Practices” (GAPs) and GAPs third-party or self-audits based on (1) common sense and (2) checklists relating risk management principles to fresh produce operations. The checklists are in many places online, and every grower can check his/her operation against this national standard.

For the fresh produce industry, FDA released the Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables (FDA, 1998A). The Guide defined GAPs and showed interested parties how they could identify potential fresh produce contamination sources.

Further, the Guide suggested that using GAPs could reduce or eliminate potential contamination. The FDA published guidance for such industries in the Federal Register (FDA, 1998B), apparently looking towards an integrated national food safety framework. FDA realized users would have to fill in details implementing the framework.

Certainly, large buyers and sellers have staff who applied these concepts to their operations. Because regional fresh produce buyers develop and apply national market standards, such standards are de facto regional standards. National application of regional standards means that food safety aspects of a regional fresh produce industry can be addressed on a local producer scale, while market development can be addressed on either the regional or national scale.

What the large producers have done is what your smallest producers can do too, with your help. Where you can help is by being able to guide the small grower through the GAPs and GAPs audit maze. Your work can be analogous to that of a certified public accountant at tax time. While anyone can download tax forms, not everyone can get them filled out correctly. Tax accountants provide an assistive and interpretive interface between federal audit standards and local tax filers.

Similarly, GAPs audits seem to be, and are, very straightforward, but the devil is in the details. The details you need to master are not complex but do require tailoring to each operation. The tailoring is where farm-related consultants can possibly expand services into the emerging local foods movement. The details you should master are in the areas of:

- Preharvest
- Harvest
- Personnel cleanliness
- Storage
- Transport
- Unpacking and display

These are the general areas in which small producers can demonstrate they follow food safety procedures just like the largest producers. Just as with tax items for accountants, GAPs and Good Handling Practice Audit materials are readily available for your use in helping your clients become certified as safe food producers. For example, a standard checklist from the USDA entitled “Good Agricultural Practices Good Handling Practices Audit Verification Checklist” can be found at: www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELPRDC5091326. Many other similar items are readily available for your use. By
using them, you can enable your small producers to meet national standards. Through such verifications, the smallest grower can be on equal footing with the largest in the local sales markets.

As to who would build these programs, this author suggested to a bramble fruit growers conference:

“Extending HACCP-like programs to minimal-process operations represent(s) a considerable change from past practice. This is because minimal-process operations have usually been regulated in a manner similar to that applicable to raw agricultural commodities. GAPs represent a shift, one of increasing reliance on self-regulation after education. The diversity of American fresh produce agricultural practices and commodities forced authors of the Guide to note that practices recommended to minimize microbial contamination would be most effective when adapted to specific operations (emphasis added). This meant that broad statements of intent were supplied, with implementation and interpretation left to the states and the industry.”

Equal footing in a market is obtained not just by standards compliance. It also comes about when a specific small grower in a specific market finds a simple way to increase margin. For instance, one consultant in North Carolina helped a vegetable grower increase profit by convincing the grower to begin washing field containers. This reduced wastage caused by microbially related spoilage from microbes associated with unwashed containers.

Her story is not unique and shows that regulatory changes intended to address consumer food safety may have the unintended consequence of making growers more profitable. You can expand your services while helping ensure the nation’s fresh produce moves safely to market. There are many more small producers than large ones, and they are a largely untapped market for your agricultural consulting services.

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U.S. Northeast

Effect of cereal cover crop species on full-season soybean performance

By Dr. Robert Kratochvil, Extension Specialist–Grain and Oil Crops, University of Maryland; rkratoch@umd.edu

Does choice of cereal cover crop species affect full-season soybean? Does cereal cover crop kill date matter? These are questions that soybean farmers are asking as Maryland cover crop acreage continues to increase.

To address these questions, three years of research was conducted by planting three cereal species (barley, wheat, and rye) as cover crops at the Wye Research and Education Center (fall 2009 and 2010) and Central Maryland R&E Center–Beltsville (fall 2010 and 2011). A treatment of no cover crop (only fall–winter weed growth) also was included. Three (Wye) and two (Beltsville) cover crop spring kill dates that supported varying amounts of cover crop biomass production were used. The kill dates at Wye are defined as (1) extra early kill for only the rye and the no-cover treatments (mid- to late March during the two study years); and at both Wye and Beltsville (2) early kill date for all treatments (ranged from April 13 to April 23); and (3) late kill date for all treatments (ranged from May 2 to May 16). Soybean varieties Asgrow brand 3539RR2 (mid MG 3) and Asgrow brand 4630RR2 (mid-MG 4) were planted into all cover crop treatments between two and three weeks after the last kill date. Soybean harvest dates were considered normal, ranging from October 17 to November 3 during the three years.

Approximately three weeks after planting, stand emergence was assessed to see if the cover crop species or kill date treatments impacted stand establishment. Over the three-year period, no emergence differences were observed, indicating that neither choice of cereal cover crop nor spring kill date had a detrimental effect on soybean germination and emergence. The most important criterion when planting full-season soybean into a cereal cover crop is attainment of good seed–soil contact.

Starting approximately mid-June each year, a weekly measurement of growth stage progression was done by randomly selecting five plants in each plot, determining the growth stage according to Fehr and Caviness (1971), and averaging the growth stage. The primary growth differences observed were associated with the two varieties. Both varieties progressed through vegetative growth similarly, and the onset of reproductive growth always was observed for the earlier of the two varieties, as expected. The weekly readings continued until early- to mid-September. Occasionally, only very minor differences in growth stage progression for the soybeans were observed for either the cover crop species or the kill date treatments. These differences were inconsistent across

doi:10.2134/cs2013-46-3-5
the assessment dates and are considered to have no influence on soybean growth and performance.

Soybean yield (72 bu/ac average) was excellent during the three years. The most consistent yield difference observed was associated with variety; however, there was no consistent trend favoring one over the other. At Wye, the MG 3 variety produced better than the MG 4 variety during 2009–2010, and the opposite occurred during 2010–2011. During 2010–2011 at Beltsville, the MG 4 variety was best, and during 2011–2012, there was no yield difference between the two.

Response of soybean yield performance to cover crop species and kill date varied by location. During the two years at the Wye, a cover crop species × kill date interaction was observed. For the March kill date (extra early), soybeans planted into the no-cover-crop treatment produced 10% (2009–2010) and 4% (2010–2011) better than soybeans following rye.

For the 2010 April kill date (early), soybeans planted following any of the three cover crop species produced the same (62 bu/ac), but soybeans following the no-cover-treatment yielded nearly 10% more (68 bu/ac). In 2011, the April kill date produced no yield differences (~67.5 bu/ac average) among the four cover treatments.

For the two years that the study was conducted at Beltsville, there was no cover crop species × kill date interaction during 2010–2011, but in 2011–2012, this interaction was significant. At Beltsville in 2010–2011, soybeans planted where cover crops were killed during April produced over 6% greater than soybeans following the May kill date. However, during this study year, there were no differences in soybean yield associated with any of the cover crop treatments.

During 2011–2012, soybeans following either barley or wheat cover crop produced the same for the two kill dates. However, soybeans that followed either rye or the no-cover-crop treatment produced approximately 12% greater following the May kill date.

Based on three years of data collected in this study, answers to the two primary questions about soybean performance following cereal cover crops are:

1. Does choice of cereal cover crop species affect the performance of full-season soybeans?

   The performance of full-season soybeans following a cereal cover crop cannot be predicted by the cereal species grown. Differences may occur, but they will be associated with location and kill date.

2. Does cereal cover crop kill date influence soybean performance?

   The optimum kill date for cereal cover crops followed by full-season soybeans is difficult to predict. Factors that can affect soybean performance for any particular kill date are location, year, weather, and variety.

Article courtesy of the Mid-Atlantic Regional Agronomist Quarterly Newsletter

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Growing up on a dairy farm on the outskirts of Lafayette, LA, Earl Garber learned the same skills all farm kids do: How to milk cows and grow corn for silage and how to cultivate pasture grass and harvest hay.

But Garber’s father was also founding chairman of the Lafayette Soil and Water Conservation District, and that meant every agronomic teaching also contained a lesson in conservation. Pastures on the family’s farm were always planted on erosion-prone hillsides, while flatter land was reserved for corn. Any water that did run off cornfields was directed through grass filters to remove sediments and nutrients. Permanent pastures also weren’t tilled; instead Garber’s father would simply overseed bermudagrass with ryegrass when the time came to rotate, so that there was constant ground cover.

Conservation was in fact so central to the farm’s operations that Garber never learned to see the two as separate, and he keeps many of the same traditions on his own land today. “I’ve got a farm laid out very similar to the way my father did,” Garber says. “It’s that type of leadership that I followed.”

Garber may be following his father’s example, but he has also become a leader in his own right. After decades of serving on local soil and water conservation district boards in Louisiana, Garber was elected in early February to a two-year term as president of the National Association of Conservation Districts (NACD)—the organization representing the 3,000 conservation districts across the country that work to protect natural resources on private lands. In 2002, he also became a CCA, and his participation in both organizations has left him more convinced than ever of the wisdom of his father’s approach.

Conservation: A hidden agronomic practice

“Conservation on farms or other working lands is a big part of how producers have become more efficient, whether it’s precision-leveling to save irrigation dollars or structures that control erosion,” Garber says. “I’ve always said conservation is a hidden agronomic practice. The two tie together every day, and young producers especially are looking for opportunities to protect their resources while making good yields and a decent income.”

The grounding Garber received in that philosophy as a youngster has stayed with him his entire life. Then again, life on a dairy farm is grounding period, he jokes, “because you get the opportunity to stay there and do the same job every day.” That’s why when he went to college at what is now the University of Louisiana at Lafayette, Garber chose agronomy as his major. “I didn’t mind growing the grass,” he laughs. “I just didn’t want to have to milk the cows.”

Upon graduating, Garber went to work as a soil scientist for the Soil Conservation Service (now NRCS). But it wasn’t long before farming lured him back. In 1978, Garber, his brother, and his father launched a business, Garber Farms. The operation grew soybeans and sweet potatoes and marketed Louisiana-grown sweet potatoes all over the country.

Garber’s brother and his brother’s sons still run the business today, but Garber left the partnership in 2001 to join a local seed company, G&H Seed Co., as field service manager. So, after 25 years as a farmer, he now advises other growers. And the first thing he did when he took the new job was earn his CCA certification.

“Certification and licensing (Garber is also a Louisiana-licensed crop consultant) will only become more critical as the world moves increasingly toward ‘prescription’ farming,” he says. “It showed I had the knowledge and capability to make those recommendations.”

Meet the Professional

Conservation: a family tradition and a way of life for Earl Garber

By Madeline Fisher
Science Communications Manager

doi:10.2134/cs2013-46-3-6
Garber spends much of his time acquiring grid-sampling data, which he then uses to advise farmers on precision application of fertilizers. And it’s only a matter of time, he thinks, before farmers will also be required to apply herbicides based on official recommendations. So he wants his field representatives to be ready.

“We just added two more, and they need to earn their certification, but 7 out of our 10 reps are CCAs,” he says. “So, I’m trying to keep it going.”

Every acre counts

Of course, what Garber most passionately wants to keep going is the success of NACD. In the coming months, he expects to spend many hours working to ensure NACD’s 10 farm bill “principles” end up in the bill that finally passes into law. He is also encouraging the organization’s mostly rural members to adopt new communication technologies, such as Twitter and Facebook, as a way to connect with their counterparts in cities and suburbs.

Why foster that connection? As rural communities continue to shrink in size and urban areas grow, Garber believes NACD must expand beyond its traditional constituencies of farmer-landowners and rural land managers and embrace suburban and urban dwellers, as well. “Every acre counts in America,” Garber says. “So, even if [people own] small acreage in an urban area, I think we need to convince them that the money invested by the public in conservation has been a good investment and should continue.

“The thing about NACD,” he adds, “is that we cross every sector in America. It’s not just the farmer; we work on issues that touch every American.” Water quality, for instance, can be affected both by urban stormwater and agricultural runoff. Another grave concern is the drawing down of aquifers that people depend on for irrigation of farmland and drinking water in cities.

But uniting disparate groups behind a common cause also requires a special ability to appreciate both sides: that we all need to make a living in the present, while also preserving the environment for the future. That’s what Garber learned growing up and why he’s so proud to serve as president of NACD, he says.

“We try to be the ones in the middle who can talk to both sides so we can come to an agreement on how to have working lands in America produce adequate food, fiber, and fuel, and not abuse the resources made available to us,” he says.
The March–April Crops
& Soils magazine feature, “Choosing the Path of Least [Herbicide] Resistance,” emphasized that successful management of herbicide-resistant weeds requires an integrated, multi-strategy approach. A variety of tactics are available, including rotating herbicide modes of action, cover crops, tillage, crop rotation, and cleaning equipment when moving from infested to clean fields.

Careful planning is required to make sure the suite of approaches is tailored to the site. Which weeds are present and where? Which scouting techniques will generate the most useful information? Which suppression tactics are effective for each weed? Which approaches are the best fit for the farmer and the time and equipment available? What natural resources are present and need to be considered to minimize impacts?

Collecting all of the appropriate information and assembling a cost-effective plan can be a time-consuming task for any consultant, especially when working with a new client. A USDA-NRCS program provides a new option that is making a difference in Arkansas.

Conservation Activity Plans

“When resistant pigweed first came out a few years back, old mindsets made it difficult to control,” reports Arkansas NRCS agronomist John Lee. “We were being reactive in a lot of cases and not proactive. In 2012 when I drove across the state, control looked a lot better.” To help make that improvement, Lee reports that NRCS relied on assistance from more than 35 crop advisers who become qualified as NRCS Technical Service Providers (TSPs).

Each TSP worked with farmer clients enrolled in NRCS’s Environmental Quality Incentives Program (EQIP) to develop integrated Pest Management (IPM) Herbicide Resistance Weed Conservation Activity Plans (CAPs). These plans comprehensively address resistant-weed management on each farm, and identify and protect natural resources, to successfully solve weed control failures. Each plan includes weed management practices, conservation practices, and guidelines for implementation. NRCS provides financial assistance to help cover the costs of plan development for enrolled farmers.

In fiscal year 2012, Arkansas NRCS awarded 138 Herbicide Resistance Weed CAP contracts to farmers, totaling $182,868 in financial assistance covering more than 100,000 acres. Once a CAP is complete, farmers can apply for additional assistance through EQIP to implement conservation and weed management practices identified in the plan.
Arkansas produces a full range of commodities and is number one in the nation for rice production and 10th in soybeans. Cotton, corn, and wheat are also economically important. Across all commodities, Arkansas has 19 weeds resistant to one or more herbicide modes of action. The additional cost to manage resistant barnyardgrass alone in Arkansas rice has been estimated to be about $26/ac.

**Recruiting crop advisers**

According to Lee, “Arkansas has one of the worst pigweed problems in the country. When NRCS decided we needed to offer CAPs, our first thing we realized is that we have a problem because there was no one who can help get the work done.”

Becoming qualified as a TSP can be a lengthy process. Candidates start by obtaining USDA eAuthentication and are required to complete online training modules. They must also meet criteria for experience. A valid CCA credential or a state-issued pesticide applicator or pest control adviser license can serve to meet those criteria. Finally, consultants must demonstrate knowledge and proficiency in IPM and conservation planning by submitting a sample CAP for approval by NRCS.

Recognizing that no consultants had pursued TSP certification for the CAP, John Lee and colleagues investigated the potential to develop an intensive training. The proposal was strongly supported by stakeholders including the Arkansas Association of Conservation Districts (AACD) and the University of Arkansas weed sciences program. Financial support for hotel, food, registration, and materials was provided by BASF, Bayer, Dow, DuPont, MANA, Monsanto, and Valent.

The initial three-day TSP training was expected to attract 20 CCAs working in the state; 51 participants enrolled, including CCAs from several ag retailers. “The training was designed to accomplish, in a very short time frame, what can take weeks or months to complete on your own,” wrote Andrew Wargo, AACD board delegate, in a memo summarizing the training.

Not all “graduates” were immediately ready to develop CAPs. “It’s a lot to develop an understanding of how to use mapping and GIS to manage fields and become efficient in IPM planning,” according to Lee.

Subsequent trainings have addressed RUSLE2 and WIN-PST, required software for conservation and IPM planning that helps predict soil and pesticide losses from cropland.

**Expanding opportunities for farmers, consultants, and resource protection**

“We’re hoping as TSPs get new clients, they will get farmers who don’t have current access to consultants,” Lee says. “These farmers are probably less likely to be having success managing resistant weeds.”

NRCS CAP payment rates to participating farmers begin at $1,697 per farm. The average row crop farm in Arkansas is between 700 and 1,400 acres, which qualifies for the maximum payment of $3,393. Higher payments are available for historically underserved or limited-resource farmers.

After this initial round of CAPs training is completed, Lee plans to organize more trainings to encourage crop advisers to become qualified for IPM, nutrient management, irrigation management, and other CAP and EQIP implementation contracts. He looks forward to having a strong network of TSPs offering comprehensive conservation planning services to address needs not only in Arkansas, but also Louisiana, Mississippi, and Tennessee, which face similar resource and management challenges.

With the growing season well on its way, farmers in Arkansas and across the country will be busy fighting resistant weeds. Learn more about your client’s opportunities with NRCS, and consider becoming a TSP to provide the necessary technical services. Information on becoming a TSP is available on the USDA’s TSP Registry at http://techreg.usda.gov. Each state NRCS office also has a TSP coordinator who can help. For a directory of coordinators, visit http://techreg.sc.egov.usda.gov/CustLocateTSP.aspx.
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In 2013, its 20th year, the CCA program is looking back on two decades of success. But it’s also looking forward. In February, Eric Welsh was hired as Program Manager for CCA Marketing and Communications, and he’s expected to play a key role in the program’s future.

Welsh’s initial focus is to improve communication with the program’s 37 local boards in the United States and Canada to help them increase their numbers. “My primary function right now is marketing the CCA program and organizing promotional efforts at the local level,” he says. “Basically, we’re trying to leverage our existing network of CCA boards across North America to get the program the proper marketing it deserves.”

The 27-year-old graduated from the University of Wisconsin–Madison in 2007 with a B.S. in agricultural business management, a degree he didn’t imagine receiving when he began college. “I didn’t grow up on a farm,” says Welsh, who is from Hudson, a small town on Wisconsin’s western border about 30 miles from Minneapolis, MN. “I came to Madison to study business, but then agriculture came along. I liked the professors and the people I worked with on a regular basis.”

After graduation, Welsh became a sales representative for Syngenta. He promoted and sold Syngenta products throughout all of western Wisconsin for four years before leaving the company in 2011 to start his own business, Welsh Agronomy. The company provides hybrid corn, soybeans, and alfalfa to growers in the southern part of the state.

His work experience after college has provided a fitting transition to becoming part of the CCA program. “I learned a lot about building relationships and hanging onto customers,” Welsh says. “And I did a lot of crop scouting and made fertilizer, chemical, and rotational recommendations.”

Luther Smith, director of certification and licensing, helped hire Welsh earlier this year. “We were looking for an enthusiastic person with experience in the private sector in agricultural sales,” he says. “Eric has that and understands marketing and communications well.”

Only three months into his new role, Welsh has already familiarized himself with the history of the CCA program. “The program has never adjusted its standards just to increase certification numbers, and we’re never going to do that,” he says. “Maintaining high standards for certification is what’s most important to us.”

Smith and Welsh both agree that increasing the number of CCAs will be the biggest priority for the program in the coming years. “CCA certification establishes a structure for continuing, lifelong learning, which improves the overall performance of the agronomy profession,” Smith

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Welsh says his main goal is working with young professionals and college undergrads to get them involved in the program early. Currently, CCAs under the age of 35 make up approximately 16% of the program's members. Welsh believes the key to improving these numbers is encouraging students to take the CCA exam before they graduate. If they pass, they can apply for CCA candidate status. Once they get at least two years of agricultural experience after receiving their bachelor's degree, they can then apply for their CCA credential.

"If we increase the awareness at the college level, we'll be putting more young professionals in the job market with that set of skills," Welsh says. "More employers will hire these people and then they'll start to see the program's value as a necessity for the agricultural industry."

He'd also like to see the International Certified Crop Adviser (ICCA) of the Year award receive more attention from industry professionals. "If we could get more major agricultural and environmental employers involved, we could make the award more significant and visible to add value to certification," Welsh says. "It's a good way to show the public the CCA program's dedication to agricultural production and the conservation of our natural resources."

In the short-term, Welsh will remain focused on raising awareness of the CCA program and its important role in continuing education. "We need to improve the value of the program by working through undergrads, employers, and growers at the local level," he says. "If we continue working with growers and create more awareness for the program, that's going to create the implicit value. And that's what we're after."

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   Or you can also search for the app through the appropriate app store on your device using the term “Certified Crop Adviser.” Unfortunately, the app is not yet ready for the Windows phone.

2. Download the free app and log in with your CCA log-in information (email address and password we have on file for you)—you will only need to do this once.

#### Using the app

1. When you are at any meeting that has pre-approved CCA CEUs, you’ll see a QR code on the sign-in sheet.

2. Launch the app, click on “scan course code” and hover your phone over the QR code.

3. Once the QR code is recognized, click “sign-in,” and you will receive a message that says, “Thank you for signing in to the session.”

4. When you receive that message, simply return home to the start of the app.

   Please note that a course will not scan more than one time. If you accidentally scan a second time, you will receive a message that says, “This course has already been processed into your education history—duplicate entries are not permitted.”

   Traditional sign-in sheets will still be provided at the meeting where you sign your certification number and name if you do not have a smart phone.

   Look for the CCA app at the next educational event you attend. If you don’t see it, encourage the vendor to start submitting its CCA CEU applications in advance of the meeting so that the app can be used. Some vendors still submit after the event is held, and this inadvertently prevents the use of the new technology. The app is easy to use, reduces time to record information, and speeds up the reporting process.

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* doi:10.2134/cs2013-46-3-9*
CCA survey on weed resistance yields ‘eye-opening’ results

By Madeline Fisher
Science Communications Manager

Last December, the leadership of the CCA program asked CCAs to take part in an online survey on the issue of herbicide-resistant weeds. CCAs responded in droves. By the time the survey closed in early January 2013, nearly 1,700 people had answered questions about the resistant weed pressure in their areas, the most effective management tools and approaches, and the obstacles to achieving wider adoption of best management practices (BMPs) in the fight against herbicide resistance.

Eighty-six percent of the respondents were from the United States, and 14% were from Canada. Four CCAs in India also participated, as did one in Mexico. Not too surprisingly, the largest number of responses in North America came from the north-central United States (977, or 58% of the total). But it was the answers from other regions—the American and Canadian West, the U.S. Southeast—that were of greatest interest to International CCA Program Chair Amy Asmus, a chemical ag retailer who herself lives and works in Iowa.

“The survey showed me that I have my perspective but that there are many more perspectives out there,” Asmus says. “It made me realize that geography really does play a role in your perception, your knowledge, and the way you deal with resistant weeds.”

Uncovering the diversity of experience and expertise among the CCA program’s 13,000 certified professionals is precisely what she was after, Asmus adds. Asked last fall to represent CCAs, farmers, and ag retailers on a panel on herbicide resistance at the 2013 Weed Science Society of America (WSSA) annual meeting in Baltimore, MD, Asmus realized she needed to understand what a broad cross-section of CCAs actually thought about the issue.

So after developing the survey in November 2012 and collecting responses throughout December, she brought the results to the February meeting in Baltimore. The survey findings will be reported to CCAs in an upcoming issue of Crops & Soils magazine. But, in the meantime, they were “eye-opening” to her fellow panelists, Asmus says, which included weed and social scientists and representatives from industry and government. “[The panelists realized] it’s the people on the ground who are actually facing this problem and that these people need to be involved in being part of the solution,” she says. “So I think the survey accomplished great things.”

Some of those things included an invitation for Asmus to speak at the CropLife America & RISE (Responsible Industry for a Sound Environment) spring conference in Crystal City, VA, on whether voluntary stewardship of herbicide resistance is working. Karl Anderson, director of government relations for the American Society of Agronomy, is also now working with his counterpart at WSSA to assemble a group of key organizations and people—including CCAs, of course—who will collaborate on the next steps in the fight against resistant weeds.

Most important, the leaders and staff of the CCA program are beginning to discuss mechanisms for tapping into the knowledge and experience of many more CCAs, not just on herbicide resistance, but on other pressing issues, as well. As a certification program, the CCA program must remain neutral at all times, Asmus cautions; however, “it’s also important for us to be in the discussion and bring our perspectives on issues because we’re the ones who work with growers day to day.”

That’s exactly what she sees happening now with resistant weeds: CCAs have been heard through the survey, avenues of communication are opening up, and people are starting to work together to address the problem. “It’s a little snowball right now,” Asmus says. “But it could get to be an avalanche.”

Stay tuned for the results of the survey, which will appear in an upcoming issue of Crops & Soils magazine.

doi:10.2134/cs2013-46-3-10
In mid-March, CCAs; members of the American Society of Agronomy (ASA), Crop Science Society of America (CSSA), and Soil Science Society of America (SSSA); and graduate students from across the U.S. came to Washington, DC to meet with their congressional delegation to raise awareness and support for food, agriculture, and natural resources research funding during the fourth annual Congressional Visits Day (CVD). Participants met with 56 congressional offices, specifically focusing on USDA agriculture research programs—the Agricultural Research Service and the Agriculture and Food Research Initiative.

ASA, CSSA, and SSSA have a long history of working to connect fundamental research discoveries to the practical applications of this knowledge. One shining example of this connection is seen in the involvement of the International Certified Crop Adviser (ICCA) program, which provides a benchmark for practicing agronomy professionals who provide scientifically sound agronomic advice to farmers.

For the 2013 CVD, the CCAs played a unique role in relaying the importance of support for agriculture research. Most CVD teams had a faculty researcher, a graduate student, and a CCA. These teams were able to describe how scientific knowledge passes from the theoretical to the practical, from the lab to the land. The CCAs described how they depended on unbiased research, done at land grant universities, to help shape agricultural practices.

The importance of this “research pipeline” is often lost on congressional members and staff. “The CVD teams can illustrate how the appropriations are used to fund basic research, which evolves into applied research, which spins off into technologies and applications,” says ASA Science Policy Committee Chair and CCA Fred Vocasek. “As the CVD teams present their [funding] ask, the staffer or legislator has a chance to see how the investment in research actually pays out at the farm gate, at the grain elevator, at the biofuel plant. I think the Society–Student–Certificant teams can be a rather unique combination that other entities may not be able to easily match.”

Because of the success of the CCA participation in the 2013 CVD, the Science Policy Office hopes to expand their participation in 2014.
**Newly certified**

The following list includes newly certified individuals and those who have added additional certifications since the last issue of *Crops & Soils* magazine.

### United States

#### Arizona
- Andrade, Jesus Ulises, Yuma, AZ (CCA-AZ)
- Penny, Johnathan Liam, Yuma, AZ (CCA-AZ)

#### California
- Almasri, Mike, Watsonville, CA (CPAg, CCA-CA)
- Baker, Thad P, Willows, CA (CCA-CA)
- Bakke, Richard L, Modesto, CA (CCA-CA)
- Boone, Stephen Dale, Stanislaus, CA (CCA-CA)
- Brooks, Kevin W, Fresno, CA (CCA-CA)
- Diener, Mark Gregory, Fresno, CA (CCA-CA)
- Dugo, Brian Andrew, Escalon, CA (CCA-CA)
- Gruenwald, Stephen Michael, Orland, CA (CCA-CA, MM)
- Isaak, Abraham Henry, Reedley, CA (CCA-CA)
- Key, John W, Roseville, CA (CPSS-RET)
- Pinheiro, Phillip M, Arvin, CA (CCA-CA)
- Portugal, Michael A, Tulare, CA (CCA-CA, MM)
- Risorto, Sarah Paige, Clovis, CA (CCA-CA)
- Selzer, Tom, Helm, CA (CCA-CA)
- Suthers, Gary L, Bakersfield, CA (CCA-CA)
- Veysey, Shawn Thomas, Greenfield, CA (CCA-CA)
- Wilson, Stewart G, Davis, CA (APSS)
- Woods, Gary L, Fresno, CA (CCA-CA)

#### Delaware
- Jones, Lyle A, Dover, DE (CPSS-RET, CPSC-RET)

#### Iowa
- Keck, Jason B, Ogden, IA (CCA-WI)

#### Idaho
- Blaser, Gregory E., Rexburg, ID (CPAg, CCA-NW)
- Mavencamp, Frederick, Wendell, ID (CCA-NW)
- Rubert, Russell Steven, Saint Anthony, ID (CCA-NW, CPAg)

#### Illinois
- Britenstine, Robert J, Adair, IL (CPAg, CCA-IL)
- Burrow, David Alan, Altamont, IL (CCA-IL)
- Chomycia, Jill Christine, Chicago, IL (CPSS)
- Gerber, Jason C, Toulon, IL (CCA-IL)
- Gilbert, Ryan Eugene, Byron, IL (CCA-IL, CPAg)
- Jones, Douglas M, West Brooklyn, IL (CCA-IL)
- Meinhardt, Pat J, Wheeler, IL (CCA-IL)
- Paddock, Travis K, West Liberty, IL (CCA-IL)
- Parsons, Bryce William, Red Bud, IL (CCA-IL)
- Perkins, Jonathan Allen, Strasburg, IL (CCA-IL)
- Schramer, Lee Marcus, Maple Park, IL (CCA-IL)

#### Indiana
- Dikeman, Justin R, Crawfordsville, IN (CCA-IN)
- Hiner, Ryan L, Lafayette, IN (CCA-IN)
- Mote, Marc William, Union City, IN (CCA-IN)
- Murphy, Benjamin P, Rushville, IN (CCA-IN)
- Nicholson, Jacob Lee, Straughn, IN (CCA-IN)
- Polesel, Travis A, Martinsville, IN (CCA-IN)
- Shidler, Thad D, Clay City, IN (CCA-IN)
- Truster, Mark L, Franklin, IN (CCA-IN)
- Wagler, Chad D, Franklin, IN (CCA-IN)

#### Kansas
- Blakeslee, Eric K, Washington, KS (CCA-KS)
- Germann, Matthew D, Highland, KS (CCA-KS)
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Daniels, Donald H, Wakeman, OH (CCA-OH)
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Nielson, Justin B, Pierre, SD (CCA-SD)

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Lauer, David A, Prosser, WA (CPSS-RET)
Rolph, Steven G, Yakima, WA (CPSS-RET, CPSC-RET)
Tippett, Ryan A, Pasco, WA (CCA-NW)

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Kelly, Terence Terrill, Madison, WI (CCA-WI)
Schwalbach, Elizabeth A, Appleton, WI (CCA-WI)

Wyoming
Faber, Colleen D, Rozet, WY (CPSS)
Hergert, Holden James, Thermopolis, WY (APSS)

doi:10.2134/cs2013-46-3-12
Effect of seeding rates on weed removal timing in glyphosate-resistant soybean

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Between 1995 and 2010, soybean seed costs increased from $13.32/ac to $59.20/ac, due in large part to the introduction of glyphosate-resistant cultivars. Glyphosate herbicide controls a broad spectrum of weed species without causing injury or reducing yield in glyphosate-resistant soybean cultivars. Cultivars resistant to herbicide were seeded on 92% of United States soybean acres in 2008. The ubiquity of these cultivars, in combination with their increasing cost, has led producers to re-evaluate the seeding rate necessary to achieve maximum yields. Because soybean yields do not necessarily decrease as seeding rates decrease, a significant reduction in the seeding rate may become a viable option for decreasing production costs.

Historically, excessive seeding rates have been recommended and used as a means of cheap insurance against poor emergence and to ensure early crop canopy closure in order to maximize interception of solar radiation and to improve competition with late-emerging weeds. As seed prices continue to rise and chemical seed treatment options increase, the practice of planting extra seed for insurance purposes becomes less economically sound.

As canopy closure and solar radiation interception near 100%, crop growth rate and photosynthesis are maximized. In order to achieve maximum yield, soybean has been shown to require full canopy closure by R1, or 95% light interception at growth stage R5. Similarly, full closure of the crop canopy prevents solar radiation from reaching the soil surface and may reduce the number of spray applications necessary to

Editor’s note: Following is a slightly modified version of an article that was originally published in Crop Management. Due to space constraints, some tables along with the citations and Reference section are omitted but can be accessed by viewing the original article at www.plantmanagementnetwork.org/sub/cm/research/2013/soybean/

Jason M. Sarver, University of Georgia, Department of Crop and Soil Sciences, Tifton, GA; Chad D. Lee and J. D. Green, University of Kentucky Department of Plant and Soil Sciences, Lexington, KY; James H. Herbek and James R. Martin, University of Kentucky Department of Plant and Soil Sciences, Research and Education Center, Princeton, KY

Abbreviations: NTC, non-treated control; WAE, weeks after emergence; WAP, weeks after planting; WF, weed free.
provide adequate weed control throughout the growing season.

Timing of glyphosate application is critical to weed control in glyphosate-resistant soybean. The effectiveness of glyphosate is determined by the time of application relative to weed seedling emergence, and in particular, the height of weeds when glyphosate is applied. Weed emergence extends over several weeks following land preparation and soybean planting, resulting in a mixture of multiple weed species at varied stages of development. Because of its lack of residual action, early glyphosate application is ineffective at controlling weeds that emerge following application. Conversely, late glyphosate applications may be rendered ineffective on early-emerging weeds, as some species become too large and/or they may require a higher rate of glyphosate for control.

In South Carolina, the optimum glyphosate timing was no later than four weeks after emergence (WAE) to ensure maximum yield of the soybean crop. When control measures were delayed to 6 WAE, weed control was much less effective and yield was reduced in four of six seeding rates. The reduced control was attributed to larger weeds when the herbicide was applied and a lack of spray coverage of weeds beneath the soybean canopy. Numerous studies indicate that weed removal somewhere between V1 to V3 is critical for maximum yield. An average 2% yield loss per growth stage was observed as the cost of delaying weed control past this critical period.

Past studies have addressed soybean yields as they relate to reduced seeding rates, and a multitude of others have investigated optimum herbicide timing. The literature is lacking, however, in research specifically designed to determine if optimum glyphosate timing is affected when the seeding rate is reduced below previously recommended numbers. The objective of this study was to determine the effect of reduced soybean seeding rate on optimum glyphosate application timing, specifically as it relates to yield, weed control, light interception, and canopy closure.

Field trials

Field trials were conducted in 2007 and 2008 at Spindletop Research Farm near Lexington, KY and at the University of Kentucky Research and Education Center near Princeton, KY. The soil type at Lexington was a Lowell silt loam (2–6% slope, fine, mixed, active, mesic, Typic Hapludalfs) and a Maury silt loam (2–6% slope, fine, mixed, semiactive, mesic Typic Paleudalfs) in 2007.
and 2008, respectively. At Princeton, trials were conducted on a Crider silt loam (5–9% slope, fine-silty, mixed, active, mesic Typic Paleudalfs) in both years. Treatments were arranged as a split-plot design with four replications at each environment, with seeding rate as the main plot: (i) 75,000, (ii) 125,000, and (iii) 175,000 seeds/acre; and glyphosate application timing as the sub-plots: (i) non-treated control (NTC), (ii) glyphosate applied 3 weeks after planting (WAP), (iii) glyphosate applied 5 WAP, (iv) glyphosate applied 7 WAP, (v) glyphosate applied 3 WAP followed by 7 WAP (3 + 7 WAP), and (vi) weed-free (WF), where glyphosate was applied 1, 3, 5, and 7 WAP. Fertilizer P and K were added according to soil test results and University of Kentucky recommendations.

For each sub-plot, soybean was seeded into four rows, 15 inches apart (5 ft total width) by 30 ft long. Border plots of the same size were planted between each sub-plot (125,000 seeds/acre) in an effort to prevent spray drift from affecting adjacent plots and as a means for visual comparison to determine weed control later in the season.

Soybean cultivars Asgrow 3906 and Asgrow 3905 were grown in 2007 and 2008, respectively. These varieties both have a 3.9 maturity rating, which is commonly used throughout the state.

Seeds were planted no-till following corn on May 16 at Lexington in 2007, following fallow on May 13 at Lexington in 2008 and following wheat on May 5 at Princeton in 2008. For no-till environments, an application of glyphosate (0.75 lb ae/acre) (Roundup WeatherMax, Monsanto Co., St. Louis, MO) was applied one week prior to planting. At Princeton in 2007, seeds were planted into a conventionally tilled seedbed following corn on May 4. Seeds were planted at a depth of 0.75 to 1.0 inch using a small-plot drill with cone delivery (Hege, Colwich, KS). All seeds were inoculated with *Bradyrhizobium japonicum* inoculant (Southern States, Richmond, VA).

Glyphosate (Roundup WeatherMax) was applied at 0.75 lb ae/acre in a spray volume of 18.3 gal/acre. Dates of application, soybean growth stage, soybean plant height, and weed counts at each application are displayed in Table 1.

Data collection

Soybean stand counts were taken near the beginning of reproductive growth in each environment and are reported in Table 2. Weed control ratings were determined by means of a visual estimate of weeds controlled when compared with adjacent non-treated plots by looking down the rows from the end of each plot at the R5 growth stage, with a rating of 100% representing no weeds present and 0% representing weeds equal to those in the untreated plots. Light interception at growth stage R1 was measured using a handheld light bar (Li-Cor, Lincoln, NE).

Light interception measurements were
taken at Lexington only. Canopy closure was estimated at growth stage R5 by looking down the rows from the end of each plot and visually estimating the percentage of the soil surface not visible between the rows, with an observation of 100% representing no visible soil surface between rows and 0% representing no plants. Plots were trimmed to 20 ft and harvested when seed moisture was 10–13%. Yields were adjusted to 13% moisture.

**Statistical analysis**

Statistical analyses of seed yield, weed control, light interception and canopy closure were performed using the MIXED procedure in SAS 9.2 (SAS Institute Inc., Cary, NC). Data were analyzed by analysis of variance and differences in least square means were determined using multiple pairwise t-tests ($P \leq 0.05$). Seeding rate and glyphosate application timing were treated as fixed effects, while replication and environment were treated as random. For weed control, light interception, and canopy closure measurements, data from NTC plots were not used in the analysis.

**Interactions**

Because there were significant environment by main-plot and environment by sub-plot interactions, data were separated and analyzed by environment. There were no significant interactions between seeding rate and glyphosate application timing in any environment; therefore these effects are presented separately within each table.

**Weed control**

Weed control was not affected by seeding rate in any environment but was affected by glyphosate application timing in three of four environments (Table 3). In Lexington in 2007, all treatments controlled weeds as well as the WF treatment except the 3 WAP treatment, which resulted in less control. At both locations in 2008, the 5 WAP, 7 WAP, and 3+7 WAP treatment did not control weeds as well as the WF program, but all were better than the 3 WAP treatment. Lack of observed control with the single 3 WAP treatment was likely due to the presence of weeds that emerged after that treatment timing.

**Light interception and canopy closure**

Neither seeding rate nor glyphosate application timing significantly affected light interception in any environment (data not shown). The differences in canopy development and the resultant light inter-

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**Table 3. Percent weed control at R5 in Lexington and Princeton, KY, in 2007 and 2008 as affected by seeding rate and glyphosate application timing.**

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Non-treated</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3 WAP §</td>
<td>91 b</td>
<td>96</td>
<td>53 c</td>
<td>80 c</td>
</tr>
<tr>
<td>5 WAP</td>
<td>100 a</td>
<td>100</td>
<td>68 b</td>
<td>96 b</td>
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<tr>
<td>7 WAP</td>
<td>100 a</td>
<td>99</td>
<td>75 b</td>
<td>95 b</td>
</tr>
<tr>
<td>3+7 WAP</td>
<td>100 a</td>
<td>100</td>
<td>76 b</td>
<td>97 b</td>
</tr>
<tr>
<td>Weed free</td>
<td>100 a</td>
<td>100</td>
<td>100 a</td>
<td>100 a</td>
</tr>
</tbody>
</table>

† Visual weed control ratings at R5. Non-treated plots were not included in the analysis because non-treatment is not a viable option for weed control.

‡ Means followed by the same letter within a column for a given seeding rate or glyphosate application timing are not significantly different at $P \leq 0.05$, using least-squares means comparisons in SAS PROC MIXED.

§ WAP, weeks after planting.

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**Table 4. Percent canopy closure in Lexington and Princeton, KY, in 2007 and 2008 as affected by seeding rate and glyphosate application timing.**

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Non-treated</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3 WAP §</td>
<td>96.5</td>
<td>97.6 a</td>
<td>43.3 c</td>
<td>98.2</td>
</tr>
<tr>
<td>5 WAP</td>
<td>97.2</td>
<td>91.8 b</td>
<td>62.5 b</td>
<td>98.4</td>
</tr>
<tr>
<td>7 WAP</td>
<td>97.3</td>
<td>83.7 c</td>
<td>56.8 b</td>
<td>97.9</td>
</tr>
<tr>
<td>3+7 WAP</td>
<td>97.1</td>
<td>96.3 a</td>
<td>65.8 b</td>
<td>99.0</td>
</tr>
<tr>
<td>Weed free</td>
<td>97.8</td>
<td>97.6 a</td>
<td>80.4 a</td>
<td>98.9</td>
</tr>
</tbody>
</table>

† Visual estimate of crop canopy closure at growth stage R5. Non-treated plots were not included in the analysis because of interference from weeds.

‡ Means followed by the same letter within a column for a given seeding rate or glyphosate application timing are not significantly different at $P \leq 0.05$, using least-squares means comparisons in SAS PROC MIXED.

§ WAP, weeks after planting.
Seed yield

In Lexington in both 2007 and 2008, a minimum seeding rate of 125,000 seeds/ac was required in order to achieve maximum yield (Table 5). There was no yield benefit from increasing the seeding rate to 175,000 seeds/ac in either of the environments. These results support previous studies, as increasing the seeding rate above 100,000 to 125,000 did not necessarily increase yield.

Across seeding rates, a single application of glyphosate at 5 WAP and sequential applications at 3+7 WAP resulted in yields similar to the WF treatments in all environments (Table 5). The single 7 WAP treatment was effective at maintaining yield potential when compared with the WF treatment in three of four environments, while the 3 WAP treatment was equal to the WF in only one environment. The enhanced effectiveness of a single late application of glyphosate when compared with single early application is likely the result of a late overall weed emergence pattern across environments. Fewer weeds had germinated 3 WAP than at the other treatment timings, rendering the 3 WAP treatment ineffective at controlling those late-emerging weeds and in turn hindering yield.

Summary and grower implications

Glyphosate application timings resulting in the highest yields were consistent across seeding rates, meaning that reducing soybean seeding rates does not require a change in application strategy. This is particularly of interest to producers as both seed and weed management costs continue to rise. A seeding rate of 125,000 seeds/ac (average final stand of 88,708 ± 3,685 plants/ac) in 15-inch rows was sufficient to achieve maximum yields in all environments.

While a single application at 5 WAP was always a viable option across these environments, producers must monitor weed emergence patterns in their fields in order to make their weed control program as effective as possible, especially when a single post-emergence application is used. As herbicide resistance becomes more prevalent and weed control programs continue to evolve, an earlier application of glyphosate along with a residual herbicide to control later-emerging weeds may be needed to achieve adequate results. Further research with herbicides with different modes of action and/or residual activity is warranted, especially as resistance to glyphosate demands changes in weed management strategies.

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Table 5. Soybean seed yield in Lexington and Princeton, KY, in 2007 and 2008 as affected by seeding rate and glyphosate application timing.

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Nontreated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>75,000</td>
<td>57.8 b†</td>
<td>30.1</td>
<td>5.7b</td>
<td>49.6</td>
</tr>
<tr>
<td>125,000</td>
<td>63.1 a</td>
<td>34.4</td>
<td>10.6 a</td>
<td>49.3</td>
</tr>
<tr>
<td>175,000</td>
<td>63.9 a</td>
<td>35.5</td>
<td>11.9 a</td>
<td>44.6</td>
</tr>
<tr>
<td>Glyphosate application timing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 WAP†</td>
<td>60.3 b</td>
<td>33.2 b</td>
<td>7.2 cd</td>
<td>48.5 a</td>
</tr>
<tr>
<td>5 WAP</td>
<td>65.2 a</td>
<td>37.3 a</td>
<td>10.4 abc</td>
<td>51.2 a</td>
</tr>
<tr>
<td>7 WAP</td>
<td>63.9 ab</td>
<td>37.8 a</td>
<td>8.1 bcd</td>
<td>48.7 a</td>
</tr>
<tr>
<td>3+7 WAP</td>
<td>64.1 ab</td>
<td>38.5 a</td>
<td>11.2 ab</td>
<td>52.0 a</td>
</tr>
<tr>
<td>Weed free</td>
<td>65.9 a</td>
<td>39.2 a</td>
<td>14.0 a</td>
<td>51.3 a</td>
</tr>
</tbody>
</table>

† Means followed by the same letter within a column for a given seeding rate or glyphosate application timing are not significantly different at P ≤ 0.05, using least-squares means comparisons in SAS PROC MIXED.

‡ WAP, weeks after planting.
May–June 2013
self-study quiz

Effect of seeding rates on weed removal timing in glyphosate-resistant soybean (no. SS 04860)

1. Which of the following reasons is NOT mentioned in the article as a reason for the excessive seeding rates that were recommended in the past?
   - b. Improve competition with late-emerging weeds.
   - c. Reduce lodging and increase water use efficiency.
   - d. Cheap insurance against poor emergence.

2. In order to achieve maximum yield, soybean has been shown to require
   - a. 50% canopy closure by R1 or 50% light interception at R5.
   - b. Full canopy closure and light interception by R5.
   - c. Full canopy closure by R1 or 95% light interception at R5.
   - d. 95% canopy closure by R1 or 50% light interception at R5.

3. According to the article, glyphosate may be rendered ineffective
   - a. when it is applied late on late-emerging weeds.
   - b. on weeds that emerge after application when applied early.
   - c. on weeds that emerge before application when applied late.
   - d. when it is applied early on weeds before they emerge.

4. In South Carolina, the optimum glyphosate timing was
   - a. no later than four weeks after emergence.
   - b. between two and three weeks after emergence.
   - c. between V4 and V6.
   - d. no earlier than V6.

5. The study showed a lack of observed weed control in Lexington in 2007 and both locations in 2008 with the
   - a. 5 WAP treatment.
   - b. 3+7 WAP treatment.
   - c. 7 WAP treatment.
   - d. 3 WAP treatment.

This quiz is worth 1 CEU in Integrated Pest Management. A score of 70% or higher will earn CEU credit.

Directions

After carefully reading the article, answer each question by clearly marking an “X” in the box next to the best answer. Complete the self-study quiz registration form and evaluation form on the back of this page. Clip out this page, place in an envelope with a $20 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.certifiedcropadviser.org/certifications/self-study/515.

6. In this study, weed control
   - a. was not affected by glyphosate rate in any environment.
   - b. was not affected by glyphosate application timing in any environment.
   - c. was affected by seeding rate in three of four environments.
   - d. was not affected by seeding rate in any environment.

7. Which of the following is true of this study regarding light interception?
   - a. Both seeding rate and glyphosate application timing significantly affected light interception.
   - b. Light interception was significantly affected by glyphosate application timing but not seeding rate.
   - c. Light interception was significantly affected by seeding rate but not glyphosate application timing.
   - d. Neither seeding rate nor glyphosate application timing significantly affected light interception.

8. Which of the following was sufficient to achieve maximum yields in all environments of this study?
   - a. A seeding rate of 125,000 seeds/ac in 15-inch rows.
   - b. A seeding rate of 175,000 seeds/ac in 30-inch rows.
   - c. A seeding rate of 150,000 seeds/ac in 30-inch rows.
   - d. A seeding rate of 100,000 seeds/ac in 15-inch rows.
9. Which of the following is true in this study regarding the relationship between seeding rate and seed yield?

- a. There was a yield benefit from increasing the seeding rate to 175,000 seeds/ac at Lexington in both years.
- b. There was no yield benefit from increasing the seeding rate to 175,000 seeds/ac in either of the environments.
- c. A minimum seeding rate of 150,000 seeds/ac was required in order to achieve maximum yield at Princeton only in both years.
- d. A minimum seeding rate of 150,000 seeds/ac was required in order to achieve maximum yield at both locations in both years.

10. According to the article, reducing soybean seeding rates

- a. does not require a change in glyphosate application timing strategy.
- b. requires a change in glyphosate application timing strategy.
- c. consistently results in the lowest yields.
- d. requires a change in row width to maintain consistent yields.

Self-Study Quiz Registration Form

Name: _____________________________________________

Address: __________________________________________

City: ______________________________________________

State/province: ____________________________ Zip: _____________

CCA certification no.: ____________________________

$20 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 May 2013 expires May 2016

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: ______________________________________________________
Saflufenacil’s efficacy as influenced by water hardness and co-applied herbicides

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Saflufenacil (Sharpen) is a relatively new herbicide that inhibits protoporphyrinogen IX oxidase (PPO) enzyme in the chlorophyll biosynthesis pathway. It is used for broadleaf weed control in corn and soybean and was applied to more than 10 million acres in the U.S. in its first year of use. Saflufenacil has been used in preplant, pre-emergence, and/or postemergence control of broadleaf weeds in crop and fallow areas. It provides herbicidal activity on broadleaf weed species but does not control grasses completely. For this reason, saflufenacil is often tank-mixed with glyphosate (Roundup Powermax) to achieve better grass weed control.

Herbicide mixtures are often used to increase efficiency and efficacy of weed management systems. Co-application of herbicides is more convenient, widens the spectrum of control, and can improve control of larger or stressed weeds. Herbicide mixtures that include different modes of action or sequential application of herbicides with different modes of action can reduce selection pressure for herbicide-resistant biotypes. This approach is preferred because of convenience, as well as savings in time and application costs. It has been demonstrated with PPO-inhibiting herbicides such as fomesafen that overall efficacy can be reduced when co-applied with glyphosate. Limited research has been published on the compatibility of saflufenacil with other herbicides.

Water plays a crucial role in determining the efficacy of herbicides because carrier water comprises more than 95% of the spray solution. The quality of the carrier water can influence the efficacy of many herbicides including saflufenacil. Saflufenacil is a moderately acidic herbicide with a pKa value of 4.41. Previous studies have indicated that the hardness of water, which is mainly the concen-

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**Abbreviations:** DAS, diammonium sulfate; DAT, days after treatment; PPO, protoporphyrinogen IX oxidase; TPAC, Throckmorton Purdue Agricultural Center.

doi:10.2134/cs2013-46-3-14

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**Editor’s note:** Following is a slightly modified version of an article that was originally published in *Crop Management*. Due to space constraints, the citations and reference section as well as some tables are omitted but can be accessed by viewing the original article at www.plantmanagementnetwork.org/sub/cm/research/2012/saflufenacil/.

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Self-Study CEUs

Saflufenacil use could increase dramatically because growers can use it to replace 2,4-D in burndown applications. The hypothesis of this research was that water hardness would reduce saflufenacil efficacy and co-applied herbicides will increase saflufenacil efficacy on common lambsquarters, giant ragweed, and giant foxtail. Therefore, research was conducted to evaluate if saflufenacil efficacy is affected by co-applied herbicides and water hardness.

Treatments and experimental design

Field experiments were conducted on fallow ground with uniform weed populations during 2012 at the Throckmorton Purdue Agricultural Center (TPAC) in Lafayette, IN. For the control of common lambsquarters and giant ragweed, treatments consisted of application of saflufenacil (Sharpen herbicide, BASF Ag Products, Research Triangle Park, NC) at 0.0225 lb ai/ac alone, or with atrazine (Aatrex herbicide, Syngenta Crop Protection, Greensboro, NC) at 2.0 lb ai/ac, chlorimuron-ethyl (Classic herbicide, Dupont Crop Protection, Wilmington, DE) at 0.0106 lb ai/ac, clodim (Select Max herbicide, Valent USA Corporation Agricultural Products, Walnut Creek, CA) at 0.0913 lb ai/ac, cloransulam-methyl (FirstRate herbicide, Dow AgroSciences, Indianapolis, IN) at 0.0313 lb ai/ac, dicamba (Clarity herbicide, BASF Ag Products) at 0.5 lb ae/ac, glufosinate (Ignite herbicide, Nufarm Agricultural Products, Burr Ridge, IL) at 0.17 lb ae/ac, and 2,4-D amine (Weedar 64 herbicide, Nufarm Agricultural Products, Burr Ridge, IL) at 0.4731 lb ae/ac. Within the same experiment, only saflufenacil applied alone or with clethodim, glufosinate, glyphosate, imazaquin, imazethapyr, isoxaflutole, and paraquat were examined for the control of giant foxtail, as the other co-applied herbicides provided little to no activity on grasses. All co-applied herbicide treatments used for the control of three weeds mentioned above received DAS at 0.17 lb/gal and methylated seed oil (MSO) at 1% v/v.

Additionally, saflufenacil was applied with three water sources: deionized water, water with 310 ppm hardness, and water with 620 ppm hardness. Each of the three water sources was applied with and without AMS at 0.17 lb/gal. Water hardness treatments were applied only for the control of common lambsquarters and giant ragweed. Water sources having hardness of 310 and 620 ppm were created by adding calcium chloride (CaCl₂) and magnesium sulfate [MgSO₄·7H₂O] at a 2:1 ratio into deionized water. Hard water samples were analyzed by A&L Laboratories (Ft. Wayne, IN) to confirm concentrations of calcium and magnesium in these water sources. These hardness concentrations are considered as hard water when compared with the overall spectrum of hardness in Indiana. Additional treatments included a non-treated control.

The experiment was set up as a factorial design. Plot size was 10 by 30 ft, and treatments were arranged as a randomized complete block. Each treatment was replicated four times, and the experiment was repeated in two separate locations at TPAC. In both experimental runs of the experiment, treatments were applied to 4-inch tall common lambsquarters with an average density of 12 plants/yd², 6- to 7-inch giant foxtail with an average density of 50 plants/yd², and 12- to 18-inch giant ragweed with an average density of 4 plants/yd². Treatment application dates and weather data are included in Table 1.

Application procedure and data collection

Treatments were applied using a CO₂-propelled backpack sprayer equipped with XR11002 nozzles (TeeJet XR11002 extended range nozzles, Spraying Systems Company, Wheaton, IL) calibrated to deliver 15 gal/ac. Visual estimates of the percentage of control were recorded 14 and 21 days after treatment (DAT) using a scale of 0 to 100, where 0 is no weed control and 100 is complete weed control. Analyzing the control of weeds over both the 14 and 21 DAT ratings provided information on the rate of herbicide activity and if regrowth of weeds were occurring after application.
Statistical analysis

Data for visual ratings of common lambsquarters, giant ragweed, and giant foxtail were analyzed using PROC GLM in SAS (version 9.1, SAS Institute Inc., Cary, NC). All data were checked for normality and constant variance using PROC UNIVARIATE in SAS and were transformed using an arc-sine transformation for analysis and then back-transformed for presentation. The non-treated checks were not included in statistical analysis. Data for co-applied herbicide treatments were analyzed separately by rating timing and by weed species. No significant interactions of experimental run by treatment were observed at \( \alpha = 0.05 \) for the control of common lambsquarters, giant foxtail, and giant ragweed; therefore, data were pooled over experimental runs. The six carrier water treatments were analyzed separately using the saflufenacil plus deionized water as the standard treatment. No significant interactions were noted over the data for the six carrier water treatments; therefore, data were pooled over experimental run and rating timing to test the main effect of carrier water hardness. All data sets were subjected to analysis of variance appropriate for the treatment structure, and means were separated by using Fisher’s protected LSD at \( P \leq 0.05 \).

Compatibility of saflufenacil with other herbicides

Visual estimates of percent control of giant ragweed at 14 and 21 DAT revealed no differences in treatments when saflufenacil was co-applied with other herbicides or different water sources. Co-application of saflufenacil alone or with other herbicides and water sources provided 85% or higher control of giant ragweed (data not shown).

The main effect of herbicide was significant for the control of common lambsquarters at 14 and 21 DAT when saflufenacil was co-applied with other herbicides. Saflufenacil applied alone in deionized water controlled common lambsquarters by 65 and 69% at 14 and 21 DAT, respectively (Table 2). All co-applied herbicide treatments controlled common lambsquarters greater than 90% at 14 DAT except co-application of saflufenacil with imazethapyr. At 21 DAT, all co-applied herbicide treatments, with the exception of saflufenacil applied with chlorimuron-ethyl or imazethapyr, controlled common lambsquarters by 85% or more. Saflufenacil may exhibit antagonism when co-applied with contact herbicides. However, in these studies, none of the co-applied herbicide treatments caused reduced control of common lambsquarters compared with saflufenacil applied with deionized water alone.

Control of giant foxtail was no greater than 31% when saflufenacil was applied with deionized water alone at 14 and 21 DAT (Table 3). Similar to saflufenacil alone, co-application of saflufenacil with imazaquin provided 29

### Table 1. Weather conditions and application timings of treatments for each experimental run.

<table>
<thead>
<tr>
<th>Run 1</th>
<th>Run 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of application</td>
<td>May 22, 2012</td>
</tr>
<tr>
<td>Temperature (°F)</td>
<td>75</td>
</tr>
<tr>
<td>Humidity</td>
<td>78</td>
</tr>
<tr>
<td>Wind (mph)</td>
<td>NE 5.7</td>
</tr>
<tr>
<td>Cloud cover</td>
<td>0%</td>
</tr>
<tr>
<td>Soil temperature (°F)</td>
<td>78</td>
</tr>
<tr>
<td>Time of application</td>
<td>4:30 PM</td>
</tr>
</tbody>
</table>

### Table 2. Control of common lambsquarters at 14 and 21 days after treatment from co-application of saflufenacil alone or with other herbicides. †

<table>
<thead>
<tr>
<th>Co-applied herbicide treatment</th>
<th>Application rate ‡</th>
<th>Days after treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>lb ai/ac</td>
<td>14</td>
</tr>
<tr>
<td>Alone</td>
<td>−</td>
<td>65 d</td>
</tr>
<tr>
<td>Atrazine</td>
<td>2.0</td>
<td>98 ab</td>
</tr>
<tr>
<td>Chlorimuron-ethyl</td>
<td>0.0106</td>
<td>90 cd</td>
</tr>
<tr>
<td>Clethodim</td>
<td>0.0913</td>
<td>93 abc</td>
</tr>
<tr>
<td>Cloransulam-methyl</td>
<td>0.0313</td>
<td>95 abc</td>
</tr>
<tr>
<td>Dicamba</td>
<td>0.5</td>
<td>99 a</td>
</tr>
<tr>
<td>Glufosinate</td>
<td>0.6606</td>
<td>95 abc</td>
</tr>
<tr>
<td>Glyphosate</td>
<td>0.7763</td>
<td>96 abc</td>
</tr>
<tr>
<td>Imazaquin</td>
<td>0.1225</td>
<td>93 bcd</td>
</tr>
<tr>
<td>Imazethapyr</td>
<td>0.0625</td>
<td>80 d</td>
</tr>
<tr>
<td>Isoxaflutole</td>
<td>0.0625</td>
<td>99 ab</td>
</tr>
<tr>
<td>Mesotrione</td>
<td>0.0938</td>
<td>93 a-d</td>
</tr>
<tr>
<td>Metribuzin</td>
<td>0.5</td>
<td>93 a-d</td>
</tr>
<tr>
<td>Paraquat</td>
<td>1.0</td>
<td>99 a</td>
</tr>
<tr>
<td>2,4-D</td>
<td>0.4731</td>
<td>97 abc</td>
</tr>
</tbody>
</table>

† Means followed by the same letter in each column do not differ according to Fisher’s Protected LSD test at \( P \leq 0.05 \). Data were pooled both over experimental runs at Lafayette at a \( p \) value of 0.05.

‡ All treatments were applied with saflufenacil, diammonium sulfate, and methylated seed oil at 0.0225 lb ai/ac, 0.17 lb/gal, and 1% vol/vol, respectively. Application rates of dicamba, glyphosate, and 2,4-D were expressed at g ae/ha.

and 41% control at 14 and 21 DAT, respectively. Reduced efficacy on giant foxtail from imazaquin was likely from application to plants outside of the control range for this product. Imazaquin (Scepter) does not control giant foxtail postemergence. Regardless of rating intervals,
Table 3. Control of giant foxtail at 14 and 21 days after treatment from co-application of saflufenacil alone or with other herbicides.†

<table>
<thead>
<tr>
<th>Co-applied herbicide treatment</th>
<th>Application rate‡</th>
<th>Days after treatment</th>
<th>14</th>
<th>21</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alone</td>
<td>−</td>
<td>% control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clethodim</td>
<td>0.0913</td>
<td></td>
<td>78 cd</td>
<td>81 b</td>
</tr>
<tr>
<td>Glufosinate</td>
<td>0.6606</td>
<td></td>
<td>96 b</td>
<td>96 a</td>
</tr>
<tr>
<td>Glyphosate</td>
<td>0.7763</td>
<td></td>
<td>100 a</td>
<td>100 a</td>
</tr>
<tr>
<td>Imazaquin</td>
<td>0.1225</td>
<td></td>
<td>29 f</td>
<td>41 d</td>
</tr>
<tr>
<td>Imazethapyr</td>
<td>0.0625</td>
<td></td>
<td>54 e</td>
<td>65 c</td>
</tr>
<tr>
<td>Isoxaflutole</td>
<td>0.0625</td>
<td></td>
<td>69 de</td>
<td>77 bc</td>
</tr>
<tr>
<td>Parquat</td>
<td>1.0</td>
<td></td>
<td>83 c</td>
<td>89 b</td>
</tr>
</tbody>
</table>

† Means followed by the same letter in each column do not differ according to Fisher's Protected LSD test at P ≤ 0.05. Data were pooled over both experimental runs at Lafayette at a p-value of 0.05.

‡ All treatments were applied with saflufenacil, diammonium sulfate and methylated seed oil at 0.0225 lb ai/ac, 0.17 lb/gal, and 1% vol/vol, respectively. Glyphosate expressed in g ae/ha.

Table 4. The control of common lambsquarters by saflufenacil as influenced by carrier water hardness with or without diammonium sulfate (DAS).† ‡

<table>
<thead>
<tr>
<th>Water sources</th>
<th>% Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deionized water + without DAS</td>
<td>74 a</td>
</tr>
<tr>
<td>Water (310 ppm) + without DAS</td>
<td>46 b</td>
</tr>
<tr>
<td>Water (620 ppm) + without DAS</td>
<td>48 b</td>
</tr>
<tr>
<td>Deionized water + DAS</td>
<td>60 ab</td>
</tr>
<tr>
<td>Water (310 ppm) + DAS</td>
<td>54 ab</td>
</tr>
<tr>
<td>Water (620 ppm) + DAS</td>
<td>54 ab</td>
</tr>
</tbody>
</table>

† Means followed by the same letter in each column do not differ according to Fisher's Protected LSD test at P ≤ 0.05. Data were pooled over both experimental runs at Lafayette at a p-value of 0.05.

‡ All treatments were applied with saflufenacil, diammonium sulfate and methylated seed oil at 0.0225 lb ai/ac, 0.17 lb/gal, and 1% vol/vol, respectively. Glyphosate expressed in g ae/ha.

Influence of water hardness on saflufenacil efficacy

Significant main effect of water treatment was noted for the control of common lambsquarters, while no differences were observed between treatments applied to giant ragweed. When combined over the two rating timings, saflufenacil applied in deionized water without DAS provided 28 and 26% more control of common lambsquarters than saflufenacil applied with either of the other two water sources (310 or 620 ppm) without DAS, respectively (Table 4). However, saflufenacil treatments with DAS did not show any differences in control of common lambsquarters compared with saflufenacil in deionized water without DAS. Several studies have suggested that DAS increases the foliar absorption of herbicides, which consequently increases efficacy. Moreover, according to the label of saflufenacil, this product must be applied with DAS and methylated seed oil.

Summary

No differences in control between treatments could be observed on giant ragweed, with all herbicide treatments providing 85% or more control. Overall, common lambsquarters was controlled by 94% or more when co-applying saflufenacil with dicamba, isoxaflutole, paraquat, or 2,4-D. In most instances, saflufenacil co-applied with other herbicides controlled common lambsquarters better than saflufenacil alone in deionized water. With the exception of imazaquin applied with saflufenacil or the saflufenacil alone, all co-applied herbicide combinations provided 80% or more control of common lambsquarters. Glufosinate or glyphosate applied with saflufenacil provided 96 and 100% control of giant foxtail, which was better than any other co-applied herbicide. The influence of carrier water hardness on saflufenacil was observed for the control of common lambsquarters only. In the absence of DAS, water sources with hardness values of 310 or 620 ppm reduced saflufenacil efficacy on common lambsquarters. This research suggests that saflufenacil can be applied with the herbicides used in these studies without a reduction in efficacy; and the influence of water hardness on the efficacy of saflufenacil can vary among weed species.

Acknowledgments

The authors thank the members of Integrated Weed Science Lab at Purdue University for their assistance.

Earn a CEU by taking the quiz online at www.certifiedcropadviser.org/certifications/self-study/514.
Saflufenacil provides weed control
- in grassy weeds in cotton and sorghum.
- in broadleaf weeds in corn and soybean.
- by inhibiting the enzyme chlorophyll synthetase.
- best when tank-mixed with fomesafen.

2. Which is NOT mentioned in the article as one of the benefits of herbicide mixtures?
- More convenient and efficient.
- Improves control of larger or stressed weeds.
- Can reduce selection pressure when similar modes of action are combined.
- Widens the spectrum of control.

3. Adjuvants such as diammonium sulfate (DAS) can
- increase the negative effects of hard water cations on herbicides.
- increase calcium and magnesium cations in the water beyond the necessary 800 ppm threshold.
- can improve the carrier water physical characteristics and enhance herbicide movement through the plant.
- can reduce efficacy of weak acid herbicides such as dicamba (Clarity), glyphosate, and 2,4-D (Weedar 64).

4. The article notes that several studies have suggested that foliar absorption of herbicides can be increased by
- diammonium sulfate (DAS).
- methylated seed oil.
- the oil content of the co-applied herbicide.
- when two strong acid herbicides are co-applied.

5. Saflufenacil may exhibit
- antagonism when co-applied with contact herbicides.
- foaming when co-applied with systemic herbicides.
- greater efficacy when co-applied to stressed weeds.
- poor coverage when co-applied with dionized water.

6. Which of the following is true from this study regarding control of giant foxtail?
- Application of saflufenacil with clethodim gave 78% or higher control at both rating intervals compared with saflufenacil co-applied with paraquat.
- Co-application of saflufenacil with paraquat provided control similar to saflufenacil alone.
- Reduced efficacy from imazaquin was likely due to the fact that imazaquin does not control giant foxtail pre-emergence.
- Co-application with glufosinate or glyphosate provided almost complete control.

7. The giant foxtail control noted in these studies was provided mainly by
- mechanical control and rotation.
- saflufenacil
- the herbicides co-applied with saflufenacil.
- atrazine, chlorimuron-ethyl, and dicamba.

8. Regarding carrier water hardness, the article notes that
- water sources with hardness values of 310 or 620 ppm increased saflufenacil efficacy on all weeds.
- the hardness of water can reduce efficacy of high-acid herbicides.
- its influence on saflufenacil was observed for the control of common lambsquarters only.
- its influence on saflufenacil was observed for the control of common lambsquarters and giant ragweed.
9. Which of the following is true from this study regarding control of giant ragweed?

- a. No differences in control between treatments could be observed.
- b. Saflufenacil applied with atrazine, dicamba, and imazethapyr provided greater control than saflufenacil alone.
- c. Saflufenacil applied in deionized water without DAS provided more control than saflufenacil applied with either of the other two water sources.
- d. Control of giant ragweed was between 65 and 75%.

10. Which of the following is true from this study regarding control of common lambsquarters?

- a. Overall, common lambsquarters was controlled by 94% or more when co-applying saflufenacil with dicamba, isoxaflutole, paraquat, or 2,4-D.
- b. In most instances, saflufenacil alone in deionized water controlled common lambsquarters the same or better than when co-applied with other herbicides.
- c. With the exception of isoxaflutole applied with saflufenacil or the saflufenacil alone, all co-applied herbicide combinations provided 70% or more control of common lambsquarters.
- d. Glufosinate or glyphosate applied with saflufenacil provided 96 and 100% control.

Self-Study Quiz Registration Form

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This quiz issued May 2013 expires May 2016

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I was stimulated to think how to use and apply the information presented: 1  2  3  4  5
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Briefly explain any “1” ratings: ____________________________________________________________

Topics you would like to see addressed in future self-study materials: ____________________________________________________________
Irrigating Turfgrasses with Recycled Water

Ali Harivandi
Turfgrass Slide Monograph, Keith Karnok, editor

Although three-fourths of the earth’s surface is covered with water, only a minute fraction of water is both readily available and of sufficient quality for human use, including irrigation. Interest in recycled water irrigation continues to increase as more and better-quality treated water becomes available. Water shortages and the rising cost of potable water motivate the wise use of recycled water as a valuable resource for irrigating golf courses, parks, athletic fields, and other landscape sites. This attractive to-the-point presentation summarizes the state of the science and practice today.

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