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Feature

Soil scientists, crop advisers, and consulting agronomists are often called to assist in crisis situations and to render a decision on matters. The need to make a decision puts them in the position of liability, which means they could face lawsuits. While there are no guaranteed ways to avoid litigation, the chances of being sued can be substantially lowered by using common sense and taking some precautions. In this issue’s feature, three experts offer their best advice for protecting against malpractice suits.

10 Certification | The value of certification to employers. Plus, CPSC designation to be phased out.

14 Perspectives | Environmental regulations and agriculture: A conversation with the USEPA ag counselor.

18 Technology | [Spray] tips for increasing your producer’s bottom line.

24 New Research | Controlling barnyardgrass with corn hybrid selection.

26 Regional Roundup | News from Canada East and U.S. Southern regions.

27 Tales from the Pits | The tale of the roustabout and the krotovinas.

28 Career Center | An invitation to join and take advantage of the many benefits of membership.

30 Self-Study CEUs | Earn 1 CEU in Crop Management and 1 CEU in Soil and Water Management.
No one wants to think about being sued for negligence. Unfortunately, it’s surprisingly common for soil scientists, crop advisers, and consulting agronomists to find themselves facing lawsuits, according to a trio of experts who spoke during the Annual Meetings of the American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America last fall in Long Beach, CA. California civil litigation attorney Dale Dorfmeier filled his talk with tales of the critical mistakes he has seen consultants make, including giving opinions on situations outside their expertise, failing to test those opinions by collecting data, or changing their opinions at the last minute. And even when consultants are doing the most conscientious and competent job possible, they are still at risk for litigation, added CPSS Pierre Bordenave, president and principal soil scientist with InterMountain Resources, an environmental consulting firm in Sandpoint, ID. It simply comes with the territory.

“The consulting business by its nature is risk. Being in business is a risk,” he said. Expert consultants are often called to assist in crisis situations, for one. They’re also expressly hired to render a decision on matters, and the need to make a decision puts you in the position of liability, Bordenave said.

That’s why he, Dorfmeier, and CCA Fred Vocasek, a nearly 30-year employee of Servi-Tech, the nation’s largest crop consulting firm, offered their best advice at the meetings for protecting against malpractice suits. There are no guaranteed ways to avoid litigation, the speakers said. But the chances of being sued can be substantially lowered by using common sense and taking some precautions. In this article, three experts offer their best advice for protecting against malpractice suits.
think we can manage it and minimize its effects.”

He went on to define malpractice as “a type of negligence, in which the professional... fails to follow generally accepted professional standards, and that breach of duty is the proximate cause of injury to a plaintiff who suffers harm.” The term is most frequently heard in reference to doctors, who take out malpractice insurance to defend against claims of negligence by patients. For other professionals, such as real estate agents, home inspectors, property managers, and consultants, the term “errors and omissions” is more common than “malpractice,” and they tend to carry errors-and-omissions insurance—also known as professional liability insurance—instead.

Wrongful acts

Regardless of the terminology, the upshot is that professionals who claim special skills or expertise are held to a higher standard of care under the law and can be sued for mistakes or “wrongful acts” that harm their clients. Vocasek further pointed out that professionals aren’t just liable for their own wrongful acts, but also for the mistakes committed by subcontractors, subordinates, and others who work on their behalf.

So, what are wrongful acts? It’s important to understand, first of all, that a wrongful act isn’t just any blunder; the term has specific meaning that goes to the difference between professional liability and general liability, Bordenave explained. Professional liability pertains to negligence in delivering professional services, where the damage to the client is usually financial. With general liability, in contrast, the harm is typically physical: For example, a consultant runs over somebody’s foot with a tractor or backs into a porch. General liability insurance covers claims resulting from these kinds of incidents, making it vital to carry. “But it will not cover you or defend you from any financial damages or any allegations of a wrongful act” that stem from exercising your professional expertise, Bordenave warned.

These acts include negligent action and inaction, misstatements or misleading statements, ineffective or inaccurate sampling procedures, and errors and omissions in record keeping. “That last one is a huge one,” Bordenave said. There’s also the failure to deliver promised services, as well as errors and omissions in how those services were provided.

Perception is reality

The tricky thing with all wrongful acts is that whether one actually occurred or not tends to be “in the eye of the beholder,” Vocasek said. 

“We can’t completely prevent malpractice. We can’t be bulletproof. But I think we can manage it and minimize its effects.”
“One thing that is painfully apparent is that perception is reality. It doesn’t matter what you think or what you perceived, the other person’s perception is reality.”

In other words, you might be acting in accordance with the very best practices of your profession, but a client or attorney still may not see it that way. As an example, Vocasek described the environmental investigations of soil nitrate levels that he began more than a decade ago. When he first started, he collected soil samples with standard field techniques that were efficient, inexpensive, and yet precise enough to yield solid data for agronomic management. However, he was soon required to switch to more exacting, time-consuming, and costly methods, even though he knew they wouldn’t enhance the data quality in the slightest. But he had entered the realm of regulators, who were used to detecting chemicals at part-per-billion concentrations, and “their perception was that agronomic sampling methods were malpractice,” Vocasek said. “Poorly done.”

His advice, therefore, is that agricultural consultants spend some time learning about the world they’re operating in—the client’s world, the attorney’s world, the regulator’s world—and then conduct their work according to “the language, perceptions, and realities of those different worlds,” he said. It might seem like a waste of time and money, but it’s much less expensive than defending against allegations of incompetence later on.

Unmet expectations

Similarly, sometimes clients perceive that a consultant acted wrongly simply because they were looking for a different outcome from the work. “There are actually a lot of lawsuits that occur not because the work was done poorly,” Bordenave said, “but because you didn’t meet the expectations of your client.” Maybe a client didn’t get the permit she wanted or was hoping for a certain return on investment that didn’t materialize. Many clients also seem to believe that good science is measured by the weight of the report, Bordenave said. “So when you present them with a clear, concise summary of information that is really more useful to them, it may not be what they were expecting.”

Fortunately, there are many steps consultants can take to protect themselves against unmet expectations, the most critical of which is a well-written contract. “Every client wants to hear the words, ‘I’ll take care of it.’ However, you need to make sure that you both have a full understanding of what ‘it’ is,” Bordenave stressed. “Because if you say, ‘I’ll take care of it,’ and he’s thinking one thing and you’re thinking another, you’ve placed yourself at a serious level of liability.”

In writing contracts for his own consulting business, Bordenave keeps them simple. While describing the scope of the work precisely, most of his contracts run just two pages. They always spell out a payment process and a fee schedule that establishes whether Bordenave will bill on a time-and-materials basis or complete the project for a set fee. And they further state that the terms apply only for a certain period of time. If a client sits on a contract or proposal for several months without signing it, new terms will need to be negotiated.

Bordenave added that he always asks his clients to sign his contracts,
even when they have their own for him to sign. And he never starts a project—much less finishes one—before a contract and fee are finalized because “what was critical and valuable when it was needed is all of a sudden of much lower value when it’s completed,” he said.

Dorfmeier, a partner with the law firm Petrie, Dorfmeier, and Morris in Fresno, CA, had additional advice for forensic agronomists and others who are asked by an attorney, insurance company, or grower to come in after a problem has developed, assess the situation, and render an expert opinion—possibly in court. It can be a delicate spot to be in, but simply following your scientific training can take you a long way, Dorfmeier said.

To begin with, consultants should always gather data to test and confirm their opinions—and collect those data in a scientifically valid way. Dorfmeier was involved in a case, for instance, in which a consultant was asked to evaluate the damage to a fruit crop from a fungal infection. The consultant did right by carefully recording the areas in the fruit orchard where he collected his samples. However, he only sampled spots where losses of fruit were noted by the grower, rather than sampling in a random pattern across the entire orchard. While his skewed analysis suggested that significant damage had occurred, a competing analysis indicated that the yield loss from infection wasn’t any worse than in an average year. The expert’s client subsequently lost the case due to this biased report.

Certifications and standards

He further advises that consultants maintain their professional certifications and registrations, which tell clients that you know what you’re doing and have something to lose if you don’t follow professional standards. Following professional standards can also offer protection; for example, by adhering to the standards of ASTM International (formerly, the American Society for Testing and Materials) in certain assessments, your work actually becomes defensible in court, he said. At the same time, getting certified or licensed as a soil scientist or crop adviser means nothing when it comes to running a business—the two take entirely different skills.

“A professional can really make some big business mistakes. So if you don’t have the experience or don’t have the feel for it, you need to get business training.”

Don’t be groomed or scripted

This leads to another common trap that expert witnesses fall into: Allowing themselves to be groomed or scripted. As a result, they end up basing their opinions and testimony solely on information they receive from their clients or clients’ attorneys—both of whom obviously
have a huge economic interest in the case. Telltale signs that you’re being groomed include being given access only to certain exhibits, deposition testimony, or opinions in a case; only those, in other words, that your client wants you to see. Or you may find yourself having to disregard certain evidence because it conflicts with the client’s version of events. Not that experts should ignore completely what a client says, Dorfmeier noted. “But like any good scientist, you would say ‘this is a hypothesis’ that needs to be verified objectively by consulting the literature and gathering data.” Failing to form an independent opinion means “you’re not giving your client good service,” he added, “and you’re not meeting the legal standards of an expert.”

So what is the proper basis for forming a legal opinion? Expert witnesses can base their opinions on subjects (for example, soil science) that are beyond the experiences of ordinary, lay people, so long as certain conditions are met. Number one, the information must be truly helpful to the jury in understanding the case; otherwise the judge will throw it out. Number two, it must be based on evidence that is reasonably relied upon by other experts in the field, such as DNA tests, field trials, diagnostic methods, bioassays, personal observations and the scientific literature. “As long as experts in your particular area use these tools, and that’s what you rely on to form your opinion, you’re okay,” he said.

The chances of unintentionally forming a biased opinion can be further reduced by following methodical evaluation processes, such as those outlined in the article, “Assessing Plant Problems in Cropping Systems: A Systematic Approach,” by Sarah Walker and Tim Schubert of the Florida Department of Agriculture and Consumer Services. Most importantly, always remember to “stay within your area of expertise,” Dorfmeier warned. Nothing gets consultants into hot water quicker than trying to give expert opinions on subjects in which they aren’t truly an expert.

Keep records and carry insurance

Still, all the care and precautions in the world won’t necessarily keep you from being sued, which means it’s critical to keep meticulous records of everything you do in your practice, Vocasek advised. This includes the samples you take, the emails and letters you write and receive, the analyses you perform, and the conclusions you draw. This way, you’ll be able to reconstruct the details of a situation, the logic you followed in your work, and the decisions you made, should a legal challenge arise later on.

It’s also wise to carry professional liability insurance, Bordenave added—and then be reluctant to use it. If you make a dumb mistake that ends up costing your business $3,000, pay it and move on, he said. Professional liability insurance is meant to protect you from the catastrophic losses you could incur in the face of a major lawsuit, not from the minor glitches that can happen when you or an employee make a mistake. And even if you never end up using it, liability insurance can still pay dividends in the form of less worry and lost sleep over your job. The value of that to you and your business? Priceless.
The value of certification to employers

By Luther Smith
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What does value mean to you? Worth, importance, cost, price, and significance are some of the synonyms that come to mind. Has a client or employer ever told you how much you’re worth to their business? Now, I believe everyone has significant value and a purpose for their life beyond money or taking up space, but that is a discussion for another day. I’d like to discuss the value of being professionally certified to your employer or clients.

The majority of the CCAs, CPAs, and CPSS/Cs work for someone or are employed by a business of some type. In many cases, the business supports the individual’s certification through reimbursement of fees and time on the job to earn continuing education and has incorporated it into the corporate culture—meaning, it is required to be employed and you won’t advance without it. So why would a business invest in an employee to be certified, and what is the value or return on investment for that business?

A short answer might be the business owner/manager wants to provide the best customer service possible, knowing that it will lead to more customers/clients, more sales, and ultimately increased profits. To provide the best service, you need the best employees who deliver the service. Part of being good or even great at what you do is being well informed (knowledgeable about the subject matter you work with), skilled, and having integrity. Surveys have indicated that farmers want to work with people who are technically sound (knowledgeable in their field), honest, and will follow through. Those qualities would probably apply to any type of business relationship, not just farming.

A CCA, CPAg, or CPSS adds value for their employer by improving the bottom line. Pretty simple really—bring in more revenue to the company than what it costs the company to employ you. If you do that, you are probably employed for as long as that is being done.

The employer’s challenge is finding the best people to fulfill the mission, and certification helps do that. Certification programs establish standards for the profession by an independent organization (e.g., the American Society of Agronomy and the Soil Science Society of America) that can be used to evaluate the abilities of individuals to perform. Employers, by using the certification designation, have a tool to evaluate (potential) employees. There are other tools, but they are probably not as highly integrated as certification or licensing programs.

You become certified if you meet the standards—exams, experience, education, and ethics. Certification requires testing through two comprehensive exams based on performance standards; experience, education, and positive references; and signing a code of ethics. Think of the last person you hired. What did you require them to do, or what did you do before making the decision to hire them? The certification program has probably done most of it for you.

As an employer, you can rely on the certification standard to qualify people you want to employ. Naturally, it is not a perfect system, and there is a lot to be said about finding the right fit for the businesses’ culture, but certification prequalifies people who would have a higher rate of success. It manages or reduces your risk exposure in the employment process and long term for the business.

Certified professionals continue their education as required by the standards. As I mentioned earlier, it takes knowledgeable/technically competent people to provide excellent service. You do that by continually learning and upgrading your knowledge and skills. Certification requires 40 hours of continuing education every two years. It’s a driving force to keeping highly talented employees and reducing your risk to exposure. Just think of how
fast things have changed in production agriculture. Would you really want someone still working for you that has not earned any continuing education for the last 5, 10, or 20 years? If they have not, are they really delivering the best information to their customers/clients? Continuing education helps to keep an individual at their best.

Understandably, the continuing education component can be viewed as a cost for most companies because it is not inexpensive. Cost is part of the definition for value, but it can imply a negative connotation. It is really an investment in the employee, so that they will do their job better and be a better person. From a business perspective, it will lead to higher performance—more sales, better service, and ultimately, more revenue and increased profits yielding a positive return on the educational investment. Discussions with clients have indicated that certified professionals seem to have a higher level of confidence, on average, yielding higher performance, and clients view the continuing education requirements as a major reason why they want to work with a certified person over someone who is not certified.

Certification update

CCA candidate or associate professional status

If you are considering certification but may not yet have the required experience, you can still apply for the “candidate” CCA status and the “associate” CPAg or CPSS status. Each option allows you to meet all of the requirements except experience. It gets you started towards professional certification and recognition in the profession. It’s important to clients/customers and employers.

Students don’t have to wait until they gain the necessary experience to apply. Taking the exam in your senior year is probably the best time to do it, and it indicates to future employers that you are serious about the profession.

Retired status

If you are about to retire, you can apply for retired status. It keeps you connected to what is going on in the profession through Crops & Soils magazine and helps to maintain your professional network. Contact your certification representative for more details.
Over the next few months, I will be letting you know of changes that the Soils Certifying Board is making to the Soil Science Certification Program. One of these changes has to do with the types of certification that are available on a national level. Currently, an individual can be certified as a Certified Professional Soil Scientist (CPSS), a Certified Professional Soil Classifier (CPSC), or both. The two certifications are essentially the same and have many of the same requirements, including using the same application, exams, and continuing education program. The difference between the CPSS and CPSC is twofold:

1. Both the CPSS and CPSC require 15 semester-hours of soil science coursework; however, five of the hours for the CPSC must be in soil classification.

2. CPSC must show five years of cumulative professional experience, specifically in the practice of soil survey and classification.

The Soils Certifying Board has decided to phase out the CPSC for several reasons. The board sees a need to house all soil science certifications under one title; that being the CPSS. This is important because the profession tends to be perceived as “splintered” by many other professions and the general public. This hurts the soil science profession and our attempts to talk with other professions and gain the support of legislators for licensing, certification, or in the designation of who can do select types of work within state statutes and rules or ordinances. The fact is that we are all soil scientists; we just have different areas of expertise. We practice within those areas of expertise per our code of ethics.

Additionally, we do not have separate exams for different areas of expertise within the profession of soil science. The reason for this is because as soil scientists, we really need to understand all of the basic areas of soils in order to interpret the issue(s) and come up with solutions. The exams are national and all aspects of soil science are represented. We do periodically poll soil scientists across the U.S. and ask what percentage of the exam should be attributed to each major area of soil science (chemistry/miner-
alogy, fertility, physics, genesis/morphology/classification, biology/biochemistry, and land use). We try to stay close to those percentages. Last time the poll came back, soil physics was the area most soil scientists thought should be emphasized. Typically, the polls reveal a pretty even split of emphasis among the areas.

As a soil scientist, you need to be able to be conversant in all major areas of soils. Everyone is stronger in certain aspects of soil science depending on their expertise, but soil science is a science where you cannot just study/understand one aspect since they all influence one another. For example, while I might classify myself as a soil physicist, it doesn’t mean that I think there should be a separate CPSP for soil physicists. However, it would not stop me from referring to myself as a soil physicist with a CPSS.

There are several things to keep in mind with this upcoming change:

- This is for the Certification Program only; it does not apply to how licensed soil scientists are referred to in their respective licensing states.
- If you currently hold a CPSC, you will not lose that designation.
- Those who are in the process of obtaining a CPSC may continue to do so. No one will be allowed to start the process after Dec. 31, 2011.
- If you hold both the CPSS and the CPSC, please be aware that if you keep both, you will be paying for two renewals because you hold two certifications. This is not a change from current policy, just a reiteration of what is required.
- The Soils Certifying Board will be sending out forms to all current CPSCs/APSCs in the next few months to provide a mechanism by which those individuals can tell us if they:
  - Want to continue as a CPSC or on the CPSC track.
  - Want to convert from a CPSC to a CPSS or convert to the CPSS track.
  - Want to continue holding both certifications.

Please feel free to contact me with questions about this change at dferris@sciencesocieties.org.
Farmers are at the intersection of environmental issues and the demands to produce food, feed, fiber, and fuel. The USEPA is charged with protecting America’s natural resources, and a key coordinator among USEPA, USDA, and the farming community is the USEPA’s agricultural counselor to the administrator, Lawrence Elworth. *Crops & Soils* magazine recently interviewed Elworth to learn more about the agency’s thinking and positions on the intersection of environmental regulations and agriculture.

The USEPA is tasked with protecting the nation’s food, water, land, and air. As ecosystems face greater pressure due to increasing population growth, the challenges of enforcing environmental regulations are expected to increase in coming years. Farmers, because they manage large parts of the landscape, are at the intersection of environmental issues and the demands to produce food, feed, fiber, and fuel. A key coordinator among USEPA, USDA, and the farming community is the USEPA’s agricultural counselor to the administrator, Lawrence Elworth.

Elworth has responsibility as senior adviser to USEPA Administrator Lisa Jackson on anything related to agriculture, helping her make the best decision possible on agency regulations related to farming. Prior to the USEPA, Elworth worked as a fruit grower and orchard manager for 15 years. After that, he worked for a fruit checkoff program and the Clinton Administration. He also worked for a non-profit to develop economically feasible ways to solve environmental problems, while supporting farms and helping them to stay in business.

In his current position with the USEPA, he has three areas of responsibilities: (i) to understand the impacts and opportunities of environmental/regulatory issues on agriculture and to be part of the discussion in the administrator’s office about regulatory decisions; (ii) to be in constant contact with USDA both at the secretary level and also within the various agencies, such as NRCS; and (iii) finally, to stay in contact with a large cross-section of farmers, researchers, agricultural industry personal, and consumers and facilitate their communications with the USEPA.

**Informing the process**

When asked how CCAs can understand and be involved in the process of USEPA regulatory decision making, Elworth said, “CCAs need
to understand what the regulatory decisions are and how they are being made and ... they need to understand what information is critical for making a good decision. A good decision is based on the best possible information that relies on good science and that adequately looks at all of the considerations for the environment and agriculture going forward.

“Understanding how they can best be involved will take a fair amount of homework. CCAs should understand what kind of information is important and how and when the agency needs that information in the process, so it can be presented in the making of a timely decision.... If the USEPA is going to make a decision, it needs to have science to base it on, and it has to be good science and verifiable.”

As an example of informing the process, Elworth related an anecdote of a scientific organization that would send its annual meeting proceedings to the agency, and although it was excellent research, it was not timely or targeted in terms of the USEPA’s decision-making process. Groups and individuals that want to be involved in the process should take the time to be aware of specific environmental issues as these issues become important to the agency.

To illustrate how groups can inform the USEPA, Elworth said that while in the private sector, he did a lot of work with Georgia peach growers on integrated pest management; the growers were concerned that the agency was making decisions without understanding how peaches were raised. So, the group set up a seminar for researchers to come in and present to the USEPA how peaches are grown. It was a very useful workshop for the agency regulators, Elworth said. Not only did it give them information, but it also created connections between regulators and researchers working in this area.

Doing this, for example, with the USEPA’s SITE program or water and air offices before a regulatory situation is in place is helpful for two reasons: the agency’s thinking about an issue is informed early on, and once the agency is in a regulatory decision-making process, its actions are governed by a fairly strict set of rules set forth by the Administrative Procedures Act on how the agency can communicate...
with stakeholders and what kinds of advice the agency can take.

But in order for a group to have additional impact on the process, it takes some effort on the part of industry and research sectors to figure out what the agency needs.

“Taking the time for groups to come to the agency with informative science at the right time is incredibly useful,” Elworth noted. “The end goal is having an agriculture production system that works and does not create problems for the environment; those decisions are made on a farm-by-farm basis. What one would suggest to a dairy farm is not what one would suggest to a corn and soybean operation, or the same advice would not be given in different locations.”

Valuing ecosystem services

Elworth indicated that the USEPA is “very interested” in environmental markets. As an example, he cited the $1.3 million grant USEPA and USDA have with the Electric Power Research Institute (EPRI) to develop a regional water quality trading program in the Ohio River Basin. The program employs a market-based approach to enable facilities facing high pollution control costs to buy reduction credits from another facility or entity with lower pollution control costs. The goal is to achieve the same or even better water quality improvements more efficiently and at lower costs.

Within the Ohio River Basin, many sources, including power plants, wastewater treatment plants, urban stormwater, and agriculture impact water quality. Due to the many sources of impacts and high nutrient loading in some Basin areas, improving water quality requires collaboration among national and state agencies, power plants, wastewater treatment plants, farmers, environmental groups, and others.

The aim of the water quality trading project is to implement a market-based approach to achieving water quality goals for nutrients such as phosphorus and nitrogen through programs that allow permitted emit-

“I think we are at the point where it is important to look at the long-term sustainability of our farms… and being able to retain the productivity of the soil, its ability to hold water, and the availability of water is becoming critically important.”

To participate, CCAs need to keep themselves informed about environmental issues both locally and nationally. They should also be prepared to bring their in-field technical expertise and scientific knowledge to the USEPA.

“I think we are at the point where it is important to look at the long-term sustainability of our farms, both from a production point of view and environmental point of view, and being able to retain the productivity of the soil, its ability to hold water, and the availability of water is becoming critically important.”

1 USDA-NRCS administers the Chesapeake Bay Watershed Initiative. More information is available at www.nrcs.usda.gov.

2 More information about the USEPA’s advisory committee—Farm, Ranch, and Rural Communities Committee (FRRCC)—can be found at www.epa.gov/ocem/frrcc/index.html.

With this project, USEPA is addressing watershed protection through targeted watershed grants for water quality trading or other market-based projects to reduce the hypoxic zone in the northern Gulf of Mexico. The USDA is addressing agricultural credit calculation tools for water quality and greenhouse gas trading under a NRCS Conservation Innovation Grant. The project will focus on nitrogen and phosphorus discharges from sources within the Ohio River Basin and is expected to result in cost-effective water quality improvements throughout the region, which includes portions of Illinois, Indiana, Kentucky, New York, Ohio, Pennsylvania, Virginia, and West Virginia.

The USEPA is also involved with the USDA on a Chesapeake Bay Watershed Initiative. This initiative strengthens coordination and cooperation between the two federal entities to help agricultural producers improve the environment in the Chesapeake Bay Watershed. The Chesapeake Bay watershed1 has nearly 17 million residents and covers more than 64,000 square miles. It is the largest estuary in the United States and is critical to the region’s economy, culture, and outdoor recreation. Twenty-five percent of lands within the Bay Watershed are used by agriculture for crops and pasture.

Among the environmental challenges in this watershed are changing landscapes, contaminants, air pollution, sediment, and runoff. Eligible landowners can use available technical and financial assistance to address soil erosion, sedimentation, and excess nutrients in streams and waterways, as well as other related ...
natural resource concerns such as air quality, wetlands, wildlife habitat, and forestry.

A more overarching initiative that the USEPA is involved with in terms of valuing ecosystem services is the National Ecosystem Services Partnership. The partnership involves individuals and organizations, both public (federal, state, and local government) and private (business, foundations, NGOs, and academia). It has a goal of creating and communicating useful and credible information to improve public and private decisions affecting the sustainability of ecosystem goods and services. The goal is to develop systems in which ecosystem goods and services are valued and considered in public and private decisions.

Methods the group uses to reach its goal include building a network of researchers, practitioners, and policymakers that establishes a direct and interactive connection between the research community and the needs of user groups; increasing communication and collaboration among public and private organizations working on ecosystem service policy and practice; creating and evaluating data, models, policy instruments, and management approaches on the biophysical basis of ecosystem service valuation; and, finally, developing the policy and market frameworks for sustaining ecosystem services.

“We are used to looking at this country and viewing our primary competitive advantage as our technological capacity, and that is critically important,” said Elworth, “but when you look at agriculture resources in the U.S., compared to anywhere else in the world, I can’t think of any competitive advantage that is greater or more important.

“However, I think it is absolutely essential that we value these resources in a way that gives us the ability to keep them as productive working landscapes; otherwise, we will be looking for food.”

Translating regulations into action

A USEPA activity that is more directly focused on agriculture is the Farm, Ranch, and Rural Communities Committee (FRRCC). FRRCC is an independent committee that advises the USEPA on a wide range of environmental issues. Its members provide useful insight to the agency—on topics such as non-point source water pollution, agricultural air issues, and environmental markets—as it crafts environmental policies important to agriculture and rural communities.1

The group increases awareness and understanding within the USEPA of agricultural impacts and benefits to human health and the environment; works with the agricultural sector—including production, processing, and distribution—in developing and demonstrating environmental protection solutions that express the value of farmland environmental stewardship activities to the public; coordinates research and technology development and transfer so the needs of agriculture and the USEPA can be more efficiently met; and identifies existing environmental measures and develops new ones, where appropriate, to demonstrate environmental improvement related to agriculture.

When it comes to making environmentally sound improvements though, Elworth noted that farmers don’t pass on the costs. “No one offered us more per bushel for making good environmental decisions,” said Elworth, recalling his days as an orchard manager. “So the payoff had to be in the long-term benefits, and we had to see benefits in the payoffs in that year’s crop, either in yield or quality of the crop.”

Elworth discussed how farmers, through conservation programs, provide value and a service to the wider community.

“The American public expects to have clean water, and that is clean water that everyone enjoys. There is an enormous public benefit for farmers to keep soil on the land, and make sure that we have healthy watersheds, so I think that it is clear why we have conservation programs to help pay for those watersheds.

“So with the public benefit that we all enjoy and that falls on farmers to do,” said Elworth, “we should help those farmers realize some economic support in doing activities for a clean watershed.”

Getting involved in FRRCC and its activities is another way CCAs can impact USEPA’s regulatory process.

A message to CCAs

When asked about the role of CCAs in environmental issues, Elworth related how they bring science into the process and assist in translating that science for farmers so that it can be applied to field operations.

The USEPA also encourages CCAs to connect with both their regional and state USEPA counterparts. For example, CCAs and their clients could get involved in regional initiatives such as grant programs that promote the transition to reduced-risk pest management practices in agriculture to protect human health and the environment.

“The more they are able to understand the environmental issues we are in and as they look for ways to be constructively involved with the USEPA,” said Elworth, “the USEPA will be glad to work with them. They can bring real-life data to the discussion, and they can be an accurate source of good scientific information that is very important to the USEPA, and we are counting on them to continue their work with farmers.”
The spray tip may be the least expensive, yet most important component of the precision sprayer. It is a major factor in determining the amount of spray applied to an area, uniformity of application, coverage obtained on the target surface, and amount of potential drift. At the 2011 Farm Show in Raleigh, NC in February, Brian Mathis from TeeJet Technologies reviewed some of the basics of nozzle use and technology to help producers increase their bottom line.

“Spraying isn’t what it used to be. Producers used to pick a nozzle, pressure, and speed, do their best to stick to it, and spray. But things have become a little more complicated these days with all of the electronics available such as automatic rate controllers, guidance systems, and sensors. These tools can help increase your client’s bottom line and reduce negative environmental impacts, according to Brian Mathis, Southeast Regional Manager for TeeJet Technologies, but without the right spray tips in place, the sprayer will never reach its precision capability.

“The spray tip may be the least expensive, yet most important component of the precision sprayer,” Mathis said during a talk he gave at the 2011 Southern Farm Show in Raleigh, NC in February. “You can have all those nice electronics, but if you screw up at the nozzle, at the exit point of delivery of that chemical on the ground, you’ve compromised the whole precision sprayer.”

The nozzle is a major factor in determining the amount of spray applied to an area, uniformity of application, coverage obtained on the target surface, and amount of potential drift. It forms the spray pattern and determines the application volume at a given operating pressure, travel speed, and spacing.

The spray nozzle controls the flow rate, which is affected by the speed you drive. If you double your speed, you have to double your flow rate if you want to maintain the same application rate, Mathis explained. Automatic rate controllers can help with this.

“The automatic rate controller can help that system know what a gallon is and what an acre is so that it can properly allocate your gallons to your acres,” Mathis said. “The other variable in that formula is the operator. The rate controller can only do the math, but he’d better drive that width. And that’s where the guidance systems and the autosteer come into play.”

For most conventional spray tips, the flow rate has a square root relationship with pressure. To maintain the same rate per acre, if you double your speed, your flow rate must dou-
ble, but your pressure quadruples. This wide range of spraying speeds and resulting pressures can lead to drifting problems if spray droplet size is not understood and managed. So if operators plan on spraying at various speeds, they should make sure they have the appropriate size and type of nozzles to match their range of changing flow rates, pressures, and droplet sizes.

Nozzles break the liquid into droplets, which are measured in microns (1/1,000 of a millimeter). A human hair is about 100 microns. A nozzle will spray a wide range of droplet sizes, from real fine to real course. So, not all droplets coming out of a 300-micron nozzle will be 300 microns, but the median value should be 300. Selecting nozzles that produce the largest droplet size, while providing adequate coverage at the intended application rate and pressure, can minimize drift (Fig. 1 and 2).

“You can have your cake and eat it too,” Mathis said. “You can have coverage and drift control, but I’ll be the first to admit that you can take droplet sizes to one extreme or the other and not achieve the desired coverage or control. In other words, if it’s too fine of a droplet for this herbicide or if it’s too course of a droplet for that fungicide, you won’t get the performance you want. But there is a range, and if you get right where you need to be in that range, you can get both.”

There is an international standard for classifying nozzles according to colors and nomenclature. The color can tell you things like the nozzle flow capacity at a reference pressure (Fig. 3 and Table 1) while the nomenclature printed on the nozzle can tell you the brand name, nozzle type and material, flow capacity, and spray angle (Fig. 4).

“So a lot of times if we’re talking on the phone, I’ll ask what color tip are you using? You might not be able to read the tiny print on that nozzle, but if you tell me it’s a red one, I’ll at least know whether or not that’s the right size flow rate nozzle for the desired speed, pressure, and application rate.”

While there are many different types of nozzles (Fig. 5), the most common type used in agriculture is the fan nozzle. It’s is widely used for spraying pesticides—both banding (over and between rows) and broadcast applications. The standard flat-fan nozzle normally operates between 30 and 60 psi, with an ideal range of 30–40 psi. The even flat-fan nozzles apply uniform coverage across the entire width of the nozzle’s spray pattern. They are used for banding and should not be used for broadcast applications. The bandwidth can be controlled with the nozzle-release height and the spray angle.

The extended-range flat-fan nozzle provides fair drift control when operated at less than 30 psi. This nozzle is ideal for an applicator who likes the uniform distribution of a flat-fan nozzle and wants lower operating pressures for drift control. Because extended-range nozzles have an excellent spray distribution over a wide range of pressures (15–60 psi), they can be used on sprayers equipped with flow controllers.

The special-feature fan nozzles, such as the off-center fan, are used for boom-end nozzles so the swath is uniform end to end vs. tapered at the edges. The twin-orifice fan produces two spray patterns: one angled 30 degrees forward and the other directed 30 degrees backward (Fig. 5). The droplets are small due to the atomizing by two smaller orifices. The two spray directions and smaller droplets improve coverage and penetration—a plus when apply-
ing post-emergence contact herbicides, insecticides, and fungicides. Because of the small spray droplets, drift is a concern. To produce “fine” droplets, the twin-orifice usually operates between 30 and 60 psi.

Special designs such as “air induction” and “pre-orifice” designs are available to reduce drift (Fig. 6). Air induction nozzles have a hole in the side or in the shaft in the bottom, which inducts air into the passageway as the product travels through, helping to form larger droplets. With the pre-orifice design, when the product moves through the small pre-orifice chamber to the larger adjacent chamber, the pressure drops.

“Pressure drop makes my droplets a little bit bigger, and I get a little better drift control that way,” Mathis said. “It’s kind of neat how these nozzles are built so that we get the droplet size that we want in the nozzle.”

No one nozzle works for every situation, Mathis explained, because no one chemical does either.

“The chemical mode of action is a major factor in nozzle selection. If it’s a contact fungicide, it’s going to treat right where it touches—it may not move very far on that foliage. A locally systemic fungicide may move within the leaf. A translocated mode of operation means it will be applied and then translocate into the root and kill the whole plant. We have to know what we are applying to know what nozzle to use.”

If you’re using a contact chemical, you might want some pretty fine droplets to make sure you have a bunch of those droplets covering a lot of area on the plant, Mathis said. But you might be able to get away with a course droplet with a translocated chemical if it hits the plant, gets sucked in, and travels all the way to the root and kills the plant.

“I’ve had farmers say to me, ‘Man I know it’s not working unless I see fog behind me,’” Mathis said. “He’s saying he wants real fine droplets everywhere to make that particular chemical work. He would never do that same thing with a herbicide that’s going to kill everything and be a driftable problem to his neighbors. It’s not one size fits all, and it’s go-

| **Fig. 3.** VisiFlow color coding standard for nozzles. Source: TeeJet Technologies. |
| **Fig. 4.** The nomenclature printed on the nozzle can tell you the brand name, nozzle type and material, flow capacity, and spray angle. Source: TeeJet Technologies. |

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### Table 1. Droplet-size classification chart. Source: Virginia Cooperative Extension Fact Sheet 442-032—“Nozzles: Selection and Sizing.”

<table>
<thead>
<tr>
<th>Droplet category†</th>
<th>Symbol</th>
<th>Color code</th>
<th>Approximate VMD range‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very fine</td>
<td>VF</td>
<td>red</td>
<td>&lt;145</td>
</tr>
<tr>
<td>Fine</td>
<td>F</td>
<td>orange</td>
<td>145–225</td>
</tr>
<tr>
<td>Medium</td>
<td>M</td>
<td>yellow</td>
<td>226–325</td>
</tr>
<tr>
<td>Coarse</td>
<td>C</td>
<td>blue</td>
<td>326–400</td>
</tr>
<tr>
<td>Very coarse</td>
<td>VC</td>
<td>green</td>
<td>401–500</td>
</tr>
<tr>
<td>Extremely coarse</td>
<td>XC</td>
<td>white</td>
<td>&gt;500</td>
</tr>
</tbody>
</table>

† American Society of Agricultural & Biological Engineers Standard 572.
‡ VMD, volume median diameter. It is a value where 50% of the total volume or mass of liquid sprayed is made up of droplets larger than this value, and 50% is made up of droplets smaller than this value. Reported VMD ranges vary widely, based on the type of laser analyzer used.

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ing to be a matter of what chemical you’re applying and how you’re going to make that chemical effective. And droplet size is just as important as the actual flow rate, pressure, target, and pattern. It’s a puzzle, and you’ve got to put all those pieces of the puzzle together.”

Another piece of the puzzle is the spray angle on the nozzle. The most common spray angles are 65 degrees, 80 degrees, and 110 degrees. The angle you use depends on the height of the nozzle from the target, which may be the top of the ground, growing canopy, or stubble. Recommended nozzle heights for flat-fan nozzles during broadcast application are given in Table 2. Use 110-degree nozzles when booms are less than 30 inches high with 30-inch nozzle spacing; use 80-degree nozzles when the booms are higher. Although wide-angle nozzles produce smaller droplets, the lower boom height reduces the drift potential more than the corresponding decrease in droplet size. The nozzle spacing and orientation should provide for 100% overlap at the target height. Most fan nozzles should not be oriented more than 30 degrees back from vertical.

Nozzles eventually wear down and need to be replaced. Their wear rates depend on the tip material, chemicals used, water quality, operating pressure, and care taken when cleaning them out. Mathis said when measured flow rates are 10% over the nominal flow rate, it’s time to replace your tips.

“I always get asked, ‘How often do I need to change my nozzles?’ There’s not a good answer to that,” Mathis admitted. “What we suggest is that you get a calibration jug, take a brand new nozzle, and test it at, say, 40 psi to see what your [default output] is that all of the rest of your nozzles should be compared to…. The 10% rule is where you really start noticing uneven wear from tip to tip. It’s not a science—it’s just a good indicator.”

Should a nozzle become clogged, it is best to blow out the dirt with compressed air or use a soft-bristled brush such as a toothbrush. It’s important to wear chemical-resistant gloves when handling and cleaning nozzles to reduce pesticide exposure and never use a wire or nail as a cleaner because the orifice can be easily damaged.

Portions of this report were based on the Virginia Cooperative Extension Fact Sheet 442-032—”Nozzles: Selection and Sizing.”

<table>
<thead>
<tr>
<th>Spray angle</th>
<th>20-inch spacing overlap</th>
<th>30-inch spacing overlap</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50%</td>
<td>100%</td>
</tr>
<tr>
<td>65</td>
<td>22–24</td>
<td>NR†</td>
</tr>
<tr>
<td>80</td>
<td>17–19</td>
<td>26–28</td>
</tr>
<tr>
<td>100</td>
<td>10–12</td>
<td>15–17</td>
</tr>
</tbody>
</table>

† NR, not recommended.
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Barnyardgrass is a summer annual grass weed with a global impact on corn production. Corn yield losses due to barnyardgrass competition have been estimated to be up to 45% or more. It can also be a serious weed pest in rice, soybean, sugarbeet, and cotton. Integrated weed management (IWM) techniques can be used for controlling barnyardgrass in corn.

High populations of this weed can occur in fields of continuous corn. A high population of barnyardgrass may attract an infestation of armyworms, which move from the weed to feed on corn leaves. The success of barnyardgrass as a weed pest is attributable to many factors including a long germination and emergence period, seed germination under a wide range of environmental conditions, rapid growth and development, and vast production of easily dispersed seeds.

There are a variety of herbicide options for control of barnyardgrass in both preplant and postemergent situations. In a tolerant corn crop, glyphosate can be applied over the top until the V8 stage for grass control. Under drought stress conditions, barnyardgrass can be difficult to control.

IWM helps growers reduce the development of resistant weeds and mitigate the social, health, and environmental impacts of agriculture. Using competitive crops and cultivars is an important component of IWM that is useful in both conventional and organic (and other low-input) farming systems.

To develop efficient herbicide use and provide a logical basis for the development of an IWM system, information on the critical period of weed control is essential. In quantitative studies on weed-crop competition, weed growth relative to crop growth has a large impact on weed losses and is more important than other parameters, such as weed density, in determining the need for postemergence control. Also, information regarding the critical period of weed control in corn may lead to less reliance on the use of residual herbicides and more reliance on well-timed postemergence herbicides.

To date, and especially in Europe, there is little information on the crit-
ical period of weed control in grain corn. In Mexico, a weed-free period of 50 days from seeding was required to prevent corn grain yield loss. In the United States, a weed-free period of four weeks was required to prevent corn yield losses resulting from johnsongrass. In Canada, similar studies determined weed-free requirements from the 3- to 14-leaf stages of corn development.

There is also little information available on the effect of weed species and the timing of emergence that may result in minimal agronomic impact, that is, few or no weed seeds produced and little or no crop yield loss. Reproductive output of barnyardgrass is also highly variable, while information on seed return as influenced by time of emergence is required to predict future population changes.

No studies have evaluated the impact of time of barnyardgrass emergence on yield components of several corn hybrids and barnyardgrass growth and reproductive output.

A study in the January–February 2011 issue of *Agronomy Journal* offers some essential insights in the development of an IWM strategy for controlling barnyardgrass in corn. Scientists at the Laboratory of Agronomy, Faculty of Crop Science, Agricultural University of Athens in Greece found that despite the high competitiveness of barnyardgrass, careful selection of a competitive corn hybrid and control of barnyardgrass through at least the V2 to V4 growth stage could dramatically reduce grain yield loss and weed seed production. The objectives of the study were to (i) determine the effects of barnyardgrass emergence date on biomass and fecundity of barnyardgrass and corn yield components and (ii) evaluate the competitiveness of four corn hybrids under the field conditions of western Greece.

**Corn hybrid, barnyardgrass emergence key**

The researchers found that barnyardgrass biomass, tillers, canopy area, and seed production were significantly affected by the date of barnyardgrass emergence. Barnyardgrass plants emerging with corn produced 1,010 to 1,305 seeds per plant compared with only 112 to 240 seeds from plants emerging after the V4 growth stage. Maximum corn grain yield loss ranged from 24 to 34% for early emerging barnyardgrass, and less than 9% yield loss occurred from barnyardgrass seedlings emerging later than the V4 growth stage. Corn hybrids with rapid initial growth rate were more competitive than the other hybrids.

According to the researchers, the study results indicate that both corn hybrid and time of barnyardgrass emergence relative to corn growth stage were fundamental in determining the outcome of the competition between corn grain yield and barnyardgrass growth and fecundity.

In fields of Greece infested with barnyardgrass, a delay of about 7 to 12 days in barnyardgrass emergence, which could be accomplished by early herbicide application or mechanical weed control, could reduce grain yield loss by about 10 to 15%.

Another interesting finding of the study has to do with the fact that keeping the field free of weeds through most of the early development stages seems crucial for optimal corn growth, while late barnyardgrass emergence does not reduce grain yield. However, there are still many seeds produced by the barnyardgrass plants, which can easily contaminate the field and preserve the seed bank for the next growing season.

“Corn grain yield and barnyardgrass vegetative growth and reproductive ability were significantly affected by the competing corn hybrid and the barnyardgrass emergence date,” says Dr. Ilias Travlos, lead author of the study. “Consequently, selection of corn hybrid could be an important weed management tool for corn growers, especially combined with several cultural practices, but further research is required to rank the competitiveness of more corn hybrids in several soil and climate conditions.

“Our approach confirmed that keeping our corn fields free of barnyardgrass through at least V4 and selecting a corn hybrid with a relatively high first growth rate could significantly reduce grain yield loss...”
Sclerotinia is the most serious disease of canola and very difficult to predict. Losses of both yield (over 30% in some cases) and quality have been documented due to sclerotia in harvested seed. No varieties of canola are resistant, so fungicide application is the only means growers can use to protect their crop when weather conditions favor infection.

Canola has a higher requirement for boron than most field crops and is an essential micronutrient in the formation of new plant tissue and in flower development, seed set, and seed quality. A 2010 greenhouse study conducted by the University of Guelph indicated that foliar boron may help mitigate the negative effects that high temperatures can have on pollination of canola. In a 2007–2008 research trial, yield of canola was sometimes improved by application of foliar boron at early flower. Boron deficiency in canola has not been documented in Ontario.

A three-year, on-farm strip trial was completed to evaluate the benefit to yield and seed quality of managing canola more intensively with foliar application of boron alone and in combination with fungicide and insecticide. A total of 28 trials were conducted at 11, 8, and 9 farm sites in 2010, 2009, and 2008, respectively. In each year, two of the sites were located in northern Ontario. Each site included two replications of foliar treatments of boron: fungicide + boron and fungicide + boron + insecticide applied at the 10–30% flower stage. Fungicide and insecticide were applied at the recommended labeled rate. Boron was applied with the other products at rate of 0.3 lb/ac (actual). Soil samples were collected prior to planting to measure soil boron, and plant tissue analysis was completed by collecting the uppermost open leaf at the beginning of flowering. The flowering stage of canola was noted prior to fungicide application.

2008–2010 summary

Weather was favorable for spring canola in all three years, with moderate temperatures (59–82°F) and adequate rainfall during the growing season. The average yield of trials over the three years was 54 bu/ac with a range of 34–72 bu/acre, well above the long-term average of 36 bu/acre.

Over the three-year trial, foliar boron applied at early flower increased yield by 94 lb/ac (or 1.8 bu/acre, a 3.5% increase) over the check (Fig. 1). Boron improved yields 78% of the time and returns 40% of the time (cost of Can$5.50/ac + $10/ac application). The boron soil test is not a reliable indicator for the need for boron.

There was a visual difference in sclerotinia infection between the check treatments and those receiving fungicide. Growers sometimes commented that fungicide-treated plots were easier to combine with noticeable differences in stem infection. The visual differences in sclerotinia infection did not translate into a consistent improvement in yields or returns from fungicide application. During the three yields of the trials, most sites had lush growth and canola yields were excellent. On average over the three years, fungicide application improved yield 67% of time and returns only 15% of the time (canola price of $390/ton and a fungicide cost $24/acre + application). Application timing was generally at the 20–30% flower stage but
The tale of the roustabout
and the krotovinas

A note about this issue’s column from Dawn Ferris, Soil Science Program Coordinator for the Soil Science Society of America: “I am happy to announce that we have a guest author for this edition of Tales from the Pits! It’s great to see people writing about their “tales” and submitting them; I already have another guest author for the next issue. I promised when I started this column that the author could remain anonymous, and this author has chosen to do just that. Keep those tales coming!”

Practicing professionals are always responsible for fostering education, regardless if you are an extension specialist, college professor, or a consultant. Our responsibility to educate does not just stop at the farmer, student, or client; it also includes the general public. Even roustabouts enjoy learning if you can interest them and make the subject matter important to their everyday life. A roustabout is an unskilled laborer in an oilfield; ranked as the worst U.S. job by careercast.com in both 2010 and 2011 (www.careercast.com/jobs-rated/10-worst-jobs-2011).

I was performing soils assessments out in the oil patch and as part of this work assignment, I was assigned a roustabout to operate a backhoe to dig the soil pits. There is no such thing as an average roustabout. I have had some that look like the ZZ Top singer, others that have been on the Maury Povich show, and another that had a Ph.D. in psychology from the University of California–Berkeley. One thing that they all have in common is sitting on the pit walls trying to figure out why I want them to dig so many 5-ft holes. After about an hour, curiosity as to why I am so intent on the soil gets the best of them and they start asking questions. I assume this starts as more of an incredulous attitude (“Someone gets paid to dig holes and stare at dirt?”), but as you will see below, that can change and in a big way.

One day as the roustabout was sitting on the pit wall, I ran across a soil pit that was loaded with krotovinas. As I am pulling them out of the pit face, the roustabout asks, “Whatcha got in your hands? They look cool.” I mentioned that they are krotovinas, and he says, “kroto-whata?” I immediately realized that I committed the cardinal sin of consulting—talking above a client’s head—so I informed the roustabout that they were old worm holes filled with soil. The roustabout quietly left and returned to his truck. Thinking that I had completely lost all “cred” with my partner, I continued describing the pits (all the time being amazed at how many krotovinas I was finding—soil scientists are really nerdy sometimes). A few minutes later, he came back to the pit with pen and paper and asked me to spell that word. Now it was my turn to be interested; I spelled the word and asked him why he wrote it down. He went on to inform me that a roustabout helper is affectionately called a worm and that he was now going to call his worm a krotovina. The rest of the day, I had a roustabout in my soil pit asking about everything that I was writing down regarding the soil profiles.

I thought that was the end of that educational lesson until about a month or two later when I was performing another soil assessment with a new roustabout. Out of the blue, the man asked, “Have you found any kroto…kroto…ah, you know, wormholes yet?” With a startled look on my face, I asked the man how he knew about krotovinas, and he mentioned that my previous roustabout went back to the office and informed the entire company of his new word of the day. During the rest of that day, the roustabout was in the pit asking me about things that I had shown the previous roustabout months earlier.

None of these roustabouts are ever going to hire me to consult for them, but the one thing I learned is everyone is interested in learning and then displaying their new knowledge to their friends and colleagues. The other thing I learned is that if you can educate, even to the simplest aspect of soil science to a roustabout who then educates the rest of his colleagues, think of what power we have as professionals to educate the general public and protect our natural resources. This experience demonstrates that we should not let a chance go by to educate anyone regardless of their age or perceived educational background.

The tale of the roustabout and the krotovinas

| Krotovina. Photo by Patrick Baldwin. |
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- Gylling Data Management* (1–14)
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Regional Roundup [continued from p. 26]

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Call for proposals for IPM symposium

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The program committee has organized the symposium around four themes: management, research, best practices, and outreach. You are invited to submit a proposal describing your program, activity, or research that addresses effective and efficient pest management. Visit www.ipmcenters.org/ipmsymposium12/IPM_Symp_theme_Description.pdf for a description of symposium themes.

Session proposals must be submitted online at http://ipmcenters.org/ipmsymposium12 by Apr. 29, 2011 Click on “Program” to find the online form. If you have questions, contact Margaret Appleby (613-475-5850 or margaret.appleby@ontario.ca).

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Effects of soybean residue management and tillage on corn yields

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Soybean is recognized for its apparent N contributions and yield-enhancing effects in crop sequences. Since soybean is often grown in rotation with corn, most states suggest a reduction in N fertilizer rates for corn following soybean relative to corn following corn. Nitrogen balance studies suggest that soybean harvested for grain removes more N than the crop accumulates through symbiotic N fixation. This suggests that the apparent soybean N effect may be caused by factors other than a direct contribution of fixed N to a subsequent crop.

Numerous studies have attempted to quantify the soybean N contribution and to elucidate the mechanisms involved in this phenomenon. Recently, a group of Midwestern states adopted an alternative approach to N rate suggestions for corn following soybean by basing these rates on results of corn N response experiments obtained where soybean was the previous crop. This alternative approach essentially treats the soybean–corn crop sequence as a separate cropping system that includes the soybean N effect, but it requires a substantial N response database to derive the N rate suggestions.

Substantial year-to-year and site-to-site variability in the apparent soybean N contribution have been reported. The range of management practices used in corn–soybean rotations such as tillage and residue management could account for some of this variability by altering N cycling and N availability. As a result, questions remain about factors affecting the soybean N contribution.

There is interest in removing soybean residue after grain harvest and using it as a biofuel or feed or bedding for livestock and in harvesting immature soybean as forage. The removal of soybean plant material either as a forage or as residue can affect potential changes in soybean N contributions by negatively influencing soil organic matter levels, structure, storage, movement of water and air, and N availability. Since soybean is a major crop in the Midwest and economic and environmental incentives to avoid excess N fertilizer applications are likely to continue or expand, the need for field-specific techniques to estimate soybean N contributions becomes more important. However, little information exists on the effects of soybean residue management on soybean N contributions.

In the July–August 2010 issue of Agronomy Journal, researchers report on a study in which they sought to determine: (i) soybean forage harvest and soybean residue management effects on grain yields and N availability to a subsequent corn crop and (ii) corn response to applied N where soybean was the previous crop on a range of soils widely used for corn and soybean production.

Field experiments to evaluate the effects of soybean harvest management system (HMS) on soybean N contributions where corn follows soybean were established at four locations in 1993 through 1996. The effects of returning or removing soybean residue, soybean forage harvest at the R6 growth stage, and applied N on corn grain yields were determined for three years at four locations on
medium-textured soils typical of those used for soybean production in Wisconsin. Research locations were the University of Wisconsin–Platteville research farm near Platteville on a Tama silt loam (fine-silty, mixed, superactive, mesic Typic Argiudolls); the University of Wisconsin Agricultural Research Station at Lancaster on a Rosetta silt loam soil (fine-silty, mixed, superactive, mesic Typic Hapludalfs); a private farm near Belmont, WI on a Tama silt loam; and the University of Wisconsin Agricultural Research Station at Arlington, WI on a Plano silt loam soil (fine-silty, mixed, superactive, mesic Typic Argiudolls).

Initial soil tests for pH, organic matter, available P, and exchangeable K were performed at all locations before planting soybean. Soil test results showed that available P and exchangeable K at all locations were in the high or excessively high categories for corn, according to Wisconsin's soil test recommendations.

Nitrogen rate and soybean harvest management effects on corn yields

Corn grain yield was significantly increased by applied N each year at all locations, except for Platteville in 1994 and Lancaster in 1995 (Table 1). The Platteville site received manure additions in 1992, which resulted in high N mineralization and subsequent high soil NO₃–N values that prevented corn yield response to added N in 1994. Corn yields at Lancaster in 1995 did not show a response to added N; however, there was a significant N × HMS interaction. At this site, the soybean forage harvest and residue-removed HMS treatments did not respond

<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
<th>HMS†</th>
<th>0</th>
<th>40</th>
<th>80</th>
<th>121</th>
<th>161</th>
<th>Economic optimum N rate</th>
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</thead>
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<tr>
<td>1994</td>
<td>Arlington</td>
<td>1, 2, and 3</td>
<td>184</td>
<td>201</td>
<td>198</td>
<td>201</td>
<td>205</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Lancaster</td>
<td>1, 2, and 3</td>
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<td>163</td>
<td>194</td>
<td>209</td>
<td>222</td>
<td>161</td>
</tr>
<tr>
<td></td>
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<td>1, 2, and 3</td>
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<td>195</td>
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<td>198</td>
<td>201</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Belmont</td>
<td>1, 2, and 3</td>
<td>180</td>
<td>196</td>
<td>218</td>
<td>211</td>
<td>207</td>
<td>80</td>
</tr>
<tr>
<td>1995</td>
<td>Arlington</td>
<td>1, 2, and 3</td>
<td>169</td>
<td>172</td>
<td>176</td>
<td>173</td>
<td>170</td>
<td>80</td>
</tr>
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<td></td>
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<td>1, 2, and 3</td>
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<td>154</td>
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<td>154</td>
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<td>40</td>
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<tr>
<td></td>
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<td>1, 2, and 3</td>
<td>162</td>
<td>170</td>
<td>169</td>
<td>174</td>
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<td>40</td>
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<td>164</td>
<td>170</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>Arlington</td>
<td>2 and 3</td>
<td>158</td>
<td>169</td>
<td>170</td>
<td>173</td>
<td>172</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td>Lancaster</td>
<td>1, 2, and 3</td>
<td>166</td>
<td>183</td>
<td>188</td>
<td>190</td>
<td>191</td>
<td>55</td>
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<td>218</td>
<td>201</td>
<td>113</td>
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<tr>
<td></td>
<td>Platteville</td>
<td>2 and 3</td>
<td>181</td>
<td>213</td>
<td>200</td>
<td>211</td>
<td>211</td>
<td>35</td>
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<td></td>
<td>Belmont</td>
<td>1, 2, and 3</td>
<td>173</td>
<td>192</td>
<td>210</td>
<td>212</td>
<td>207</td>
<td>76</td>
</tr>
</tbody>
</table>

† 1 = soybean residue returned; 2 = soybean residue removed; and 3 = soybean forage harvested.
‡ Averaged across all harvest management systems (HMS), except where noted.
to N rate, but yields in the residue-returned treatment increased in response to applied N (Table 1). Soybean harvest management significantly affected corn grain yields at Arlington and Platteville in 1996. In both cases, the residue-returned treatment had lower corn yields and required more applied N to optimize yields than the residue-removed or soybean forage treatments (Table 1). Corn yields also tended to be lower with soybean residue returned at other locations and years; however, this lower yield was not significant at the $p \leq 0.05$ level (data not shown). In addition, tillage did not significantly affect yields at Arlington in 1995 or 1996, and chisel plow or no-till had no significant interactions with N rate or HMS.

Economic optimum N rates (EONR) for corn after soybean ranged from 0 to 161 lb/ac in 1994, 0 to 121 lb/ac in 1995, and 35 to 113 lb/ac in 1996 (Table 1). These results confirm earlier research showing that there is substantial variation across sites and years in the apparent soybean N contribution to a following corn crop. Where soybean HMS significantly affected subsequent corn grain yields, the soybean residue-returned treatment had a higher EONR than where residue was removed or soybean forage was harvested.

According to Wisconsin N recommendations for continuous corn, about 160 lb N/ac would be recommended at all of the research locations; therefore, the observed variation in EONR across sites and years (Table 1) indicates that applying typical soybean N credits of 27 to 40 lb/ac usually does not accurately reflect the observed N needs for corn following soybean.

**Soybean grain and dry matter yields**

Since the management of soybean residue may help to identify the mechanisms involved in apparent soybean N contributions and soybean effects on subsequent corn grain yields, it is important to consider soybean grain yields and N content of the residues removed or returned in soybean HMS. Soybean grain yields ranged from 38 to 66 bu/ac across sites and years. These yields were not well related ($r^2 = 0.09$) to the EONR for subsequent corn crops. This suggests that corn N rate adjustments to account for the effects of a previous soybean crop on soils similar to those used in this study should not be based on soybean yield.

The soybean forage and soybean residue N concentration and total N content for all locations are shown in Table 2. The amount of N in soybean residue is relatively small, and the decomposition rate is rapid compared with corn residue. In the current study, returning soybean residue to the soil affected subsequent corn yields or corn N response (N × HMS interaction) in 3 of 12 site-years. Where these effects were significant, return of the residue resulted in a higher EONR for corn (Table 1), indicating that N release from soybean residue is not a major source of the apparent soybean N contribution.

**Soybean residue management effects on soil nitrate-nitrogen**

Soil samples collected from the top 12 inches of soil when the corn was 6 to 12 inches tall (pre-sidedress) often showed that the forage removed or the grain harvested with the residue-removed treatments had somewhat greater soil NO$_3$−N content than the grain harvested with the residue-returned treatment (Tables 3 and 4). Although some of the differences in soil NO$_3$−N content between soybean residue management treatments were significant, these differences were usually small and did not affect corn grain yields or optimum N rates (Table 1). The increase in soil NO$_3$−N content in the forage-harvested and residue-removed treatments, relative to the residue-returned treatment, is probably a result of warmer soil temperatures where forage or residue was removed. In the current study, average surface soil temperatures during June 1995 and 1996 were warmer in the soybean residue-removed and forage-harvested treatments. After June, this difference in soil temperature diminished due to corn canopy closure. Warmer soil temperatures should stimulate soil N mineralization where soybean forage or residue is removed, but immobilization of soil NO$_3$−N in the residue-returned treatment could also contribute to lower soil NO$_3$−N in this treatment.

Soil NO$_3$−N contents (0 to 12 inches) measured in the N rate control treatment at 7- to 14-day intervals during the 1994 and 1995 corn growing seasons at Arlington illustrate the influence of HMS treatments on temporal

<table>
<thead>
<tr>
<th>Year</th>
<th>Soybean material</th>
<th>Nitrogen concentration</th>
<th>Dry matter</th>
<th>Nitrogen content</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>tons/ac</td>
<td>lb/ac</td>
<td></td>
</tr>
<tr>
<td>1993</td>
<td>forage</td>
<td>3.0</td>
<td>267</td>
<td>165</td>
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<tr>
<td></td>
<td>residue</td>
<td>0.8</td>
<td>142</td>
<td>24</td>
</tr>
<tr>
<td>1994</td>
<td>forage</td>
<td>2.8</td>
<td>528</td>
<td>293</td>
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<tr>
<td></td>
<td>residue</td>
<td>0.8</td>
<td>334</td>
<td>54</td>
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<tr>
<td>1995</td>
<td>forage</td>
<td>2.6</td>
<td>460</td>
<td>236</td>
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<tr>
<td></td>
<td>residue</td>
<td>0.8</td>
<td>313</td>
<td>53</td>
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</table>
Changes in the amounts of NO$_3$–N in the soil. Changes in soil NO$_3$–N during the growing season were similar in all HMS treatments. Net mineralization of N from early spring (April) through early summer (June) resulted in soil NO$_3$–N accumulation followed by a period of N removal by corn during its period of rapid N utilization (July). For the remainder of the growing season, soil NO$_3$–N values were relatively constant. The small difference in soil NO$_3$–N between HMS throughout the growing season did not significantly affect corn yields in 1994 or 1995. These results support the conclusion that N release from soybean residue is not a major contributor to soybean effects on subsequent corn yield or N response. Tillage effects on soil NO$_3$–N content show that the chisel plow treatment had greater NO$_3$–N than no-till, especially early in the growing season (May through June). This difference is probably due to increased N mineralization from warmer soil temperatures in the chisel plow plots.

<table>
<thead>
<tr>
<th>Location</th>
<th>HMS †</th>
<th>1994</th>
<th>1995</th>
<th>1996</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PPNT</td>
<td>PPNT</td>
<td>PSNT</td>
<td>PPNT</td>
</tr>
<tr>
<td>Arlington</td>
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<td>44 b§</td>
<td>8</td>
<td>23</td>
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<tr>
<td></td>
<td>2</td>
<td>65 a</td>
<td>11</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>59 ab</td>
<td>10</td>
<td>19</td>
</tr>
<tr>
<td>p &gt; f</td>
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<td>0.12</td>
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<tr>
<td>Lancaster</td>
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<td>4</td>
<td>13 b</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>38</td>
<td>5</td>
<td>16 ab</td>
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<td>17 a</td>
</tr>
<tr>
<td>p &gt; f</td>
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<td>0.56</td>
<td>0.10</td>
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<tr>
<td>Platteville</td>
<td>1</td>
<td>104 b</td>
<td>16 b</td>
<td>37</td>
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<tr>
<td></td>
<td>2</td>
<td>129 b</td>
<td>20 b</td>
<td>37</td>
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<td></td>
<td>3</td>
<td>201 a</td>
<td>30 a</td>
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<td>0.01</td>
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<td>Belmont</td>
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<td>20</td>
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<td></td>
<td>2</td>
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<td>96</td>
<td>13 a</td>
<td>25</td>
</tr>
<tr>
<td>p &gt; f</td>
<td>0.34</td>
<td>0.10</td>
<td>0.33</td>
<td></td>
</tr>
</tbody>
</table>

† 1, grain harvest with residue returned; 2, grain harvest with residue removed; 3, harvested as forage at R6.
‡ PP, preplant; PS, presidedress; NT, nitrate test.
§ Mean values for each location followed by the same letter are not significantly different at the 0.10 probability level.
trend continues through mid-June when corn growth rapidly depletes the N supply, and by mid-July, there are no significant differences in soil NO₃⁻⁻N between the chisel plow and no-till systems.

Comparison of surface (0 to 12 inches) soil NO₃⁻⁻N contents at preplant (PPNT) and presidedress (PSNT) sampling times (Tables 3 and 4) shows that soil NO₃⁻⁻N increased as expected at all locations in 1994 and 1995 but not in 1996. These results are likely due to excessive rainfall at all sites during June 1996, which probably caused leaching of NO₃⁻⁻N below the 12-inch sampling depth and/or promoted NO₃⁻⁻N loss through denitrification. Although growing season precipitation at the Lancaster and Platteville/Belmont locations was less than the 30-year average (Table 2), June 1996 precipitation was substantially greater than the 30-year average for June at all three locations (data not shown). Most of this precipitation occurred before the PSNT samples were collected in 1996.

Table 4. Effect of soybean harvest management system (HMS) and tillage on soil N test values at Arlington, 1995 and 1996.

<table>
<thead>
<tr>
<th>Soil N test depth, inches†</th>
<th>1995</th>
<th>1996</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PPNT</td>
<td>PPNT</td>
</tr>
<tr>
<td></td>
<td>PPNT</td>
<td>PPNT</td>
</tr>
<tr>
<td>Tillage</td>
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<tr>
<td>No-till</td>
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<td></td>
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<tr>
<td>1</td>
<td>95</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
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<td>8</td>
</tr>
<tr>
<td>3</td>
<td>107</td>
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<tr>
<td>Chisel plow</td>
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<tr>
<td>1</td>
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<td>2</td>
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<td>7</td>
</tr>
<tr>
<td>3</td>
<td>90</td>
<td>7</td>
</tr>
<tr>
<td>No-till</td>
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<td></td>
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<tr>
<td>1</td>
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</tr>
<tr>
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<tr>
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<tr>
<td>p &gt; f</td>
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<td>0.95</td>
</tr>
<tr>
<td>Tillage × HMS</td>
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<td></td>
</tr>
<tr>
<td>p &gt; f</td>
<td>0.55</td>
<td>0.59</td>
</tr>
</tbody>
</table>

† 1 = grain harvest with residue returned; 2 = grain harvest with residue removed; and 3 = harvested as forage at R6.
‡ PP, preplant; PS, presidedress; NT, nitrate test.
§ Mean values within each column followed by the same letter are not significantly different at the 0.10 probability level.

Conclusions

Economic optimum N rates for corn following soybean varied substantially across sites and years but were not greatly affected by soybean HMS or tillage at most sites. Optimum N rates for corn were not related to previous soybean crop yield, indicating that adjustments in corn N rates following soybean should not be based on soybean yield. Results also indicate that soybean forage harvest and residue management have little effect on subsequent corn grain yields. Where there were significant effects, the soybean residue-returned treatment required more fertilizer N to maximize yields. This significant effect may be the result of either greater soil NO₃⁻⁻N in the soybean residue-removed or soybean forage harvest treatments due to increased N mineralization from warmer soil temperature or N immobilization from the soybean residue returned. These findings also suggest that N in soybean residues is not a major source of the apparent soybean N contribution. The surface soil (0- to 12-inch) NO₃⁻⁻N values over time show that all soybean HMS follow a similar pattern in net N mineralization and N removal by corn and that early in the growing season, chisel plow may have significantly greater soil NO₃⁻⁻N content than no-till in some years.

March–April 2011 self-study quiz

Effects of soybean residue management and tillage on corn yields (no. SS 04127)

1. Nitrogen balance studies suggest that soybean harvested for grain
   ○ a. retains more N than the crop accumulates through symbiotic N fixation.
   ○ b. removes half of the N that crop accumulates through symbiotic N fixation.
   ○ c. accumulates much more N than is removed with the grain.
   ○ d. removes more N than the crop accumulates through symbiotic N fixation.

2. This study was conducted to determine the effects of three soybean harvest management systems and
   ○ a. tillage on subsequent corn grain yields and apparent soybean N contributions.
   ○ b. planting methods on subsequent corn grain yields and apparent soybean N contributions.
   ○ c. fertilization methods on subsequent corn grain yields and apparent soybean N contributions.
   ○ d. tillage on total soil conditions of the field.

3. The soybean residuereturned treatment affected subsequent corn yields or corn N response in
   ○ a. 7 of 12 site-years.
   ○ b. 6 of 12 site-years.
   ○ c. 3 of 12 site-years.
   ○ d. 7 of 12 site-years.

4. One objective of this research was to determine
   ○ a. corn response to applied N where soybean was the previous crop on a range of soils.
   ○ b. soybean response to a range of row spacings.
   ○ c. residue management effects on soybean yields.
   ○ d. how soil organic matter is affected by soybean residue management.

5. Although some of the differences in soil \( \text{NO}_3^- \text{N} \) content between soybean residue management treatments were significant, these differences
   ○ a. were usually small and did not affect corn grain yields or optimum N rates.
   ○ b. were usually small but did affect corn grain yields and optimum N rates.
   ○ c. were usually related to air temperature differences when the forage or residue was removed.
   ○ d. were usually related to soil moisture differences.

6. The amount of N in soybean residue is relatively small and the decomposition rate is
   ○ a. slower than corn residue.
   ○ b. rapid compared to corn residue.
   ○ c. not markedly different from that of corn residue.
   ○ d. somewhat slower than corn residue.

7. Average surface soil temperatures during June 1995 and 1996 were warmer in the soybean residueremoved and forage-harvested treatments. This difference
   ○ a. increased as rain increased after July.
   ○ b. increased as the weather grew warmer after June.
   ○ c. diminished due to less rain after July.
   ○ d. diminished due to corn canopy closure after June.

Quiz continues next page
8. Results from this study on silt loam soils indicate that soybean forage harvest and residue management have little effect on subsequent corn grain yields. Where there were significant effects,
   - a. the soybean residue-returned treatment required more fertilizer N to maximize yields.
   - b. the soybean residue-removed treatment required more fertilizer N to replace that lost in the residue.
   - c. the soybean residue-returned treatment required less fertilizer N to maximize yields.
   - d. The soybean residue-removed treatment required less fertilizer N to maximize yields.

9. Results suggest that corn N rate adjustments to account for the effects of a previous soybean crop on soils similar to those used in this study should not be based on
   - a. soybean yield.
   - b. soybean stand.
   - c. forage yield.
   - d. soil condition.

10. Warmer soil temperatures should stimulate soil N mineralization where soybean forage or residue is removed, but
   - a. changes in soil water content could lower soil NO₃–N in the residue-returned treatment.
   - b. loss of soil NO₃–N in the residue-returned treatment could contribute to lower soil NO₃–N in this treatment.
   - c. immobilization of soil NO₃–N in the residue-returned treatment could contribute to lower soil NO₃–N in this treatment.
   - d. Soil temperature reductions due to shading might contribute to lower soil NO₃–N in this treatment.
Soil testing and nitrogen mineralization from soil organic matter

Earn 1 CEU in Soil and Water Management by reading this article and completing the quiz at the end. CCAs may earn 20 CEUs per two-year cycle as board-approved self-study articles. 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.agronomy.org/certifications/self-study.

By John Gilmour, CCA
John Gilmour, Inc., Fayetteville, AR
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Mineralization is defined as “The conversion of an element from an organic form to an inorganic state as a result of microbial activity” in the Glossary of Soil Science Terms published by the Soil Science Society of America. For nitrogen, the first step is conversion of organic nitrogen (N) in soil organic matter (SOM) to ammonium (NH$_4^+$) by a process called ammonification. Often, the ammonium is rapidly converted to nitrate (NO$_3^-$) by the microbial process of nitrification. The amount of inorganic N (NH$_4^+$ and NO$_3^-$) originating from SOM is termed N mineralization (NM). Nitrogen mineralization is a product of the amount of organic N in the soil and the N mineralization rate (NMR).

Soil organic matter originates from crop residues, manures, and other organic amendments applied to soils. As these organic materials decompose, a portion becomes part of SOM. Trumbore (2000) showed that SOM mean age can vary from a few years to several centuries in temperate soils. As mean age increases, the less decomposable the SOM fraction and the lower the NMR. Mean ages of a few years are characteristic of SOM that originates from recent additions of crop residues, roots, manure, and other organic amendments. Longer mean ages represent more stable SOM fractions. Cropping system features that can affect NM include tillage, irrigation, fertilization, manure and other organic additions, and crop rotation. Climate determines soil temperature and moisture, which directly impact NMR.

A simplified depiction of the concepts described above is shown in Fig. 1 (next page). N Pool I in SOM originates from organic additions to soil, while N Pool II comes from organic matter in N Pool I that has aged to a point where the NMR is much lower than that in N Pool I. The figure implies that most of the ammonification occurs from N Pool I even though that N pool is only a few percent of total N (TN) in the soil.

Traditional soil-testing methods extract the plant-available form(s) of the nutrient and then correlate the amount extracted with plant response. While this approach has been applied to the N needs of specific crops over a limited geographic area, wide adaptation of a single method has not occurred. Part of the challenge has been extracting only organic N from N Pool I, which is the primary contributor to NM. In addition, an extraction method only takes a snapshot of NM, which is not a static process, but rather ongoing as microbes decompose SOM.
The latter has been addressed by research where the time course of NM has been described mathematically and the terms in the equations have been related to soil properties that can be determined in a soil-testing laboratory. The equations selected to date have assumed that NM from N Pools I and II occur simultaneously. These simultaneous models do describe the time course of NM for limited geographic areas, but just like the traditional approach, they have not been shown to have widespread use.

**A solution**

In a recent paper published in the *Soil Science Society of America Journal* (Gilmour and Mauroumoustakos, 2011), the authors assumed that N Pool I and N Pool II decomposed sequentially; i.e., N Pool I must be completely exhausted before N Pool I undergoes NM. They evaluated long-term, laboratory N mineralization studies from the southeastern United States, Connecticut, Israel, and Australia. Soils represented differing soil depths, tillage practices, organic amendments, and cropping systems. In all, NM was calculated for 108 soils at 95°F and optimum soil moisture for 32 to 41 weeks. When they tested the simultaneous model, they found that variables in the sequential-model equations were not related to soil properties across this diverse group of soils. The key finding was that NMR varied with NM during the first week estimated from long-term data in a statistically consistent manner for the sequential model but not for the simultaneous model. Another feature of the sequential model was that NM was the product of NMR and total N, unlike the simultaneous model where NM was the product of NMR and organic N in N Pool I.

Using the sequential model, the NMR for N Pool I was related to first-week NM estimated from the long-term data. The size of N Pool I was then related to NMR for that pool. The NMR of N Pool II was related to both the size and NMR of N Pool I. There were no statistical differences among the four studies, which suggested that the sequential model has widespread application for the estimation of NM from SOM. Emphasis was placed on the NMR and size of N Pool I because NM from N Pool II is not likely in most agricultural systems.

**Does all this fit into routine soil testing?**

The next step was to see if the results could be put in the perspective of a routine soil-testing program. Since a routine soil-testing program cannot depend on studies lasting 30 weeks or more to estimate first-week NM and one-week laboratory incubations can lead to erroneous results, the authors sought to relate first-week NM to soil analyses using data from one of four studies that included detailed soil test results (Schonberg et al., 2009). The authors of these studies evaluated total N, total C, C/N ratio, carbon dioxide evolution at three days (3d CO₂), cold KCl extract, hot KCl extract, sodium hydroxide distillation, calcium hypochlorite oxidation, and soil texture. Three analyses were found to best describe differences in first-week NM: total N, 3d CO₂, and percentage clay. The size and NMR of N Pool I were also best described using total N, 3d CO₂, and percentage clay.

A somewhat surprising finding was that the size of N Pool I and the NMR of N Pool I declined as total N increased. A possible explanation as to why this occurred can be found by considering that both N Pool I size and NMR are on a total N basis and that changes in total N among soils must be mostly in the more stable N Pool II. This underlines the concept that SOM from recent additions of organic materials (crop residues, roots, manure, etc.) is not as important in determining total N as more stable forms of SOM, the amount of which is a consequence of long-term cropping system and climate. For example, a soil that is 1% total C contains 20,000 lb of C if an acre furrow slice (6-inch depth) weighs 2 million lb. If the C/N ratio of that SOM is 12, the soil contains 1,667 lb of organic N (20,000 lb C/12 lb C/lb N). If annual organic matter additions are 5,000 lb/ac and the organic matter is 40% total C and has a C/N ratio of 40, only 50 lb of organic N (5,000 lb OM × 40 lb C/100 lb OM/40 lb C/ lb N) is added to the soil each year.

N Pool I size and NMR increased as 3d CO₂ increased. Thus, as initial SOM decomposability increased, so did the size and NMR of N Pool I. This effect is most likely related to the types and amounts of SOM originating from recent organic additions to the soil. Percentage clay had a much smaller impact on N Pool I size and NMR. As percentage clay increased, both decreased, suggesting that clay increased recent SOM stability.

The results described above were obtained at 95°F and optimum soil moisture in the laboratory, conditions that do not often exist in the field. In order to extend laboratory results to the field, the NM found in the laboratory...
should be multiplied by a temperature–moisture factor (TM factor). Examples of the TM factors are shown in Table 1. The moisture factor is based on water-holding capacity (WHC), which is the percentage of water (dry soil basis) in an initially saturated soil after free drainage has ceased. The equation used to calculate these factors can be found in Gilmour and Maumomouatakos (2011).

Thirty-two of 38 soils reported by Schomberg et al. (2009) that represented 0- to 2-inch and 2- to 6-inch soil depths for three tillage systems were the data base for estimation of field NM. The tillage systems were conventional till (16 soils), no-till (10 soils), and no-till with non-inversion deep tillage (six soils). Laboratory NMR was corrected for field temperature and soil moisture using the TM factor. Mean TM factor was 0.26 (range was 0.21 to 0.29). In calculating the TM factor, soil moisture was assumed to be 30% WHC, and soil temperature was the mean for each soil location for the 15 weeks \( t = 15 \) weeks) from May to August. Seasonal N mineralization was calculated per acre-inch of soil to eliminate soil depth increment differences. One acre-inch of soil was assumed to weigh 333,333 lb. Equation 1 below was used to make the seasonal NM calculation.

\[
\text{Seasonal NM} = \frac{\% \text{TN}}{100} \times 333,333 \times \frac{\text{NMR}}{100} \times \text{TM factor} \times t \quad [1]
\]

No statistically significant differences in total N, 3d \( \text{CO}_2 \), percentage clay, N Pool I size, NMR, seasonal NM in pounds of N per acre-inch, or seasonal NM in percentage of total N were found due to tillage practices (data not shown). However, there were significant differences when the two depths were compared. Table 2 presents the laboratory portion of that comparison.

Total N and 3d \( \text{CO}_2 \) were higher in the surface 2 inches than in the next 4 inches, while there was no difference due to depth for percentage clay. N Pool I size and NMR were larger for the 0- to 2-inch depth than the 2- to 6-inch soil depth.

Seasonal estimates of NM in the field using Equation 2 are presented in Table 3. Seasonal NM in the 0- to 2-inch depth was 2.8 times that in the 2- to 6-inch depth. As a percentage of total N, seasonal NM was 1.3 times larger in the 0- to 2-inch depth as compared with the 2- to 6-inch soil depth. On a total depth increment basis, the 0- to 2-inch depth contributed 34.6 lb N/acre, while the 2- to 6-inch depth contributed 24.8 lb N/acre, giving a to-

### Table 1. Examples of soil temperature/moisture correction factors (TM factors).

<table>
<thead>
<tr>
<th>Temperature</th>
<th>TM factor at 20% WHC†</th>
<th>TM factor at 30% WHC</th>
</tr>
</thead>
<tbody>
<tr>
<td>°F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>90</td>
<td>0.38</td>
<td>0.51</td>
</tr>
<tr>
<td>80</td>
<td>0.22</td>
<td>0.32</td>
</tr>
<tr>
<td>70</td>
<td>0.12</td>
<td>0.19</td>
</tr>
<tr>
<td>60</td>
<td>0.06</td>
<td>0.11</td>
</tr>
<tr>
<td>50</td>
<td>0.06</td>
<td>0.08</td>
</tr>
</tbody>
</table>

† WHC, water-holding capacity.

### Table 2. Mean laboratory data for two depths. N Pool I size and N mineralization rate (NMR) were determined at 95°F and optimum soil moisture (55% water-holding capacity).

<table>
<thead>
<tr>
<th>Soil depth</th>
<th>Number of soils</th>
<th>Total N percentage</th>
<th>3d ( \text{CO}_2 )</th>
<th>Clay percentage</th>
<th>N Pool I size</th>
<th>NMR</th>
</tr>
</thead>
<tbody>
<tr>
<td>inches</td>
<td>no.</td>
<td>%</td>
<td>ppm</td>
<td>%</td>
<td>% of total N</td>
<td>% of total N/week</td>
</tr>
<tr>
<td>0 to 2</td>
<td>16</td>
<td>0.129</td>
<td>175</td>
<td>7</td>
<td>12.7</td>
<td>1.07</td>
</tr>
<tr>
<td>2 to 6</td>
<td>16</td>
<td>0.067</td>
<td>65</td>
<td>8</td>
<td>8.3</td>
<td>0.64</td>
</tr>
</tbody>
</table>

† LSD, least significant difference.

### Table 3. Estimated seasonal nitrogen mineralization (NM) for three tillage practices.

<table>
<thead>
<tr>
<th>Soil depth</th>
<th>Seasonal NM</th>
</tr>
</thead>
<tbody>
<tr>
<td>inches</td>
<td>lb N/acre-inch</td>
</tr>
<tr>
<td>0 to 2</td>
<td>17.3</td>
</tr>
<tr>
<td>2 to 6</td>
<td>6.2</td>
</tr>
</tbody>
</table>

† LSD, least significant difference.
tal for the 0- to 6-inch soil depth of 59.4 lb N/acre. When the seasonal NM as a percentage of total N was compared with the size of N Pool I, 31% of N Pool I organic N was mineralized for the 0- to 2-inch depth, while 35% of N Pool I organic N was mineralized for the 2- to 6-inch soil depth.

What does the future hold?

One of the challenges of moving this technology from the research laboratory to routine soil testing is finding simple, rapid, and repeatable methods. In many soil test laboratories, TN is a common soil analysis. If it is not, SOM is commonly determined and TN can be estimated from SOM. For example, assume that SOM is 50% organic C and that the typical C/N ratio is 12. A soil with 2% SOM would contain 1% organic C and 0.0833% organic N. If an acre furrow slice was assumed to weigh 2 million lb, TN would be 1,667 lbs (2,000,000 lb × 0.0833% TN/100). Percentage clay can be estimated from soil texture and, as discussed above, has a minor impact on the size of N Pool I and NMR, so percentage clay estimates do not have to be exact. The stumbling block for many soil test laboratories will be 3d CO₂ due to the set up required and the three-day delay in obtaining results. One promising replacement for 3d CO₂ is a hot 2 M KCl extract of the soil (see Schomberg et al., 2009). This method requires incubating the soil KCl mixture in a 212°F water bath for four hours, cooling the mixture, and filtering and analyzing it for ammonium N.

Seasonal NM estimated using hot KCl is compared with seasonal NM using 3d CO₂ in Fig. 2 above for the 32 soils from Tables 2 and 3. A statistically significant relationship ($R^2 = 0.91$) was found where the slope was 0.99 and the intercept (0.05) was not significantly different from zero. These results support the use of the hot KCl extract in place of 3d CO₂.

It should be emphasized that the NM values obtained for a given field should be put in the perspective of NM values for soils used in determining N fertilization programs. The latter serve as a benchmark against which NM for specific soils can be compared. This approach can be used to identify situations where crop response to N fertilizer can be expected and where a response is less likely. Each soil-testing laboratory will have to set and adjust these benchmarks based on available data.

Soils should be sampled prior to preplant spring additions of organic amendments such as manures and biosolids. Prior-year manure or biosolid additions are part of TN, N Pool I size, and NMR. The amount of N mineralization from organic amendments for the current year should be estimated independently and added to NM from SOM to give total plant-available N. If the hot KCl extract is used, soils should be sampled before preplant inorganic N fertilizer additions as the extract will include fertilizer N.

And finally, how often should the seasonal NM be determined? Until more experience is gained with this method, the frequency should be similar to that for other soil tests. When a management practice is changed that might impact seasonal NM, that would be a good time to see if the management change has affected seasonal NM.


References


Soil testing and nitrogen mineralization from soil organic matter

1. **The first step in nitrogen mineralization is**
   - a. ammonification.
   - b. nitrification.
   - c. denitrification.
   - d. nitrate leaching.

2. **The overall process where organic N in soil organic matter is converted to inorganic N is called**
   - a. mineralization.
   - b. nitrification.
   - c. decomposition.
   - d. volatilization.

3. **As soil organic matter becomes more resistant to decomposition, the mean age of soil organic matter**
   - a. does not change.
   - b. increases.
   - c. decreases.
   - d. can either increase or decrease.

4. **Often two pools of organic N (N Pool I and N Pool II) are identified in soil organic matter. These pools vary in**
   - a. size.
   - b. N mineralization rate.
   - c. decomposability.
   - d. all of the above.

5. **In the ________ model, N Pool I is completely exhausted before N Pool II begins to be mineralized.**
   - a. sequestered.
   - b. monopool.
   - c. simultaneous.
   - d. sequential.

6. **Recent research has shown that _____ is related to first-week N mineralization (NM) from long-term data.**
   - a. P availability.
   - b. N mineralization rate.
   - c. nitrification rate.
   - d. P availability and nitrification rate.

7. **A routine soil test that partly explains the amount of first-week N mineralization is**
   - a. total C.
   - b. sodium hydroxide distillation.
   - c. total N.
   - d. cold KCl extract.

8. **A surprising finding was that the N mineralization rate of N Pool I**
   - a. increased as total N increased and increased as 3 d CO₂ increased.
   - b. decreased as total N increased and decreased as 3 d CO₂ increased.
   - c. decreased as total N increased and increased as 3 d CO₂ increased.
   - d. increased as total N increased and decreased as 3 d CO₂ increased.

This quiz is worth 1 CEU in Soil and Water 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.agronomy.org/certifications/self-study.
9. What is needed to make estimates of N mineralization rate (NMR) for field conditions?
- a. Soil temperature.
- b. Number of sunny days.
- c. P fertilizer rate.
- d. Slope.

10. The N mineralization rate (NMR) is statistically larger for which of the following tillage practices?
- b. No-till.
- c. No-till with non-inversion deep tillage.
- d. None of the above.

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