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Feature

The 4Rs of nutrient management—applying the right fertilizer source at the right rate at the right time and in the right place—easily summarize the increasingly complex fertility decisions that have to be made by CCAs and their farmer clients. In this issue, we take a look at how this concept is being implemented in the field.

Cover: Photo courtesy of Dan Schaefer. Cover design by Pat Scullion.
The 4Rs of nutrient management—applying the right fertilizer source at the right rate at the right time and in the right place—easily summarize the increasingly complex fertility decisions that have to be made by CCAs and their farmer clients. In this issue, we take a look at how this concept is being implemented in the field.

By Tanner Ehmke
Crops & Soils magazine contributing writer
Whether you know it or not, you’ve been a steward of the 4Rs of nutrient management if you’ve promoted or practiced the benefits of greater fertility efficiency in the field.

The 4Rs are simple: Apply the right fertilizer source at the right rate at the right time and in the right place. Promoted by The Fertilizer Institute, The Canadian Fertilizer Institute, The International Plant Nutrition Institute, and the International Fertilizer Industry Association to encourage better fertility management among farmers and CCAs, the 4Rs are more than just a catchy title. They are the commonsense rules that are the foundation for a high efficiency, high yielding, and environmentally sensitive crop producer keen on maintaining soil health while managing costs.

Farmers and their CCAs have been quick to grasp the 4Rs, too, says Brandon McClure, CCA with Morral Companies in Morral, OH. “It’s spread really fast,” says McClure, who works one-on-one with farmers to implement the 4Rs on their operations. “Our company started working with the 4Rs two years ago, and it’s just taken off like crazy.”

At the farmer level, the 4Rs easily summarize the increasingly complex decisions that have to be made when practicing nutrient management, says Harold Reetz, a veteran CCA with Reetz Agronomics in Monticello, IL, and former International CCA chairman. “They’re interconnected,” he says. “It’s easily depicted as four puzzle pieces in the middle of a circle (Fig. 1, next page). They all link together.”

The 4Rs have also reached far beyond those who employ it in the field, Reetz adds, encompassing government agencies, environmental groups and universities around the world.

And, in an age of increasing government regulations amidst growing concern of ground water contamination and the Hypoxic Zone in the Gulf of Mexico, the 4Rs illustrate to the public and the officials they vote for that agriculture can manage fertility on its own with individual growers able to tailor a system that works best on their particular operation.

“I always feel like we’re better off if we don’t legislate fertilizer management,” Reetz says. “It should be done on

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the basis of science instead of politics. One of our big objectives is to avoid getting into legislative controls. Hopefully science, the applications of science, and using the 4Rs prove we can manage our nutrients according to the best practices available. And in the process, increase profits, increase yields, and reduce environmental impacts. That should be a win-win-win for everybody.”

The first right step—information

Getting the right information is the beginning of bringing the other pieces of the puzzle together, Reetz explains. That starts with soil sampling—the critical first step that enables farmers and their CCAs to make the right prescriptions to the field, like taking a patient’s temperature before prescribing a medication.

For farmers like Bruce Favinger, a corn and soybean farmer near Minden, NE, soil sampling has long been an essential practice on his farm for greater nutrient efficiency. By quantifying the fertility needs for every acre of his farm, Favinger and his CCA, Ty Fickenscher with Cooperative Producers, Inc., in Wilcox, NE, have the knowledge to make the most accurate decisions possible when managing his multi-faceted fertility program throughout the growing season.

“We do variable-rate soil sampling on every acre and then do variable-rate fertilizer application,” Favinger says. “We do split applications. We put some on pre-plant, we put some on with the planter. We sidedress some fertilizer, and we do use some chemigation, if it’s necessary.”

Right source

When tailoring a fertility program to each individual farmer client, McClure stresses that the right source may not work for everybody.

“Choosing the right product is obviously key,” McClure says. “We don’t sell a particular program, per se, or bundle things together just for sales efforts. At ground level, we have to make sure that we’re just watching very closely the nutrients that we’re using. We judge nutrient needs strictly field by field. So product wise, there’s always a reason.”

Selecting which fertilizer source to use begins with evaluating which nutrients are actually required for optimal plant growth, determined by soil sampling or tissue testing, say experts at the International Plant Nutrition Institute.

But the work doesn’t stop there. Soil conditions, environmental risks, product price and availability, fertilizer delivery issues, and economic constraints
also require thoughtful consideration when evaluating which fertilizer source is most appropriate.

Even proximity to urban development matters, McClure adds. Since manure application is visual and has an obvious odor noticed by residential neighbors, other fertilizer alternatives might have to be considered.

**Right rate**

While the 4Rs work as a system, Favinger feels that rate has a special place in the puzzle.

“We’ve always felt the right rate was the most important thing,” Favinger says, stressing the importance of variable-rate application, which reduces the risk of over- or under-applying a nutrient.

Newer, more sophisticated technologies on the market have helped Favinger achieve even greater efficiencies with fertilizer use with precision control over rate.

“With the electronics that are available today with GPS and autosteer, it’s a lot easier to do variable rate now than it used to be,” he says. “We used to try to do it by manually setting up two to three zones in fields when we needed some different application rates. Now, it can all be done automatically with computers. It’s just progressed over time. It’s a much easier thing to do now.”

Rate can now even be adjusted on the go and in-season by using sensors, processors, and controllers mounted on the tractor or applicator. Reetz adds. That innovation, which Reetz has seen develop over the years since its inception, has helped farmers today gain even more control on the amount of nutrients the crop is receiving. “It’s a very significant change over what we had 20 years ago,” he says.

New innovations in the realm of aerial photography and satellite imagery may also give farmers more information on application rate, Reetz notes. Some experimenters today, he adds, are even working with small model airplanes and helicopters equipped with cameras to aid in variable application rates.

**Right time**

Pulling the trigger on a fertilizer application at the right moment is also crucial for optimizing a fertilizer’s contribution to the plant, says Dan Schaefer, Director of Nutrient Stewardship at the Illinois Council on Best Management Practices.

With a split application of fertilizer where the farmer applies fertilizer at different points of the year and delivers nutrients when the plant needs them the most, less fertilizer is lost to leaching and more is utilized by the plant.

“To minimize producer risk, we put part of it on in the fall—maybe 50% of our nitrogen with a stabilizer,” Schaefer advises. “In the spring for pre-plant, use a low rate of UAN stabilized. And then, we go in in-crop and can look back to determine if we need an in-season application by using the MRTN [maximum return to nitrogen] as the guide to our rate.”
Corn begins its rapid uptake of nitrogen at V12, Schaefer explains, with the plant having used only 20% of its total nitrogen needs prior to that point. Waiting until that key growth period to deliver nutrients to the plant, he says, optimizes plant uptake of the nutrient while minimizing loss.

Nitrogen stabilizers are a useful tool that give farmers another level of control over timing of fertilizer applications, McClure adds, particularly when contending with wet, saturated soils. With the heavy soils of his region of Ohio, he says, excessive rain in the last two years has resulted in ponding or flooding, which causes problems with nitrogen leaching and denitrification. With a stabilizer, the grower is still able to have fertilizer available to the plant early in the growing season without losing it.

“Stabilizers have increased our yield because we’re holding onto those nutrients,” he explains. “We’re not cutting back our nitrogen rates, but we’re getting all the use out of them with these products without having to use more product than necessary.”

For Fickenscher in Nebraska, timing the delivery of nutrients during the growing season via pivot fertigation has produced big results for his farmer clients.

“That’s one great thing about the application. It’s when the crop really needs it, and we have seen improved yield from doing that,” Fickenscher says.

In addition to better crop utilization, he says, in-season applications through the pivot have also reduced leaching and runoff.

**Right place**

Right placement of nutrients in the soil is also a key ingredient for increasing plant utilization and minimizing nutrient loss, McClure says.

But choosing where in the soil to place the fertilizer, Reetz adds, depends much on the fertilizer source you’re working with.

“If you change the product that you’re using, then you may need to change placement,” he advises. “Some have to be incorporated, some of them can be surface applied. Some need to be put on before planting, and others need to be sidedressed or topdressed.”

For example, if a farmer is used to using anhydrous ammonia, he explains, you can’t switch to topdressing without changing the product that you’re using since anhydrous can only be applied below the soil surface.

Right placement of the fertilizer also means having the right technology and using it properly, he adds.

“You adopt new technology where the needs are and where you can justify it,” Reetz says. “There are some people who buy a new piece of equipment and look for a problem to solve with it. You’ve got the wrong things driving the issue there, I think, when that happens.”

**Does 4R mean high tech?**

Technology undoubtedly enables farmers and their CCAs greater control over delivering nutrients to the plant to increase yield and reduce nutrient loss. But growers can still incorporate the 4Rs even if they lack sophisticated technology or elaborate fertility programs.

“We can print [the field map] off on a paper, and they keep it in the cab with them,” McClure says. “As the farmer
goes across the field, he can say, ‘This 10 acres here only needs two or three thousand gallons of manure.’ It’s not being done automatically, but we’re doing it as we go. So, you don’t have to have the latest technology to start doing things right.”

Reetz agrees that farmers can have access to variable-rate application even by doing things by hand. Farmers can use a color chart to judge the nitrate levels of a crop and then properly apply the nutrients. The 4R management concept, he says, fits anywhere in the world.

“Technology certainly does play a role in fertility rates. But, I think it’s important to realize that it doesn’t have to be just our North American broad-acre farmers,” he points out. “Some of these technologies also work on the small one-hectare plots in southeast Asia, too.”

The 4R future

With global commodity and fertilizer prices sure to continue rising as world food and fiber demand grows, the 4Rs will without question continue to grow in importance among farmers, Schaefer says.

“In the last several years, we’ve gone from $400/acre gross margins to $800 to $900—even $1,200/acre. When you do that, your inputs go up and the chance of making a profit is there, too. So, you’ve got to move to an intensively managed crop rather than just throw the fertilizer out there and be done with it. It’s something that farmers are really looking at hard.”

The only barrier to wider adoption of the 4Rs, Schaefer believes, is education and getting the word out. That’s where crop advisers come into play, he says.

McClure agrees that to help growers navigate the increasing complexities of new technologies and rising input costs, the relationship the grower has with CCAs and retailers is going to be more important than ever.

“That’s who the grower ultimately is going to listen to and have a good relationship with,” he says. “It sounds kind of corny, but it makes a huge difference being able to sit down and have a good working relationship with a good grower. We know what each other’s plan is and what we’re doing, and we can focus on what works.”

Building a relationship with the farmer, he explains, opens the lines of communication, which helps the CCA better understand the farmer’s specific problems and in turn helps the farmer become more open to adopting 4R principles or relevant technologies.
For farmers like Favinger who anticipate a more complex future in agriculture, a supportive and knowledgeable CCA will be a crucial asset for continued implementation of the 4Rs as technology changes.

“There’s so much information technology that we can’t be an expert in everything we do,” Favinger says. “We have to rely on the people and consultants to come in and help us with it.”

Information management will also be key to effective fertility programs in the future, Reetz stresses. Good record keeping ties into the new technologies with GIS, computers, and communication, he says.

On Favinger’s farm, that’s taken the form of the CPI 300 database program from Cooperative Producers, Inc., or CPI.

“With CPI, they’ve helped us with the variable-rate program called CPI 300 where we are trying to bring all this information together—the information from the yield maps, satellite imaging, seed maps. It’s just bringing the whole thing together as a system.”

The CPI 300 program sorts Favinger’s crop data, analyzes the information, and tells him what methods are working. It also allows him to do in-field test plots where he can try different farming methods on particular hybrids or soil types, he says.

“You can take a small block—a two- or three-acre block in the middle of the field—and change your fertilizer rate or change your seeding rate on that block, and when you come through with the yield monitors, it will tell you if what you did was an improvement, or if it stayed the same, or if it changed the yields. It’s just kind of an in-field test plot all the time,” he says. “There are so many variables, this will take us to the next step of finding what works.”

However, good old agronomic practices like soil testing won’t be replaced with technology, but new technology will enhance their value, adds Reetz. And, the 4Rs will help growers and CCAs remember the fundamentals in an increasingly complex world.

Nonetheless, he says, having a sound record-keeping system to help pull technology and information together will be instrumental for effective implementation of the 4Rs in the future, helping farmers and their advisers make better-informed crop management decisions.

“The guys who have a 20-year database in their records are better off than those who have a five year,” Reetz says. “Those who haven’t started yet better get with it.”

Growers of the future will also need as many fertilizer options as possible, Favinger adds. That means using them responsibly today to ensure their availability in the future.

“I think it’s important we use commercial fertilizers, and I think if we can act responsibly and get ahead of the game, maybe we can avoid being forced into it later,” he warns. “And, it’s just good management. If we can utilize our fertilizers to the best of our ability, it makes financial sense for us.”
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Soil salinity and sodicity pose a threat to soil productivity. In North Dakota, 5.8 million acres are affected by salinity and about 4.7 million acres are affected by sodium (Table 1 and Fig. 1, J. Brennan, personal communication, North Dakota USDA-NRCS, 2008). Most saline soils in North Dakota develop due to high water tables or saline seeps. Higher evaporative demand than precipitation inhibits the leaching of salts. Finally, land use practices and rainfall patterns add to the spread and variability of salinity (Franzen, 2007).

Since 1993, excess precipitation has significantly impacted crop production in the Northern Great Plains, both with increased soil moisture and the effects of salinity. For example, within North Dakota’s Red River Valley, the annual estimated lost revenue from decreased crop production due to salinity is about $150 million (Hadrich, 2012). Farmers of the Red River Valley have adopted subsurface tile drainage to manage their excess water. It is generally perceived that tile drainage has the potential to improve root zone salinity by preventing increased upward movement of salts through capillary forces.

Soils become saline due to high concentrations of soluble salts, particularly with solubilities greater than calcium sulfate (gypsum; CaSO4). The solubility sequence of salts commonly present in soils is as follows: calcium chloride (CaCl2) > sodium chloride (NaCl) > magnesium chloride (MgCl2) > magnesium sulfate (MgSO4) > sodium sulfate (Na2SO4) > magnesium sulfate (MgSO4) > sodium bicarbonate (NaHCO3). The most common salts in North Dakota soils are those of sulfate (SO4), carbonate (CO3), and chloride (Cl) with sulfate salts being the most abundant. When saline soils are dominated by sodium salts, soils are termed “sodic.” The severity and extent of soil salinity can

### Table 1. Saline and sodic soil area distributions (acre) within 75 cm of the surface in Northern Great Plains (NGP) states depending on soil EC value (mmho/cm) (J. Brennan, personal communication, NRCS North Dakota, 2008).

<table>
<thead>
<tr>
<th>State</th>
<th>State acreage (NGP only)</th>
<th>Slight salinity (EC ≥ 4 mmho/cm)</th>
<th>Moderate salinity (EC 8–16 mmho/cm)</th>
<th>Strong salinity (EC≥16 mmho/cm)</th>
<th>Saline acreage</th>
<th>Sodic SAR ≥ 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minnesota</td>
<td>6,137,839</td>
<td>18,765</td>
<td>28,881</td>
<td>2,054</td>
<td>49,700</td>
<td>40,000</td>
</tr>
<tr>
<td>Montana</td>
<td>50,748,014</td>
<td>5,759,776</td>
<td>4,232,391</td>
<td>816,309</td>
<td>10,808,476</td>
<td>9,650,000</td>
</tr>
<tr>
<td>Nebraska</td>
<td>6,159,382</td>
<td>21,220</td>
<td>113,805</td>
<td>5,350</td>
<td>140,376</td>
<td>400,000</td>
</tr>
<tr>
<td>North Dakota</td>
<td>45,341,198</td>
<td>2,216,638</td>
<td>3,434,435</td>
<td>146,810</td>
<td>5,797,884</td>
<td>4,730,000</td>
</tr>
<tr>
<td>South Dakota</td>
<td>45,972,193</td>
<td>3,686,677</td>
<td>4,245,279</td>
<td>551,347</td>
<td>8,483,303</td>
<td>7,920,000</td>
</tr>
<tr>
<td>Wyoming</td>
<td>15,839,425</td>
<td>417,162</td>
<td>613,408</td>
<td>26,889</td>
<td>1,057,459</td>
<td>990,000</td>
</tr>
<tr>
<td>Total</td>
<td>170,198,049</td>
<td>12,120,239</td>
<td>12,668,200</td>
<td>1,548,760</td>
<td>26,337,198</td>
<td>23,720,000</td>
</tr>
</tbody>
</table>
be measured by determining four soil properties: (1) pH, (2) electrical conductivity (EC), (3) sodium adsorption ratio (SAR), and (4) exchangeable sodium percentage (ESP). Depending on the values of these properties, soils are categorized into four different groups: (1) normal, (2) saline, (3) sodic, and (4) saline-sodic (Table 2).

Root zone salinity hinders plant roots from water uptake by reducing plant-available water leading to water stress, and in some cases, can be toxic to plants. In addition, salinity can also affect soil physical properties like flocculation and dispersion of clays. Depending on the sodium ion ($\text{Na}^+$), concentration on the soil’s exchange sites (measured by ESP) and soil water EC, soils can be aggregated or dispersed. While increasing concentrations of soluble calcium and magnesium salts have positive effects by binding soil particles together (flocculation), increasing concentrations of sodium salts can have the negative effect of dispersing soil particles. Clay dispersion leads to sequentially (1) deterioration of soil structure, (2) plugging of soil pores, (3) reductions in hydraulic conductivity and infiltration rate, and (4) surface crusting. Soil type (clay

### Table 2. Classification of soil salinity according to USDA-NRCS (DeSutter, 2008).

<table>
<thead>
<tr>
<th>Groups</th>
<th>pH</th>
<th>EC (mmho/cm)</th>
<th>ESP</th>
<th>SAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>&lt;8.5</td>
<td>&lt;4</td>
<td>&lt;15</td>
<td>&lt;12</td>
</tr>
<tr>
<td>Saline</td>
<td>&lt;8.5</td>
<td>&gt;4</td>
<td>&lt;15</td>
<td>&lt;12</td>
</tr>
<tr>
<td>Sodic</td>
<td>&gt;8.5</td>
<td>&lt;4</td>
<td>&gt;15</td>
<td>&gt;12</td>
</tr>
<tr>
<td>Saline-sodic</td>
<td>&gt;8.5</td>
<td>&gt;4</td>
<td>&gt;15</td>
<td>&gt;12</td>
</tr>
</tbody>
</table>
Regional Roundup

Subsurface tile drains have been used successfully throughout many regions of the United States to manage excess water and salinity. However, most of the non-irrigated regions do not have appreciable amounts of sodium in their soils and parent materials whereas many soils in the Northern Great Plains do have sodium. The combination of excess sodium on the soil’s exchange sites and the reduction of soluble salts in the soil water due to subsurface drainage can promote the dispersion of soils, which destroys soil structure and reduces or eliminates water movement. Although not all soils in the Northern Great Plains have excess sodium, many of these soils are within current corn- and soybean-producing regions, and therefore, there is increased interest in improving the productivity of these soils through subsurface drainage.

To better help farmers, land managers, and tiling companies make informed decisions regarding the drainage of sodium-affected soils, the USDA-NRCS recently added a “Subsurface Water Management” tool for North Dakota within the Web Soil Survey (websoilsurvey.nrcs.usda.gov). The Web Soil Survey is a free online tool that provides detailed descriptions of soil properties. Explanatory guidelines for using this tool are available at the website above or in Malo (2008).

In brief, to use the Web Soil Survey, first navigate to the field location from the “Area of Interest” tab (AOI) by providing the address in your preferred format. Then select the area of interest using the polygon tool and click on the “Soil Map” tab. Different soil map units in the AOI will appear on the map, and their relative distribution in acres and percentage will appear on the left pane in a table format. Clicking on an individual “Map Unit Name” will open up a new window with detailed description of the unit. For parameters most pertinent to subsurface drainage system suitability, one may want to focus on (1) depth to restrictive feature, (2) drainage class, (3) capacity of the most limiting layer to transmit water (KSat), (4) frequency of flooding, (5) frequency of pond-
ing, (6) calcium carbonate maximum content, (7) gypsum maximum content, (8) maximum salinity, and (9) sodium adsorption ratio.

If the problem of salinity and high SAR values are found in the general information of any map unit, proceed to the description of soil chemical properties linked with salinity, particularly, (1) pH, (2) EC, and (3) SAR. Values of these salinity parameters for different map units can be viewed separately by clicking sequentially, “Soil Data Explorer” → “Soil Properties and Qualities” → “Soil Chemical Properties” → “Electrical Conductivity”/“Sodium Adsorption Ratio”/“pH (1 to 1 water).” To view rating or description, there are several options to choose for “aggregation method” (dominant component/dominant condition/weighted average/all components) and “layer option” (surface layer/depth range in inches or centimeters/all layers). Clicking on “View Rating” will display the ratings for individual properties on the AOI map and also in table format below the soil map (scroll down to view the table).

After the above soil parameters have been understood for your AOI, proceed to “subsurface water management,” which can be located by clicking sequentially “Soil Data Explorer” → “Suitabilities and Limitations for Use” → “Water Management” → “Subsurface Water Management Installation/Outflow Quality/Performance” tab (Fig. 2; available only for North Dakota). Clicking on the view rating for installation/outflow quality/performance of subsurface water management will display ratings on the map (Fig. 2) and also in table format (Fig. 3). Ratings for individual map units are divided into three categories: (1) not limited, (2) somewhat limited, and (3) very limited; and specific reasons for each rating are found in the “Rating Reason” column. Under the rating column, “Excess Sodium,” “Sedimentation,” and “Percs (Percolation) Slowly” warn about the possible chances of dispersion that may lead to reduced water movement or tile system failure (Cihacek et al., 2012). Sometimes, “limited” and “not limited” map units can be found on the same parcel of land, and therefore extra caution may be needed when designing tile placement. If land is found to have subsurface water management that is “somewhat” or “very” limited, farmers should consult with professionals to determine an alternative water or salinity management practice, which may include fall-seeded crops, cover crops to use excess soil moisture, or applications of gypsum as a means to remediate their sodic soils.

References


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Ohio CCA of the Year recognized

By Tina Lust, Chairman, Ohio CCA Board, Marion, OH

Mike Dailey, an independent crop consultant from Mt. Vernon, OH, was recognized as the Ohio CCA of the Year at the Conservation Tillage and Technology Conference in Ada, OH last March. The award, sponsored by the Ohio CCA Program, recognizes a highly motivated individual who delivers exceptional customer service for farmer clients and who contributes substantially to the exchange of ideas and the transfer of agronomic knowledge within the agriculture industry in Ohio.

As the winner of the award, Dailey received a plaque, industry recognition, and a $1,500 cash award from DuPont Pioneer. Dailey has worked as an independent crop consultant for more than 30 years and has served on the Ohio CCA Board for eight years as vice chairman, chairman, and past chair. In addition, he has taught Sunday school, volunteered at the Kenyon College Environmental Center, and served on the Owl Creek Conservancy board, with the mission to protect local land against development. Dailey plans to use the cash award he received to provide advanced training to his agronomic customers and to support a broader training session for the Independent Crop Consultants of Ohio.

The Ohio State University, along with the Allen Soil and Water Conservation District, and the USDA-NRCS, organized the Conservation Tillage and Technology Conference. More than 1,500 growers and agricultural industry representatives, crop consultants, and CCAs attended from 16 states and Canada. A wide range of agronomic topics were discussed among 61 different speakers with more than 45 different CEU credits being offered in all four core competence areas over the two-day program.

The conference was sponsored by Ohio State University Extension and OARDC, northwest Ohio Soil and Water Conservation Districts, USDA-NRCS, USDA Farm Service Agency, The Ohio No-Till Council, Wingfield Crop Insurance, and the Ohio Corn and Wheat Growers Association.
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Some CCAs enjoy reputations as “wizards.” Their clientele make statements such as “I don’t know how she knew what to do, but she saved my crop!” When clients ask their CCAs how they knew just what to do about a problem, most CCAs cite “experience.” But experience to new CCAs means something very different than it does to those who credit experience for their success.

The difference is that the latter have undergone a mental shift from studying facts as a student to deeply understanding an ever-widening circle of factual relations. If merely observing problem situations over many years in a CCA practice or if growing up on a farm were the only paths to developing the deep understanding of a CCA wizard, then many who want to be a CCA might reasonably feel they can never achieve that distinction.

While not discounting the contributions to success afforded by time spent farming or advising farmers, we know there are highly successful, relatively new CCAs from non-farm backgrounds. Clearly, these CCAs have found a path to becoming a CCA wizard other than just time spent in the work. Their path often relies upon using a specific analytic approach that any CCA can use to gain the experienced world view.

The approach that can fairly quickly turn a beginner into a wizard has many names. Sadly, the number of names obscures the basic concept of the approach. That concept is using “landscape scale” thinking, and for our purposes, it is an approach applicable to almost all CCA work. Successful CCAs intentionally or intuitively use the landscape-scale approach with their clientele; those who do not use it likely have hit-or-miss successes over time. They slowly gain what many believe is experience but without developing deep understanding. Fortunately, for new CCAs in the U.S. South, southern crops are grown in fields on landscapes that readily reward a practitioner using the landscape-scale approach to problem solution. Here is why:

In the South, traditional farm culture often applies generations of environmental knowledge gained on a single farm to continued production on that farm. In traditional culture, generations of trial and error developed field guidelines applicable to micro-units. A landscape-scale approach marries those empirical guidelines to universally applicable science. A CCA using the landscape approach who understands why the empirical guidelines work on one farm can extrapolate to any scale and from farm to farm in the region.

The difficulty for a CCA wanting to begin doing landscape-scale consulting is that the concept relies upon thinking in four dimensions (length, width, depth, and time). This way of thinking is more often taught in philosophy courses than in agriculture and natural resources programs. Using landscape-scale consulting is not a “doing” thing as much as it is a thinking thing. How can new or old CCAs not using the landscape-scale approach begin to think in that paradigm and use it in practice?

First the CCA needs to consider farms as collections of “landscape units.” CCAs know that variations in field systems occur at whatever scale anyone chooses to look. The art is mentally juggling many scales at one time. When the juggling is effortless and unconscious, a mental shift has occurred and understanding begins.

For example, on its top, a broad ridgecrest may somewhere have a small sideslope area bordering and descending to a depressional area, a pocket, on the ridgecrest. Also, a sideslope descending from a ridgecrest to a floodplain may itself have a small ridgecrest from an old agricultural terrace meandering across its face. Behind the old terrace
is a depression in which water concentrates even though on a hillside.

Consciously juggling scale, this reinforces what we intuitively know: at a large scale on any landscape, there are parts named hilltops, shoulders, sideslopes, and toeslopes (among other parts). At ever smaller scales of inspection, each of these individual parts can be subdivided into smaller subunits also using the same part names we just listed.

The typical approach is to view a field as a planar surface from hilltop to bottomland. This ensures one will overlook extremely important predictive variables. Root zone pH, plant and soil nutrient status, soil moisture, and disease organisms vary among and between landscape elements. The variation can be located and incorporated in a management plan if the effects of the landscape are understood. Further, minimum tillage and conventional tillage effects can mask landscape effects.

This means CCAs must begin to think of how water moving over and through the landscape might affect the root micro-environment. They must consider how the landscape might affect that water movement.

The soybean field example

To show how this can work: a soybean field on the highest part of a farm has an acre of young plants that are very pale green to pale yellow in contrast to the uniformly green plants nearby. The yellow is not on leaf margins; the leaf surfaces are pale. The area with off-color plants is nowhere near a stream; instead it is near a high point of the farm. Is the problem potassium deficiency? Should denitrification be considered as an agent of the yellowing?

In the landscape-scale approach, denitrification absolutely should be considered! Think: excess moisture can lead to denitrification. Everyone understands that excess moisture accumulates in low-lying areas of this farm. If the problem with the soybeans is occurring on a high landscape area of the farm, how could moisture accumulate on uplands a long way from a stream?

Obviously, there must be either a lowland on the upland or there must be a soil horizon near the root zone that holds moisture relative to horizons in which normally colored plants are living. The likelihood of someone not applying nutrients in just the pale plant area is almost nil unless the area’s shape is rectilinear rather than subrounded. (Southern soils aren’t naturally found as rectilinear or square bodies; they have amoeba-like forms.)
Now our CCA thinks further in the landscape approach: If the field has a depression behind an old terrace, and plowing has blocked the discharge from the terrace, surface water can readily accumulate in that depression unseen under the crop cover. If grading removed loamy or sandy surface soils down to a clay rich subsoil when the terrace was built, clay rich soil horizons may now be very near today's soil surface in the depression.

Not only would water accumulate in the root zone in such a depressional landscape element, but moisture would also stay in the root zone much longer than might be the case in closely proximate deeper, higher sand or loam content root zones on the terrace crest and original side-lope into which the terrace was cut.

Conceptually, the reverse landscape-scale situation occurs as well. When watercourses flood, fast-moving water deposits coarse sediments near a stream. Ever finer sediments are deposited in slower-moving backwaters further inland from the stream.

This means that soils a long way horizontally from a stream can have high subsurface moisture while soils near a stream can have so little plant-available water that the soils may be considered droughty. One importance of these landscape-scale processes is that nutrient availability can be predicted as a function of many landscape scales in Southern Coastal Plain, Piedmont, and Mississippi Delta regions.

Also our CCA must remember that if a farm has very little overall elevation change across it, extreme soil water relational differences will be expressed between areas of very minor elevation change, while the converse is not necessarily true. In other words, very gently sloping to flat landforms will have slower overland water flow than will steeper landscapes. Slower removal of applied water means more water stays for longer times in lower-lying areas.

As a result, one area of a field may have lower root zone temperatures in spring in one place than that occurring in only slightly higher field portions. This is because the root zone with more water acts more as a solar energy sink than does the slightly drier root zone in the slightly higher elevation. The temperature difference can make for surprising differences in planted seed germination, weed and pest control, and nutrient uptake.

Finally, in general terms, CCAs often are looking at crops in fields at times when they obscure the soil surface and landscape. This means that during production seasons, the landscape is either obscured by a growing crop or unseen. If the first visit to a farm reveals a crop canopy covering the subject field, CCAs should immediately locate a professionally made soil survey of the farm. The soil survey is a three-dimensional picture of the landscape that can be used to develop sampling and scouting plans in the midst of a growing season.

A CCA using the landscape approach to problem analysis can adapt the best of indigenous culture to a rapidly changing agricultural industry. Southern agronomists can no longer take generations to evolve production dynamics. Southern agriculture and its CCAs must use prediction and adaptation as opposed to muddling along through trial and stagnation.

In conclusion, the more swiftly CCAs can move to understanding what the farm itself is saying, the more swiftly they will become a “wizard” whose skills will help all of us have better lives.
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Silicon (Si), second to oxygen as the most abundant element in the earth’s crust, is seldom given much attention as a limiting factor in soil fertility and crop production. This view is changing as agronomists become aware of the valuable function of silicon nutrition in crops and soils and even animal life. Until recently, silicon soil fertility studies were mostly conducted on tropical soils and on crops such as sugarcane and rice.

Current research conducted in New Jersey and other places are showing that applying supplemental silicon can suppress plant disease, decrease injury from some insect pests, and improve crop tolerance to environmental stress.

One of the barriers to awareness of silicon as an important factor in crop production is that it has not been classified as one of the “essential” plant nutrients. However, it is now officially designated as a “plant beneficial substance” by the Association of American Plant Food Control Officials (AAPFCO). Plant-available silicon can now be listed in the “guaranteed analysis” section on fertilizer labels.

The composition of a typical mineral soil is about 30% silicon by weight. While the amount of silicon in soil is huge, only a small fraction is soluble and available for plant uptake. On many soils, there is enough available silicon to grow a “satisfactory crop” without adding any. However, on some soils, adding plant-available silicon will result in healthier plants, less need for pesticide, and higher yields. Without an awareness of the multiple benefits of silicon nutrition, growers may be using more pesticide than necessary to reach their crop production goals.

Soil fertility research on silicon in New Jersey

Field and greenhouse experiments have been conducted since 2000 to evaluate crop responses to amending New Jersey soils with silicon. Most field trials used a calcium magnesium silicate slag as the source of silicon. The parent material of this silicate source is stainless steel slag. It is commercially available for field crops as AgrowSil or in the turf market as Excellerator (Harsco Minerals, Sarver, PA). These steel-making by-products, after processing to remove metals, contain 12% silicon and have a calcium carbonate equivalent (CCE) of 93%. When applied to soil, these amendments serve both as silicon fertilizer and a liming material.

In some greenhouse experiments, we used a naturally occurring mined source of calcium silicate know as Wollastonite.

Pure calcium carbonate has by standard definition a CCE of 100% and does not contain silicon. In our field trials, we used calcium magnesium carbonate or commercial limestone as an amendment in control plots. This provided the same soil pH environment without adding silicon.

Most of our silicon research has been conducted on soils classified as Ultisols. The Quakertown silt loam soil at the Rutgers Snyder Research and Extension Farm, near Pittstown, NJ was selected for field trials because it had an initial soil pH of 5.7, which allowed for application of liming materials. Field plots were established with applications of calcium magnesium silicate as a silicon treatment or limestone as the control. Crops grown on these plots since 2000 include pumpkin, field corn, wheat, oats, red clover/orchard grass hay, cabbage, and snapbean. Details of the research methods are given in the original journal articles.

In greenhouse pot experiments, 18 different soils have been used to examine crop responses to silicon.
Crops studied included pumpkin and Kentucky bluegrass. Another greenhouse study involved potted dogwood trees growing in a potting media (a mix of peat and pine bark) containing very little silicon.

**Summary of responses to supplemental silicon**

Findings from field and greenhouse experiments demonstrated that calcium magnesium silicate slag is an effective liming material and silicon fertilizer. Plants grown on calcium silicate slag-amended soil exhibited large increases in silicon uptake. In some years, pumpkin fruit (increase 70%) and wheat grain (increase 10%) yields were increased in association with suppression of powdery mildew disease. Corn plants grown on soil previously amended with calcium magnesium silicate slag exhibited less injury to the stem tissue from European corn borer. Forage yields were similarly improved by liming low-pH soil with either limestone or calcium magnesium silicate slag three and four years after the last application. Cabbage yields were improved by liming low-pH soil, but calcium magnesium silicate slag increased market-head yield more than limestone. The residual benefits of calcium magnesium silicate slag applications were evident in crops produced at least four years after the last application.

In greenhouse studies, silicon amendment of soils increased biomass yield in Kentucky bluegrass and suppressed powdery mildew disease in pumpkin. Silicon amendment of potting media used to grow dogwood suppressed powdery mildew disease while silicon fertilizer applied to foliage was not effective.

Calcium magnesium silicate slag resulted in enhanced levels of silicon uptake, which sometimes imparted benefits to crops beyond its service as a liming material to acid soils. Figure 1 (next page) illustrates the value of adding silicon to soil for suppression of powdery mildew disease.

Beyond New Jersey, a substantial body of international research has demonstrated crop production benefits from enhancing silicon soil fertility. The following section summarizes facts on silicon in agriculture with specific information on soil fertility and nutrition based on experiences in New Jersey and that of other researchers from around the world.

**Chemical names and function**

Silicon, or Si, is elemental silicon while silica, also known as silicon dioxide or SiO₂, is the chemical compound containing silicon and oxygen. Silicate refers to silicon compounds such as CaSiO₃, MgSiO₃, or K₂SiO₃. Silicic acid or mono silicic acid [Si(OH)₄ or H₄SiO₄] refers to the soluble, plant-available form of silicon in soils. Silicone refers to R₂SiO, where R is an organic group such as methyl, ethyl, or phenyl.

Silicon is a beneficial nutrient in plant biology. Although the element is classified as essential for only a few plant species, many crops respond positively to supplemental silicon. Plants, especially grasses, can take up large amounts of silicon, and this contributes to their mechanical strength. Besides a structural role, silicon helps to protect plants from insect attack, disease, and environmental stress. For some crops, silicon fertilization of soils increases crop yield even under favorable growing conditions and in the absence of disease.

Specific benefits observed due to silicon nutrition are extensive:

- Directly stimulates growth and yield
- Counteracts negative effects of excess nitrogen nutrition
- Suppresses plant diseases caused by bacteria and fungi (powdery mildew on cucumber, pumpkin, wheat, and barley; gray leaf spot on perennial ryegrass; and leaf spot on bermudagrass)
- Suppresses stem borers, leaf spider mites, and various hoppers
• Alleviates various abiotic stresses including lodging, drought, temperature extremes, freezing, UV irradiation, and chemical stresses including salt, heavy metals, and nutrient imbalances.

In animals, silicon is regarded as an essential element. It strengthens bones and connective tissue. Vegetables, grains, and fermented grain products such as beer are sources of silicon in human nutrition. Cooking with broth prepared from bones may be another source of dietary silicon.

Silicon-deficiency symptoms

Symptoms of silicon deficiency are generally not visually apparent in an obvious way in the field. Indirectly, silicon deficiency may be exhibited as an increase in susceptibility to certain plant diseases. Crops, such as pumpkin, cucumber, wheat, and Kentucky bluegrass, are susceptible to powdery mildew disease. Providing enhanced levels of silicon nutrition for these crops can suppress or delay the onset of the disease. As a result of increasing silicon concentrations in plant tissues, the mechanical strength may be improved. Grain crops lacking adequate silicon may be more susceptible to lodging. The amount of insect attack on plant tissues may be inversely related to silicon concentration.

Plant tissue analysis

It is not unusual to find silicon concentrations in plants at levels comparable to or above those for macronutrients nitrogen, phosphorus, or potassium.

Concentrations of silicon in plant tissue can vary widely depending on plant species and silicon availability from the soil. Grasses and monocots in general tend to accumulate silicon. Concentrations as high as 10% silicon are possible in some plant species such as *Equisetum* sp.

Dicotyledonous plants in general have fewer tendencies to accumulate silicon, and some species may grow adequately with levels at about 0.1% Si in plant tissue.

Optimum silicon concentration levels have not been established for many crops. Research conducted on New Jersey soils indicates concentration ranges that may occur for some crops. For example, supplying supplemental silicon to Ultisols used to grow pumpkin, corn, and wheat resulted in remarkable increases in concentrations of silicon in the plant tissue.

Soil analysis

Soils contain on average 30% silicon by weight, but most of it resides in minerals that are only sparingly soluble. With such abundance of silicon in nature, the economic value of this element in agronomy and horticulture has sometimes not been fully appreciated.

In general, older and more highly weathered soils are more depleted of silicon than geologically young soils. Soils that have been subjected to continuous leaching in a humid environment for a very long time tend to have little remaining weatherable minerals. Consequently, Ultisols tend to be relatively depleted of silicon. Oxisols are the most strongly weathered and silicon-depleted soils. Histosols are naturally low in silicon content and are often silicon deficient.

Although soil testing for silicon availability is not a routine part of soil fertility testing, some laboratories

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- Check out the research article by Dr. Joseph Heckman (Rutgers) & Dr. Lawrence Datnoff (LSU) found in this issue.
- Harsco is a proud sponsor of the Silicon Soil Fertility & Nutrient Management Symposium at the ASA-CSSA-SSSA International Annual Meetings, Oct. 24, Cincinnati, OH.

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offer an acetic acid soil-extractable soil silicon analysis. At present, the database is very limited in correlat-
ing silicon soil test levels with plant silicon uptake. Research is needed to find better soil test methods to predict silicon availability.

Interpretation of any soil test requires years of field research experience to provide a meaningful database. At present, the database is very limited for interpretation of silicon soil test levels.

When 18 New Jersey soils were collected and tested using the acetic acid soil extraction method, they exhibited ranges of soil test silicon from 4 to 35 mg/L. The average soil test silicon level was 14 mg/L.

Soil factors affecting silicon availability

Soil texture refers to percent sand, silt, and clay particles in a soil. Silicon is a component of these mineral particles of varying size. Although sand is largely composed of silicon dioxide, this material provides very little soluble or plant-available silicon. Thus, it is not unusual for crops grown on sandy soils to benefit from applications of soluble silicon.

Silicon is not a major component of soil organic matter. Soils composed almost entirely of humus and organic matter are called muck soils or Histosols. Because the substrate of such soils contains little silicon, certain crops grown on these soils may benefit from silicon application.

The use of soilless mixes in greenhouse production means that very little silicon is being supplied from the growth medium. Greenhouse and hydroponic production systems have also been shown to benefit from silicon fertilization.

Silicon availability does not change markedly across the soil pH spectrum used to grow crops. However, the application of acidifying fertilizers, such as ammonium sulfate, may enhance silicon uptake by crops. Repeated use of these fertil-
izers may contribute to depletion of silicon from agricultural soils. Many of the commonly used silicon fertil-
izer materials also serve as liming agents, and their application results in neutralization of soil acidity.

Crop responsiveness to silicon

Crops may benefit from supplemental silicon as disease suppression, reduced injury from insect pests, stronger stems, tolerance to stress, or direct stimulation of yield.

Around the world, rice and sug-
arcane are the crops that very often exhibit beneficial responses to silicon fertilization. Of crops commonly grown in New Jersey, pumpkin, corn, wheat, oats, Kentucky bluegrass, and cabbage have exhibited positive responses to silicon.

Crop groups that are considered good candidates for silicon fertiliza-
tion include cucurbits, grasses, and small grains. Silicon may be useful to any crops susceptible to powdery mildew disease and/or grey leaf spot.

Silicon sources

Crop residues, manures, and compost are sources of silicon. Straw from wheat and other small-grain crops may contain valuable amounts of silicon with concentrations ranging from 0.15 to 1.2% Si depending on the silicon fertility level of the soil on which it is produced. Demand for silicon by crops on some soils may exceed the ability of plant residues and compost to supply it. Increased soil biological activity associated with organic matter may improve to solubility of silicon from soils. Additionally, it may take several years for silicon from crop residues to become available for plant uptake.

Some of the silicon in plant residues occurs in the form of “plant stones” or phytoliths. These sili-
structures are very resistant to decomposition and many persist in soils for very long periods. Phytoliths provide a kind of durable “plant fossil” useful in archaeological and paleoecological research.

To be an effective source for crops, a silicon fertilizer should provide a high percentage of silicon in soluble form. Other characteristics to consider are cost of material, physical properties, ease of application, and ability to raise soil pH. Because silicon in nature is always combined with other chemical elements, the agronomic value of the other elements that accompany the product should also be considered. Some of these elements may be valuable plant macro- and micronutrients.

Commercial silicon products are marketed as either solids or liquids. In the case of solid silicon sources, plant-available silicon increases as particle size decreases.

Calcium silicate products are the most commonly applied silicon fertil-
izers for field application. Steel mill slags are a rich source of calcium silicate. Because they neutralize soil acidity and supply calcium, they are commonly applied to soil as an alter-
ative liming agent in much the same way as agricultural limestone. Slags vary in purity, silicon availability, and liming ability (rated as calcium carbonate equivalent or CCE). A fine particle size, purity, and a high percent concentration of soluble silicon are desirable properties of a calcium silicate slag product.

Agrowsil is a commercially avail-
able silicon product for agronomic and vegetable crops. It is made from stainless steel slag that has been subjected to processing to remove metals resulting in a calcium magnesi-
num silicate product that typically contains 30% Ca, 7% Mg, and 12% Si. With a calcium carbonate equivalent value of 93%, Agrowsil can be used as a liming material at about the

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Silicon fertilizer practice and rates of application

In general, silicon fertilizers should be applied to the soil, soilless mixes, or added to nutrient solutions. Spraying silicon fertilizers on plant foliage is generally not as effective.

The need for silicon fertilizer is not easily predicted by currently available soil tests for extractable silicon. But soil testing for soil pH and need for liming can be very useful in determining the proper application rates for calcium silicate sources.

A practical approach to managing soil fertility for enhanced silicon nutrition of crops is to use calcium silicate products as liming materials. Application rates can be determined by the need for soil pH adjustment or lime requirement of the soil. The greater the lime requirement of the soil, the higher the application rate possible for calcium silicate.

Another soil test factor to consider is the percent saturation of the soil colloids with calcium, magnesium, and potassium. Silicate products containing these cations can be used to supplement the balance of soil fertility on the cation exchange complex (CEC).

Over-application of silicon to soil from calcium silicate is generally not a concern because soil pH elevation would limit how much can be applied. Thus, application rates for calcium silicate may range from 1 to 4 tons/acre depending on the initial soil pH level and the target soil pH range for the crop to be grown.

Experience suggests that for encouraging plant uptake of silicon, it may be better to apply calcium silicate supplements yearly at lower application rates to maintain a satisfactory soil pH and calcium saturation of the soil CEC. This approach may provide a continuous supply of readily available silicon for crop uptake. If heavier application rates are to be applied, direct it to the crop fields most likely to benefit from the silicon application. For example, fields to be planted to pumpkin, wheat, or other crops know to be more responsive to silicon.

When crops need nitrogen, applying the fertilizer N as ammonium sulfate may help enhance silicon availability and plant uptake from silicon fertilizers.

High-value horticultural crops may benefit from soluble silicon fertilizers, such as potassium silicate or sodium silicate, applied through drip irrigation system or through calcium silicate additions to soilless mixes.

Silicon symposium in Cincinnati

The Soil Science Society of America’s Nutrient Management & Soil & Plant Analysis division will be hosting a symposium on “Silicon Soil Fertility and Nutrient Management” on October 24 from 1:00-5:00 pm during the 2012 ASA, CSSA, and SSSA International Annual Meetings in Cincinnati, OH. It will include seven oral presentations from silicon researchers around the world as well as a poster session. See http://scisoc.confex.com/scisoc/2012am/webprogram/Session10608.html.

Further reading


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The American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America recently launched the new Science Societies Career Center with an updated interactive jobs board, improved functionality, and expanded services. With its focus on the agronomic, crop, soil, and environmental sciences, the Career Center is your roadmap to success with easy-to-navigate and highly targeted resources for online employment connections.

Employers can post jobs online and in print, search for qualified candidates based on specific job criteria, and create an online resume agent to email qualified candidates daily. Employers will also find new options to promote their jobs and companies and create brand awareness.

In addition to building an online professional profile, job seekers can browse jobs based on their criteria, forward job information to themselves or a friend, and save jobs for later review. Job seekers can even create a search agent to provide email notifications of jobs that match their criteria.

Click on “Careers” at any of the Society’s home pages or go directly to www.careerplacement.org. Whether you’re seeking a new employee, changing career routes, or just along for the ride, take a trip to the Science Societies Career Center and find your roadmap to success.

The Career Center at the Annual Meetings
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This October, check out the Career Center at the ASA, CSSA, and SSSA Annual Meetings in Cincinnati, OH, conveniently located in the Duke Energy Center, Exhibit Hall A. New features will make it easier than ever for employers and job seekers to connect and communicate. And you won’t want to miss our Career Fair on Monday, October 22, from 3–6 pm.

Job seekers: Visit www.careerplacement.org before the Annual Meetings to create your professional profile, peruse the employers and job postings, and request interviews. Then visit us in Cincinnati for on-site, face-to-face interviews with motivated employers.

Advertise your job opening in Crops & Soils magazine

The deadline for Career Center listings is the 15th of the month preceding publication (e.g., 15 February for the March–April issue). Charges are based on the number of characters and whether or not the listing will appear online, in Crops & Soils magazine, or both.

For complete information about advertising opportunities, including rates and deadlines, and to submit a listing, visit www.careerplacement.org. If you have questions, please call 608-273-8080 or email jobs@sciencesocieties.org.

Employers: Reserve your Career Center table, post positions, browse resumes, and schedule interviews at www.careerplacement.org. Then connect with the most qualified job seekers in our sciences and professions in Cincinnati.

New for 2012! Exhibitors: Enjoy the convenience of accessing the Career Center scheduling system right from your exhibit booth when you sign up for the complimentary Exhibitor Access package at www.careerplacement.org.

The Graduate School Forum

During the Annual Meetings in Cincinnati, OH, prospective students and university representatives from top graduate schools will meet face to face in the relaxed, informal setting of the Grad School Forum located next to the Career Center. University representatives will provide information about their schools and departments, discuss assistantships and fellowships, and interview students for M.S. and Ph.D. programs.

The Career Center and Graduate School Forum hours are Sunday, Oct. 21: 7–9 pm; Monday, Oct. 22: 9 am–6 pm; Tuesday, Oct. 23: 9 am–6 pm; and Wednesday, Oct. 24: 9 am–4:30 pm. &
The fall/winter meeting season, when the majority of certified professionals earn their continuing education, is rapidly approaching. Although we do educational programming throughout the year, the vast majority of CEUs are earned between November and March. Not surprising when you consider the professions we represent.

The American Society of Agronomy (ASA) and the Soil Science Society of America (SSSA) will be offering several new online courses in the coming months. All ASA and SSSA courses are 100% online and are designed to be very practical with the practicing professional in mind. Both ASA and SSSA have a “fundamentals” course (for agronomy and soil science, respectively) for those who want to brush up on the foundational principles and practices or are new(er) to the profession. They are great preparatory courses for the credentialing exams.

ASA is again offering the “Nitrogen Fundamentals and Management” course this fall. SSSA’s course “Soil and Wa-

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Certification

Update

By Luther Smith  
Director of Certification Programs  
ASA and SSSA  
lsmith@sciencesocieties.org

Certification
Newly certified

The following list includes newly certified individuals and those who have added additional certifications since the last issue of *Crops & Soils* magazine. This list is alphabetized by surname within each state/province.

**Canada**

**British Columbia**
- Witt, Michael, Coldstream, BC, (CCA-NW)

**Ontario**
- Delover, Robert, Mitchell, ON, (CCA-ON)
- Ribey, Margaret, Guelph, ON, (CCA-ON)

**United States**

**Alabama**
- Trull, Ross, Andilusion, AL, (CCA-AL)

**Arkansas**
- Ellis, Brian, Jonesboro, AR, (CCA-AR)
- Morgan, Jerry, Stuttgart, AR, (CCA-AR)
- Sullivan, Walter, Gillett, AR, (CCA-AR)

**California**
- Benzel, Eric, Gridley, CA, (CCA-CA)
- Cuevas, Adrian, Soledad, CA, (CCA-CA)
- Filice, Nicholas, Oakville, CA, (CCA-CA)
- Harrington, Jeffry, Bakersfield, CA, (CCA-CA)
- Knapec, Karla, Eureka, CA, (CPSS)
- Miller, Eric, Wasco, CA, (CCA-CA)
- Sproul, Joseph, King City, CA, (CCA-CA)

**Delaware**
- Rohrer, Jr., William, Milford, DE, (CCA-CB)

**Florida**
- Hayes, Ryan, Wauchula, FL, (CCA-FL)

**Georgia**
- Harris, Erin, Athens, GA, (CPSS)

**Iowa**
- Wykoff, Steve, Pomeroy, IA, (CCA-RET)

**Idaho**
- Bleazard, Kevin, Twin Falls, ID, (CCA-NW)
- Firth, Aaron, Heyburn, ID, (CCA-NW)
- Greenwalt, Barry, DeSmet, ID, (CCA-NW)
- Paul, Craig, Twin Falls, ID, (CPSS)
- Smith, Kevin, Post Falls, ID, (CCA-NW)
- Sparks, Lonnie, American Falls, ID, (CCA-NW)
- Turnbull, Jacob, Grangeville, ID, (CCA-NW)

**Illinois**
- VerHalen, Patrick, St. Charles, IL, (APSS)

**Kansas**
- Kwapisnioski, Andrew, Manhattan, KS, (CCA-NE)
- Zimmerman, Benjamin, Manhattan, KS, (CCA-KS)

**Missouri**
- Patton, Jamie, Maryville, MO, (CPSS)

**Montana**
- House, Kelley, Belgrade, MT, (CPSS)

**Nebraska**
- Borges, Darin, Dalton, NE, (CCA-NE)
- Johnson, Chase, York, NE, (CCA-NE)
- Klug, Lyndon, Battle Creek, NE, (CCA-NE)
- Kroeger, Kurt, Dannebrog, NE, (CCA-NE)
- Livgren, Joel, Fairfield, NE, (CCA-NE)
- Paseka, Brent, David City, NE, (CCA-NE)
- Porter, Travis, Utica, NE, (CCA-NE)
- Shank, Todd, Kearney, NE, (CCA-NE)
- Wallin, Clay, Minden, NE, (CCA-NE)
- Winkelbauer, Chris, Randolph, NE, (CA-NE)

**New Jersey**
- Cramer, Nicholas, Rocky Hill, NJ, (CPSS)

**New Mexico**
- Sandor, Jonathan, Corrales, NM, (CPSS)

**New York**
- Gaffney, Frederick, Syracuse, NY, (CCA-RET)
- Reese, Frances, Spencerport, NY, (CPSS)
- Weeks, David, Lancaster, NY, (CCA-NR)
Certification update
[continued from p. 31]
	er Management—Ag Perspectives” is currently running and will be offered again in early 2013.

Courses under development and to be released later this year or early 2013 are “Phosphorus Management,” “Biotech Basics,” “Watershed Management 1,” and “4Rs Adaptive Nutrient Management.” The 4Rs course is also being considered as part of a new CCA specialty certification that the fertilizer industry is very supportive of to help improve water quality.

You can get more details on all of these courses at: www.agronomy.org/education.

Requiring certification in job descriptions

When you think about the certification process and what it took for you to become certified—exams, education, experience, and ethics—it can be quickly compared with the hiring process for an employee. Although I would argue becoming certified is a far more detailed process than what most organizations do when they are hiring someone. In essence, most companies could use the certification as part of their employment practices, and some do.

Requiring certification as part of a job description would be a very positive move for an organization, helping to ensure that the right person is hired. Certificants have to pass exams, have their education and experience evaluated, and sign a code of ethics. So if you do the hiring in your company or know the person who does, consider adding the appropriate certification (CCA, CPAg, or CPSS) to the job description as part of the position requirements (or at least indicate that candidates with the credentials would be preferred). I think you will be glad you did.

Ohio
Gentry, Jason, Washington Court House, OH, (CCA-OH)
Johnson, Alexander, Lewisburg, OH, (CCA-OH)
Mullen, Robert, Wooster, OH, (CCA-OH)
Polek, James, Norwalk, OH, (CCA-RET)
Schmerge, Matthew, Anna, OH, (CCA-OH)
Strow, Richard, Custar, OH, (CCA-OH)

Oregon
Cruickshank, Brian, McMinnville, OR, (CCA-NW)
Gerig, Jim, Silverton, OR, (CCA-NW)
Hafner, Theodore, Jefferson, OR, (CCA-NW)
Hartmann, Justin, Portland, OR, (CPSS)
Jansen, Scott, Forest Grove, OR, (CCA-NW)
Keller, Lucas, Ontario, OR, (CCA-NW)
Schultz, Brian, Pendleton, OR, (CCA-NW)
Thorud, Dennis, Hillsboro, OR, (CCA-NW)
Vangrunsven, Steven, Forest Grove, OR, (CCA-NW)

Pennsylvania
Rice, Tyler, Mount Pleasant Mills, PA, (CCA-NR)

South Dakota
Bergheim, Jody, Madison, SD, (CCA-SD)
Johnson, Benjamin, Flandreau, SD, (CCA-SD)
Tipton, Bryan, Pierre, SD, (CCA-SD)

Texas
Brown, Brent, Hereford, TX, (CCA-TX)

Virginia
Fajardo, Gabriela, Williamsburg, VA, (CPSS)

Washington
Bare, Steve, Ellensburg, WA, (CCA-NW)
Haberman, Tyler, Quincy, WA, (CCA-NW)
Lutz, Aaron, Quincy, WA, (CCA-NW)
Meek, Blaine, Kennewick, WA, (CCA-NW)
Ollard, Graham, Selah, WA, (CCA-NW)
Van Wechel, Joshua, Spokane, WA, (CCA-NW)

Wisconsin
Barta, Amanda, Algoma, WI, (CCA-WI)
Haak, Amy, Fond du Lac, WI, (CCA-WI)
Mansfield, Amy, Clinton, WI, (CCA-WI)
Minks, Kyle, Madison, WI, (CCA-WI)
Nieman, Clint, Marshfield, WI, (CCA-WI)
Rabas, Jeff, Lena, WI, (CCA-WI)

Wyoming
Osmond, Travis, Grover, WY, (CCA-RM)
Introducing fall-seeded pea and lentil into conventional wheat-based crop rotations

Wheat is a dominant crop in Montana with about 5.4 million planted acres and 6 million tons of produced grain annually. The widely adopted wheat–fallow cropping system stabilizes yields and is generally economically successful, especially in a low-precipitation region. However, this system has a low soil water storage rate and precipitation use efficiency and lacks crop diversity. It also results in soil erosion and soil organic matter degradation. With the shallow soil profile in central Montana, when precipitation exceeds the soil water-holding capacity during the summer fallow, the excess water carries N and salts out of the soil profile, causing groundwater contamination and saline seep.

Pea and lentil have been successfully introduced to wheat-based cropping systems in Montana. The production land area of pea and lentil increased from 56,800 ac in 2003 to 454,500 ac in 2010. Introducing pea and lentil to wheat-based production systems makes weed control of grass species easier by using selective herbicides, breaks disease cycles in wheat monocropping, improves yield and water use efficiency, and produces greater economic returns in some contexts.

Fall-seeded winter-type peas and lentils have shown some advantages over the spring-type, including a longer growing period that results in greater forage and grain yields and early vegetative growth in the spring with early flowering to avoid water and heat stress in the summer. Winter pea and lentil can be seeded into wheat stubble in the fall after the wheat harvest. These legume crops provide soil surface cover and biomass with high N content. The legume crops can be terminated in June of the following year for green manure or hay or be allowed to grow to maturity for grain harvest.

Nitrogen is the most expensive input for growing grain crops, and optimal use of N fertilizer can help to increase the profitability of agricultural production while reducing the impact of excessive N on the environment. In the inland Pacific Northwest low precipitation zone of the United States, the economics of alternative no-till spring crop rotations compared with the traditional wheat–fallow system showed that continuous spring wheat had a positive net return equivalent to the winter wheat–fallow system, but all alternative spring crop rotations had higher annual income variability than the traditional winter wheat–fallow system. Farmers’ risk attitudes affect their choice of alternative cropping systems and various N input levels, and researchers found that these attitudes can alter decisions, with optimal choice influenced by risk preferences and government programs.

In a recent issue of Agronomy Journal, researchers describe two no-till rotation studies that they conducted in central Montana. The objectives of these studies were to: (i) determine the effects of winter pea or lentil cover crops (for hay or green manure) on winter wheat grain yields and (ii) estimate the effects of the alternative crop rotations on net economic returns. In Experiment 1, a winter

Abbreviations: FW, fallow; NRG, nitrogen recovery in grains; SW, spring wheat; WL(g), winter lentil for grain; WL(m), winter lentil for green manure; WP, winter pea hay; WW, winter wheat.
pea hay–winter wheat (WP–WW) rotation was compared with fallow–winter wheat (FW–WW) and spring wheat–winter wheat (SW–WW) rotations. In Experiment 2, a winter lentil for green manure–winter wheat [WL(m)–WW] rotation was compared with a winter lentil for grain–winter wheat [WL(g)–WW] rotation. Four different N rates were applied on wheat. For more information about the experimental design, see the complete article (Agronomy Journal 104:215–224).

Economic analyses

Enterprise budgets were used to estimate costs and returns for each two-year crop sequence. All prices were adjusted for inflation to 2010 values. Crop prices and protein premiums for spring and winter wheat were derived from expected local cash prices at planting time based on futures prices and historic basis in Montana’s largest wheat-production regions.

Fertilizer and herbicide prices were based on the USDA National Agricultural Statistical Services (NASS) annual agricultural price reports. Fertilizer prices were averages across markets in the U.S. mountain region (Montana, Wyoming, Utah, and Colorado), while herbicide prices were national annual averages.

The costs of machine use were estimated, and net returns were calculated as a difference between gross revenues and total costs, both of which are determined using the expected market prices.

Crop yield and protein

Experiment 1

In Experiment 1, winter wheat grain yields were influenced by crop rotation and N input level. Averaged over years (rotation cycles) and N levels, grain yields from WW in FW–WW and WP–WW rotations were greater than in the SW–WW rotation. Grain yields increased with increasing N rates until reaching a peak value. Averaged over three years, the regression models indicated that the WW yield in the FW–WW and WP–WW rotations responded to N input rates similarly, except the WW yield was slightly greater in the WP–WW rotation than in the FW–WW rotation without N application. The SW–WW rotation resulted in lower grain yields than WP–WW and FW–WW rotations at all N input levels (Fig. 1).

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The protein content of winter wheat grain increased linearly with increasing N rates, although the protein contents varied among years. Protein content was not affected by crop rotation.

**Experiment 2**

In Experiment 2, winter wheat grain yields were influenced by crop rotation and N input level. Average grain yield was greater from the WL(m)–WW than WL(g)–WW rotation. Grain yields increased with N rates. Greater grain yield was obtained from the WL(m)–WW rotation than the WL(g)–WW rotation for all N input levels, and regression equations for these two rotations were almost parallel (Fig. 2).

The protein content of winter wheat grain was influenced by crop rotation and N input level. The WL(m)–WW rotation had greater protein content than the WL(g)–WW rotation. Protein content in both rotations increased linearly with increasing N input levels, but the WL(m)–WW rotation had higher protein contents at lower N input levels. The yield of hard red winter wheat response to N fertilizer had been found to follow quadratic models, and the protein content response to N was found following linear models in Colorado and Montana.

Greater yield and protein content from the WL(m)–WW rotation than the WL(g)–WW rotation at 0 N was likely due to more N returned to the soil under the WL(m)–WW rotation. In Experiment 1, the WW yield at 0 N was similar for the FW–WW and WP–WW rotations, whereas the WW yield was much higher after WP than SW. Such yield increase was likely attributed to both residual N and less water use due to early termination of the WP compared with spring wheat in the previous crop. Moisture was saved and N mineralized during the fallow period; thus WW following the summer fallow and winter pea hay produced similar yields. However, the WW had a much lower yield after SW than FW and WP for all N input levels (Fig. 1). This implies that the yield increase over the continuous wheat monocropping was not only due to N applications, but also to other rotational effects, such as breaking disease cycles and better weed management.

The WW yield was greater from the WL(m)–WW rotation for all N input levels (Fig. 2), indicating a yield advantage of WW following the WL cover crop terminated by chemical herbicide in early June, which is likely attributed to more N return and less moisture consumption compared with that following WL grown for seed. The amount of available N from legumes depends on the legume spe-
cies, total biomass production, N content in plant tissue, and the mineralization process.

Total nitrogen uptake and nitrogen recovery in grains

Experiment 1

In Experiment 1, the total N in the aboveground biomass of WW was affected by crop rotation and N input level. The total N of WW varied among the rotation cycles. Averaged over years, the WP–WW rotation had the highest N uptake, followed by FW–WW and SW–WW rotations. The total N uptake increased with increasing N input levels until it reached a peak value. The total N uptake in the WP–WW and FW–WW rotations was greater than that in the SW–WW rotation for all N input levels (Fig. 3).

The nitrogen recovery in grains (NRG) was affected by crop rotation and N input level and varied among years.

Averaged over years and N rates, the NRG was greater from the FW–WW rotation (28.0%) and WP–WW (25.4%) rotation than the SW–WW (18.1%) rotation. The NRG decreased linearly with increasing N rates, but the regression models differed among the rotations (Fig. 3).

Experiment 2

In Experiment 2, the total N in this study was influenced by crop rotation and N input level. Averaged over years and N levels, total N uptake was greater from the WL(m)–WW rotation than WL(g)–WW rotation. The total N response to N input levels fit quadratic models. The equations for total N were slightly different for WL(g)–WW and WL(m)–WW rotations. The NRG was influenced by N but not by crop rotation.

Results from Experiments 1 and 2 indicate that NRGs are small in dryland winter wheat, ranging from 16 to 44% (Fig. 3 and 4). WW following WP improved NRG compared with WW following SW. Therefore, using legume cover crops in crop rotations may help to improve NRG.

System net economic returns

Experiment 1

In Experiment 1, the net economic returns of the rotation systems were influenced by crop rotation and N

Fig. 2. (a) Grain yield and (b) protein content of winter wheat (WW) in response to N input level in two crop rotations (winter lentil (grain)–winter wheat [WL(g)–WW] and winter lentil (green manure)–winter wheat [WL(m)–WW]) during 2008 and 2010. The error bars in the graphs represent ± 1 standard error.
Fig. 3. (a) Total N uptake in aboveground biomass and (b) nitrogen recovery in grains (NRG) of winter wheat (WW) in response to N input level in three crop rotations (fallow–winter wheat [FW–WW], spring wheat–winter wheat [SW–WW], and winter pea–winter wheat [WP–WW]) during 2006, 2008, and 2010. The error bars represent ± 1 standard error.

Fig. 4. (a) Total N uptake in aboveground biomass and (b) nitrogen recovery in grains (NRG) of winter wheat (WW) in response to N input level in two crop rotations (winter lentil (grain)–winter wheat [WL(g)–WW] and winter lentil (green manure)–winter wheat [WL(m)–WW]) during 2008 and 2010. The error bars in the graphs represent ± 1 standard error.
Although the net returns varied among years, averaged over years and N levels, the WP–WW rotation generated the most net return ($79.3/ac), followed by FW–WW ($46.8/ac) and SW–WW ($16.7/ac) rotations. The net return responded to N input levels. It was highest from the WP–WW rotation and lowest from the SW–WW rotation for all N input levels, while the FW–WW rotation generated a net return between the WP–WW and SW–WW rotations (Fig. 5).

The net return increased with increasing N rates at lower N rates until reaching a peak value and fit a quadratic model (Fig. 5). The N rate with the maximal realized net return is considered as the optimal N input level for each rotation. Grain prices were subjected to the premium and discount structure depending on the protein content of the grain. Therefore, the economically optimal N rate was estimated from the net return function for high and low grain and fertilizer prices as well as for different premium and discount structures.

The optimal N rate was greater for the FW–WW rotation than the SW–WW and WP–WW rotations. This indicates that more N can be applied to the FW–WW rotation to obtain higher yield and profit due to reserved moisture from the fallow period.

**Experiment 2**

The net returns in Experiment 2 were influenced by crop rotation and N input level. The net returns varied over years, and averaged over all years and N rates, they were much greater in the WL(g)–WW than in WL(m)–WW rotation, even though the WW yields were greater in the WL(m)–WW rotation. This was due to lentil grain prices in recent years and little value added to the lentil green manure (cover crop). The net return increased with increasing N rates (Fig. 6).

The net returns from the cropping systems were directly associated with yields and input as well as output prices. High production costs and low wheat yields in the monocropping resulted in the lowest net returns compared with other cropping systems.

To test the effects of price changes on the profitability of cropping systems, a sensitivity analysis was conducted by applying 2009 and 2010 input and output prices to all rotations. The sensitivity analyses showed that profits from the FW–WW rotation did not change much, but profits from the WP–WW and SW–WW rotations increased.
However, the net profits increased in the WL(g)–WW rotation but decreased in the WL(m)–WW rotation in the sensitivity analysis. Higher-than-average market prices allowed producers to increase net returns. Even though the WL(m)–WW rotation had greater N benefits, the N cost savings in this rotation did not make up for the revenue reduction compared with the WL(g)–WW rotation.

Wheat producers normally use a long-term average precipitation to set yield and protein target to determine N application rate. Montana wheat producers often apply a higher N rate than recommended for the maximum yield to achieve a higher protein content. The results showed that the protein content of winter and spring wheat continues to increase linearly with increased N input even though the yield has reached the maximum. Hard red wheat grown in Montana has a high protein content, but wheat with a low protein content often suffers a price discount. The estimated optimal N rates in this article may provide a reference for farmers to improve system profitability and avoid groundwater contamination due to overapplication of N under different crop rotations.

Conclusions

In central Montana, the traditional fallow–WW rotation has been generally economically successful. However, this rotation has low precipitation use efficiency, lacks crop diversity, and may result in excess of water leaching out of shallow soil profiles, causing groundwater contamination and saline seep. Winter (fall-seeded) pea and lentil can serve as cover crops. Winter wheat following winter pea cover crop, cut in early June for hay, produced much greater yields, used more N, and had a greater NRG compared with the WW in the SW–WW rotation. The WP–WW rotation generated greater net returns than the traditional FW–WW and SW–WW monocropping systems. Winter wheat, following winter lentil cover crop terminated in early June for green manure, produced greater grain yields and protein contents compared with the WL(g)–WW system. However, the WL(g)–WW rotation generated much greater net returns than the WL(m)–WW rotation because the N cost saving in the WL(m)–WW system did not make up for the revenue reduction. The WL(g)–WW rotation generated highest profits and was the most profitable rotation in this study.

September–October 2012 self-study quiz

Introducing fall-seeded pea and lentil into conventional wheat-based crop rotations (no. SS 04813)

1. Which of the following is NOT mentioned as an attribute of the wheat–fallow cropping system?
   - a. It results in soil erosion and soil organic matter degradation.
   - b. It has a low yield stability.
   - c. It has a low precipitation use efficiency.
   - d. It lacks crop diversity.

2. Introducing pea and lentil to wheat-based production systems as rotation crops makes weed control of grass species
   - a. easier by being more competitive with them.
   - b. easier by using selective herbicides.
   - c. more difficult by requiring spring applications of herbicides.
   - d. more difficult by requiring an extra harrow or rotary hoe pass.

3. According to the article, some advantages have been seen with
   - a. fall-seeded winter-type peas and lentils over the spring-type including greater forage and grain yields.
   - b. spring-seeded and summer-type peas and lentils over the fall-type including early vegetative growth.
   - c. fall-seeded winter-type peas and lentils over the spring-type including delayed flowering to avoid water and heat stress in the summer.
   - d. spring-seeded and summer-type peas and lentils over the fall-type including a longer growing season.

4. Results from both Experiment 1 and 2 indicate that nitrogen recovery in grains (NRGs) range from
   - a. 2 to 7%.
   - b. 55 to 63%.
   - c. 15 to 28%.
   - d. 16 to 44%.

5. High production costs and low wheat yields
   - a. in the monocropping resulted in the lowest net returns compared with other cropping systems.
   - b. in the WP–WW rotation resulted in net returns that were lower than those of FW–WW and SW–WW systems.
   - c. in the WL(g)–WW rotation resulted in net returns that were lower than those of FW–WW and monocropping systems.
   - d. in the fallow-based systems make monocropping a better choice.

6. Which of the following is true?
   - a. The WL(g)–WW rotation had greater N benefits and greater revenue than WL(m)–WW rotation.
   - b. The WL(m)–WW rotation had greater N benefits and greater revenue than WL(g)–WW rotation.
   - c. The WL(m)–WW rotation had greater N benefits than WL(g)–WW rotation but generated less revenue.
   - d. The WL(g)–WW rotation had greater N benefits than WL(m)–WW rotation but generated less revenue.

7. According to the article, Montana wheat producers often apply a higher N rate than recommended for the maximum yield to
   - a. achieve higher protein content.
   - b. stimulate tiller growth.
   - c. promote establishment.
   - d. guard against unpredictable precipitation.
8. The optimal N rate was greater for the FW–WW than the SW–WW and WP–WW rotations. According to the article, this indicates that more N can be applied to the FW–WW rotation to obtain higher yield and profit due to
☐ a. reduced N from legume crops with the fallow period.
☐ b. less runoff with the fallow period.
☐ c. less weed competition with the fallow period.
☐ d. reserved moisture from the fallow period.

9. Winter wheat following winter pea cover crop, cut in early June for hay, produced much greater yields and ____ compared with the WW in SW–WW rotation.
☐ a. used less N
☐ b. had a greater net N recovery in grain
☐ c. more protein
☐ d. yet lower net returns

10. The FW–WW rotation generated a net return
☐ a. between the WP–WW and SW–WW rotations.
☐ b. higher than the WP–WW and SW–WW rotations.
☐ c. lower than either the WP–WW and SW–WW rotations.
☐ d. lower than the WP–WW and SW–WW rotations.

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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 ☐ American 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 September 2012 expires September 2015

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: ____________________________________________
Comparing enhanced-efficiency N fertilizers in bermudagrass forage production

Earn 1 CEU in Nutrient Management by reading this article and completing the quiz at the end. Fill out the attached questionnaire and mail it with a $20 check (or provide credit card information) to the American Society of Agronomy. Or, you can save $5 by completing the quiz online at www.certifiedcropadviser.org/certifications/self-study.

When urea-based fertilizers are applied to the surface without incorporation, losses of fertilizer N as NH₃ have been reported to range from 14 to 30% of applied N and occasionally exceed 40% of the applied N. Volatilization loss of NH₃ is greater in alkaline or calcareous soils, soils that are low in clay or humus, or environments with high temperature and humidity.

Decreased yields, production efficiency, N content, total N uptake, and recovery of applied N by forage fertilized with urea compared with ammonium nitrate (AN) have been attributed to the NH₃ losses. Some chemical or physical modifications of urea-based N sources may reduce NH₃ volatilization and/or release N more slowly than traditional fertilizers. Recently, several of these chemical or physical modification technologies have been developed and marketed as enhanced-efficiency (EE) fertilizer products.

The urease inhibitor NBPT (Agrotain, Koch Agronomic Services, Wichita, KS) has been on the market since 1996. When added to urea-based sources of N, NBPT inhibits the activity of the urease enzyme, which reduces volatilization loss of N. Combination products that include a nitrification inhibitor, dicyanamide, to create a dual-purpose N stabilizer for use on urea (SuperU) and in UAN solutions (AgrotainPlus) are available.

A granular urea product that has a microthin polymer coating (ESN Smart Nitrogen) is marketed by Agrium Advanced Technologies, (Brantford, ON, Canada). The coating acts as a physical barrier that slows and controls the release of urea by osmotic exchange with moisture from the soil. Water is diffused through the coating, dissolving the urea inside the particle and diffusing the urea through the coating into the soil solution.

Specialty Fertilizer Products (Leawood, KS) markets another EE product (NutriSphere-N) that is designed to control volatilization and nitrification. Its active ingredient is a maleic-itaconic copolymer. The mechanism of activity of this treatment is not well known, but the claim is that the product interferes with the availability of nickel (Ni) ions that are necessary for urease function.

These EE products are commercially available, but their effect on NH₃ volatilization loss and forage yield, production efficiency, N concentration, N uptake, and recovery of applied N is poorly understood. Further, it is unknown what the impact may be of switching from AN to urea, urea-based products, or EE product-treated sources on the concentration of nitrate-nitrogen (NO₃⁻N) in the forage and the associated risks of nitrate toxicosis.

Materials and methods

This investigation was conducted during the 2008 and 2009 growing seasons at two sites in a well-established stand of bermudagrass (cv. Russell). One site was on the University of Georgia’s Northwest Georgia Research and
Education Center near Calhoun, GA, on a Shellbluff silt loam (fine-silty, mixed, active, thermic Oxyaquic Dystruderts). The second site was on the University of Georgia’s Central Georgia Research and Education Center located near Eatonton, GA, on a Davidson loam (fine, kaolinitic, thermic Rhodic Kandiudults).

Treatments included applications of AN, urea, four EE urea N formulations (NBPT-treated urea [NBPTU], NBPT and dicyanamide–treated urea [NDU], a polymer-coated urea [PCU], and a maleic-itaconic copolymer–treated urea [MICPU]), UAN (32% N), two EE UAN formulations (NBPT-treated UAN [NBPTUAN], NBPT and dicyanamide–treated UAN [NDUAN]), and a 0 N control. The control plot was not included in the statistical analysis and mean separations.

An acid trap was housed within a chamber constructed of polyvinyl chloride (PVC) pipe placed into the soil and covered with a PVC end-cap. Within the chamber, the acid was contained within a widemouthed plastic bottle placed within a loop of heavy wire anchored to the soil so that the bottle was suspended above the soil surface.

The acid traps and chambers were left in place for seven days following fertilizer application. Ammonia gas released from the fertilizer application and trapped by the H₂SO₄ was measured. The PVC domes used in the volatilization traps create a microclimate, which likely affects the environment and rate of NH₃ volatilization. Though this volatilization trap procedure cannot estimate true volatilization, this semiquantitative measurement does allow the comparison of relative differences between the treatments.

Acid traps were used to measure ammonia gas released from the fertilizer application.

The forage was cut with a forage harvester, and the mass was measured. Grab samples from each plot were taken and dried until they reached a stable weight. Soil samples were collected from both the Eatonton and Calhoun sites on the day of the second harvest before any fertilizer was applied.

After the N application was made to the treated plots following the second harvest, volatilized NH₃ was measured. Because of higher temperatures and relative humidity during the summer, measurement of volatilized NH₃ after the mid-summer application was more important and cost-effective than assessing the volatilization at other application times.

Since the effects of weather patterns (such as rainfall, temperature, and humidity) that affect volatilization rates are substantially altered in the microclimate created by the enclosure around the NH₃ trap, specific attention was given to monitoring the maximum and minimum daily temperatures and the volumetric water content (VWC) at the site during the three days before fertilizer application, on the day of fertilizer application and volatilization trap installation, and the seven days following application.

The data on trapped NH₃, total seasonal forage yield, production efficiency, mean forage N concentration, total N uptake, and N recovery were analyzed, with treatment, site, and year treated as fixed effects and replication effects and their interaction with these other factors considered random effects. Because of the nature of the NO₃ concentration analysis, treatment effects were analyzed separately and in a different procedure. Even after a natural logarithm transformation was applied to the NO₃ data to account for skewness in the data, a skewed distribution remained because approximately one-third of the data were left-censored (below the detection limit). Special tests were used to include the left-censored data in the analysis. A limitation of this approach is that analyses across years and sites are not legitimate because the procedure is unable to parse the interaction of factors. The researchers performed separate analyses within each of the strata (each unique combination of site, year, and harvest). Within some strata (usually the earliest harvests within a season), all measurements were below the detection limit and, thus, left-censored. Thus, a limitation of this procedure is that it does not directly facilitate all pair-wise comparisons like conventional analyses.

Results and discussion

Environmental conditions

Rainfall totals in 2008 for both the Calhoun and Eatonton sites were lower than the 30-year mean. It
is important to recognize, however, that soil texture differences between the Shellbluff silt loam soil type (Calhoun) and the Davidson loam (Eatonton) resulted in higher VWC in Eatonton than in Calhoun. The Shellbluff silt loam soil type provides more plant-available soil moisture than the Davidson loam.

Urease activity and ammonia volatilization trap

Soil from Calhoun exhibited more urease activity relative to soil from the Eatonton site at the 0- to 2-inch and 2- to 4-inch increments. These differences likely caused or contributed to the interactions between the effects of the site and the effects of the other factors in some of the response variables in this experiment. Despite the difference in urease activity at the two sites, there was no effect of site on the amount of trapped NH₃, nor did year, site, and treatment exhibit a significant three-way interaction. However, year and treatment effects did interact. This interaction likely resulted from a combination of higher VWC in the soil, light rainfall, and higher relative humidity in the seven days following the N applications after the second harvest in 2008 compared with the conditions at both sites in 2009.

In 2008 and 2009, the urea treatment resulted in the most N lost to volatilization (Table 1). As expected, the AN treatment produced less NH₃ in both years than the urea treatment. The UAN treatment resulted in volatilization losses that were similar to AN in 2008. Though it produced a level that was higher than the AN treatment in 2009, it tended to be intermediate to the urea treatment in 2009.

All of the EE N fertilizer products (NBPTU, NDU, PCU, NBPTUAN, and NDUAN), except MICPU, produced less NH₃ than the urea treatment in both years. As expected, the addition of the nitrification inhibitor, dicyanamide, to NBPT-treated urea (i.e., NBPTU vs. NDU) did not result in further decreases in volatilization.

In contrast to the results with granular urea products, plots provided EE N product-treated UAN (NBPTUAN and NDUAN) did not produce significantly less trapped NH₃ than plots provided untreated UAN.

Total forage yield and production efficiency

In all four site-years, the AN treatment provided the highest seasonal forage yields and production efficiency (Table 2). The yield and responsiveness to added N was greater in AN-fertilized plots relative to the urea treatments in Calhoun in each year, in Eatonton in 2008, and tended to do the same in Eatonton in 2009.

Of the EE N product-treated ureas, only the NBPTU treatment produced yields and production efficiencies that were similar to the AN treatment in each of the four site-years, though NDU was similar in all but one site-year (Calhoun 2009). The NBPTU treatment produced greater yields than the urea treatment in both years in Calhoun but failed to do so in either year in Eatonton, while the NDU treatment provided a similar improvement over urea only during 2008 at Calhoun. Neither MICPU nor PCU improved yield production relative to urea in any of the site-years.

The high seasonal forage yields produced by the AN treatment were the result of its consistently producing the highest or similar to the highest yields in each harvest at Calhoun in both years and in the first, third, and fourth harvests in Eatonton in both years. The other treatments seemed to affect yields in individual harvests in the same

<table>
<thead>
<tr>
<th>Table 1. The mean concentration of ammonium trapped during the seven days following the second application of treatments for 2008 and 2009 averaged across both sites.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product</strong></td>
</tr>
<tr>
<td>AN</td>
</tr>
<tr>
<td>Urea</td>
</tr>
<tr>
<td>NBPTU</td>
</tr>
<tr>
<td>NDU</td>
</tr>
<tr>
<td>MICPU</td>
</tr>
<tr>
<td>PCU</td>
</tr>
<tr>
<td>UAN</td>
</tr>
<tr>
<td>NBPTUAN</td>
</tr>
<tr>
<td>NDUAN</td>
</tr>
<tr>
<td>Control§</td>
</tr>
<tr>
<td>LSD⁺₀.₁₀</td>
</tr>
</tbody>
</table>

† AN = ammonium nitrate, NBPTU = N-(n-butyl) thiophosphoric triamide (NBPT)–treated urea, NDU = NBPT and dicyanamide–treated urea, MICPU = maleic-itaconic copolymer–treated urea, PCU = polymer-coated urea, UAN = 32% N urea–ammonium nitrate solution, NBPTUAN = NBPT-treated UAN, and NDUAN = NBPT and dicyanamide–treated UAN.

‡ Within a column treatment, means followed by the same letter are not different at an α level of 0.10.

§ The control treatment was not used in the data analysis, but is included for reference.
general pattern observed for the seasonal totals, but only rarely were there differences within a harvest that were significant treatment effects.

Comparing the yield at each site for these two treatments illustrates the differences in yield potential of the two sites. Indeed, the Shellbluff silt loam soil type (Calhoun) is superior to the Davidson loam (Eatonton) in many respects (e.g., soil texture, organic matter content, cation exchange capacity, water holding capacity, etc.). However, a combination of two other factors provides a more plausible explanation for NBPTU improving the yield and production efficiency relative to urea at Calhoun but not Eatonton. One of these factors is the difference in urease activity at the two sites (i.e., the urease activity at the Calhoun site was 93% and 65% greater. Second, there were substantial differences in weather conditions at each site soon after the second fertilizer application in both years.

### Nitrogen concentration, uptake, and recovery

The mean N concentration in the bermudagrass was affected by treatment and was not affected by interactions between and among the year, site, and treatment. Therefore, data are presented as a mean across sites and years (Fig. 1). As with total forage yield, there was an interaction among year, site, and treatment in their effect on total N uptake in the forage and N fertilizer recovery.

Bermudagrass from the AN treatment took up more total N and recovered more of the applied N in all four site-years (Table 3). However, the UAN treatment resulted in N uptake and recovery similar to AN in Eatonton in both years. None of the EE N product-treated ureas consistently demonstrated greater N uptake and recovery than the urea treatment. Similarly, neither of the EE N product-treated UAN treatments improved on the N uptake and recovery of the UAN treatment. It is noteworthy that N uptake and recovery in forage from the PCU treatment was lower than the urea treatment in Eatonton in both years.

### Table 2. Mean total forage yield and the production efficiency of the added N at the Calhoun and Eatonton locations in 2008 and 2009.

<table>
<thead>
<tr>
<th>Response†</th>
<th>Calhoun</th>
<th>Eatonton</th>
<th>Calhoun</th>
<th>Eatonton</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Yield</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AN</td>
<td>20,169a§</td>
<td>10,216a</td>
<td>19,294a</td>
<td>11,739a</td>
</tr>
<tr>
<td>Urea</td>
<td>17,318cd</td>
<td>8,498b</td>
<td>14,968cd</td>
<td>10,740ab</td>
</tr>
<tr>
<td>NBPTU</td>
<td>19,308ab</td>
<td>8,917ab</td>
<td>17,542ab</td>
<td>11,441a</td>
</tr>
<tr>
<td>NDU</td>
<td>19,149ab</td>
<td>9,030ab</td>
<td>15,519bcd</td>
<td>11,166ab</td>
</tr>
<tr>
<td>MICPU</td>
<td>17,000cd</td>
<td>8,711ab</td>
<td>16,479bc</td>
<td>10,236b</td>
</tr>
<tr>
<td>PCU</td>
<td>16,048d</td>
<td>6,437c</td>
<td>17,035abc</td>
<td>8,171c</td>
</tr>
<tr>
<td>UAN</td>
<td>18,909ab</td>
<td>8,921ab</td>
<td>15,679bcd</td>
<td>10,932ab</td>
</tr>
<tr>
<td>NBPTUAN</td>
<td>19,212ab</td>
<td>9,582ab</td>
<td>14,055d</td>
<td>10,381b</td>
</tr>
<tr>
<td>NDUAN</td>
<td>18,098bc</td>
<td>8,752ab</td>
<td>16,028bcd</td>
<td>11,459a</td>
</tr>
<tr>
<td>Control¶</td>
<td>10,019</td>
<td>2,691</td>
<td>10,419</td>
<td>2,180</td>
</tr>
<tr>
<td>LSD0.10</td>
<td>1,570</td>
<td>3,536</td>
<td>2,373</td>
<td>1,027</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Production efficiency#</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>AN</td>
<td>37.9a</td>
</tr>
<tr>
<td>Urea</td>
<td>27.2cd</td>
</tr>
<tr>
<td>NBPTU</td>
<td>34.7ab</td>
</tr>
<tr>
<td>NDU</td>
<td>34.1ab</td>
</tr>
<tr>
<td>MICPU</td>
<td>26.1cd</td>
</tr>
<tr>
<td>PCU</td>
<td>22.5d</td>
</tr>
<tr>
<td>UAN</td>
<td>33.2ab</td>
</tr>
<tr>
<td>NBPTUAN</td>
<td>34.3ab</td>
</tr>
<tr>
<td>NDUAN</td>
<td>30.2bc</td>
</tr>
<tr>
<td>LSD0.10</td>
<td>5.86</td>
</tr>
</tbody>
</table>

† See definitions in Table 1.
‡ DM = dry matter.
§ Within a column, treatment means followed by the same letter are not different at an α level of 0.10.
¶ The control treatment was not used in the data analysis but is included for reference.
# Production efficiency = (Yieldfertilized_plot − Yieldcontrol_plot)/300 lb N/ac.
is striking given the fact that it had the highest mean N concentration. This is a result of its poor yield performance in the first harvest of each site year and Eatonton in particular.

**Frequency and severity of elevated nitrate concentrations**

Approximately one-third of the data were left-censored (i.e., below the detection limit), and some treatments resulted in all measurements being left-censored at a harvest date within a site-year. This violates the assumption of normally distributed data and necessitated the use of a Tobit model procedure for analyzing left-censored data. A consequence of this procedure is that it does not allow for an accurate assessment of the interactions between treatments and other variables.

Because the fertilizer treatments were applied at dormancy break and after the second harvest, it is instructive to look at conditions that could have influenced NO₃ accumulation during the growth cycle leading up to the first and third harvests. In each site-year, the VWC was low when fertilizer treatments were applied after the second harvest. The VWC decreased before subsequent rains slightly increased the VWC. This moisture increase appears to have been just enough for the plant to take up the applied N, but decreases in VWC during the later weeks of the third growth period appear to have limited the ability of the bermudagrass to grow and dilute the accumulated NO₃. Nonetheless, it is important to recognize that one of the most critical factors that led to the accumulation of nitrates in the forage was the high rate of N at a given application time.

**Conclusions**

This research confirms other reports that indicate that, relative to AN, surface applications of untreated urea to hay and pasture fields may be a risky choice, as it can result in excessive NH₃ volatilization and decreased yields, production efficiency, N uptake, and recovery of N fertilizer. Use of UAN solutions produced a result that was generally intermediate in effect relative to urea and AN for the response variables monitored in this study.

Compared with when it is unadulterated, treating urea with NBPT (Agrotain) reduced ammonia volatilization and, under some conditions, resulted in increased yields, production efficiency, N uptake, and recovery of N fertilizer. Response to NBPT amendment seems to be greatest when conditions are most likely to result in volatilization loss (e.g., high temperature, humidity, and VWC in the soil; absence of a rainfall event providing > 0.5 inches of rain within a few days of N application; soil pH near neutral or above). Under those conditions where an agronomic response was not observed, the addition of NBPT was not detrimental relative to the untreated urea. To gain a better understanding of the effectiveness of using NBPT as a risk abatement strategy, further research into the frequency of agronomic response to NBPT treatment is warranted.

Urea treated with the maleic-itaconic copolymer (NutriSphere-N) was not different from untreated urea in any of the response variables that the researchers observed. One should conclude that either the product was ineffectual under the conditions of the study or the rate of product on the treated urea supplied to them by the company was insufficient.
The PCU (ESN Smart Nitrogen) consistently reduced ammonia volatilization and increased the concentration of N in the forage relative to untreated urea, producing responses for these variables that were similar to the AN treatment. However, PCU resulted in inferior agronomic performance (i.e., yield, production efficiency, N uptake, and recovery of applied N) relative to the untreated urea. Lower yields in the first harvests of each year, which was likely caused by an insufficient rate of N release from the polymer-coated product, appears to have been the primary reason for this decreased agronomic performance. The researchers conclude that either the formulation of the product supplied by the company was not suitable for bermudagrass forage production and/or this product requires an application timing that is different from the conventional recommendation.

In contrast to the improvements observed in urea performance, treating UAN solutions with NBPT (with or without dicyanamide) did not affect its performance.

Though AN generally exhibited superior agronomic performance relative to the urea-based N sources in this study, it more frequently resulted in forage that contained a nitrate concentration that is considered at risk of chronic nitrate toxicosis. In general, none of the EE N products produced forage that had higher or lower NO₃−N concentrations than their granular urea or liquid UAN cohorts. In the absence of a discernible trend, the researchers conclude that the EE N products do not increase or decrease the risk of NO₃−N accumulation in forage bermudagrass.

1. When urea-based fertilizers are applied to the surface without incorporation, losses of fertilizer N as NH₃ have been reported to range from 14 to 30% of applied N and occasionally exceed [ ] of the applied N.
   - a. 40%
   - b. 50%
   - c. 70%
   - d. 75%

2. Volatilization loss of NH₃ is greater in
   - a. highly acidic soils.
   - b. soils high in clay or humus.
   - c. high temperature and humidity environments.
   - d. soils with high water-holding capacity.

3. Recently, several chemical or physical modification technologies for urea-based N sources have been developed and marketed as [ ] fertilizer products.
   - a. super N
   - b. dual-mode N
   - c. enhanced-efficiency
   - d. slow-go

4. The high seasonal forage yields produced by the AN treatment were the result of its consistently producing the highest or similar to the highest yields in each harvest at Calhoun in both years and in
   - a. the first, third, and fourth harvests in Eatonton in both years.
   - b. the second, third, and fourth harvests at Eatonton in the first year.
   - c. first and last harvests at Eatonton in the second year.
   - d. all harvests at Eatonton in both years.

5. Use of UAN solutions produced a result that was generally [ ] for the response variables monitored in this study.
   - a. greater in effect relative to urea and AN
   - b. lesser in effect relative to urea and AN
   - c. intermediate in effect relative to urea and AN
   - d. about the same as urea but less effective than AN

6. This research confirms other reports that indicate that, relative to AN, surface applications of untreated urea to hay and pasture fields can result in
   - a. substantial N losses via NH₃ volatilization and decreased yields.
   - b. increased production efficiency and N uptake.
   - c. increased NO₃ emissions.
   - d. stabilization of the N pool.

7. The volatilization trap procedure in this study
   - a. estimates actual volatilization and can allow direct comparison between treatments.
   - b. did not estimate actual volatilization but allows a quantitative comparison of volatilization rate differences between the treatments.
   - c. estimates actual volatilization but cannot allow direct comparison between treatments.
   - d. did not estimate actual volatilization, but allows a comparison of relative differences in volatilization between the treatments.

8. Polymer-coated urea generally resulted in inferior agronomic performance relative to the AN, NBPT-treated products, and untreated urea because
   - a. the PCU released the N too quickly because of dry weather.
   - b. the PCU was applied too early.
   - c. a higher rate of N as PCU was applied compared to the other N sources.
   - d. the PCU released the N too slowly because of dry weather.

This quiz is worth 1 CEU in Nutrient 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.
9. Though AN generally exhibited superior agronomic performance relative to the urea-based N sources in this study, it more frequently resulted in forage:

   - a. that yielded less than urea-based sources.
   - b. with higher ADF and lower relative feed values.
   - c. that had lower feed preference ratings.
   - d. considered at risk for chronic nitrate toxicosis.

10. In the absence of a discernible trend, the researchers conclude that the EE N products:

   - a. do not increase or decrease the risk of NO$_3$-N accumulation in forage bermudagrass.
   - b. may slightly increase the risk of NO$_3$-N accumulation in forage bermudagrass.
   - c. may double the risk of NO$_3$-N accumulation in forage bermudagrass.
   - d. may actually decrease the risk of NO$_3$-N accumulation in forage bermudagrass.

Self-Study Quiz Registration Form

Name: __________________________
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☐ $20 check payable to the American Society of Agronomy enclosed.
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Credit card no.: __________________________
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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 September 2012 expires September 2015

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Graphics/tables (if applicable) were appropriate and enhanced my learning: 1 2 3 4 5

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