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When it comes to manure management and deciding whether to compost the manure or store it in lagoons, some producers may choose the latter because they believe that it costs more to compost. The compost needs to be turned in order to introduce oxygen into the system and break down the organic material as well as expose all of it to temperatures high enough to kill pathogens and weed seeds. This requires labor, energy, and equipment like windrow turners that are not needed with lagoon systems. Also, there are costs associated with composting pads or facilities and amendments added to the compost (e.g., sawdust, straw, and sand).

However, during a presentation on farm-scale composting at this year’s Midwest Manure Summit in Green Bay, WI in March, Frederick C. Michel, Jr. from the Ohio State University said that the costs may not be more than those associated with lagoon management.

“Dairy manure composting costs can be competitive with paying to haul manure off farm,” explained Michel, an associate professor in the Department of Food, Agricultural, and Biological Engineering at the Ohio Agricultural and Research Development Center in Wooster. “The selling price [for compost] in Ohio is about $20 to $25 [per yd³], whereas a farmer is paying $70 to $150 per animal per year for someone to come onto the farm, pump out manure, and take it somewhere for land application…Composting economics are positive when compost can be sold for greater than ↩

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Safe handling of manure for a biosecure farm

Most livestock professionals are well aware of safety issues on their farms and operate with a great deal of common sense. Basic observation can point out, for instance, when operators are mishandling equipment or when that equipment becomes faulty, and experience can prevent one from being harmed by the animals. When it comes to processing an animal’s manure, however, common sense is often defied because invisible hazards like gases and pathogens carry the most risk. Enhancing the biosecurity of a farm is an important part of a professional’s daily routine.

“(There are) two components to risk,” said John Shutiske, University of Wisconsin Extension Program Director for Agricultural and Natural Resources, who delivered a talk on manure biosecurity at the Midwest Manure Summit in Green Bay, WI in March. “One is to prevent bad things from happening, and the second one is to be prepared when those bad things happen so that we minimize the damage, and that’s just another way of reducing risk.”

Proper manure handling is perhaps the most essential element to ensuring the safety of many farming operations, as unrealized missteps can lead to serious public disease outbreaks. The key to a secure farm is for workers to be trained in preventing the spread of pathogens, to be prepared for how to handle incidents when they do occur, and to respond immediately when accidents do happen. In addition to pathogens, professionals should also be aware of the risks of infecting injuries, especially cuts, while working on the farm, as well as the presence of toxic levels of manure gas.

The greatest risk that comes from working with manure is from pathogens, including bacteria and viruses, that can cause disease or illness. Industrial farms can be especially susceptible to the spread of these pathogens, given the dense population of animals and the use of equipment that can pick them up and carry them.

Among the most common pathogens that occur on industrial animal farms are E. coli bacteria and Salmonella, both of which are prevalent in dairy herds throughout the U.S. Midwest. Both pathogens carry a particularly high risk of spread because people are fairly susceptible to them. E. coli bacteria, some of which is resistant to antibiotics, is capable of being transferred by employees and can spread very quickly if introduced to water supplies. Salmonella, a very...

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Software for creating manure management plans

Manure contains the three major plant nutrients—nitrogen, phosphorus, and potassium—as well as many essential micronutrients such as calcium, sulfur, zinc, boron, copper, magnesium, and manganese. In addition to supplying plant nutrients, manure generally improves soil tilth, aeration, and water-holding capacity and promotes growth of beneficial soil organisms. Manure applied in the proper amounts at the appropriate time can supply some, if not all, of the nutrient requirements of most crops.

Mixed livestock and row-crop production enterprises should have a comprehensive manure nutrient management plan to take advantage of the animal manure benefits and reduce the risk of environmental problems when manure is used as a nutrient source for farm crops. A manure management plan is a specific combination of physical components, conservation practices, and management measures for manure handling, storage, treatment, and use on cropland or pastureland.

The benefits of good manure management include reduced cost of commercial fertilizer inputs, improved production efficiency, improved animal health, and protection of water/air resources and air quality. A good manure management plan covers all aspects of manure management on a farm, from feeding the animal to eventual field application.

Proper manure management can also help protect valuable ground and surface water resources. If producers apply too much manure, apply it at the wrong time, or improperly handle it, excess nutrients may leach through the soil and pollute the ground water. Increased nitrate levels from...
somewhere around $20/ yd³ and amendments are available at low costs.”

Michel found that composting costs could be reduced 10 to 15% by turning windrows once every 10 days instead of once every three days without affecting the properties of the finished product. He said some believe that more frequent turnings result in a higher-quality product and associate aeration of the compost with mixing, which isn’t the case.

“We find that the aeration of the compost really isn’t due to mixing by the compost turner, it’s due to passive convection—movement of air to the pile. So the only reason you do turning is to mix the material....You can get away with turning the windrows two or three times initially to get everything well mixed, but then you don’t have to turn every three days or every day. You can turn it every 10 days or two weeks and minimize the amount of labor you’re devoting to that process.”

Composted manure is easier to handle and transport and has less odor when it is applied to fields. And even though it initially loses nitrogen via ammonia volatilization at a faster pace than lagoons during the first month or so, it actually loses less nitrogen overall after several months.

“We eventually lost about 50% of the nitrogen from the manure lagoon, which was much more than we lost in the compost,” Michel said, referring to results from one of his studies. “So the compost actually is immobilizing nitrogen, and it’s not being lost as much as it is in a lagoon. And this makes sense because in a manure lagoon, the nitrogen stays in the form of ammonia whereas in a compost, it’s converted to organic forms, which are less mobile than ammonia.”

Pathogen destruction

Michel’s research findings also suggest that composting may be more effective at destroying pathogens. After three days of dairy manure composting at 131°F, naturally occurring E. coli, Salmonella, and Lysteria were not detectable. In swine manure, Salmonella and Lysteria were reduced more than 3 logs after three days of composting. These pathogens were eventually reduced to similar levels in the liquid storage systems as well, but it took longer, up to 56 days in some cases.

“High-temperature composting of both dairy and swine manure was most effective in reducing these priority pathogens....We would recommend thermophilic composting for the treatment of manure destined for pathogen-sensitive areas such as use in fruit or vegetable production, home gardening, or application to well-drained fields where there may be the danger of preferential flow.”

However, there are specific metrics to meet for pathogen destruction if you’re selling the compost into organic markets. The windrows have to have temperatures at 131°F or greater for at least 15 days with five turns. Michel’s research found that not all amendments met these requirements. He tested sawdust, straw, and sand and found that only the sawdust-amended dairy manure met these organic standards every time.

Antibiotic-resistant bacteria are another concern with animal manure. Antibiotics are often used for livestock growth or to maintain the health of the animal, but they can cause human disease if they enter the food chain.

“We find that composting reduces the level of these antibiotic-resistant bacteria by three to four quarters of magnitude than the liquid storage,” Michel said. “Composting addresses many unaccounted for negative impacts of liquid manure systems such as pathogen destruction, antibiotic resistance genes destruction, nitrogen loss and odors, and transportation effects on infrastructure.”
active bacteria, is also at risk of moving through the food products of industrial farms.

“What we’re talking about is protecting people and/or animals from these different types of infectious diseases,” Shutske explained. “When we talk about protecting animals, a lot of this is common sense. And what we’re really talking about is the potential sources or reservoirs for protecting our animals and protecting people from those coming onto our farms. Probably quite a bit easier said than done.

“It is quite shocking to me sometimes to really look at how little we pay attention to this in some cases. [In other cases], we often do pay a lot of attention to it, protecting animal-to-animal contact, making sure that if we bring new animals into a herd, there’s quarantine procedures and places to hold and watch animals for a period of time so that we can discover any type of problem.”

Minimizing exposure

Minimizing the amount of exposure between the livestock and the outside world is also important to creating a lasting healthy environment.

“Limiting access of people and equipment is quite important,” Shutske said. “Animal health and human health are very closely intertwined. The things that we do to take care of our animals from an animal health perspective also help to protect people.”

Basic infection control procedures include limiting outside access because pathogens can be moved through people’s boots and the tires of equipment. Traditional boot baths are often not changed frequently enough; they can harbor pathogens when farmers walk through them with boots carrying large chunks of organic matter. Tires also need to be scrubbed well, as they frequently pick up large pieces of organic matter, which can be spread through the vehicle’s movement.

Water systems are also highly susceptible to spreading pathogens from manure on these farms. For manure operations, it is important to carefully examine how and where groundwater runs and to understand ways that manure could be introduced to local water systems. For instance, using contaminated manure as fertilizer over thin soils with fractured bedrock can lead to contaminants flowing into the groundwater when those water tables are high.

Pathogen spread is not the only danger that livestock professionals face. In an agricultural setting, one of the most common injuries that can occur to workers are simple cuts. However, when combined with exposure to manure and other organic materials, those open wounds are at a high risk of infection. Workers should take care to seek immediate treatment for these injuries.

“It doesn’t take a lot of bacteria cells to actually cause problems,” Shutske noted. “It can potentially be a big deal.”

John Shutske, University of Wisconsin, talked about manure biosecurity at the Midwest Manure Summit in Green Bay, WI in March.

Manure pits

Manure pit gases are also a great danger for farming operations, and exposure to high levels can lead to a rapid incapacitation and ultimately fatalities. Often problems occur when people believe that the danger is minimal, only to be quickly overtaken by these gases. People are advised to take extreme precaution when entering manure pits and to pay close attention to gas monitoring systems that are present.

“You need to be thinking about either staying out of the pit entirely, particularly during any type of period of agitation or movement taking place,” Shutske advised. “And if that’s not possible, then you need to find some way to evaluate the hazard, a gas monitor of some sort. And we also need to talk about controlling the hazard by having some sort of confined space entry program.”

If venturing into a manure pit is absolutely necessary, a fully self-contained breathing apparatus is what is needed to survive this environment, as typical cartridge respirators don’t offer nearly enough protection. A review of design systems can also help to reduce unnecessary risks.

Understanding the risks associated with manure and applying common sense approaches to creating a biosecure work environment are essential to a successful operation. Basic preventative measures, such as thorough hand washing and equipment scrubbing to prevent the spread of contaminants, are often the most effective means of safety. Following through on these precautions can go a long way to ensuring that a livestock site does not become an example of the dangers associated with manure.
manure contamination in ground water can contribute to bacterial contamination and fish kills in surface waters. Excess phosphorus can also be transported to surface water impoundments such as ponds and lakes via erosion or runoff from fields. This phosphorus can stimulate unwanted plant growth, such as algae, which causes turbidity and other undesirable conditions in the water.

A common misuse of manure is to spread it on a field and then apply commercial fertilizer to supply a crop's nutrient needs with no consideration for the manure's nutrient value. An efficient manure management and application system meets, but does not exceed, the nutrient needs of the crop. This minimizes pollution.

Improper manure management can also harm the image of production agriculture and lead to stricter regulations if producers do not take the lead in implementing effective waste management systems.

The USDA–USEPA Unified National Strategy for Animal Feeding Operations, released in 1999, requires that Comprehensive Nutrient Management Plans (CNMPs) be developed for all animal-feeding operations by this year. The CNMP should address feed management, manure handling and storage, land application of manure, land management, record keeping, and other options for making use of manure. The plan should address liquid and solid manure produced in the operation as well as runoff and erosion control from areas where manure is stored or applied. It should include manure collection and storage at the point of production and appropriate use of manure on cropland or pastureland.

In some cases, manure will be applied to land not owned by the animal production enterprise, and so the plan should include the appropriate agreements or easements to ensure land availability. The overall purpose of a CNMP is to guide manure management in a manner that prevents degradation of water, soil, and air resources and protects public health and the environment.

Nutrient management planning can challenge even experienced planners. Not only are there numerous differences between types of animal operations, storage facilities, field limitations, crop needs, and equipment capabilities, but there are often differences between what various states and conservation partners want to see out of the planning process.

Manure Management Planner software

Brad Joern and Phil Hess from Purdue University recently developed a USEPA-approved software called Manure Management Planner (MMP) that's used to create manure management plans for crop and animal-feeding operations. The Windows-based computer program currently supports 34 states' by automatically generating fertilizer recommendations and estimating manure nitrogen availability based on each state's extension and/or USDA-NRCS guidelines.

A MMP user enters information about the operation's fields, crops, storage, animals, and application equipment. MMP helps the user allocate manure (where, when, and how much) on a monthly basis for the length of the plan (1–10 years). This allocation process helps determine if the current operation has sufficient crop acreage, seasonal land availability, manure storage capacity, and application equipment to manage the manure produced in an environmentally responsible manner. MMP is also useful for identifying changes that may be needed for a nonsustainable operation to become sustainable and determining what changes may be needed to keep an operation sustainable if it expands.

Nutrient management planning can also be done for farms that import and utilize manure but don't generate any manure or for farms that use commercial fertilizer to meet all of their crop nutrient needs and don't have anything to do with manure.

There are several steps in developing and implementing a CNMP. Producers can use MMP to develop a nutrient management plan by entering all production data, RUSLE2 data, and risk assessment data. The software then helps plan all manure and fertilizer applications and manure transfers, generate the CNMP document and the producer activity document, and edit the generated documents to insert maps and additional required text.

Resources

CCA Continuing Education Videos: www.certifiedcropadviser.org/certified/education/videos/nutrient-management.flv. Online seminar by Brad Joern and Phil Hess demonstrating a practical example of the use of the MMP to document a manure management plan. CCAs can obtain 1 CEU from watching the seminar and answering a quiz.

Contact the MMP Developers. Have a question about MMP? Email Brad Joern (bjoern@purdue.edu) and Phil Hess (pjhess@purdue.edu).

Manure Management Planner Home Page: www.agry.purdue.edu/mmp. Users can download the latest copy of the MMP software with links to additional resources such as documentation and the web-based Crop Fertilizer Recommendation Calculator and Manure Nutrient Availability Calculator.

University of Missouri Extension Nutrient Management Home Page: www.mmplanner.missouri.edu. A comprehensive nutrient management site from the University of Missouri Extension program including information on nutrient management planning, manure management, and regulations affecting animal-feeding operations.
n 2001, work started at the University of Saskatchewan’s department of agricultural and bioresource engineering to develop a prototype, field-scale, precision manure applicator. But it wouldn’t be injecting liquid manure, a fairly common practice among manure applicators; instead, this new technology was aimed at injecting solid and semi-solid manure.

Eventually, the project would be moved to the Prairie Agricultural Machinery Institute (PAMI) in Humboldt, SK, Canada for further development of the injection system. The aim of the research is to develop a commercially viable piece of equipment that can be used successfully by farmers. There have been technological challenges in the past to deal with solid manure injection. It’s hoped this research might bring an answer to that problem in the near future.

But why this interest in solid manure injection?

According to researchers involved in the project, solid manure injection technology promises to drastically reduce odors associated with traditional broadcasting methods. They are also looking at the potential of solid manure injection to reduce volatilization losses of nitrogen and losses of phosphorus and other nutrients due to runoff. By injecting the manure, the nutrients are locked into the soil, ready for use by plants.

The technology is also very versatile.

“The system was designed to work with anything that cannot be pumped,” explains PAMI project leader Dr. Hubert Landry. “Typically we’ve been working with beef cattle manure, but really, the product could come from any type of livestock production or even other by-products like municipal sludge.”

He adds that if the technology can be developed to the same level as existing liquid injection systems, it will mean potentially huge savings on transportation costs for farmers since liquid manure is much heavier to move than solid manure due to its high water content.

How does the solid manure injector work? The implement is basically a trailer with a large hopper containing the manure to be land applied, explains Landry. At the bottom of the hopper are four discharge screw conveyers. The screw conveyers move the manure to the rear of the machine where it falls into a transverse distribution conveyor for distribution along the width of application. From the transverse distribution conveyor, the manure is moved to coulter openers by flexible screw conveyors. The coulters open a trench into which the material is deposited, and the trench is then closed. Although the term “injection” is used, and although a fair amount of force is used to move the manure towards its eventual exit point, Landry points out that it might be technically more correct to call it “sub-surface application” of the manure. In a nutshell, the machine makes six trenches, the manure is dropped into them and covered right away.

It’s the injection aspect of the applicator that makes it so novel, according to Landry.

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Harvey’s Farm Cycle introduces manure record-keeping program

Harvey’s Farm Cycle, Inc. has introduced a software program for manure record keeping. The farm nutrient accounting system was designed to track various types of nutrient sources on the farm. The system records manure, fertilizer, and pesticide applications and also details areas where nutrient buildup is occurring, improving management decisions and helping to ease the burden of regulatory reporting.

The main goal of the program is to help producers record and maximize the benefits of nutrients applied to their cropland. The program also helps to keep farms in compliance with the requirements set forth by the National Pollutant Discharge Elimination System (NPDES) permit and requirements outlined in the Generally Accepted Agricultural Management Practices (GAAMPS).

Harvey Farm Cycle consultants enter the data (since most growers find this tedious), or growers can do it themselves. The company is also looking for consultants who would like to use this program for their customers on a subcontract basis.

The program is internet-based and offers options that fit into most management systems. Information can be entered online by the producer who can view his/her records at anytime. For more information, see www.harveysfarmcycle.com.
Agriculture and air quality have an intimate relationship. Large and small livestock operations and other agricultural activities—such as prescribed burning, for example—can release hazardous air pollutants (HAPs) such as carbon monoxide, volatile organic compounds (VOCs), and particulate matter, as well as odorous compounds, into the air.

While these agricultural air emissions have been, and still are, regulated under the 1990 Clean Air Act (CAA), there have been no reliable tools for the agricultural industry to use to establish an emission profile for facilities (emissions per animal, etc.).

This information roadblock has prevented federal and state governments from determining air emissions from agricultural facilities and fully regulating the industry under the CAA rules. However, new data being gathered by the USEPA will allow federal and state governments to standardize measurements of air emissions from agricultural facilities and enforce existing regulations. The USEPA will likely finish its work on this sometime next year with the new standards taking effect shortly after.

“What other industries are being regulated with will be the same tools that will be imposed on the agricultural industry,” said John Ferguson, a mechanical engineer and associate with Conestoga-Rovers & Associates. He spoke during a presentation at the Midwest Manure Summit in Green Bay, WI in March.

Monitoring program

In 2007, the USEPA began collecting data from a variety of farms, which will be used to develop emission factors for ammonia, hydrogen sulfide, VOCs, and particulate matter. Emission units will likely be tied to the type and number of animals at each farm, Ferguson explained, and will allow producers to evaluate the emissions from their properties and the regulators to evaluate their compliance with the regulations.

“Based on those emission factors, you’re either going to be a major source or a minor source. If you’re over those threshold criteria and you’re a major source, you’re going to be into those Title V permits and dealing with the USEPA at that level,” Ferguson said. “It’s not the end of the world—we get Title V permits for industrial facilities on an ongoing basis.”

However, record keeping and maintenance can be time consuming and expensive, Ferguson noted, and “if you are a large facility… you will want to be keen to know where you’re going to land.”

Under the CAA rules, major sources of pollutants emit 100 tons/year or more of carbon monoxide, NOx, SOx, VOCs, or particulate matter; 25 tons/year total HAPs; or 10 tons/year of a single HAP. Each major source of pollutants must obtain a Title V air permit, perform air dispersion modeling, meet ambient air criteria, provide emissions reports and certify compliance, and pay fees (typically based on the quantity of emissions).

Best management practices

Conversely, state requirements, scheduled to take effect in 2011 regulating facilities classified as minor sources of emissions, will allow pro-
Producers to achieve compliance through the implementation of state-approved best management practices (BMPs). If a facility classified as a minor source is unable to comply through BMPs, it may use emission factors, doing offsite impact analyses and comparing the results to state criteria.

“Compliance with state requirements is through best management practices,” Ferguson said. “That’s likely your easiest ticket. There’s no math; it’s probably stuff you’re already doing. Producers, however, must be proactive regarding compliance… You will have to demonstrate that you are in compliance. The onus is on you to find the paperwork and send it in.”

There are a variety of on-farm sources that can emit air pollutants and will need to be considered under the regulations. These may include production buildings, housing buildings, feedlots, waste lagoons, manure storage piles, and land application of manure. Typical pollutants released from concentrated animal feeding operations include VOCs, particulate matter, hydrogen sulfide, ammonia, and odor. Secondary pollutants of concern may include products from the combustion of fossil fuels and methane.

“If you don’t know where your air emissions are coming from, walk around [and] have a sniff; you’ll find out soon enough,” Ferguson said. “[Fossil fuel combustion products and methane emissions] are other types of air emissions that you’re going to be considering putting a quantitative value on to evaluate your future compliance with the regulations.”

Currently, there are no approved BMPs at the state or federal level. However, there are a variety of proven BMPs that are effective in reducing odor and emissions from agricultural facilities, according to Ferguson. These include controlling odor-carrying dust through vegetable oil sprinkling, using impermeable or permeable covers, installing dust collectors on exhausts, or implementing a water program on the facility. Neutralizing agents can also be effective in reducing odor. Installing an odor fence along a fence line or in doorways and using lagoon sprays can both help reduce odor.

Manure management is an important part of reducing agricultural air emissions. Locating new manure storage as far as possible from residences, removing manure from buildings at least once per week, covering storage piles, using manure additives, and locating manure storage downwind from homes and high-use areas are all effective methods to reduce the amount of nuisance odor produced in an agricultural facility, Ferguson said. He noted that these are not novel ideas.

“None of this is new information, but these are the tools that they are going to be using to come up with the BMPs to evaluate your compliance,” Ferguson explained. In addition, “if you have something on one of your facilities that can actually be controlled, which might be a lagoon, depending on what comes out of this study… there may be a best available control technology that will be imposed on you.”
Selecting the right fertilizer rate: A component of 4R nutrient stewardship

By S.B. Phillips, International Plant Nutrition Institute, Owens Cross Roads, AL; J.J. Camberato, Purdue University, West Lafayette, IN; and D. Leikam, Fluid Fertilizer Foundation, Manhattan, KS

The 4R nutrient stewardship concept defines the right source, rate, time, and place for fertilizer application as those best suited to achieve the economic, social, and environmental goals desired by all stakeholders to crop production systems. While this article will discuss only those decisions and principles related to selecting a fertilizer rate, every nutrient application involves all four components, and all nutrient best management practices link to one or more of the 4R components.

Liebig’s Law of the Minimum states that the yield of a crop will be determined by the element present in the most limiting quantity. In other words, the deficiency of one nutrient cannot be overcome by the excess of another. Thus, all of the 17 essential nutrients must be present in quantities sufficient to meet the requirements of the growing crop. The dilemma for crop advisers and growers is how to determine those quantities and answer the question: What is the “right” fertilizer rate for my cropping system?

Under- or overapplication of a particular nutrient may have crop production, economic, and/or environmental consequences. When fertilizer and other nutrient sources are relatively inexpensive compared with the value of the crop being produced, the incentive to make a precise nutrient recommendation is small unless the crop responds negatively to excessive nutrient levels (e.g., too much N causing lodging of small grains, reduced sugar content of beet, or rank cotton) or a perceived environmental consequence of the nutrient is acknowledged and valued (e.g., P contamination of the Everglades or Chesapeake Bay). However, in times of higher nutrient costs and/or lower crop prices, grower interest in developing efficient fertilization programs increases considerably.

Selecting appropriate nutrient application rates is always important regardless of crop price and nutrient cost.

Total crop nutrient requirement

A key scientific principle of selecting the right fertilizer rate is matching nutrient supply with plant nutrient uptake requirements. Nutrient uptake refers to the total amount of nutrients that will be taken up by the crop during the growing season. Some of these nutrients will be removed from the field in the harvested portion of the crop while the remainder will be recycled back into the system as crop residue. In some cases, nutrient uptake and nutrient removal values will be similar as in harvesting forage for hay where most of the aboveground biomass is removed. In other situations, such as cereal grain production, only a portion of the total nutrient uptake requirement is removed from the field. The total nutrient requirement of a crop depends on the type of crop and the yield potential of that crop. The higher the yield, the greater the nutrient requirement will be. Some of this requirement will be met through the soil nutrient supply, and the remainder will need to be provided as fertilizer inputs. However, determining fertilizer application rates based only on expected total nutrient removal by a crop is risky as it does not take into account the amount of crop nutrient supplied by the soil throughout the growing season or the reduced availability of some applied nutrients by the soil (for example, fixation of P by aluminum or K in the interlayer of 2:1 clays) and leads to decreased crop production efficiency.

Soil testing

Soil sampling and nutrient analysis are the foundation for many nutrient recommendations. The relatively soil-mobile nutrients such as P, K, Zn, Mg, and several others are best managed by implementing a long-term, sound soil-testing program. In lower-rainfall areas (e.g., the Great Plains and other western states), the more soil-mobile nutrients such as N, S, and Cl are also assessed and managed based on a pre-plant soil-testing program. However, N application rates are generally not based on soil testing in more humid climates because weather-induced variations in inorganic N concentrations greatly affect the ability of a soil test to accurately predict N availability to the crop in a given growing season. So, while a soil test is one of the best methods to determine the right rate of P, K, and several other nutrients in these higher-rainfall areas (e.g., Corn Belt, southern/southeastern states, etc.), pre-plant soil-testing programs are generally not used to develop N fertilization programs.

The soil testing process is based on: soil samples taken from representative areas in a field to a consistent and speci-
fied soil depth, analysis using an extraction technique appropriate for the soils in the region, correlation of soil test values with plant nutrient uptake or crop yield, and calibration with different nutrient application rates at different soil test levels. While much research has been directed toward the development of appropriate soil test procedures that help predict crop nutrient needs, these soil tests do not provide the final answer of what fertilizer rate needs to be applied to an individual field in a given year. As a result, two main approaches to utilizing soil test results for the development of fertility programs have resulted: (1) nutrient sufficiency and (2) build maintenance.

For the sufficiency approach, the goal is to apply, on average, just enough fertilizer to maximize profitability in the year of application without considering future soil test values. The recommended rate will be relative to a “critical” soil test level, at which the soil is capable of supplying nutrient amounts sufficient to achieve about 90 to 95% of maximum yield. The recommended rate will exceed crop removal at very low soil test levels and approach zero as the soil test value reaches the critical level—although a small amount of fertilizer (particularly P and/or K) is often suggested in starter applications. Over time, using this method will result in soil test levels equilibrating in the low, or deficient, category and nutrient applications will be required each year.

In the build-maintenance approach, fertilizer rate recommendations are made to meet the nutrient requirement of the immediate crop and to raise soil test values to the critical level over a specified time period. Once the soil test value is raised to the critical level, the soil is largely capable of meeting the crop nutrient requirement in a given year and only the amount of nutrients removed with the crop are applied to maintain the soil test levels in a target range slightly above the critical level. Once soil test values exceed this target range, no nutrient application will be recommended—except for the small amounts supplied in starter fertilizer applications.

Soil-testing laboratories differ in nutrient recommendation approaches. Some universities and commercial laboratories suggest using the nutrient sufficiency approach, others suggest following a build-maintenance approach, and others have adopted fertilizer rate recommendation systems that have attributes of both approaches. Kansas State University provides guidelines for both the sufficiency and the build-maintenance approaches depending on the fertility program objectives of the individual farmer. Build-maintenance approaches are impractical in some situations; for example, building soil test K in soils with low cation exchange capacity in high rainfall areas. But in general, sufficiency approaches are more common in the western USA while build-maintenance approaches are more common in the eastern USA.
Determining nitrogen fertilizer rates

Making accurate N fertilizer recommendations is very challenging. Chief factors hindering accurate N recommendations are the difficulties associated with estimating inherent soil N supply and predicting variable losses of both soil and fertilizer N. Difficulty in predicting N availability of green manures, animal manures, composts, biosolids, and other N sources also increases the uncertainty of N recommendations. Nitrogen fertilizer rate recommendations are made in many crops on a per-unit-of-yield basis. One of the major challenges in using a yield-based approach for determining fertilizer rates is obtaining an accurate estimate of crop yield potential. Another problem with approaches based solely on yield potential is that they assume that crop responsiveness to fertilizer inputs is constant across locations and years. In other words, a high-yielding crop has a high N fertilizer requirement. Yield levels are known to vary widely in a given environment from year to year. However, crop responsiveness to N fertilizer also fluctuates as a result of the environment, independent of crop yield potential. Both yield potential and crop responsiveness affect the annual N fertilizer rate requirement.

Other alternatives to yield-based N recommendation systems include determining N fertilizer requirements based on cropping system, soil type, or productivity or based on crop to fertilizer price ratios. Equations and models that predict crop yield and thus N uptake and availability of soil and applied N are also being utilized to fine-tune N rate recommendations.

In-season methods for determining the right nutrient rate

Most fertilizer rate recommendations are made prior to establishing the crop or very early in the growing season. However, to be fully committed to matching nutrient supply with plant demand throughout the growing season, some in-season monitoring may be necessary. One of the more common in-season methods is plant tissue analysis.

Plant tissue analysis is the sampling of a diagnostic plant part and measuring of the nutrient concentration in the tissue or the sap from the tissue. Nutrient deficiencies identified by tissue testing can be corrected in some situations or direct corrective action for future crops. While a range of nutrient concentrations is often provided to help guide the plant nutrient analysis interpretation, adequate concentrations can vary with crop, variety, plant part sampled, growth stage when sampled, environment, geographic area, and other factors. Collecting tissue and soil samples from both “poor” and “good” areas of a field often helps to diagnosis nutrient deficiencies.

Other in-season tools used to assess nutrient status of plants employ “indirect” methods of determination. An indirect, or nondestructive, measurement of plant nutrient content can provide information that can help guide in-season fertilizer applications without needing to collect, process, and analyze plant or soil samples. One such tool is the leaf color chart (LCC). First developed for use in southeast Asian rice production systems, the LCC is a hand-held card that allows growers to make real-time decisions regarding N requirements on a site-specific basis by comparing their crop to colors on the card that range from N deficient to excessive leaf N content. One of two methods employing a LCC is typically used to determine in-season N rate requirements in rice. One involves a pre-determined program of N application rates and timings. Leaf color chart measurements are made at critical growth stages, and the pre-determined N rates are adjusted up- or downwards depending on leaf color. The other method employs a real-time approach. Using this approach, a fertilizer application is made whenever the LCC value falls below an established critical level. Leaf color charts have also been evaluated for making in-season fertilizer rate decisions in wheat, maize, and sugarcane.

Another indirect measurement-based tool for monitoring in-season nutrient status is the chlorophyll meter. A chlorophyll meter provides a quantitative measure of the “greenness” of the plant leaf, which is indicative of chlorophyll content. When clipped onto a leaf, the meter provides an indexed reading, which is correlated with leaf N content. These readings can then be compared with research-based critical levels, or in-field reference (non-nutrient limited) areas, to determine an N fertilizer requirement. The meters are much more sensitive to subtle changes in color than the eye, and deficiencies can be detected much earlier in the season.

A strategy for determining in-season N fertilizer application rates that is rapidly gaining popularity is the use of optical sensors. Most optical sensors currently being used for making N rate decisions are active sensors, meaning they have an internal light source, rather than using sunlight. The sensors emit light at specific wavelengths and measure the portion of the light reflected back to the sensor. The amount of reflected light is correlated with plant characteristics such as greenness (much like a chlorophyll meter) and biomass.

One type of sensor that has been used to make on-the-go adjustments in N rate is the GreenSeeker. This sensor measures reflected red and near-infrared light to calculate a vegetation index [Normalized Difference Vegetation Index (NDVI)], which has been correlated with leaf area index, leaf N content, and crop yield. The NDVI values measured by the sensors are entered into an algorithm using an on-board computer and an N rate requirement is calculated. Nutrient rate algorithm components vary by region, but most are fairly sophisticated, taking into consideration several factors. Some of the factors used in various N rate algorithms include in-field reference measurements that are usually collected from “nonlimiting” or “nutrient-rich” areas established earlier in the growing season to compare with the target measurements at the time of fertilization; consideration of spatial and temporal conditions that affect crop growth, soil nutrient availability, and overall yield potential; and estimates of crop responsiveness to applied fertilizer that account for...
other nutrient sources such as manures or early-season mineral fertilizer applications.

Conclusion

The best approach for determining fertilizer rate requirement will be site-specific and depend on several factors including soil, climate, economics, labor supply, and logistics. The specifics will be different for each site, crop, and grower, but the principles are the same for all. Selecting the “right” rate for the most efficient and effective use of fertilizer requires that several factors be considered including:

- Plant demand for nutrients
- Soil nutrient supply
- Other available sources of nutrients
- Season-to-season variability in nutrient demand
- In-season changes in nutrient demand

Just as this list is not all inclusive, the topics covered in this article are only some of the tools available for making fertilizer rate decisions. It is also important to state again that rate is only one component of 4R nutrient stewardship. It is linked completely with and dependent on the other fertilizer “rights”—source, time, and place. It is the interconnectivity of 4R nutrient stewardship that can help meet the economic, environmental, and social goals of sustainable agricultural systems.

July–August 2009 Self-Study Quiz

Selecting the right fertilizer rate: A component of 4R nutrient stewardship (no. SS 03920)

1. When is it important to select an appropriate fertilizer application rate?
   - a. When crop value is high.
   - b. When potential environmental consequences of misapplication of nutrients are evident.
   - c. When fertilizer price is high.
   - d. It is always important.

2. Total crop nutrient requirement is
   - a. the total amount of nutrients removed in the harvested crop.
   - b. the same for all crops.
   - c. the total amount of nutrients that will be taken up by the crop during the growing season.
   - d. a good way to determine fertilizer application rate.

3. The soil-testing process is based on
   - a. collecting a representative soil sample.
   - b. appropriate extraction techniques.
   - c. correlation of soil test values with plant nutrient uptake.
   - d. all of the above.

4. Two main approaches to utilizing soil test results for the development of fertility programs are
   - a. nutrient sufficiency and build maintenance.
   - b. correlation and calibration.
   - c. buildup and maintenance.
   - d. nutrient sufficiency and critical levels.

5. The nutrient sufficiency approach does not consider
   - a. future soil test values.
   - b. profitability in the year of application.
   - c. critical soil test levels.
   - d. all of the above.

6. A major difficulty in making accurate N fertilizer recommendations is
   - a. estimating soil N supply.
   - b. predicting losses of soil and fertilizer N.
   - c. determining N availability of animal manures and other N sources.
   - d. all of the above.
7. Which of the following statements is true?
   - a. Crop yields are usually consistent from year to year in a given environment.
   - b. Crop response to N fertilizer applications varies from year to year.
   - c. A high-yielding crop always requires high N fertilizer rates.
   - d. None of these statements are true.

8. Which of the following is an indirect method of determining plant nutrient content?
   - a. Soil test.
   - b. Leaf color chart.
   - c. Tissue test.
   - d. Petiole sap analysis.

9. Optical sensors measure
   - a. reflected light.
   - b. plant nutrient content.
   - c. leaf area index.
   - d. plant N requirement.

10. Which of the following statements is false?
    - a. 4R nutrient stewardship can help meet sustainability goals.
    - b. The right rate depends on the other fertilizer rights—source, time, and place.
    - c. Fertilizer rate is the most important component of 4R nutrient stewardship.
    - d. The best approach for determining the right fertilizer rate is site-specific and depends on several factors.

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SELF-STUDY QUIZ REGISTRATION FORM

Name: ____________________________

Address: ____________________________

State/province: __________________ Zip: __________

CCA certification no.: __________________

☐ $20 check payable to the American Society of Agronomy enclosed.

☐ Please charge my credit card (see below)

Credit card no.: __________________

Type of card: ☐ Mastercard ☐ Visa ☐ Discover ☐ Am. Express

Name on card: __________________

Expiration date: __________________

Signature as it appears on the Code of Ethics: __________________

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

This quiz issued July 2009 expires July 2012

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SELF-STUDY QUIZ EVALUATION FORM

Rating Scale: 1 = Poor  5 = Excellent

Information presented will be useful in my daily crop-advising activities: 1 2 3 4 5

Information was organized and logical: 1 2 3 4 5

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

I was stimulated to think how to use and apply the information presented: 1 2 3 4 5

This article addressed the stated competency area and performance objective(s): 1 2 3 4 5

Briefly explain any “1” ratings: ____________________________________________________________

Topics you would like to see addressed in future self-study materials: ____________________________
Effect of manure application on corn yield, phosphorus uptake

Estimating crop availability of manure P and changes in soil test P (STP) with manure application are essential components of nutrient management planning. Animal manure is a traditional source of N and has been used with little regard to P content. Since animal nutrition demands varying amounts of nutrients from animal rations, it is likely that manures will have varying amounts of residual nutrients. If farmers are to use manures effectively, more knowledge is needed to select and manage manures from different animal species with varying nutrient contents and fit these to the needs of specific crops. The practice of considering only N has led to elevated levels of soil P on manured land. To reduce the impact of manure P applications on water quality, nutrient management regulations in Wisconsin and other states are now based on P. According to Wisconsin nutrient management standards, P Index or critical STP levels are used as guidelines for minimizing entry of nutrients into surface water. Within the Wisconsin P Index, changes in STP levels resulting from P applications and crop removal are estimated using a mass balance approach and the assumption that Bray 1 STP will increase or decrease by 18 lb P\textsubscript{2O\textsubscript{5}}/acre applied or removed to medium- and fine-textured soils and 12 lb P\textsubscript{2O\textsubscript{5}}/acre for coarse-textured soils. If the STP strategy is used instead of the P Index, the critical STP level above which P applications should be eliminated is 100 ppm.

In planning nutrient addition, P credits from manure application are subtracted from crop nutrient need to determine if excess P has been applied or if additional P fertilizer is required to meet crop need. It is assumed that because a portion of the P in manure is in organic forms, manure P is not 100% available to a crop in the year of application and P availability may be linked to the percentage of inorganic P. A number of studies have shown that guidelines regarding the first-year availability of manure P vary by state but typically fall within 60 to 100% of total manure P. Most states do not account for additional manure P mineralization in subsequent years; however, in Wisconsin, second- and third-year availability of manure P is assumed to be 10 and 5%, respectively, but current (2005) nutrient management regulations do not require most farms to take second- and third-year credits. Because nutrient management planning depends on estimating both changes in STP and crop availability of manure P, it is important to understand the effect of manure application on STP to comply with P-based nutrient management standards as well as meet crop needs for growth and development.

Past studies have observed that as manure or fertilizer P applications increased, so did STP levels and that, in most cases, these relationships were linear. When comparing P sources, fertilizer increased STP more than manure sources in several incubation studies. However, not all studies showed that fertilizer increased STP more than manure sources. Some studies showed that swine manure increased Olsen, Bray 1, and Mehlich 3 STP less than fertilizer for the first 28 days after application, but increases in STP were similar between sources after 28 days. On a sandy loam soil, poultry manure and swine slurry were found to increase Mehlich 3 STP similar to KH\textsubscript{2}PO\textsubscript{4}, whereas beef and dairy manures increased STP significantly less than KH\textsubscript{2}PO\textsubscript{4}. In the same study, Modified Morgan STP was increased more with application of poultry manure compared with the other manures, and the other manures were greater than KH\textsubscript{2}PO\textsubscript{4}.

Other studies found that swine slurry increased STP more than fertilizer regardless of initial STP level or manure application history. Dairy slurry was found to be more available than fertilizer in another study, but fertilizer increased STP more than all other P sources, which consisted of sewage sludge, poultry litter, and poultry manure.

In previous greenhouse and growth chamber studies, manures commonly had greater crop P uptake and yield compared with inorganic fertilizers. A growth chamber study in 2005 found that solid swine manure, swine slurry, and dairy slurry increased barley P uptake and dry matter yield more than fertilizer, whereas beef manure and composted dairy manure increased P uptake and yield less than fertilizer. A study completed in the mid-1980s found that inorganic fertilizer increased P uptake and dry matter yield of pasture grasses more than pig, beef, and sheep manures.

In contrast to greenhouse and growth chamber studies, field studies assessing availability of manure P have often found that manure P is less available to crops than fertilizer P. A field study with six site-years and variable Bray 1 P levels reported 14% average apparent recovery of manure P in corn biomass compared with 23% fertilizer P recovery, which suggested that manure P was approximately 60% as available as fertilizer P with regard to crop utilization. Greater fertilizer P use efficiency (40%) compared with raw and composted beef feedlot manure at various application rates (12–25%) for corn was found on a soil with a very high Bray 1 P level of 69 ppm. Other field studies have found manure P to be as available as fertilizer P. Swine slurries, from swine fed traditional corn diets as well as low-phytate corn diets, were applied to two sites and resulted in similar.
corn grain and total biomass P uptakes as fertilizer. Swine slurry applied at rates that contained three times as much P resulted in barley P uptake similar to fertilizer, whereas lower slurry application rates resulted in lower P uptakes. The apparent inefficiency of swine slurry to supply crop needs in studies may be related to the inadequate N supplied relative to crop need at lower slurry application rates. In most of the field studies to date, comparisons of manure and fertilizer P utilization by a crop are not clear because often levels of nutrients other than P are not equalized and initial STP levels are in a range where the expectation of crop responses to applied P are low to minimal.

The effect of manure application on P availability beyond the first year of application has both agronomic and environmental implications. Phosphorus additions with manure have been shown to impact crop production for at least one growing season after the initial year of application with STP impacts lasting even longer. Corn grain and total biomass P uptake during the second year after swine slurry application were generally not different than in the second year after fertilizer P application.

The majority of studies evaluating the relationship between manure P and fertilizer P have been incubation studies using controlled settings and parameters. Few field studies have been conducted with the goal of evaluating only crop P response from manure application. Understanding the effect of manure application on crop utilization of P and changes in STP is important to ensure that nutrient management planning is both agronomically and environmentally sustainable.

Wisconsin field study

The May–June 2009 issue of Agronomy Journal describes a field study, done in Wisconsin, to (i) evaluate manure P availability to crop growth through crop P uptake and yield, (ii) determine if second-year residual P availability from manure application is different than fertilizer, and (iii) evaluate the effect of P source on changes in STP levels. The study was conducted at the University of Wisconsin Agricultural Research Stations in Arlington (south central) and Marshfield (central) Wisconsin during the 2005 and 2006 growing seasons. The soils at Arlington and Marshfield are Plano silt loam (fine-silty, mixed, superactive, mesic Typic Argiudolls) and Withee silt loam (fine-loamy, mixed, superactive, frigid Aquic Glossudalfs), respectively. The experimental design at both locations was a randomized complete block with four replications. usual methods were used for preparing the seed bed, and adapted corn hybrids were used. For more specific information, see the article in Agronomy Journal (101:663–670).

Treatments consisted of five P sources at Arlington (triple superphosphate fertilizer, dairy slurry, dairy semisolid, swine slurry, and pelletized poultry litter) and four P sources at Marshfield (triple superphosphate fertilizer, dairy slurry, dairy semisolid, and swine slurry), each applied at three target P application rates, as well as a no P control for both locations. The dairy slurry and dairy semisolid used were supplied by farms near each study site. Both dairy slurries were collected from lactating dairy cattle operations. The dairy semisolid used at Arlington was from a heifer facility that used straw bedding. The dairy semisolid at Marshfield was collected from a breeding age heifer facility that used sawdust bedding. The same swine slurry was used at both locations and was collected from a covered anaerobic pit. The pelletized poultry litter consisted of dehydrated and pelletized poultry manure from layers fed a phytase-amended diet. Manures were analyzed for total N, total P, total K, total S, and percentage dry matter. Manure water-extractable P was also measured at 1:100 and 1:1,000 dry matter to deionized water ratio. Manure water-extractable P is expressed as a percentage of total manure P (Table 1).

In 2005, each P source was hand-applied in the spring before planting at low, medium, and high application rates based on previous manure analyses. The rates were selected to be approximately one, two, and three times corn...
Silage P removal rates, which represent low to very high manure application rates. Solid manures were applied by weight, and liquid manures were applied by volume. Actual P application rates were calculated based on samples collected at the time of application (Table 2). Manure credits for N, K, and S were taken, and inorganic fertilizer was applied to all plots to meet total P application rates. Before treatment application, one soil core was collected in each plot to a depth of 6 inches.

Data analysis

To ensure low variability in STP between plots before treatment application, pre-application STP data were analyzed using general linear models. At Arlington, one block had a significantly greater and more variable initial STP level than the other three blocks. The higher mean initial STP is in the optimum STP category, and 38% of the plots within the block had STP in the high category. In contrast, the mean initial STP levels of the other blocks were in the low STP category, and 25 to 50% of the plots within these blocks were in the very low STP category. Because one of the main objectives of this study was to observe the effects of P source and P application rate on crop response and because of the reduced probability for a P response in the block with the optimum and high STP levels, this block was removed from data analysis, leaving three replications at Arlington and four replications at Marshfield.

Apparent percent P recovery in 2005 was calculated using silage P uptake as:

\[ \text{Percent P recovery} = \frac{\text{treatment P uptake} - \text{control P uptake}}{\text{total P applied in the treatment}} \]

Apparent P recovery in 2006 was calculated using the equation above, where P uptake from the treatment and control are from 2006 and total P applied is the P rate applied in 2005 with no adjustment for 2005 crop removal. Crop response measurements, such as tissue P concentration, biomass, and P uptake at each sampling date and percent P recovery were analyzed using the MIXED procedure in

Table 1. Manure characteristics.

<table>
<thead>
<tr>
<th>Manure</th>
<th>DM†</th>
<th>Total N</th>
<th>Total P</th>
<th>Total K</th>
<th>Total S</th>
<th>MWEP&lt;sub&gt;100&lt;/sub&gt;‡</th>
<th>MWEP&lt;sub&gt;1,000&lt;/sub&gt;§</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arlington</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dairy slurry</td>
<td>103</td>
<td>40.1</td>
<td>6.1</td>
<td>23.6</td>
<td>1.9</td>
<td>26</td>
<td>76</td>
</tr>
<tr>
<td>Dairy solid</td>
<td>189</td>
<td>28.5</td>
<td>4.3</td>
<td>16.4</td>
<td>1.6</td>
<td>36</td>
<td>24</td>
</tr>
<tr>
<td>Poultry</td>
<td>840</td>
<td>42.0</td>
<td>20.0</td>
<td>25.4</td>
<td>2.3</td>
<td>20</td>
<td>23</td>
</tr>
<tr>
<td>Swine slurry</td>
<td>26.8</td>
<td>105</td>
<td>21.2</td>
<td>53.7</td>
<td>5.0</td>
<td>29</td>
<td>77</td>
</tr>
<tr>
<td>Marshfield</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dairy slurry</td>
<td>60.8</td>
<td>40.3</td>
<td>7.7</td>
<td>31.6</td>
<td>2.7</td>
<td>17</td>
<td>71</td>
</tr>
<tr>
<td>Dairy solid</td>
<td>199</td>
<td>23.7</td>
<td>4.1</td>
<td>26.3</td>
<td>1.7</td>
<td>57</td>
<td>47</td>
</tr>
<tr>
<td>Swine slurry</td>
<td>27.5</td>
<td>110</td>
<td>20.5</td>
<td>45.5</td>
<td>4.4</td>
<td>29</td>
<td>77</td>
</tr>
</tbody>
</table>

† DM, dry matter.
‡ MWEP<sub>100</sub>, manure water-extractable phosphorus (1:100 manure/water extraction ratio) expressed as a percentage of total P in the manure.
§ MWEP<sub>1,000</sub>, manure water-extractable phosphorus (1:1,000 manure/water extraction ratio) expressed as a percentage of total P in the manure.

Table 2. Amount of P applied for each P source and rate at Arlington and Marshfield.

<table>
<thead>
<tr>
<th>Source</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arlington</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fertilizer</td>
<td>37</td>
<td>73</td>
<td>110</td>
</tr>
<tr>
<td>Dairy slurry</td>
<td>33</td>
<td>67</td>
<td>100</td>
</tr>
<tr>
<td>Dairy solid</td>
<td>29</td>
<td>59</td>
<td>88</td>
</tr>
<tr>
<td>Poultry pellets</td>
<td>34</td>
<td>68</td>
<td>102</td>
</tr>
<tr>
<td>Swine slurry</td>
<td>28</td>
<td>55</td>
<td>82</td>
</tr>
<tr>
<td>Marshfield</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fertilizer</td>
<td>37</td>
<td>73</td>
<td>110</td>
</tr>
<tr>
<td>Dairy slurry</td>
<td>25</td>
<td>50</td>
<td>76</td>
</tr>
<tr>
<td>Dairy solid</td>
<td>30</td>
<td>60</td>
<td>90</td>
</tr>
<tr>
<td>Swine slurry</td>
<td>26</td>
<td>52</td>
<td>78</td>
</tr>
</tbody>
</table>
SAS with Tukey-Kramer means separation at the 0.05 probability level. Tukey-Kramer means separation was used in an effort to balance experiment-wise and comparison-wise error. Phosphorus fertilizer application rates were grouped as low, medium, and high as per Table 2. There were significant location interactions with P source and/or rate for several of the crop response measurements. Thus, locations were analyzed separately, and neither location had significant P source × P rate interactions. The analysis to test for interactions was conducted without using the control (no P applied). The main effect of P application rate was analyzed using the P application rate groups plus the control, which resulted in unbalanced data because there was only one control for all levels of P source. The main effect of P source was analyzed without the control.

Analysis of soil test data was based on the change in STP. This change was calculated as the treatment STP measurement for a given date and replication minus the control STP measurement for the same date and replication. Because initial STP levels were statistically not different across plots at a location, this calculation method allows for the assumption that P mineralization not associated with treatments was removed as well as changes in STP that were a result of P uptake by the crop in the control treatment.

**Results**

During the 2005 growing season, corn responded to P application as measured by increases in biomass and P uptake at V5 at both locations, silage P uptake at Marshfield, and grain P uptake at Arlington. There was no difference in silage or grain yield, silage or grain P uptake, or P recovery between fertilizer and any manure in the year of P application. First-year crop availability of total P in manure was similar to fertilizer. These data suggest that taking only partial credit for the total P in manure during the first year of application may not be justified from an agronomic standpoint. It should be noted that manure application in this study was likely many times more precise and uniform than typically occurs on many farms. Thus, the use of availability coefficients may still have a place in nutrient management planning, but should likely be related more to nonuniformity of application rather than nutrient unavailability.

In 2006, there was a crop response (biomass and P uptake at V5 at Marshfield, grain yield at Marshfield, and grain and silage P uptake at both locations) to residual P that was applied in 2005. There was no significant difference between fertilizer and various manures with regard to grain or silage yield and P uptake in the second year after P application. Thus, the use of second-year manure P credits is agronomically risky on low or optimum P-testing soils that receive recommendations for P as fertilizer or manure.

Manure changed STP levels after harvest as much as fertilizer per unit of total P applied, though nonsignificant variability existed between P sources in their effectiveness at changing STP at each location. In general, more manure P was required to increase soil test levels 1 ppm at Marshfield compared with Arlington. The data suggest that location, or more specifically soil series, and perhaps climate are important factors determining how much STP will change when P

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**Solid manure injection technology** | FROM PAGE 11

The equipment also brings uniformity of distribution plus good control of the rate of application of manure. “This is a great improvement over what is commercially available as far as equipment,” he says.

Meanwhile, the research team is hard at work to test the machine under different scenarios and on different crops. Two years of studies have been completed so far.

One of the studies, started in 2007 and being conducted near Humboldt, involves the research team comparing a variety of manure treatments to an unfertilized check. According to Dr. Jeff Schoenau, a research scientist with the University of Saskatchewan’s department of soil science, the scientists are looking at three different rates of solid cattle manure plus three different application methods—injection, broadcast, and incorporated. They are also examining broadcast only. The effect of the different rates, as well as placements and combinations, are being evaluated for their effects on crop yield, crop nutrient uptake, soil nutrient levels and distribution, and nutrient runoff potential.

“We’re not seeing really much difference between the different placements of the manure in terms of effects on yield or whether it was broadcast, broadcast-incorporated, or injected,” says Schoenau, adding this isn’t too surprising considering the cattle manure used in the study didn’t have a lot of readily available nutrients in it.

The research team did see some response in yield to the manure additions in both 2007 and 2008, but not a great effect from placement, Schoenau says. “We found our highest yields were when we combined urea fertilizer with the manure that was injected,” he says. “I think that can be attributed to the fact that the solid cattle manure has pretty low nitrogen availability in the year of application.”

Landry is upbeat about the future viability of the injection technology. “From a mechanical point of view, we would be fairly close to being able to go to market,” says Landry, adding the technology is not fully proven in the areas of agronomic and environmental benefits. “The market uptake is not under our control. We have to demonstrate the technology and generate enough interest to make sure that we have successful marketed uptake.”

The study still has one more season to go and a final report is expected in about a year.

—Reprinted with permission from the January–February 2009 issue of Manure Manager magazine (www.manuremanager.com). Information about the solid manure injector project can be obtained from Dr. Hubert Landry at 306-682-5033 or HLandry@pami.ca. Visit the PAMI website at www.pami.ca.
is applied. Further research—comparing laboratory-derived P source effectiveness values to field-measured values—could be useful to help determine if nutrient management planning tools should be revised to include more site-specific P source effectiveness values.

Effect of manure application on corn yield, phosphorus uptake (no. SS 03921)

1. The practice of considering only N in manure has led to
   - a. elevated levels of soil P on manured land.
   - b. reduced levels of soil P on manured land.
   - c. unchanged levels of soil P on manured land.
   - d. little change in soil P on manured land.

2. In planning nutrient addition, P credits from manure application are subtracted from crop nutrient need to determine if excess P has been applied or
   - a. if only N need be considered.
   - b. if additional P fertilizer is required to meet crop need.
   - c. if P is important to plant nutrition.
   - d. if P will run off into adjoining land.

3. In contrast to greenhouse and growth chamber studies, field studies assessing availability of manure P have often found that manure P is
   - a. more available to crops than fertilizer P.
   - b. interchangeable with fertilizer P.
   - c. less crop available than fertilizer P.
   - d. not measurable.

4. The apparent inefficiency of swine slurry to supply crop needs in studies may be related to the
   - a. inadequate N supplied relative to crop need at lower slurry application rates.
   - b. excess N supplied at high rates of slurry application.
   - c. the difficulty in delivering slurry at an even rate.
   - d. changes in N and P after delivery.

5. Manures were analyzed for total N, total P, total K, total S, and
   - a. fiber content.
   - b. inorganic matter.
   - c. percentage dry matter.
   - d. bacterial content.

6. During testing, treatments consisted of five P sources at Arlington and four P sources at Marshfield, each applied at
   - a. varying rates.
   - b. three target rates.
   - c. two target rates.
   - d. consistent amounts.

9. In 2006, there was a crop response (biomass and P uptake at V5, silage, and grain) to residual P that was applied in 2005. Which of the following is true?

- a. There was no significant difference between fertilizer and various manures with regard to grain or silage yield and P uptake in the second year after P application.
- b. There was a small difference between fertilizer and various manures with regard to grain or silage yield and P uptake in the second year after P application.
- c. There was a small difference between fertilizer and various manures with regard to grain but not to silage yield and P uptake in the second year after P application.
- d. There was no difference between fertilizer and various manures with regard to grain and a small increase in silage yield and P uptake in the second year after P application.

10. In 2006, there was a crop response (biomass and P uptake at V5, silage, and grain) to residual P that was applied in 2005. There was no significant difference between fertilizer and various manures with regard to grain or silage yield and P uptake in the second year after P application. Thus, the use of second-year manure P credits

- a. is agronomically risky despite recommendations for additional P as fertilizer of manure.
- b. is agronomically risky on low or optimum P testing soils that receive recommendations for additional P as fertilizer or manure.
- c. is agronomically risky for all soils.
- d. is useless.
Nitrogen nutrition index: an efficient diagnostic tool for nitrogen management

Nitrogen (N) is the most limiting nutrient in crop production, and large amounts are required to achieve high yields and maximize profitability. However, the negative impact of N use, especially through excess inputs, on the environment is widely recognized. The development of management practices to improve N use efficiency is therefore required both for economic and environmental reasons. Plant-based diagnostic methods of N nutrition can be used for an a priori diagnostic aimed at adjusting N fertilization to the crop N needs during the growing season and for an a posteriori diagnostic aimed at detecting N effects within experimental trials or fields in production. These methods, however, require a critical N concentration, which is the minimum N concentration required for the maximum rate of crop growth.

These diagnostic methods can be based on the N concentration of specific plant parts (e.g., leaves and petioles) or of whole plants. With whole plants, the N concentration is known to decrease during the growing season. For that reason, proposed critical N concentrations are usually only valid for a given stage of development. Alternatively, ranges of critical N concentration are proposed. The concept of a critical N curve, based on the N concentration for whole plants, was first developed in France for tall fescue and has been successfully applied to other crops such as wheat, rapeseed, potato, rice, grain sorghum, and corn. This concept has never been tested in North America. The following describes a study that was conducted to validate for corn hybrids in eastern Canada the parameters of the critical N curve developed in France and to assess the plausibility of using this tool to estimate the level of N nutrition in corn production.

New concept of critical N concentration

For the majority of crops, the critical N concentration ($N_{c}$) can be represented by the following allometric function:

$$N_{c} = aW^{-b}$$

where $W$ is the total shoot biomass expressed in tons of dry matter/acre, $N_{c}$ is the total N concentration in shoots expressed in percent dry matter, and $a$ and $b$ are estimated parameters (Fig. 1). The parameter $a$ represents the N concentration in the total shoot biomass with 0.45 tons/acre, and the parameter $b$ represents the coefficient of dilution, which describes the relationship of decreasing N concentration with increasing shoot biomass. During the early stages of growth (biomass < 0.45 tons/acre), however, $N_{c}$ takes a constant value due its small decline with increasing shoot biomass and the lack of competition for light of isolated plants. Above the threshold of 0.45 tons/acre, $a$ and $b$ parameters can be estimated using the allometric function.

The critical N curve (Eq. 1 and Fig. 1) discriminates three different types of N status. Data points below the curve indicate situations where N is limiting growth, whereas data points above the curve indicate situations of excessive N nutrition. Data points located on or near the curve correspond to situations where N does not limit growth and N nutrition is not excessive.

In corn, this concept of critical N concentration based on whole-plant biomass has been tested in France and Germany. Parameters $a$ and $b$ were estimated to be 3.41 and 0.37, respectively. This concept has never been tested in North America. The following describes a study that was conducted to validate for corn hybrids in eastern Canada the parameters of the critical N curve developed in France and to assess the plausibility of using this tool to estimate the level of N nutrition in corn production.

Site description, methods

To determine the parameters of the critical N curve and to estimate the N nutrition index (NNI), an experiment was conducted over two years (2004 and 2005) in Quebec, Canada at six sites with different soil textures and different crop histories (Table 1—next page). Corn hybrids and dates of planting and fertilization were specific to each site.
Six N application rates (18, 45, 89, 134, 179, and 223 lb N/acre) with a split application and one N rate (223 lb N/acre) with a single application at planting (hereafter referred to as the “223s lb N/acre treatment”) were compared, except at one site (L’Acadie) where only four N rates (18, 65, 112, and 159 lb N/acre in 2004 and 27, 74, 121, and 168 lb/acre in 2005) with a split application were compared. The 223s lb N/acre treatment received 223 lb N/acre at planting. All other plots received 18 lb N/acre at planting, except at L’Acadie in 2005 where 27 lb N/acre was applied. At either the V8 or V10 stage of development (Table 1), a second N application was added to reach the desired N application rates for each plot.

Shoot biomass was sampled weekly for eight weeks in 2004 and seven weeks in 2005 using a 6.6-ft-row section in each plot. Data from the sampling dates for which the shoot biomass was <0.45 tons/acre were excluded (Table 2). Whole plants were cut at ground level using pruning scissors. Shoot biomass was weighed fresh, and subsamples were collected for dry matter determination and laboratory analyses. Grain yield was determined in each plot by harvesting whole plants manually from a 32.8- by 2.5-ft area (Table 1). Harvested ears were wet shelled, and a grain subsample was dried at 131°F until the weight stabilized; grain yield was adjusted to 14% moisture.

Limiting and nonlimiting N conditions were determined using the analysis of variance and a LSD test. Sampling dates were not used in determining the critical N curve if the analysis of variance (F values) indicated no significant (P ≤ 0.10) differences among N application rates. For the remaining sampling dates, treatments were classified using the LSD test. Treatments with significantly (LSD0.10) lower shoot biomass were considered to be limiting while treatments with significantly (P ≤ 0.10) higher shoot biomass were considered to be nonlimiting; treatments were not included if their shoot biomass was classified in more than one group.

The NNI of the crop at each sampling date was determined by dividing the N concentration of the shoot biomass by Nc, the minimum N concentration required to achieve maximum shoot growth. The Nc was calculated using the allometric function proposed for corn in France [Nc = 3.41 x (2.24W)−0.37, with W being shoot biomass in tons/acre]. The relative yield was calculated as the ratio of the grain yield obtained for a given N rate with the highest grain yield among all N application rates.

Results

Shoot biomass during the growing season ranged from 0.45 to 5.40 tons/acre, depending on N application rates, sampling date, site, and year. Shoot biomass generally increased with increasing N fertilization, although this effect was not always statistically significant.

<table>
<thead>
<tr>
<th>Table 1. Site characteristics and cropping practices.</th>
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<tr>
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<tr>
<td>Organic matter, %</td>
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<td>pH (water)</td>
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<td>Clay content, % †</td>
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<tr>
<td>Silt content, % †</td>
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<td>Sand content, % †</td>
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<table>
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<tr>
<th>Soil classification‡</th>
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<th>Typic Haplorthods</th>
<th>Typic Humaquepts</th>
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<td>Corn</td>
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<td>Pioneer 39W54</td>
<td>Pioneer 38A24</td>
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<td>May 18</td>
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<td>July 9</td>
<td>June 28</td>
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<td>V8</td>
<td>V8</td>
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<td>Harvesting date</td>
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<td>Oct. 28</td>
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† Evaluated in the A horizon.
‡ Soil Survey Staff (2006).
§ Calculated from the planting date to the harvesting date.
¶ Corn heat units recommended for those hybrids.
# Second N application following the application of 18 or 27 lb N/acre at planting.
†† Stage at the second N application; defined by Ritchie et al. (1996).
Table 2. Corn shoot biomass on different sampling dates at three sites in each of two years (2004 and 2005).

<table>
<thead>
<tr>
<th>Sites</th>
<th>Year</th>
<th>Sampling dates</th>
<th>CHU†</th>
<th>Shoot biomass (tons dry matter/acre)</th>
<th>LSD‡</th>
<th>F test</th>
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<tr>
<td>St. Louis</td>
<td>2004</td>
<td>July 6</td>
<td>976</td>
<td>3.2 2.8 3.4 3.3 3.2 3.0 3.5 0.4</td>
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<tr>
<td></td>
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<td>July 13</td>
<td>1149</td>
<td>3.4 3.9 3.7 3.5 4.0 3.3 4.3 0.7</td>
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<td></td>
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<td>July 20</td>
<td>1334</td>
<td>10.8 12.3 11.2 11.3 11.6 12.2 13.1</td>
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<td>July 27</td>
<td>1494</td>
<td>15.0 17.0 17.7 16.2 16.6 17.8 18.1</td>
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<td>NS</td>
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<tr>
<td></td>
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<td>Aug. 2</td>
<td>1656</td>
<td>19.2 21.7 21.8 21.5 23.1 21.9 25.5</td>
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<td>**</td>
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<tr>
<td></td>
<td></td>
<td>Aug. 9</td>
<td>1802</td>
<td>21.9 22.8 27.0 25.2 26.8 26.1 26.2</td>
<td>2.3</td>
<td>***</td>
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<td></td>
<td>2005</td>
<td>July 6</td>
<td>1034</td>
<td>2.8 3.1 3.0 3.4 3.4 3.0 3.3 0.6</td>
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<td>1.7</td>
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<td>July 27</td>
<td>1579</td>
<td>12.5 13.7 15.4 17.7 16.6 17.4 16.4</td>
<td>2.2</td>
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<td>St. Basile</td>
<td>2004</td>
<td>July 30</td>
<td>1285</td>
<td>5.2 7.1 6.7 7.1 6.9 7.0 5.5 1.3</td>
<td>*</td>
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<td>Aug. 20</td>
<td>1727</td>
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<td>Ste. Catherine</td>
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<td>1084</td>
<td>2.2 2.7 2.9 2.8 2.9 3.0 2.7 ND</td>
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<td>1265</td>
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<td>July 25</td>
<td>1433</td>
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<tr>
<td>L’Acadie</td>
<td>2004</td>
<td>July 6</td>
<td>960</td>
<td>4.1 4.9 5.1 4.7 1.4 NS</td>
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<td>July 14</td>
<td>1168</td>
<td>8.0 7.6 8.1 8.5 1.5 NS</td>
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<td>1354</td>
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<td>July 30</td>
<td>1569</td>
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<tr>
<td></td>
<td></td>
<td>Aug. 4</td>
<td>1701</td>
<td>20.0 21.3 23.0 22.6 1.9 *</td>
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<td></td>
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<td>July 7</td>
<td>1145</td>
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<td>July 21</td>
<td>1532</td>
<td>9.1 10.9 10.3 11.0 ND§</td>
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<tr>
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<td></td>
<td>July 28</td>
<td>1700</td>
<td>11.8 15.9 15.9 17.8 ND **</td>
<td>NS</td>
<td></td>
</tr>
</tbody>
</table>

* Indicates significance at $P \leq 0.10$.
** Indicates significance at $P \leq 0.05$.
*** Indicates significance at $P \leq 0.01$.
† CHU, corn heat units accumulating from planting to the sampling date.
‡ LSD, least significant difference.
§ Not significant.
¶ ND, not determined.

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Nitrogen concentration in the shoot biomass decreased during the growing season. Decreased N concentration with time, or advancing maturity, has been reported for other crops such as wheat, potatoes, and timothy. This decline in N concentration with time, or increasing biomass, is attributed to a decrease in the fraction of total plant N associated with photosynthesis in relation to a concomitant increase in the N fraction of structural and storage constituents. This is observed in all field crops.

Statistical analysis based on significant ($P \leq 0.10$) differences in shoot biomass at each sampling date, site, and year clearly identified the limiting (20 data points) and nonlimiting (24 data points) growing N conditions. In general, the critical N curve ($N_c = 3.41 + (2.24W)^{-0.37}$) discriminated between the limiting and nonlimiting N conditions. All data points identified as limiting N conditions, except one, were under the critical N curve, and most data points identified as nonlimiting N conditions were above or near the critical N curve. These results obtained with corn hybrids in eastern Canada confirm that the model from France can be used for corn grown in eastern Canada.

At each sampling date, NNI values were calculated using the critical N curve. Values of NNI equal to or greater than 1.0 indicate that the crop is in a situation of nonlimiting supply of N, whereas values of NNI smaller than 1.0 indicate N deficiency. For instance, at St. Louis in 2004, the data points with N applications of 18, 45, and 89 lb N/acre were generally smaller than 1.0, indicating that N was limiting growth. With 134 and 179 lb N/acre, however, the data points were generally near 1.0, indicating that N was not limiting growth, and with 223 and 223 lb N/acre, the data points were generally well above the critical N curve, indicating excessive N nutrition.

A relationship between relative yield and NNI was established and accounted for 90% of the variation. For a NNI equal to or greater than 1.0, the relative yield was near 1.0. With decreasing NNI below 1.0, the relative yield decreased. The model of $N_c$ and the resulting NNI, therefore, adequately identified situations of deficient and non-deficient N nutrition in corn, making it possible to quantify the level of corn N nutrition.

### Agronomic implications of NNI

The NNI could be used for at least two different purposes: (i) for an a priori diagnostic aimed at optimizing fertilizer N management for economic reasons and for reducing the risks of polluting the environment through N losses to ground and surface waters and (ii) for an a posteriori diagnostic aimed at detecting limiting factors for crops within experimental trials or fields in production. The a priori diagnostic of crop N status consists of an early detection of plant N deficiency during the crop growth cycle in order to determine the necessity of applying additional N fertilizer. An a priori diagnostic of N deficiency in corn, therefore, should ideally be done at around the V6 to V8 stages of development for a remedial action to be effective. In this study, most of the data were obtained at the V12 stage of development; however, some of the data were collected as early as the V8 stage of development. We are therefore confident that this relationship could be valid, and remedial action effective, at the V8 stage of development. Further research, however, is required to validate this relationship at the V8 stage of development.

The a posteriori diagnostic of crop N status allows the analysis and interpretation of the agronomic performance of crops as it quantifies the intensity and length of the N deficiency. The timing of an a posteriori diagnostic of crop N status is therefore not as critical as that done for an a priori diagnostic aimed at deciding on a remedial action. Consequently, the NNI established at the V12 stage of development is satisfactory for the purpose of analyzing and interpreting a posteriori the agronomic performance of crops either in research studies or in production fields.

The NNI has been successfully used as a diagnostic of N status and in crop models to account for the effect of N on growth and yield of many species. A major limitation, however, in using the NNI at the farm level is the need to determine the actual crop mass and its N concentration. More practical plant tests are needed. The NNI could be used as a reference for simpler procedures to determine crop N status. In winter wheat, a field test using the relationship between NNI and the nitrate concentration in stem base extract has been developed, and the relationship between NNI and the chlorophyll meter is under investigation. In corn, relationships between NNI and the nitrogen concentration of the uppermost collared leaf and between NNI and the chlorophyll meter are also under investigation.

The critical N curve developed in France can be applied to corn grown under the pedoclimatic conditions of eastern Canada. In addition, the NNI calculated from that curve is valid, and remedial action effective, at the V8 stage of development. The NNI has been successfully used as a diagnostic of N status and in crop models to account for the effect of N on growth and yield of many species. A major limitation, however, in using the NNI at the farm level is the need to determine the actual crop mass and its N concentration. More practical plant tests are needed. The NNI could be used as a reference for simpler procedures to determine crop N status. In winter wheat, a field test using the relationship between NNI and the nitrate concentration in stem base extract has been developed, and the relationship between NNI and the chlorophyll meter is under investigation. In corn, relationships between NNI and the nitrogen concentration of the uppermost collared leaf and between NNI and the chlorophyll meter are also under investigation.

The critical N curve developed in France can be applied to corn grown under the pedoclimatic conditions of eastern Canada. In addition, the NNI calculated from that curve is a reliable indicator of N stress level during the growing season.

### References


July–August 2009
Self-Study Quiz

Nitrogen nutrition index: an efficient diagnostic tool for nitrogen management (no. SS 03922)

1. Plant-based diagnostic methods of N nutrition require a critical N concentration, which is
   - a. the minimum N concentration required for maximum crop growth rate.
   - b. the minimum N concentration required for maximum economic return.
   - c. the minimum N concentration required for minimum crop growth rate.
   - d. the maximum N concentration for crop utilization, which is important for avoiding N loss.

2. These diagnostic methods can be based on the N concentration of specific plant parts or of whole plants. With whole plants, the N concentration is known to
   - a. decrease during the growing season.
   - b. increase during the growing season.
   - c. remain essentially the same throughout the growing season.
   - d. behave independently of the N content in plant parts.

3. Which of the following is true about the critical N curve?
   - a. It takes into account crop biomass since as plants grow, the concentration of N in the crop declines.
   - b. It takes into account crop biomass since as plants grow, the concentration of N in the crop declines.
   - c. It measures the N concentration of specific plant parts (e.g., leaves and petioles).
   - d. It can be used to determine plant-available nitrogen.

4. The nitrogen nutrition index could be used for an a posteriori diagnostic aimed at
   - a. optimizing fertilizer N management for economic reasons.
   - b. limiting factors for crops within experimental trials or fields in production.
   - c. optimizing fertilizer N management for environmental reasons.
   - d. limiting factors used in crop models.

5. An a priori diagnostic of N deficiency in corn should ideally be done
   - a. as soon after germination as possible.
   - b. when the plant is 2 inches tall.
   - c. around the V6 to V8 stages of development.
   - d. during the early reproductive stages of development.

6. Which of the three different types of N status does the critical N curve (as shown in Eq. 1 and Fig. 1) discriminate?
   - a. Data points below the curve indicate situations where N is limiting growth, data points above the curve indicate situations of excessive N nutrition, and data points located on or near the curve correspond to situations where N does not limit growth and N nutrition is not excessive.
   - b. Data points below the curve indicate situations of excessive N nutrition, data points above the curve indicate situations where N is limiting growth, and data points located on or near the curve correspond to situations where N nutrition is not excessive and N does not limit growth.
   - c. Data points above the curve indicate above-average N utilization, data points below the curve indicate below-average N utilization, and data points located on or near the curve correspond to optimal N utilization.
   - d. Data points above the curve indicate high N use efficiency, data points below the curve indicate low N use efficiency, and data points located on or near the curve correspond to average N use efficiency.

7. The objectives of this study were to validate certain parameters of the critical N concentration concept for corn hybrids in eastern Canada to
   - a. determine the difference between N uptake in European hybrids vs. Canadian hybrids.
   - b. determine whether this tool can predict midseason N needs.
   - c. determine whether this tool can reliably predict corn yields based on N levels.
   - d. determine whether this tool can be used to estimate the level of N nutrition in corn production.
8. In the future, the NNI could be used as a reference for simpler procedures to determine crop N status. Winter wheat, for instance, is currently being tested to
- a. determine the relationship between NNI and growth rate.
- b. determine the relationship between NNI and the PSNT.
- c. determine the relationship between NNI and grain yield.
- d. determine the relationship between NNI and the chlorophyll meter.

9. The model of $N_c$ and the resulting NNI adequately identified situations of deficient and non-deficient N nutrition in corn. This makes it possible to
- a. estimate uptake rate.
- b. adjust the amount of N.
- c. quantify corn N nutrition.
- d. predict crop yields.

10. The decline in N concentration with time, or increasing biomass, in the study reported in this article is attributed to
- a. an increase in the fraction of total plant N associated with photosynthesis in relation to concomitant increase in the N fraction of structural and storage constituents. This is observed in some field plants.
- b. decrease in the fraction of total plant N associated with photosynthesis in relation to a concomitant increase in the N fraction of structural and storage constituents. This is observed in all field crops.
- c. increase in the fraction of total plant N associated with photosynthesis in relation to a concomitant decrease in the N fraction of structural and storage constituents. This is observed in most field plants.
- d. decrease in the fraction of total plant N associated with photosynthesis in relation to a concomitant decrease in the N fraction of structural and storage constituents. This is observed in all field crops.
Canada East

New website for identifying Ontario weeds

By Brian Hall, Edible Beans and Canola Specialist, Ontario Ministry of Agriculture, Food, and Rural Affairs, Stratford, ON, Canada

ontarioweeds.com is a powerful new online search tool for identifying and accessing information on more than 90 weeds in Ontario. Combining biological and identifying characteristics of top interfering species along with new emerging research articles, media, and control options, the website provides the tools to make informed risk-reducing weed control decisions.

Search feature

Search weeds by common, botanical name, or by Bayer code, or if the name of the weed is not known, you can do a simple search using a descriptive feature such as “yellow flower” or “thistle.” Weeds in the system can also be selected from the “Weed Index” page, which lists weeds alphabetically by common name. Once on an actual weed information page, all the information for that specific weed is displayed, including reference illustrations and photographs. Photographs include both seedling stage and key distinguishing characteristic features at later stages, all of which can be enlarged when selected. Every weed species within the ontarioweeds.com database contains a “power ranking.” The power ranking considers two components: how abundant and how difficult the species is to control in corn and soybeans. These initial rankings have originated from informal grower and crop adviser surveys where participants were asked to prioritize a number of weed species in terms of management importance. Where applicable, various links to outside research sites connect you to the most up-to-date information available.

Weed control ratings in corn and soybeans

Many of the weeds include information on control options in field corn or soybeans. Herbicide control options rate herbicides for “Percent Control” and “Treatment Environmental Impact (EIQ).” The EIQ is designed to provide growers and other decision makers with one number that indicates the magnitude of relative risk. The EIQ was developed by Ohio State University researchers to estimate the risk to farm workers, consumers, and the environment of pesticide active ingredients. The toxicology, as well as persistence and movement in the environment, were used to calculate the EIQ. At ontarioweeds.com, the environmental impact of a pesticide product is determined by multiplying the application dose by the EIQ value for the active ingredient.

Weed identification service

If users are still uncertain about a weed’s identification, they can submit photos and/or weed description online for identification. For further information on ontarioweeds.com, contact the project lead: Mike Cowbrough, Ontario Ministry of Agriculture, Food, and Rural Affairs, at mike.cowbrough@ontario.ca.

North Central

Innovative CEU opportunities emerging in Iowa

By Laura Sinnwell, Communications Director for the Agribusiness Association of Iowa, Des Moines, IA

The Agribusiness Association of Iowa (AAI) has held trade shows for many years. The unfortunate reality of industry trade shows is that these events are struggling to remain popular “draws” for attendees and vendors for a multitude of reasons. Whether the issue is readily available information through other mediums, changes in sales and marketing techniques by vendors, or the cost associated with running a booth in today’s economy, trade shows that lack a unique aspect are struggling to remain profitable and relevant within the agribusiness industry.

AAI hopes to reinvigorate its annual show by creating an educational opportunity for CCAs while showcasing industry innovation and technology. Iowa’s new event has been named the “2010 Agribusiness Showcase and Conference” to clearly and transparently convey the intent of AAI’s expo reinvention. This showcase and conference is about giving agribusiness, vendors, and attendees the opportunity to explore the innovative tools and education they need to grow their business, now and in the future.

CCAs will be able to earn CEUs over the course of two days. The first day of the 2010 Agribusiness Showcase and Conference will offer up to 10 hours of CEUs through a traditional seminar-based setting. The CEU speakers will be selected with the input and assistance of Iowa CCAs. In addition, on the evening of the first day, AAI will hold a banquet in honor of the CCAs, recognizing “years of service” in the profession.

ontarioweeds.com
Western Copper sulfate foot baths on dairies and crop toxicities: What are the risks?

By Amber Moore, Assistant Professor and Extension Soil Specialist, University of Idaho, Twin Falls Research and Extension Center, Twin Falls, ID; and Jim Ippolito, Research Soil Scientist, USDA–ARS, Northwest Irrigation and Soils, Kimberly, ID

A rising concern with the application of dairy wastes to agricultural fields is the accumulation of copper (Cu) in the soil. Copper sulfate (CuSO₄) from cattle footbaths are washed out of dairy barns and into wastewater lagoons. The addition of CuSO₄ baths has been reported to increase Cu concentration significantly in manure slurry from 4.8 ppm to 88.6 ppm. The Cu-enriched dairy waste is then applied to agricultural crops, thus raising concerns about how soils and plants are impacted by these Cu additions.

Once added to the soil, the Cu²⁺ from CuSO₄ can: (1) remain in the soluble form of Cu²⁺, which is available to plants; (2) adsorb to organic matter; (3) adsorb to clay particles; or (4) be converted to less available mineral forms. Typically, the majority of Cu strongly adsorbs to organic matter and clay surfaces in the soil. In fact, Cu binds to organic matter more strongly than any other micronutrient. Dairy waste materials that are rich in organic matter, such as stockpiled manure, will naturally have greater Cu adsorption than dairy lagoon water, which is low in organic matter. In soils with pH values greater than 7.0, soluble Cu²⁺ will react with water to form either Cu(OH)₂, or associations

Regional Roundup

with many of their employers in attendance. The banquet will take place at Prairie Meadows Racetrack and Casino in Des Moines.

The second day of the conference will tentatively offer 5 to 6 CEUs as part of an “indoor field day.” This CEU event will allow CCAs to visit with vendors about emerging technologies, innovative applications, and cutting-edge stewardship practices under the roof of the Iowa State Fairground’s 90,000+ ft² Varied Industries building, in the middle of Iowa’s winter.

The “indoor field day” will require substantive conversations at vendor booths in exchange for CEU credit. An assessment will be completed by AAI staff after the event to determine what types of CEU credits individual CCAs will receive based on the vendor’s expertise (e.g., soil and water management) and the topic discussed.

“The response from Iowa’s CCAs has been fantastic,” says Mark Reisinger, CEO of AAI. “Creating an interactive event to supplement the one-day seminar has become a very popular prospect for Iowa’s CCAs. In addition, earning up to 16 hours in two days is very popular with both the CCAs and a few of their employers.”

Due to the unique nature of the CEUs held in conjunction with a trade show and seminar, and the initial positive response AAI has received from CCAs, this could quite possibly re-establish the AAI trade show as one of the premiere trade shows in the nation.

The 2010 Showcase and Conference will be held February 9-10, 2010 at the Iowa State Fairgrounds in Des Moines, IA. Additional information and registration materials will soon be posted on the AAI website at: www.agribiz.org.

July SCN, Corn Nematode Workshops

Iowa State University (ISU) will be holding two all-day workshops in July. The first will be held on Wednesday, July 29, 2009, near Ames, IA and will focus on soybean cyst nematode (SCN). The second will be held the next day, July 30, also near Ames, and will focus on the basics of the biology and management of corn nematodes.

The SCN workshop will include discussions of the basic biology of SCN and how the nematode modifies living soybean cells to support itself. Other topics of discussion will include how to scout fields for SCN and manage the nematode to maintain profitable soybean production. There will be SCN-infected plants and microscopes for study and hands-on demonstrations of procedures used to extract SCN cysts from soil and to extract SCN eggs from cysts. Workshop instructors will be Palle Pedersen, ISU extension soybean agronomist, and ISU nematologists Thomas Baum and Greg Tylka. Participants can earn 7 Integrated Pest Management CEUs.

For the corn nematode workshop, specific topics will include a review of the nematode species that can damage corn, their life cycles and feeding habits, the symptoms of nematode damage on corn, how to sample to determine if nematodes are damaging corn, and current and future management options for nematodes on corn. The workshop also will include hands-on demonstrations of procedures used to extract plant-parasitic nematodes from soil and corn root tissue. ISU nematologist Greg Tylka will lead the workshop, which is approved for 7 Integrated Pest Management CEUs.

Participants of both workshops will receive printed course notes, other print publications, and computer training modules on CDs. The registration fee for each workshop is $150, and there is a 10% discount on registration fees for individuals registering for both workshops. For more information or to register, either email Greg Tylka at gltylka@iastate.edu or call Carla Harris at 515-294-1160.
with Fe oxides. Thus, almost all Cu added to soils typically stays in soil. (For more information regarding soil Cu reactions, see www.saanendoah.com/cudefromsoil.html.)

Research findings for land applying copper sulfate

With the strong binding of soluble Cu to soils, very little of the applied Cu is plant available. Overall, the potential for Cu toxicities in plants is relatively small given the amount of Cu that is applied through dairy waste. Preliminary results from the USDA-ARS in Kimberly, ID showed that extractable soil Cu concentrations ranging from 1 to 154 ppm in a calcareous soil had no effect on alfalfa or corn silage biomass yields while plant survival was drastically impeded at concentrations greater than 323 ppm. It should be mentioned that Cu application rates used in this study to achieve reductions in yields and plant survival greatly exceeded rates typically seen for dairy manure applications. In a similar study in New York, Flis et al. (2006) applied CuSO4 at 0, 6.3, and 12.6 lb Cu/acre to corn silage, orchardgrass, and timothy grass using Cu rates equivalent to those typical to dairy waste applications. Corresponding soil Cu concentrations were 11, 13, and 18 ppm, respectively. The varying Cu application rates had no effect on grass or corn silage yields, although tillering and regrowth rates were significantly reduced for the grasses.

While these results are encouraging in the short-term, repeated applications of dairy manures could potentially raise Cu concentrations to levels toxic to plants, with very limited possibilities for remediation. A few fields in Idaho that have received frequent applications of lagoon water have shown evidence of copper accumulation. Because Cu is so tightly bound by the soil, it is very difficult to remove. Succeeding crops can only remove 0.1 lb Cu/acre per year. As it stands now, if growers wait until Cu plant toxicity symptoms occur (including plant death), they will continue to see Cu toxicities on that field for an indefinite period of time.

In terms of regulation, there is an existing USEPA 503 “worst case scenario” standard that limits annual loading of Cu from biosolids to 66 lb Cu/acre and lifetime loading to 1,339 lb Cu/acre. (Limits are based on biosolids land application. For more information, see www.epa.gov/owm/mtb/biosolids/503pe/503pe_2.pdf). Reaching these limits is almost impossible with dairy waste applications and would devastate most agricultural crops long before the lifetime loading limits were met. New York has set lower lifetime loading limits for Cu at 75 lb/acre to avoid the potential of irreversible toxic accumulations of Cu in the soil. (For more information, see Table 5 at www.dec.ny.gov/regs/4411.html).

Recommendations for avoiding copper toxicities

While more studies are needed, based on what we know thus far, it would be advisable to cease Cu additions to soils with greater than 50 ppm extractable Cu; this value is advisable if a producer was raising alfalfa for dairy cow consumption to avoid Cu accumulation greater than National Research Council recommendations. To determine if you currently have a Cu accumulation problem in your soil, or to identify a developing accumulation, request an analysis for diethylenetriaminepentaacetic acid (DTPA) extractable Cu every two to three years from an NAPT accredited soil testing laboratory.

References


This article was prepared by members of the Western Extension and Research Activities (WERA 103) Committee on Nutrient Management and Water Quality. For more information about WERA 103 including upcoming meeting dates see: http://cropandsoil.oregonstate.edu/wera103.
Educational opportunities abound to help you meet your CEU requirements  

By Luther Smith, Director of Certification Programs; lsmith@agronomy.org

Are your CEUs due by the end of this year? Do you know how many you currently have or have you met the requirements already?

It’s summer! Continuing education may not be at the top of the priority list, but it is a good time to take inventory. There are approximately five months left in the year, and if your two-year cycle ends in 2009, you may want to make sure you have enough earned to meet the educational requirements or develop a plan to attend some training by December 31.

You can check your CEU totals online by going to www.agronomy.org or www.soils.org and clicking on the appropriate certification in the box on the right side of your screen. Have enough? Congratulations, you are in good shape to maintain your certification. No, not yet? Well, there is still time to earn more.

Requirements

All of the certifications for ASA and SSSA have the same total requirement, 40, every two years. CCAs must earn at least 5 CEUs in each of four categories (Nutrient Management, Crop Management, Integrated Pest Management, and Soil and Water Management), and at least 20 of the 40 need to be board approved. There is not a minimum or a maximum number of CEUs required for the Professional Development category. You can earn up to 20 CEUs from self study. All of the certifying boards accept all board-approved CEUs and self-reported CEUs.

The certifying boards have the right to audit your CEUs. That means they will randomly select certified professionals and ask them to prove that what appears on their CEU statement is factual. This is specifically directed at self-reported CEUs. What you need to do is keep records of what you attended, when you attended it, and where you attended it and any related materials for at least three years. After three years, you can discard it if you like.

A simple approach to record keeping would be to create an excel spreadsheet showing the date, location, instructor, topic/title of the event, and CEUs earned by category. Place all of the handout materials you were given in a folder, especially the agenda and speaker bios. Print your CEU statement when the event appears in your record and place that in the folder. You should be good to go if you do all of that.

Self study or self reported

Self-study CEUs are those that are contained in the magazine (and on our website). They are printed or online courses that you complete at your own pace (read the article and answer the quiz questions). All self studies are board approved and count towards that total. CCAs can earn a maximum of 20 of these types of CEUs. See www.certifiedcropadviser.org/certified/education/self-study.

Self-reported CEUs are the same as board-approved, live professional meetings, but the sponsor has not requested CEUs for the event and a board has not approved them. A CCA, CPAg, and CPSS/C may report the event by using the online self-reporting form.

Professional meetings

Live events—professional meetings, seminars, and field tours—are by far the most popular way for certified professionals to earn CEUs. Regardless of your certification, if at an event, you are asked to sign a form or scan your card, those CEUs will automatically appear in your record. No further action is required.

Educational opportunities

Throughout the year, you should be seeking out the best educational programs that are of interest and benefit to you. Strive to be an active learner instead of a passive learner.

Active learner: You decide what you want to learn, develop a learning plan and set some goals, and then seek out and schedule the professional meetings and self-study programs that will help you achieve those goals. Each certified professional must earn at least 40 hours of continuing education every two years. No one would ever want to admit that they just throw away 40 hours of their life every two years, so take charge, plan what you want to do, and demand excellence from the programs.

Passive learner: “Oh, $#*! I need 20 more CEUs, or I’ll lose my certification. I’ll just go to that meeting in November. I don’t know what they are talking about, but the food is always good, and it’s free.” Now I know that not more than a handful of readers of this magazine would fit into this...
NAPT working for you

How does the NAPT program help labs serve you better?

By Janice Kotuby-Amacher, NAPT Coordinator, Berkeley CA

What do you look for in a soil-testing laboratory? You want a lab that delivers accurate, precise data in a timely manner so that you can make the best recommendations to your client. But how can you be sure that the laboratory is delivering that accurate, precise data that you want? That’s where the NAPT program comes in. We provide soil, plant, and water samples to labs on a quarterly basis, which the labs analyze and then submit their results back to us for statistical comparison. We look at how close a lab’s results are to the median of all the labs (precision) and how similar the results are for a soil repeated throughout the year (accuracy). Labs use this information to correct any deficiencies in their analyses, check how well new employees perform, and just ensure that they are doing their best.

How do you know if a lab is a participant in the NAPT program? You can ask or you can check out our website to see if they are on the list: www.napt-program.org/about/participants. Ask to see their results from a recent quarter, realizing that labs do not pass 100% of their results, but should pass 80% or better. That way, you know that a lab is performing at its best.

Other things that the NAPT offers to labs include quality control samples for them to check their analyses on a regular basis; papers on methods of analysis which are new or revised; and workshops on laboratory management, quality control, laboratory methods of analysis, etc. The NAPT program also cooperates with state and provincial programs in Iowa, Minnesota, Missouri, Nebraska, and Ontario, as well as the PAP program (Performance Assessment Program) for labs doing USDA-NRCS samples in the Northwest. For further information on the state and provincial programs, you can contact me (jkotuby@mendel.usu.edu), NAPT coordinator, or the individual program coordinators:

- Iowa: Travis Knight (Travis.Knight@idals.state.ia.us)
- Minnesota: Jerry Floren (jerry.floren@state.mn.us)
- Missouri: Manjula Nathan (nathanm@missouri.edu)
- Nebraska: Charles Focht (cfocht@agr.ne.gov)
- Ontario: Keith Reid (keith.reid@ontario.ca)

The NAPT program was developed to provide an external quality assurance program for agricultural laboratories, develop a framework for long-term improvement of quality assurance of the agricultural laboratory industry, and identify variability of specific analytical methods. Thus, the NAPT program ensures that soil-testing laboratories provide the most precise and accurate data for you and your clients. So whenever you are in the market for a soil-testing lab, be sure to use one that participates in the NAPT program.
Economics of manure exchanges

By Kevin Erb, CCA, University of Wisconsin Extension, Green Bay, WI

A manure exchange is an agreement between two farmers where one (or both) agree to provide manure to cropland under the management or ownership of the other. With fuel and fertilizer prices well above the 5-, 10-, 15-, and 20-year averages, many cash grain producers and dairy feed producers are open to the idea of accepting manure from neighboring livestock operations. While these exchanges can be beneficial to both parties, there are significant issues that must be dealt with before moving manure from one farm to another.

From outright cash sale of manure to a feed-for-manure contract, these exchanges can take many forms. The list below highlights some of the more common ones found in Wisconsin:

- **Dutch treat.** In a Dutch treat exchange, two livestock producers agree to apply manure to land owned or operated by the other. This commonly occurs when both producers have owned or rented land across the road or next to the neighbor’s barn. Each agrees to haul the same amount of manure onto the neighbor’s property.

  The benefit here is that each saves fuel and wear and tear on equipment and can cut several hours to more than a day off their manure-hauling time. We have also seen these agreements work well when two farms are on opposite sides of a busy highway or other obstacle (railroad, stream with narrow bridge, etc.) and it is easier and safer not to cross the road with loaded manure equipment. If a farm saves 2 miles one way per load at three loads per acre, Dutch treating a 20-acre field would save 240 miles on the tractor/spreader and 10 hours of labor for each farmer.

- **Manure for feed.** Here, the cash grain producer agrees accept a certain amount of manure from the dairy as part of a contract to produce feed for the dairy. Rates, time of application, and field selection are all spelled out in the contract.

- **Manure for cash.** With a cash sale, the dairyman provides the manure for a set price per ton or thousand gallons. The price is usually determined by the nitrogen content of the dairy manure.

- **Manure for services.** This type of trade involves the manure recipient providing a set amount of services to the manure producer.
(e.g., hoof trimming, feed hauling, and tillage) in exchange for the manure. One benefit of this type of exchange is that, if the dairyman can contract with a dependable neighbor with the right equipment, the dairy can avoid investing in that tool (and in the case of large tillage equipment, a tractor large enough to pull it).

Considerations

A written contract is essential with any type of manure exchange. Unlike a tractor repair where the mechanic can put a lien on the tractor and possibly seize it, manure cannot be taken off the field and hauled somewhere else. A contract should be reviewed by both farms’ attorneys. Key factors to put into the contract include:

- **Environmental responsibility**
  - Who must provide the nutrient management plan for acres applied?
  - Who is responsible for cleanup if the tanker tips over turning into the field?
  - Who is responsible for cleaning mud off the road?
  - How many hours after application must incorporation be done? Who is responsible?
  - What rate will be applied? Who is responsible if the proper rate is not applied?
  - Whose crop consultant makes the rate determination?
  - If the tenant changes post-application, is the contract enforceable on the tenant? In almost all cases, the nutrient management plan will be enforceable on the new tenant.

Note that, in the eyes of the Wisconsin Department of Natural Resources and USEPA, the primary responsible party is the farm that generated the manure. Farms under permits or nutrient management plans are ultimately responsible for ensuring that plans and records are followed and maintained on all acreage receiving manure.

- **Field responsibility**
  - If it is too wet, can either party request waiting a few days without penalty?
  - If the fall is wet, are other fields eligible, or must it be applied to certain fields?

- **Manure sampling**
  - A manure sample is essential. How many samples, who pays, and who is responsible for taking them?

- **Application**
  - Who provides the tractors for agitation, application, and incorporation?
  - Who provides fuel for those tractors?
  - Who notifies neighbors of applications?
  - Who provides on-site assistance the day of application (in case questions arise about which field, setbacks, application areas, etc.)?
  - Who pays the applicator?
  - When is the applicator paid?

- **Penalties for breach of contract**
  - Should spell out exact penalties in case the contract is violated (one year’s rent plus any legal cost arising from enforcement is common).

- **Length of contract and renewal provisions**

- **Record-keeping responsibility**
  - Who is responsible and what is the timeline for providing to other party?

- **Economics**
  - In determining the cost of hauling, distance and time are key.
  - If a commercial applicator is hired, assume an extra half cent to penny per gallon if the distance is greater than 2 miles, but the number of stop signs makes a significant difference. Most haulers charge by the hour (farmer provides fuel). Each stop sign will add 4 minutes to the round trip hauling time (if road speed is 55 mph with a truck). Each stop sign can reduce efficiency by one trip per hour.

- **Value of manure**
  - A lab sample is critical in all cases.
  - Contract may need to be adjusted based on the actual analysis (post-application).
  - At a penny per gallon, a 10,000-gallon application will cost $100/acre. (Nutrient value is $6 to $8 per thousand gallons, on average. Expecting the cash grain producer to cover the entire cost of hauling means he/she will lose money.)

**Summary**

Experience has shown that the most common factor of complete and successful manure exchanges is early involvement of both farms’ nutrient management plan writer/crop consultant/agronomist. Their knowledge of manure rates, soil conditions, and other factors will make them a key player in any successful agreement. A manure exchange between farms can be a very profitable venture for both cash grain and dairy producers. A well-thought-out written agreement is essential for the short and long term success of any exchange.

*This is a modified version of an article that was submitted as part of the Midwest Manure Summit, held in Green Bay, WI in March.* See [www.midwestmanure.com](http://www.midwestmanure.com).
What makes a good job candidate?

Having the right academic background and training is important to employers, and having the right employability skills can set one candidate apart from others. The type of attitudes, skills, and behaviors a potential employee has and how well he/she fits into an organization is just as important to employers when hiring. More often, candidates who possess these traits can have the competitive edge in landing a position. To find out more about what makes a good hire, we asked Steve Watts, CCA and Vice President and General Manager of The McGregor Company, Colfax, WA, about what he looks for in a job candidate.

**Q:** What specific skills are you seeking in a job candidate?

**A:** From our perspective, far and above the other skill sets are communication skills. This includes both verbal and written. While it is possible to train for other skill sets, including communication skills, they must have an ability to communicate.

**Q:** What traits or attitudes would signal you to not hire a candidate?

**A:** The tip-off is if a candidate comes to the interview with an attitude that they are deserving of a position. On the flip side, if a candidate exhibits an intense desire to learn and show us what he/she can do, this a positive trait and attitude.

**Q:** How much weight to you place on the resume, interview, and references?

**A:** We place a fair amount of weight on all three. The resume demonstrates a basic overview of written communications. I also request transcripts, which is important in determining how well a candidate did in school and what they learned academically. The interview provides an opportunity to gauge their verbal communication skills. We also conduct some personality testing, looking at how the candidate fits in the types of company roles, both for the current and future positions. We do check references.

**Q:** How should a job seeker prepare for the interview?

**A:** We have seen many different levels of interview preparation. It is important to demonstrate professionalism through attention to personal appearance—both in how a candidate dresses for the interview and punctuality. Candidates should focus on demonstrating strong verbal and written skills and expressing themselves clearly and concisely. While it is important to learn about the company from the website, as a base of information, a strong candidate would also take the initiative to visit with others to learn more about the company and what it means to work for McGregor.

**Q:** Do you prefer job candidates who are certified (or in the process of being certified) and could it give the candidate the competitive edge?

**A:** While being certified is preferable, it is not a pre-requisite for employment. First and foremost, communication skills will outweigh certification. That being said, certification would give a candidate the competitive edge if there were two who were well suited for a position. In addition, we do require our front-line staff in advisory roles to be certified. This includes being licensed in our state if they are providing pest control recommendations.

**Q:** During the past year, has it been more or less difficult for your company to find qualified applicants? Is there currently a labor shortage or surplus of applicants with the skills that are required?

**A:** We are always on the lookout for good candidates. They would certainly be hired if the fit was right even if there is not an opening. We have not experienced as strong a shortage, possibly because of our proactive recruiting program.
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