Amending soils with Gypsum
In January, the American Society of Agronomy (ASA) and the Soil Science Society of America (SSSA) are providing an excellent opportunity to build your agronomy and soil science skills with the following online courses:

**Fundamentals in Applied Agronomy**

ASA has designed this introductory agronomy course for practitioners hoping to build their knowledge and skills in the topics most needed for a fundamental understanding of agronomy. There will be one two-hour session each week from January through March 2012. For more information and to register, visit www.agronomy.org/education/fundamentals-agronomy. If you have questions, email Michele Lovejoy at mlovejoy@sciencesocieties.org.

**Fundamentals of Soil Science**

SSSA has designed this introductory course for practitioners hoping to build their knowledge and skills in the topics most needed for a fundamental understanding of soil science. There will be one two-hour session each week from January through March 2012. For more information and to register, visit www.soils.org/education/fundamentals-soils. If you have questions, email Michele Lovejoy at mlovejoy@sciencesocieties.org.
Feature

Gypsum has received renewed attention in recent years as a potential soil amendment. Some farmers who’ve adopted it are finding that its effects on soil physical properties can lead to higher yields and profits, and data are mounting on the mineral’s capacity to reduce nonpoint source pollution contributed by agriculture. But is there enough information out there to justify applying it on any one farm?

On the cover: Photo reprinted with permission from the Ohio State University Extension Bulletin 945: Gypsum as an Agricultural Amendment.
Amending soils with Gypsum

By Madeline Fisher
Lead Writer
Crops & Soils magazine
mfisher@sciencesocieties.org
Gypsum has received renewed attention in recent years as a potential soil amendment. Some farmers who’ve adopted it are finding that its effects on soil physical properties can lead to higher yields and profits, and data are mounting on the mineral’s capacity to reduce nonpoint source pollution contributed by agriculture. But is there enough information out there to justify applying it on any one farm? A group of industry representatives, scientists, and growers addressed this question at the Midwest Soil Improvement Symposium this past August.

**Gypsum**, or calcium sulfate dihydrate, has been used by farmers for a very long time. It was applied extensively as a fertilizer in 18th century Europe, U.S. founding father Ben Franklin touted its benefits—even the Greeks and Romans reportedly used it. More recently, it has become a proven soil amendment to reclaim sodic and other degraded soils. And its use as an economical fertilizer continues to this day.

However, gypsum can seem like a brand new product these days, thanks to the renewed attention it’s receiving for several reasons. Gypsum is more plentiful now, for one. It was mostly mined in the past, but today a “synthetic” form is surpassing natural sources: Flue gas desulfurization (FGD) gypsum, a by-product of scrubbing sulfur dioxide gases from the emissions of coal-fired power plants. Production of FGD gypsum doubled from 12 to 25 million tons between 2004 and 2010, according to the U.S. Geological Survey, and it’s projected to reach 40 million tons by 2020. Meanwhile, manufacturing markets for gypsum have steadily declined, and the combination of increased supply and reduced demand has sparked efforts to find new applications and expand old ones—including agricultural uses.

Another factor in gypsum’s resurgence is its potential to reduce nonpoint source pollution contributed by agriculture. Through the work of scientists like Darrell Norton, a long-time gypsum researcher with USDA-ARS, data are mounting on the mineral’s capacity to curb erosion, improve infil-

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Loading gypsum on a truck. Photo courtesy of GYPSOIL/Ron Chamberlain.
tration, decrease runoff, and retain phosphorus in soils. Berms designed to prevent nutrient runoff into the Chesapeake Bay now contain gypsum, and it’s being studied as one tool for alleviating other large-scale water quality problems, as well. Meanwhile, farmers who’ve adopted gypsum are finding that its effects on soil physical properties—better infiltration, for example—can also lead to higher yields and profits.

But is any of this—gypsum’s history as a fertilizer, its availability, its positive effects on soils—enough to justify applying the mineral on any one farm? That’s the critical question that a group of industry representatives, scientists, and growers tried to answer at the Midwest Soil Improvement Symposium this past August. Hosted and sponsored by the University of Wisconsin (UW)-Madison College of Agricultural and Life Sciences, UW-Extension, the Conservation Technology Information Center at Purdue University, and GYPSOIL—a leading supplier of synthetic gypsum—the symposium covered everything from how FGD gypsum is first produced at power plants to its ultimate effects on farms. The goal was to present all sides of the gypsum story, said GYPSOIL’s president and CEO, Robert Spoerri, in his opening remarks, because even though gypsum has been a part of agriculture for ages, widespread use of it remains controversial.

Roughly 23% calcium and 19% sulfur in its pure form, gypsum comes today not only from mines and coal-fired power plants, but also from recycled casting materials and drywall and as a by-product of citric acid production and phosphorus mining. Importantly, gypsum is also about 200 times more soluble than agricultural lime, or calcium carbonate, allowing it to move readily down the soil profile, where it can provide nutrients to deep plant roots and help alleviate subsoil problems.

Gypsum is not a liming agent, however: It does not neutralize hydrogen ions or change soil pH like calcium carbonate does, stressed Ohio State University professor Warren Dick, although this is a common misconception. Still, one of gypsum’s main advantages, emphasized by Dick and several other speakers, is its ability to reduce the aluminum toxicity that often accompanies soil acidity.

In soils below pH 5, aluminum becomes soluble Al³⁺, which is extremely toxic to plant roots. So harmful is aluminum, in fact, that plant roots bend away from regions of subsoil acidity and wind up restricted to a shallow depth. Gypsum corrects this by moving into the subsoil, where its calcium ions (Ca²⁺) displace aluminum ions from the soil’s exchange sites. Sulfate ions (SO₄²⁻) supplied by gypsum can also react with the free aluminum ions to produce aluminum sulfate complexes that are less toxic and more capable of being leached away.

In studies in Ohio, root growth in the acidic subsoil has been found to increase as a result, Dick said, allowing plants to tap deep reserves of moisture and nitrogen that would otherwise be unavailable. Gypsum has also been used to treat aluminum toxicity in the South, added Harry Schomberg, a cropping systems ecologist with USDA-ARS in Georgia, where many soils exhibit acidity below about 12 inches. In a study by Schomberg’s USDA-ARS colleague, Fred Rhoton, for example, adding gypsum at 3 tons/ ac substantially reduced concentrations of soluble, subsoil aluminum over three years, compared with 0 and 1 ton/ac applications.

The forgotten nutrients

Gypsum is also a source of calcium and sulfur, or what Dick called
the “forgotten nutrients.” Nitrogen, phosphorus, and potassium get most of our attention, but plants also need calcium and sulfur in relatively large amounts, he explained. Plant cell walls and membranes require calcium for proper functioning, and growing root tips and developing fruits also need a lot of the nutrient. Sulfur, meanwhile, is critical to making protein because the amino acids methionine and cysteine both contain sulfur atoms. The nitrogen-fixing enzyme, nitrogenase—important in alfalfa and soybean—also has a very high requirement for sulfur.

But are these nutrients deficient in soils? This certainly wasn’t the case historically with sulfur. Previously, nitrogen and phosphorus fertilizers contained sulfur as a by-product. More significantly, coal burning releases sulfur into the atmosphere that subsequently returns to earth in precipitation, providing a free source of sulfur to many areas of the country, Dick said.

Sulfur impurities have been mostly eliminated from fertilizers today, however. And now that sulfur is being scrubbed from flue gases, much less is coming from the atmosphere, as well. In Wooster, OH, for example, deposition dropped from 30 lb/acid in 1971 to 17 lb/acid in 2002. Add to these changes the greater sulfur requirements of today’s high-yielding crop varieties, Dick said, and sulfur deficiency is emerging in the Midwest.

He proceeded to present several studies from the 1980s to 2000s in which adding sulfur as gypsum or other forms corrected sulfur deficiency and boosted yields of corn and forages. In a 2002 to 2005 study near Wooster, OH, for instance, average corn yield increased from 182 bu/acid without gypsum to 193 bu/acid when sulfur was supplied (as FGD gypsum) at 30 lb/acid. “It will pay, if you get that kind of boost,” Dick said.

Another key finding of that study was that nitrogen use efficiency improved significantly with gypsum addition, Dick added, suggesting “if you don’t satisfy the sulfur requirement of the crop, it can’t really use the nitrogen either.” Likewise, applying gypsum won’t help if the crop doesn’t have enough nitrogen, added UW-Madison emeritus extension soil scientist Richard Wolkowski. In research plots at Arlington, WI, his group found that grain yield didn’t respond to the sulfur in FGD gypsum until adequate nitrogen was provided. In fact, gypsum actually lowered yields when nitrogen was applied at sub-optimal rates.

“So, like Warren said, you need both adequate nitrogen and where you have a sulfur responsive situation, you need the sulfur,” Wolkowski said. “The interaction [between them] is highly significant.”

Although Wolkowski reiterated that “sulfur really has become a nutrient of interest that 10 years ago we didn’t think too much about,” he also cautioned that it should still be treated like any other. This includes testing for sulfur deficiency (there are tools available for doing so) and looking at factors such as soil type, farm location, and history of manure. “There’s not always an automatic need for sulfur,” he said.

Gypsum also provides calcium. Calcium fertilization is generally unnecessary for crops and soils in Wisconsin, Wolkowski said. However, work by UW soil scientists in the 1980s found that gypsum can increase the yield and tuber quality of potatoes grown on sandy soils with low organic matter. Moreover, stored potatoes are frequently bumped and bruised when handled, Wolkowski explained, and the added calcium “tends to build stronger cell walls that allow the potato to maintain its integrity, improving storability.”

Dick also noted that growing root tips are especially sensitive to
calcium deficits. They require a lot of the nutrient, to start, and they depend entirely on the soil to get it since calcium can’t be transported to them from other plant tissues. This is an important reason to supply calcium as gypsum rather than lime, Dick said. Because of its greater solubility, gypsum moves into deeper soil layers within three to four years, whereas lime typically remains in the top 6 to 10 inches even after a decade or more. His final recommendation was to add the two together: Lime to bring soils to the proper pH and gypsum to deliver nutrients into the root zone.

**Improving soil structure**

But nutrition isn’t the most important thing calcium offers. All the speakers agreed its greater value is as a “flocculating” agent that can improve soil structure. Flocculation, or the aggregation or clumping together of soil particles, depends largely on which positively charged ions are present on the exchange sites in soil. Large concentration of ions with more than one positive charge, such as calcium (Ca²⁺) and magnesium (Mg²⁺), help soil particles hold together in stable aggregates. In contrast, high levels of single-charge ions, especially sodium (Na⁺), will cause soil particles to disperse, or separate. Put another way, if sodium’s relative flocculating power is set at 1, potassium’s (K⁺) is 1.7, magnesium’s is 27, and calcium’s is the highest, at 43.

Lack of aggregation, or dispersion, in turn, causes poor soil structure—and a number of problems. Soils erode easily when particles don’t hold together well. A lack of stable aggregates also means fewer pore spaces for water to move through, leading to rapid waterlogging and poor infiltration when it rains and surface-crusting and cement-like compaction when soils dry out. Plant roots have a hard time penetrating poorly structured soils. And less infiltration, of course, causes greater runoff, erosion, and loss of nutrients.

Especially well documented is gypsum’s ability to improve the structure of soils containing high sodium ion concentrations, or sodic soils. As it does with aluminum, gypsum adds calcium ions that knock sodium ions off exchange sites, helping sodium leach from the soil and consequently improving aggregation, infiltration, crop rooting, and so on. Gypsum is commonly used to reclaim sodic and saline soils in arid and semi-arid regions, for example, especially where salty water is used for irrigation.

Gypsum has also been shown to increase aggregation, reduce surface crusting, improve crop rooting, and boost yields in soils of the Southeast’s Piedmont and Coastal Plain regions. There the problem isn’t so much sodicity, Schomberg said, as highly weathered, often clayey soils with minimal capacity for cation exchange or nutrient and water retention. Because of the region’s low soil organic matter levels, in particular, clay particles disperse easily unless the right flocculating ions are present, he said. “So, that’s one of things that we’re really interested in utilizing gypsum for.”

Along similar lines, Wolkowski and his co-investigator, University of Wisconsin–Stevens Point assistant professor Meghan Buckley, have found that gypsum has a greater effect on the physical properties of soils that are high in clay or poorly structured. In on-farm studies in 2010, for example, adding gypsum at rates of 0.5, 1, and 2 tons/ac didn’t affect the porosity of three Wisconsin loam soils, but did seem to increase porosity slightly in two clay loams. Likewise, gypsum increased infiltration in one clay loam (but not the other) while failing to boost infiltration substantially in the three loams.

Buckley cautioned that the results represent just one year’s worth of data while it can take many years to change soil physical properties. Still, the data seem to suggest that “some of the troublesome soils—the tighter soils, the denser soils, the clayey soils—are where we’re seeing some effects initially,” she concluded. “But we’re not seeing many wide-ranging effects.” The pair also attributed the yield responses they’ve seen to better sulfur nutri-

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**Illustration courtesy of Dr. Jerry Bigham, the Ohio State University (OSU), and reprinted with permission from the OSU Extension Bulletin 945: Gypsum as an Agricultural Amendment.**
tion, rather than improved soil properties.

That has been the experience of the researchers so far, but a trio of corn and soybean growers got the last word on gypsum near the symposium’s end. “We don’t think you can ever say with confidence that something will work (or won’t) until you try it on your own farm,” said fourth-generation Indiana farmer Rodney Rulon, which is why he and his co-presenters have been doing their own experiments with gypsum. And although their levels of experience with it varied, they all reported gains in soil health, crop rooting, infiltration, and yield.

For example, Nick Miller, who farms 3,500 acres near Oconomowoc, WI, said his soybean yields hit 65 bu/ac the first year he applied gypsum compared with the previous 10-year average of 45. He also described a 1-ac low spot in a field where standing water prevented him from sowing crops in previous years. “With one application of gypsum, the water filtered right through, the roots got air, and the beans in that one acre went 110 bushel,” he said.

Jack Maloney, Rulon’s neighbor in Indiana and another fourth-generation farmer, also emphasized gypsum’s value in helping regulate drainage, a critical issue on his farm. “We’re on a soil type that’s rated somewhat poorly drained, and I guarantee you when it’s wet, it’s really poorly drained,” he said. But, he added, his real “aha” moment with gypsum came five years ago, during a drought. To prepare for a meeting with Purdue soil scientists, he dug a 4.5-ft-deep soil pit the evening before and was surprised to see corn roots extending all the way down. By the morning, too, the bottom was filled with water, despite the dry conditions. “So, the water was down there, and the roots were down there,” he said. “That corn never gave up all summer.”

For his part, Rulon highlighted the tremendous improvement in soil color, texture, and quality he has seen over the years. “[The soil] is a testament to how this system works,” he said. But there’s a caveat here, and it lies in the word “system,” he cautioned. He, Maloney, and Miller use gypsum as part of a suite of practices designed to protect and build the soil, including no-tillage, cover cropping, and intercropping. And when you do that, “you start getting one plus one equals three,” Miller said, making it tough to identify any one component as the factor making the difference—gypsum included.

That point underscored what seemed to be the take-home message of the day: Gypsum is not a stand-alone, magic bullet solution to improving soils, or boosting crop yields and profits. True, it can have dramatic impacts in some cases, such as when soils are sodic. But, in general, farmers will need to weigh gypsum’s benefits against the costs of buying and applying it—just as they do with everything else on the farm.

**Additional Resources**

For more information on gypsum, including the latest research results and management guidelines, visit:

- GYPSOIL: www.gypsoil.com
- National Research and Development Network of FGD Products in Agriculture: www.oardc.ohio-state.edu/agriculturalfgdnetwork
- National Soil Erosion Research Laboratory, gypsum fact sheet: www.ars.usda.gov/Services/docs.htm?docid=18103
About half of the 14,000 or so CCAs, CPAg’s, CPSS’s, or CPSCs will be ending their two-year CEU cycle in December. If you are part of this group, hopefully you have already earned your 40 hours, but if not, there is still time and opportunities to meet your requirements. To find out how many CEUs you have on record, go to the website and click on “check CEUs” listed in the right hand side menu.

If you still need CEUs, the first place to start might be the online calendar: www.certifiedcropadviser.org/meetings/calendar. The calendar provides a search of educational programs being offered, many of which are CCA board approved. If a live event is not available or does not suit your needs, there are also online opportunities, which can be found here: www.certifiedcropadviser.org/certifications/self-study.

CCA and CPAg

The CPAg program will be fully integrated into the ICCA program infrastructure beginning Jan. 1, 2012. There will be no changes for current CCAs or those wishing to become a CCA. CPAg will become a specialty certification, and CCA will be the base certification. CPAg will be optional and open to any CCA that can meet the additional requirements. Through this collaboration, there will be one agronomy certification process that builds on the strengths of the programs.

If you are currently a CPAg, you should have received a letter explaining all the details and how this will impact you. The ICCA board did confirm the new CPAg CEU requirements as outlined in the letter, so those are now official. A second letter is being sent in November.

New ICCA board structure

The ICCA board will be implementing its new board structure in January. With the addition of new countries to the program like India and Argentina, the program had to become more international in its board structure. There will now be an International Council that will focus on global policies and procedures that impact all countries and oversee the standards of the program. Each country will have a National Board or coordinating group to focus on those issues that are unique to the host country. Local Boards will still be in place to implement the policies and procedures of the CCA program.

CPSS and CPSC

The CPSC program will no longer take new applications after 2011. Those that have it will be able to maintain it, but no new CPSC designations will be granted. The soils certifying board determined last year that focusing on one credential, CPSS, would help to unify the profession of soil science.

The soils certifying board added a requirement for 1 CEU in an ethics
course. CPSS’s and CPSCs must earn at least 1 CEU in ethics during their two-year cycle. The board is also evaluating the educational standards to become certified and the continuing education requirements to maintain a CPSS or CPSC.

RPSS and CPSS

The National Society of Consulting Soil Scientists (NSCSS) membership voted to dissolve as a separate corporation and fully integrate into the Soil Science Society of America (SSSA). About half of the NSCSS members were already SSSA members, and those that are not will be offered a one-year free trial membership. Those details will be sent to each NSCSS member who is not a SSSA member towards the end of the year. NSCSS also had a registry of soil scientists called Registered Professional Soil Scientist (RPSS). CPSS has worked with RPSS to grandfather those RPSS’s that were not already a CPSS into the CPSS program.

International expansion

Interest from other countries in our certification programs continues to increase. Discussions are ongoing with multiple countries to add the agronomy and/or soils certification programs along with those who are starting out or under development. Here’s a brief update: India now has 145 CCAs with the next exam being held in December. Argentina continues to develop its performance objectives with the goal of offering the exam for the first time in 2012 or 2013. Mexico is on a similar time frame and will probably offer the exam for the first time in 2013.

Several countries have begun exploratory discussions: Australia, Bangladesh, Brazil, Kenya, Liberia, Nepal, Micronesia, Scotland/Britain, and South Africa.

We would like to work with companies that do business internationally and are already supportive of certification in North America to develop relationships with their staff in the country that is considering certification. It greatly helps explain why the certification program is important and adds value if they can hear from their North American based counterparts. Please contact me (lsmith@sciencesocieties.org) if you work for a company that does business internationally and would like to learn more.

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Newly certified

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

**Canada**

**Alberta**
- Creek, David, Coaldale, AB (CCA-PP)
- Gerow, Kira, Calgary, AB (CCA-PP)
- Koester, Megan, Rockyford, AB (CCA-PP)
- MacIntyre, Cathryn, Westlock, AB (CCA-PP)
- Miller, Trevor, Bittern Lake, AB (CCA-PP)

**Manitoba**
- Falk, Shane, Morden, MB (CCA-PP)
- Kohinski, Kendell, Neepawa, MB (CCA-PP)
- Kroeker, Brittnye, Birch River, MB (CCA-PP)
- McDougald, Matthew, MacGregor, MB (CCA-PP)
- Melnychenko, Andrew, Grandview, MB (CCA-PP)
- Penner, Colin, Winnipeg, MB (CCA-PP)
- Shaw, Jeff, Brandon, MB (CCA-PP)
- Sirski Tanis, Grandview, MB (CCA-PP)

**Prince Edward Island**
- Delodder, John, Montague, PE (CCA-AP)
- Drummond, Bryce, Elmsdale, PE (CCA-AP)
- Pauly, Donald, Charlottetown, PE (CCA-AP)

**Saskatchewan**
- Caldwell, Daniel, Dalmeny, SK (CCA-PP)
- Doane, Brian, Grenfell, SK (CCA-PP)
- Grimard, Chelsea, Wilkie, SK (CCA-PP)
- Heaver, Caroline, Battleford, SK (CCA-PP)
- Hildebrand, Elliott, Rabbit Lake, SK (CCA-PP)
- Hinz, Michael, Warman, SK (CCA-PP)
- Ismaeel, Muhammad, Watrous, SK (CCA-PP)
- Kenny, Jeremy, Saskatoon, SK (CCA-PP)
- Maxwell, Jacquelyn, Rockhaven, SK (CCA-PP)
- Nattrass, Katherine, Drake, SK (CCA-PP)
- Poole, Kevin, Regina, SK (CCA-PP)

**United States**

**Alaska**
- Smeenk, P. Jeffrey, Palmer, AK (CCA-NW)

**Alabama**
- Haas, John Kade, Huntsville, AL (CCA-AL)
- Ray, Harold, Hanceville, AL (CCA-AL)

**Arizona**
- Sherry, Seth, Yuma, AZ (CCA-CA)

**California**
- Balvert, Daniel, Ballico, CA (CCA-CA)
- Brown, Edward, Cherry Valley, CA (CCA-CA)
- Brush, David, Modesto, CA (CCA-CA)
- Calabro, Shane, Gonzales, CA (CCA-CA)
- Chabot, Darin, Paso Robles, CA (CCA-CA)
- Denning, Christopher, Spreckels, CA (CCA-CA)
- Ferrari III, Joseph, San Miguel, CA (CCA-CA)
- Hardoy, Michel, Lockwood, CA (CCA-CA)
- Iverson, Peter, King City, CA (CCA-CA)
- Kramer, Matthew, Tulare, CA (CCA-CA)
- Molatore, John, Hollister, CA (CCA-CA)
- Oliveira, James, Turlock, CA (CCA-CA)
- Vanden Berg, Darin, Modesto, CA (CCA-CA)
- Waggoner, Donald, Lindsay, CA (CCA-CA)

**Colorado**
- McGovern, Theresa, Grand Junction, CO (CCA-CO)

**Florida**
- Busey, Philip, Davie, FL (CCA-FL)

**Iowa**
- Anderson, Scott, Dayton, IA (CCA-IA)
- Brekke, Brent, Ames, IA (CCA-IA)
- Carlson, Brian, Vinton, IA (CCA-IA)
- Eichenberger, Steven, Ackley, IA (CCA-IA)
- Halbach, Rachel, Clarion, IA (CCA-IA)
- Hommer, Phillip Derek, Kellogg, IA (CCA-IA)
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As this issue of *Crops & Soils* magazine is moving to press, the House and Senate Agriculture Committees are forwarding their recommendations for cuts to the farm bill to the super committee charged with reducing federal debt. The 2012 farm bill will undoubtedly be leaner than the current bill as federal funding for agriculture and everything else will be declining in the years ahead. However, reduced federal funding opens wider opportunities and expanded options for professionals who have the know-how and skills to help grow the agricultural sector.

In virtually any future scenario, U.S. farmers will plant more acres to crops. If the next farm bill eliminates commodity payments, highly erodible land that today is protected by sodbuster and swampbuster requirements will face greater pressure from the marketplace. It may be tough to maintain the balance between production and protection of natural resources.

As the next farm bill begins to take shape, three major opportunities are likely to arise for CCAs:

- A smaller, better targeted Conservation Reserve Program (CRP),
- Increased emphasis on agricultural research, and
- A shift from idling land to conservation on working lands.

**Reforming CRP**

Today, CRP covers about 30 million acres. Given the characteristics of the land idled under CRP, a more reasonable approach is to drop that to 20 million acres. About 10 million acres are indeed fragile, highly erodible lands that need to be protected from erosion. Keep that land in CRP—in filter strips, contour strips, grass waterways, and buffers.

Roughly another 10 million acres are good for grazing or forage crops. This land can produce hay or biomass for energy production and serve as habitat for nesting birds and pollinators as well. These acres would retain most of the wildlife, soil, and water benefits currently provided by the CRP and should continue in the program at a reduced payment while producing feed and grazing.

The remaining 10 million acres can be responsibly managed to again produce crops to feed people. According to the USDA, eight million acres idled under CRP today are prime farmland. Bring them back into production. Use no-till and precision agriculture to minimize environmental risks and yield a cost-effective harvest. Certified crop advisers can provide the technical knowledge to make that happen. In addition, this would greatly expand the number of acres potentially served by CCAs.

**Targeting agricultural research**

The time to prepare for the harvests of tomorrow is today. That means focusing agricultural research on the most promising areas and the most critical issues. A critical goal is developing high-yielding crop varieties that can withstand drought and resist pests.

Even in a time of pared budgets and tight wallets, putting extra money into research will result in paybacks well beyond the costs—not only for U.S. producers, but also for consumers around the world.

Farmers would welcome new seed varieties appropriate for double-cropping to make maximum use of productive land as well as strategies to integrate cover crops into working lands for forage, grazing, or biomass...
Emphasizing precision conservation

Conservation management practices supported through agricultural conservation programs like the Conservation Stewardship Program (CSP) and the Environmental Quality Incentives Program (EQIP) should increasingly emphasize precision conservation. Precision placement of fertilizer and chemicals provide tremendous environmental benefits. This approach cuts costs for farmers and also reduces the release of excess nitrogen and pesticides into waterways.

Using GPS and precision conservation requires expert assistance and guidance. The greater the emphasis on putting the right amount of chemicals in exactly the right place at exactly the right time, the greater the need for the help of CCAs.

Expanding opportunities for CCAs

As the next farm bill comes together, CCAs may find other opportunities as well. A number of USDA agencies, such as the Natural Resources Conservation Service (NRCS), along with the Environmental Protection Agency, are interested in identifying specific activities that would constitute compliance with various environmental requirements. This concept is sometimes called a regulatory safe harbor or certainty. Direction to develop such strategies could be part of the next farm bill. Expertise in evaluating new technologies. Increased emphasis on precision conservation also requires the assistance of experts who can help producers optimize use of inputs and minimize the flow of excess nutrients and chemicals into waterways.

Conclusion

As the next farm bill comes together, CCAs can use their professional knowledge and skills to provide expert guidance as more acres come into production. Further, as agricultural research leads to strategies for increased production, CCAs will be well positioned to advise farmers on how to take advantage of new technologies. Increased emphasis on precision conservation also requires the assistance of experts who can help producers optimize use of inputs and minimize the flow of excess nutrients and chemicals into waterways.

Certification update [continued from p. 11]

International learning opportunity

The ICCA board encouraged the American Society of Agronomy (ASA) to develop a new program around continuing education that includes international travel. For example, a group of U.S. CCAs would travel to India to meet with a group of India CCAs to learn about production agriculture in India from India CCAs and India farmers or vice-versa. It would allow for the exchange of ideas and experiences under situations that individuals might not have been familiar with before and would be a learning opportunity for both groups of CCAs and farmers. The program would provide the opportunity to build relationships with your counterparts around the globe and develop a global network of certified professionals. We are in the very early stages of development of this program, so if you have an interest and experience with international programs, please contact me (lsmith@sciencesocieties.org).

Online education

ASA and SSSA are offering an expanding lineup of online courses. ASA has offered the Fundamentals in Applied Agronomy course for the last three years and will continue it in 2012. SSSA launched the Fundamentals in Soil Science course in the fall of 2011 and will be offering it again in January 2012. Other courses will also be offered including Nitrogen Management, Soil and Water Management, Precision Agriculture, and Topics in Applied Soil Science. To learn more and to register for a class, visit www.agronomy.org/education or www.soils.org/education. New courses will be added as they become available. If you have ideas for potential courses, please send me a note (lsmith@sciencesocieties.org), and we will look into it further.
I have hesitated to write on this particular topic because, well, I don’t want to offend anyone, but in thinking about it, I believe it is a tale that needs to be told. I think sometimes we need to recognize, especially those early in their careers, the types of obstacles and challenges that we may face; in this case, women working in geosciences. In my career, I have had to face the challenges of working in a male-dominated field, and I’d like to share some of those experiences as well as offer some advice. Some might argue that my past experiences no longer reflect the current state of the geoscience field and that the demographics are changing, but I still hear stories from women that would refute this. And so my tale...

Let me say up front that this is not an article in which I want to provide anything but some examples and some advice to those who wish to consider it. Many men will read this and find it hard to believe, but I would submit from years of experience that men don’t always catch what is going on. It is not so much that they are oblivious (unless it is pretty obvious), but they don’t tend to catch the comments that are made or the mannerisms that can convey a whole lot of meaning to the female standing there. I believe most of these events take place in the consulting world; at least that is where most of my challenges have been. While I have seen some things in academia and the government positions I have held, it has been to a much lesser extent. Let me give you some examples of what I am referring to.

My first taste of being discriminated against or being dismissed from a client’s consideration was during an internship I had while still in college with the USDA Soil Conservation Service (now USDA-NRCS). I found that some farmers couldn’t comprehend, much less talk with, a woman on their farm looking at engineering solutions such as grassed waterways or terraces for their erosion issues. It was an eye opener for me, but at that young age, it was somewhat dismissed and taken in stride since I was the intern and still learning.

In my consulting career, there were many times that I was on a job site and was the project manager. My project team would consist of men from our company who were doing a myriad of tasks key to the project from soil/water chemical analyses to assessing plant species. I cannot even count the number of times that the subcontractors on a site, or representatives for the client, would talk around me to my male team members and totally ignore me. In one particular incident, I told a subcontractor that decisions had to go through me, and he wanted to know where my high-heeled work boots were at. Let’s just say that by the time I got done speaking “contractor slang” back at him, he understood my role on the project much better. In another situation, I was asked to go bake some cookies for the people that were on the site. That went over just about as well.

The situations and things said aren’t always so obvious though. Working for one smaller company, I was asked to fill in for the receptionist when she was out sick. When asked why me and not one of the guys, I was told because no one expected a man to do that particular job. Really? Or, there is always the boss who wants you to go fetch a cup of coffee—this I have actually seen more in academic settings with grad students.

Then there are the clients who seem to be great until you figure out that they treat you differently and talk to you in an inappropriate manner. This is demeaning and can catch you off guard when you think you have built an honest working relationship with a client based on good work. Then they decide to call you “honey” or “sweet-
heart” when they want something done on the project that may be in addition to what was contracted. I don’t pull out the Ph.D. card very often, but that one usually got the “you can call me Dr. Ferris, not honey” response. And, of course, there are those clients who want something more and will hit on a consultant, which is never a good thing. Being involved with a client on anything but a business level is a conflict of interest and will only result in a bad reputation. My advice is don’t go there.

And then there is that “glass ceiling” concept where men get paid more and get promotions more often. Unfortunately, it is true. I was passed over a few times at one place of employment until I called my boss on it, and then he didn’t have a whole lot to say since my employee reviews, client relations, and billable hours were as good, or better, than some of my male counterparts. This can be extremely frustrating. There is also the male boss who is reluctant to invest time in female professionals because he is afraid that they’ll go out on maternity leave at some point and, when they come back, will focus more on their children than work and take more sick leave as a result.

And last, but not least, are the office conversations and joking around. Not always appropriate, but on the flip side (and to be fair), I have also seen women do the same thing.

What can you do?

So now the advice—and I would welcome others to write to me and tell me what they think. If I get enough comments, I will publish them in a future article. What do you do if you find yourself in one of these situations? What has worked for me is picking my battles and the extent to which I fight those battles. With the subcontractors I mentioned above, I chose to come down hard on them and establish who was in charge. That was necessary for those situations.

Do you have a tale to share?

Do you have a tale you’d like to share about being a professional soil scientist? If so, email it to dferris@sciencesocieties.org. You may remain anonymous if you like.
When the Wisconsin CCA courses began in 1994, Carl Nachreiner was first in line to get certified. “It was a pretty tough test,” he remembers. “I had been out of college for 14 years, so I had to brush up on a lot of material.”

Nearly 20 years later, Nachreiner is the recipient of the 2011 International CCA of the Year Award, an honor that culminates a career of hard work and success. The award recognizes CCAs who are innovative, have shown leadership in their field, and have made substantial contributions to the exchange of ideas in the agriculture industry. Nachreiner received his award in October at the 2011 Annual Meetings of the American Society of Agronomy (ASA), Crop Science Society of America, and Soil Science Society of America in San Antonio, TX.

Like many CCAs, Nachreiner grew up on a farm. In the small town of Caledonia, located in central Wisconsin, his family grew cash crops and raised dairy cows and hogs. “I knew I’d be involved in agriculture when I got older. It’s kind of in the blood,” Nachreiner says.

He began his college education at the University of Wisconsin–Baraboo, where he continued to live at home and help his parents with their farm. But when his family sold the farm a year later, Nachreiner moved his studies to the University of Wisconsin–River Falls, where he received a B.S. degree in agricultural education in 1980.

Out of college, Nachreiner began working for Agriliance, where he served as an agronomy production specialist for 26 years. In 2006, he brought his agronomy expertise to Landmark Services Cooperative in Dane County, one of Landmark’s 20 locations in southern Wisconsin and northern Illinois. As the co-op’s agronomy territory account manager, Nachreiner offers crop-consulting services to more than 100 farms in Wisconsin, his family grew cash crops and raised dairy cows and hogs. “I knew I’d be involved in agriculture when I got older. It’s kind of in the blood,” Nachreiner says.

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the Dane County area. He also helps Landmark customers make difficult chemical, fertility, seed, and pest management decisions.

Experience and hard work valued by colleagues, clients

Nachreiner’s hard work and experience are greatly valued by his colleagues, according to Gregg Langer, an agronomy sales manager at Landmark. “When we had a turn over at our Dane location, Carl came to mind as a person that could lead our location with professionalism and expertise in agronomy management,” Langer recalls.

Nachreiner’s areas of expertise include soil fertility, pest management, and farm nutrient and conservation planning. Being a CCA validates his knowledge of these topics. “Being certified shows what your qualifications are,” Nachreiner says. “You’ve passed the test, and you’re continuing your education. It tells the farmers that you’re going through training to ensure you can do the best job for them.”

Nachreiner has supported the CCA program since he became certified in 1994. Four years later, Nachreiner joined the Wisconsin CCA board, serving on the board until 2004. After close to 20 years of CCA experience, Nachreiner says education has remained the primary goal of the program. “More training opportunities have been made available because people need certification. Education is the key to this program, and it’s always been like that.”

Jon Ballweg, a dairy and crop farm owner in Lodi, WI, has relied on Nachreiner’s consulting services for more than 20 years. He hasn’t been disappointed yet. “He was the first to provide information on soybean aphids and rust,” Ballweg remembers. “Carl knows our farms, and if a problem is found, he will give us practical solutions.”

Nachreiner has helped Jon and his wife Carrie with several demonstration trials on their home farm and rental farms. “We’ve had corn and alfalfa trials that have helped show real differences that aided us in making better informed decisions on varieties, fertility, and weed control,” Ballweg says.

What makes Nachreiner such a great crop adviser isn’t only his expertise in a variety of relevant subjects, but his ability to communicate with his clients. “If you’re the one doing most of the talking, you’re not going to get much information to help that farmer out,” Nachreiner says. Instead, he says it’s important to consider what farmers have to say and work together to develop a plan to take their operation to the next level.

Aside from Nachreiner’s responsibilities as a CCA, he is a member of the Wisconsin Agrichemical Technical Advisory Committee, a council that deals with matters involving the agricultural herbicide atrazine. In the past, Nachreiner has served on the Wisconsin Nutrient and Pest Management Advisory Board, the WEEDsoft Advisory Committee, and several other agricultural organizations.

Nachreiner is also involved in his community, often facilitating tours for agricultural industry emergency preparedness and planning programs. He is also an active member of his community church and works with the Knights of Columbus in his hometown of Waunakee, WI.

When it comes down to it, Nachreiner’s honesty and strong work ethic are what make him such a valued employee, adviser, and friend. “He is one of those guys that you couldn’t get to lie if you tried,” laughs his co-worker Gregg Langer. “He has very strong ethics on what he believes is right, and if it doesn’t fit his ethics, he’s not going to do it. That’s Carl.”

Tales from the pits

[continued from p. 17]

my record, I went straight to the data and let that speak for me. (Just a note, I ended up with a raise, but no promotion. I also looked for a new job.) Other times, when the guys are joking around, I think sometimes you need to ignore it and let it go. Or turn the tables on them by joking right back. But as with any situation, you also need to make that judgment based on what the conversation is, who you are, and what you can tolerate. I don’t mean to excuse rude behavior, but in the scheme of things, sometimes I have found it better to walk away. As the saying goes, don’t sweat the little things. On the other hand, if the situation is really bad, there are laws against harassment in the workplace.

Overall, I look back on these experiences and occasionally come into contact with this type of behavior these days, and I have to laugh. In many cases, it is just ridiculous, and I think it often needs to be viewed that way. I also understand that these are the minority and not the majority of people that I deal with. Sometimes you need to let it go, or it will eat you up inside, which will not help your career. I have known too many women in my career who couldn’t let it go, became bitter, and ended up getting labeled as “trouble,” which resulted in issues with teamwork. Many of them have left the field because of it.

The choices and challenges of working in a male-dominated field are many. How you choose to respond to those challenges, while up to you, also defines who you are. It isn’t easy and sometimes the choices are hard and many things have to be considered. As I said, I don’t excuse rude behavior, but at times I have chosen to look at it as minor compared with the greater good. With all that being said, I have enjoyed my career, and I enjoy working with men. Sometimes I just have to help set the boundaries.
Like so many large water bodies around the globe, Lake Winnipeg in Manitoba, Canada is experiencing deteriorating water quality that is caused partly by agriculture. And just as in other regions, the problems have spurred efforts to identify beneficial management practices (BMPs) that can curb inputs of nitrogen (N) and phosphorus (P) fertilizers to the lake—the world’s 10th largest.

However, unlike the warm, humid, and more temperate climates where most of today’s agricultural BMPs have been tested and established, the climate of the Canadian Prairies where Lake Winnipeg sits is cold and dry. Despite the contrast, a suite of five temperate-region BMPs cut total N and P losses by 41% and 38%, respectively, in a small sub-watershed of Lake Winnipeg, according to research in the September–October 2011 issue of the Journal of Environmental Quality. The findings could have implications for reducing nutrient exports across the lake’s entire watershed, which spans four Canadian provinces and four U.S. states.

At the same time, the scientists found that most of the nutrients left the sub-watershed in dissolved form during snowmelt events—a type of export not well targeted by current BMPs. Research is now underway to enhance existing practices, as well as create new ones aimed at reducing dissolved losses specifically, says one of the study’s leaders, Jane Elliott of Environment Canada, the Canadian government’s department of environment.

The authors explain that although agricultural BMPs have been around for decades, most have been developed in warmer, wetter places, such as the U.S. Midwest, where nutrients are mainly lost in particulate form through rainfall and erosion during the summer. In the Prairie Provinces of Canada, in contrast, total rainfall is much lower and erosion much less significant because of the extremely flat landscape.

More importantly, most of the runoff in the Canadian Prairies occurs during snowmelt when the ground is usually still frozen. Runoff water from snowmelt does not easily detach particles from the soil, causing nutrients to be mostly exported in dissolved, rather than particulate, form. In the current study, for example, more than 80% of N and P in runoff were lost in dissolved form, 50% during snowmelt and 30% during rainstorms.

All of this has called into question whether BMPs originally designed for warmer, wetter areas can be effective in Manitoba and other cold, dry climates. To find out, a team of researchers conducted a study from 1999 to 2008 in the South Tobacco Creek (STC) watershed, located near the town of Miami, Manitoba, and within Lake Winnipeg’s drainage area.

Specifically, two agricultural sub-watersheds within the larger STC watershed were examined and compared. In one, the 511-ac Madill sub-watershed, no BMPs were used. In the other, the 506-ac Steppler sub-watershed—farmed by a single producer—five BMPs were established that are recommended in Manitoba: a holding pond to collect effluent from a beef cattle overwintering feedlot; grazing restrictions close to the stream; enhancement of the riparian zone; conversion of annual cropland to forage; and fertilizer applications based on soil tests.
Continuous monitoring of water flow and quality revealed that the five BMPs cut losses of total N and P by roughly 40% in the Steppler watershed compared with the Madill. Nutrient concentrations in runoff water were also similarly reduced. Although the researchers attribute these reductions to combined use of all five BMPs, two practices had especially large impacts: the holding pond and nutrient management based on soil tests. According to the scientists’ estimates, retaining nutrients in the holding pond accounted for as much as 63 and 57% of the BMP-induced reductions in total N and P, respectively. Likewise, nutrient management improvements reduced N inputs onto croplands by 36% and P inputs by nearly 60%, without substantially affecting crop yields.

Research is now underway to determine the impact of the other BMPs by themselves, especially since farmers are rarely able to implement several practices at once, Elliott says. The group also hopes to learn which practices best suit the climate and types of nutrient export that occur most often in the Canadian Prairies. For now, though, the study suggests that use of existing, temperate-region BMPs can go a long way toward reducing N and P losses in Lake Winnipeg’s watershed, despite the colder and drier conditions.

Water quality studies in the STC watershed were initiated in the 1990s by the Deerwood Soil and Water Management Association (a producer conservation group) in conjunction with Agriculture and Agri-Food Canada (AAFC) and Environment Canada. Ongoing studies, including the current one, are now being conducted as part of AAFC’s Watershed Evaluation of BMPs (WEBs) project, with additional collaborators from the University of Manitoba, Department of Fisheries and Oceans, Manitoba Agriculture Food and Rural Initiatives, and other provincial agencies.

The Ontario average farm yield of soybeans has been stagnant over the past two decades. With higher commodity prices and larger yield gains found in corn and wheat, soybean growers are seeking a solution to overcome the limitations on soybean yields. Current agronomic recommendations in Ontario are not comprehensive enough to overcome limitations to yield; most recommendations are based on research with relatively narrow objectives that focus on simple effects of a few factors at a time. Management needs to consider potential additive and synergistic effects on yield and profitability.

A recent research project assessed the additive impact of multiple inputs on yield. The project included both field-scale and small-plot intensive experiments. The field-scale results are presented here. Field-scale trials included four main treatments:

1. Untreated check—normal no-till practices (i.e., no pre-tillage, no seed treatments, and no fertilizer or foliar fungicides or insecticides).
2. Cruiser Maxx seed treatment + HiStick NT inoculant.
3. Cruiser Maxx + HiStick NT + fertilizer + pre-tillage (fertilizer = 40 lb P and 70 lb K per acre and pre-tillage = Salford RTS run at 3-inch depth three days before planting).
4. Cruiser Maxx + HiStick NT + fertilizer + pre-tillage + foliar Quadris + foliar Matador.

Table 1 provides a summary of the soybean no-till yield results from 2008–2010.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Untreated</th>
<th>Cruiser Maxx + HiCoatNT</th>
<th>Cruiser Maxx + HiCoatNT + fertilizer + pre-tillage</th>
<th>Cruiser Maxx + HiCoatNT + fertilizer + pre-tillage + Matador + Quadris</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average yield (bu/ac)</td>
<td>51.3</td>
<td>53.3</td>
<td>53.8</td>
<td>55.9</td>
</tr>
<tr>
<td>Yield advantage (bu/ac)</td>
<td>2.0</td>
<td>2.5</td>
<td>4.6</td>
<td></td>
</tr>
<tr>
<td>Input cost/ac†</td>
<td>$15</td>
<td>$80</td>
<td>$110</td>
<td></td>
</tr>
<tr>
<td>Return/ac at $10/bu soybean price</td>
<td>+$ 5/ac</td>
<td>(−$ 55)</td>
<td>(−$ 64)</td>
<td></td>
</tr>
</tbody>
</table>

† Costs/ac: CruiserMaxx ($11), HiCoat NT ($4), pre-tillage ($15), fertilizer ($50), Quadris + Matador ($30).

Summary

All treatments improved yield over the untreated check. Following are some of the key findings:

1. An average yield gain of 4.6 bu/ac was realized when seed treatments, fertilizer, pre-tillage, and foliar insecticide and fungicides were applied together in these no-till fields.
2. A yield increase of 2.0 bu/ac resulted from the use of CruiserMaxx seed treatment along with HiStick NT inoculant. In previous separate field studies with CruiserMaxx, yields were improved by 1.9 bu/ac on average, and inoculant improved yield by 1.25 bu/ac over no inoculant in fields with a history of soybeans. Results from this project indicate that there is not an additive yield effect from the inoculant and seed treatment indicated by the previous separate studies.

3. No statistical benefit was found to the additional fertilizer and pre-tillage in these trials. Please note that the soil test was relatively high at these sites. Sites that showed a response were generally those where the soil test indicated a recommendation for P or K. In a previous fertility study using five different fertilizer treatments, soybean yields were improved the greatest by the 40 lb/ac P + 70 lb/ac K (broadcast and incorporated) treatment. This treatment improved yields by 2.3 bu/ac, but when costs and soybean price were factored in, the results showed a net loss in return. Previous pre-tillage trials using residue manager type equipment increased no-till soybean yields by approximately 1.8 bu/ac on average.

4. An additional yield increase of 2.1 bu/ac resulted from the use of foliar Quadris and Matador. The only foliar disease evident throughout the study was septoria brown spot. Insect pressure was generally low. These results support earlier trials that indicated a 2 bu/ac yield improvement through the use of a strobilurin foliar fungicide. None of the studies have indicated a benefit to using an insecticide unless insects were at threshold levels.

Results of this study and prior studies mentioned may be found on the Ontario Soil and Crop Improvement website at www.ontariosoilcrop.org/default.htm.

Project contacts
- Dr. Dave Hooker, Ridgetown Campus, University of Guelph, Ridgetown, ON (phone: 519-674-1500, ext. 63559 or email: dhooker@ridgetown.uoguelph.ca)
- Horst Bohner, OMAFRA, Stratford, ON (phone: 519-271-5858 or email: horst.bohner@ontario.ca)

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Saveen Randhawa, located in New Delhi, India, joined the Indian Society of Agribusiness Professionals (ISAP) as the new India CCA program manager in August. With a large percentage of the population in India depending on farming, Randhawa sees a great need for additional sources of information and methods of technology transfer for the best agronomic practices.

“Sixty percent of the population in India is dependent on agriculture for their livelihood,” he says. “So it is a very important economic and social sector in India. There is a need for unbiased information and technology transfer for agricultural practices, but these needs are currently not being fulfilled. We are building a program so that Certified Crop Advisers can fulfill this need.”

The American Society of Agronomy (ASA) and the India CCA program have partnered with a range of public- and private-sector organizations to enable sustainable cereal production in India. ASA has an agreement with ISAP to be the administrative organization for the India CCA program. ISAP coordinates the efforts of the India CCA board, which will implement the policies and procedures of the ASA International CCA program.

“Although we have just started the CCA program in India, we already have more than 140 advisers who have passed the exam and are working in the field,” Randhawa says. “And we plan to expand and build the program.”

Several agricultural input suppliers in India, such as Tata Chemicals Ltd., Shriram Fertilisers and Chemicals, Deepak Fertilisers and Petrochemicals, Monsanto India Ltd., and Pioneer Hybrid International, have endorsed the program as a skill enhancement and continuing education tool for their employees in the field.

Early feedback on the India CCA program positive

The feedback we’ve received from both industry and CCAs on the India CCA program has so far been positive. Here are some comments:

“A strong need was felt in India to initiate a certification program that could set a standard for advising farmers on agriculture-related issues. The CCA program has been devised to fill in this gap and has set a benchmark in the area of farm advisory.

This program will certainly enhance the competence of all who are engaged in farm advisory. This kind of certification will help the employer to employ a highly qualified and competent work force and also upgrade the skills of the existing talent pool. This certification also helps ensure that the right people with the right skills are advising farmers on the latest technology and agronomic practices and is ethically bound to do what is in the best interests of the farmers. CCA gets differentiated from other programs as continuous education is integral part of curriculum.

Tata Chemicals supports this program, which aims at enhancing competence of its entire field force and certifies all those who are engaged in servicing farmers. I congratulate the CCA program coordinator and its entire team who are managing this program efficiently and professionally!”

–Ranjeet Singh Chhabra, VP Sales & Marketing, TATA Chemicals

“Thank you for CCA updates. I feel good after joining this program. One thing I want to share: after getting the material for examination, I read it carefully and found that the course content designed in these booklets is very useful for me. Earlier I studied in a classroom when I was student, but now this knowledge is very useful in the field when I am going to meet the farmers. I like most the knowledge about plant nutrients.”

–Ajay Kr. Verma, Rallis India Pvt. Ltd.

“India CCA training material provides a deep and practical knowledge of a wide variety of farmer-centric query spectrum. If you devote some time in going through the study material document, you will get a very good knowledge on all the disciplines including nutrient, soil and water, and pest and crop management, which will help in updating your knowledge and in providing quality information to the farmers for improving their productivity.”

–Mr. Gurvinder Singh, Agriculture Information Officer, DoA–Punjab
“The feedback received from the participants as well their companies has been overwhelming,” Randhawa says. “The program has been recognized by the public and private sector around the world as a tool to enhance and upgrade one’s knowledge in agriculture. It is with great hope that the India CCA program translates into profitable productivity in farmers’ fields.”

Randhawa’s background is in agribusiness sales and marketing, agriculture extension, and food processing. He earned an MBA in agribusiness management from the Symbiosis Institute of International Business (SIIB), Pune and a B.S. degree in dairy technology from National Dairy Research Institute, Karnal.

Prior to joining ISAP, he worked with Monsanto India Ltd. in the sales and marketing of agriculture inputs. He has also worked on business development and concept marketing for Reuters Market Light, an agriculture initiative of Thomson Reuters during his tenure in Global AgriSystem Pvt. Ltd.

The India CCA program was initiated in 2009 by the International Rice Research Institute (IRRI) in collaboration with the International Maize and Wheat Improvement Center (CIMMYT), International Food Policy Research Institute, International Livestock Research Institute, IRRI Fund Singapore, and numerous public, private, and international partners. Working with the various groups, IRRI launched the Cereal Systems Initiative for South Asia (CSISA), an umbrella program supported by the Bill & Melinda Gates Foundation and the United States Agency for International Development.

Under CSISA, IRRI partnered with ASA to establish an International CCA program in India through a memorandum of understanding (MOU) in March 2009. Prior to this, Punjab Agricultural University, Ludhiana, had signed an MOU with ASA and IRRI in February 2009 for technical and academic inputs to the India CCA program. After a round of consultations, ISAP became that local partner. ISAP administers and implements certifications through a formal licensing agreement between ASA and ISAP and between IRRI and ISAP during the first quarter of 2010.

For more information on the India CCA program, visit www.certifiedcropadviser.org/india or www.isapindia.org, call +91-11-43154100, or email indiacca@isapindia.org. Saveen Randhawa can be contacted at saveen@isapindia.org. &
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Following the oil shocks of the 1970s, a number of analysts examined agriculture's relationships with fossil energy. Attention to that topic faded during the subsequent three decades of relatively stable supplies and low fossil energy prices. Though many individual agricultural management practices have been shown to reduce dependence on fossil energy inputs, the impacts of whole production systems that incorporate multiple alternative practices over time have received relatively little attention. This is especially important as agricultural systems are being evaluated for their ability to provide multiple goods and services, including protection of environmental quality, generation of adequate income, and food security.

This article reports on fossil energy use and production efficiencies in a multi-year comparative cropping systems experiment conducted in Iowa, within the central U.S. Corn Belt. Experimental treatments encompassed a conventionally managed two-year rotation system (corn–soybean) as well as a three-year rotation (corn–soybean–small grain + red clover) and a four-year rotation (corn–soybean–small grain + alfalfa–alfalfa) managed with substantially lower inputs of synthetic fertilizers and herbicides. The two-year rotation is typical of cash grain systems in the region, whereas the three- and four-year rotations are representative of low-external-input (LEI) cropping systems in the region that are integrated with cattle production through the feeding of crops to livestock and the application of manure to crop fields.

The energy analyses focus on “economic energy,” or “forms of energy that command a price.” This reduces the scope of energy sources to those that can be controlled directly by an individual farmer’s management decisions. For example, solar energy inputs are not included in the analyses, whereas fuel usage is. Energy measurements in the study were made on components that flowed across field boundaries (Fig. 1, next page). The study also takes a reductionist point of view in that it considers only in-field management of the cropping systems, which is a departure from past studies of agricultural energy use that have used wide system boundaries to attempt to quantify energy use in agriculture more holistically.

Abbreviations: LEI, low external input.
The two-, three-, and four-year rotation systems were compared during 2003 to 2008, a period that experienced large fluctuations in input costs and crop prices. In the three- and four-year systems, triticale was used as the small-grain crop in 2003 to 2005, whereas oat was used in 2006 to 2008. Manure was applied in the three- and four-year rotations before corn production, representing, for the four-year system, about 70% of the manure that would be available on a farm where cattle were raised on the quantities of corn and forage obtained from the experimental plots. All crops were managed with standard farm machinery.

Five categories of energy inputs were considered: field operations, seed, fertilizer, pesticides, and grain handling. Grain handling included both hauling harvested material out of the field and drying the material to standard storage conditions. Energy costs of grain storage were not included in the analyses as they are part of grain marketing, not production. Grain drying energy costs were only applied to the corn crop, so as to imitate a standard Iowa production system, and were based on actual moisture concentrations of harvested corn and a high-temperature system with air circulation. All seeds used for planting were assumed to be produced with 1.5 times the fossil energy used for regular harvested grain except for corn, for which a factor of 4.7 was used.

The appropriate energy value of manure is a topic subject to substantial debate, so we conducted two types of energy analyses. In the first analysis, manure was considered a waste product of a livestock operation and its only energy cost was energy used for application. We termed this analysis the “low-energy manure” analysis. A second energy analysis was conducted by adding the energy cost of application to the energy costs of the manure nutrients assessed as commercial fertilizers. The second analysis thus created considerably higher energy costs for manure and was termed the “high-energy manure” analysis.

Weight outputs of crop materials were based on dry weights of recorded harvests. To determine energy outputs in crop materials, random samples of all harvested material were collected in 2008 from individual plots at each crop’s harvest date. Samples were then dried at 140°F for 48 hours, ground, and processed to determine their caloric values at the Central Analytical Laboratory of the University of Arkansas Division of Agriculture. Samples from a single year were accepted as representative across all years because similar crop varieties were grown throughout the study and fertilizer rates did not vary widely throughout the study, which has been shown to influence seed composition.

Crop prices for 2003–2007 were from USDA statistics; prices for the 2008 marketing year were estimates from Iowa State University Extension specialists. Crop prices represented the average price for the entire year after harvest in the state of Iowa. Crop subsidies were not included in the analyses. Labor costs were accounted for in the economic analyses at a rate of $10 per hour, but since energy input from labor was so small, labor energy was omitted.

Statistical analyses were conducted using SAS version 9.1.3 and the PROC MIXED function. Block and year were treated as random factors; cropping system (i.e., rotation) and crop were treated as fixed factors. Means were separated using Tukey’s multiple comparison test with significance determined at the \( \alpha = 0.05 \) level.

Results

For both energy analyses (i.e., low-energy and high-energy manure), all cropping systems differed significantly in fossil energy inputs. The two-year rotation had the largest...
annual energy investment whereas the three-year rotation annually required 59 and 77%, respectively, and the four-year rotation annually required 44 and 58%, respectively, of the energy invested in the two-year rotation. Compared with the two-year rotation, the three- and four-year rotations had greater fossil energy requirements for field operations but lower energy requirements for fertilizers and pesticides. For all rotations and both energy analyses, corn was consistently the crop with the largest energy input levels and was significantly different from all others.

During the period from 2003 to 2008, synthetic N fertilizer inputs were reduced 66% in the three-year rotation system and 78% in the four-year rotation system compared with the two-year system; similarly, herbicide use was reduced by an average of 80% in the three-year system and 85% in the four-year system. Despite these reductions in inputs, corn and soybean yields in the LEI three- and four-year systems matched or exceeded levels obtained from the conventionally managed two-year system. Crop yields in all of the experimental systems were similar to, or greater than, mean yields of commercial farms in the surrounding county in all years of the experiment.

Mean weight output of crop materials for the three-year rotation was 96% of the output for the two-year rotation, whereas weight output from the four-year rotation was 7% higher when compared with the two-year rotation. The only significant difference in weight output was found between the three- and four-year rotations. Ratios of crop weight/fossil energy input, using the low-energy manure analysis, increased with rotation length, with significant differences among all rotation systems. Using the high-energy manure analysis, the crop weight/fossil energy input ratios also increased with rotation length, but the only rotation that was significantly different from the others was the four-year rotation. In the two-year rotation, the corn crop weight/fossil energy input was lower and significantly different than the soybean ratio. For both energy analyses, in the three- and four-year rotations, the corn and soybean crop weight/fossil energy input ratios were statistically similar and smaller than the other crops, and the largest crop weight/fossil energy input ratio was realized in the four-year alfalfa crop.

Under the assumption that manure was an economically free input to cropping systems (other than labor and machinery costs for its application), researchers reported
that monetary return to land and management for the period of 2003 to 2006 was greatest in the four-year rotation, lowest in the three-year rotation, and intermediate for the two-year rotation. Using a similar assumption for the period of 2003 to 2008 led to a similar trend, although the differences among the rotation systems were not significant. For the low-energy manure scenario, revenue returned to land and management per unit of fossil energy input was significantly lower for the two-year rotation than both the three- and four-year rotations, which were not statistically significantly different from one another. However, for the high-energy manure scenario, the ratio for the four-year rotation was significantly higher than ratios for both the two- and three-year rotations, which were not significantly different than each other.

Pricing manure nutrients at levels commensurate with synthetic fertilizer reduced annual return to the three- and four-year rotations significantly. Under this high-cost manure scenario, a significant difference was found in economic returns between the two- and three-year rotations, whereas the two- and four-year rotations were not significantly different. Combined with the low-energy manure scenario, the economic return per unit of fossil energy input was significantly greater for the four-year system than for the two-year system; the three-year system was intermediate. Combined with the high-energy manure scenario, the economic return per unit of fossil energy input was also significantly greater for the four-year rotation, whereas the two- and three-year rotations were statistically similar.

On an individual crop basis, corn had the smallest economic return per fossil energy input for all crops regardless of rotation, economic analysis, or energy analysis; alfalfa had the largest ratio for economic return per fossil energy input.

Discussion

On a fossil energy input basis, the LEI three- and four-year rotation systems required lower inputs than did the conventional two-year rotation. Results of this study also indicate that management at harvest time has a large potential impact on fossil energy use, as grain handling and more specifically grain drying accounted for proportionally the largest or second largest fossil energy input for all system analyses.

For the low-energy manure scenario, much of the energy savings that was observed between the conventional two-year system and the LEI systems was due to reduced use of N fertilizer, which is consistent with the results of past research. For the efficiency ratios presented, both LEI systems were more efficient than the conventional system. Most of the variability observed among systems in energy use efficiency ratios was due to differences in fossil energy input values, not in outputs from the systems. For the high-energy manure scenario, the difference between the conventional and LEI systems in fossil fuel energy input was reduced, and the differences in efficiency ratios were also reduced. The energy values for manure presented here are likely the two extreme values, with the real value depending on the configuration and management of the livestock operation.

The true economic value (price) of manure depends on local market conditions but probably lies between the low and high costs examined in this study. The incorporation of alfalfa into the four-year rotation was important: in all economic analyses, the four-year rotation was significantly more efficient in energy use than the two-year rotation, whereas the three-year rotation was not. Previous research has shown that the diversification of corn-based cropping systems through the addition of small grains and forage legumes can provide higher, more stable net returns.

Fossil energy use is not the only factor to be considered when choosing a cropping system. Labor and management requirements are also important factors influencing farmers’ decisions. In this study, labor inputs followed an opposite trend to that seen for fossil energy inputs, with the four-year rotation having the largest input and the two-year rotation having the smallest input. As compared with the two-year rotation, the three-year rotation required 54% more labor, whereas the four-year rotation required 91% more labor. Incorporation of small-grain crops (triticale and oat) and alfalfa into the three- and four-year rotation systems would place much of the extra time investment into parts of the year that do not overlap with peak activities associated with corn and soybean production.

For the management practices and economic conditions used for this study, our analysis shows that a conventional two-year rotation system widely used in the central U.S. Corn Belt (corn–soybean) relies on fossil energy to reduce labor requirements while allowing net economic returns to remain constant, effectively allowing greater wage rates for the producer. If demands from ethanol plants or overseas markets increase the price of corn grain faster than input costs rise, or if commercial-scale production of biofuels from corn stover becomes economically viable, Midwestern cropping systems might become less diverse and more focused on corn. Alternatively, if fossil energy prices rise significantly without concomitant increases in crop value, diversified LEI cropping systems, such as those described in this study, may become preferable to conventional cropping systems and used more widely.

November–December 2011 self-study quiz

Fossil energy use in conventional and low-external input cropping systems (no. SS 04797)

1. The energy analyses in this article focus on “economic energy,” or “forms of energy that command a price.” This reduces the scope of energy sources to those that can be controlled directly by
   a. changing suppliers.
   b. environmental conditions.
   c. management decisions.
   d. changing crop systems.

2. In the three- and four-year rotations, an amount of manure was applied that represented about ___ of the manure that would be available on a farm where cattle were raised on the quantities of corn and forage obtained from the experimental plots.
   a. 70%
   b. 35–45%
   c. 90%
   d. 25–30%

3. Five categories of energy inputs were considered: field operations, seed, fertilizer, pesticides, and grain handling. What does grain handling encompass?
   a. Harvesting, hauling material out of the field, and drying it.
   b. Transporting grain from the grain bin to the lab and testing it.
   c. Hauling harvested material out of the field, cleaning it, and drying it.
   d. Hauling harvested material out of the field and drying it.

4. During the period from 2003 to 2008, herbicide use was reduced by
   a. 66% in the three-year system and 78% in the four-year system.
   b. 80% in the three-year system and 85% in the four-year system.
   c. 20% in the three-year system and 30% in the four-year system.
   d. about half in both systems.

5. For all rotations and both energy analyses, which crop consistently used the most energy inputs and was significantly different from all others?
   a. corn.
   b. triticale.
   c. soybean.
   d. oat.

6. The two-year rotation had the largest annual energy investment while the three-year rotation annually required ____, respectively, and the four-year rotation annually required ____, respectively, of the energy invested in the two-year rotation.
   a. 55 and 65% / 43 and 60%.
   b. 43 and 60% / 59 and 77%.
   c. 44 and 67% / 34 and 43%.
   d. 59 and 77% / 44 and 58%.

7. Most of the variability observed among systems in energy use efficiency ratios was due to
   a. differences in fossil energy input values and not outputs from the systems.
   b. differences in outputs from the systems and not fossil energy input values.
   c. a combination of reduced fossil energy input values and outputs from the systems.
   d. differences in fossil energy input values, divided by yield differences.

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

Directions

After carefully reading the article, answer each question by clearly marking an “X” in the box next to the best answer. Complete the self-study quiz registration form and evaluation form on the back of this page. Clip out this page, place in an envelope with a $20 check made out to the American Society of Agronomy (or provide your credit card information on the form), and mail to: ASA c/o CCA Self-Study Quiz, 5585 Guilford Road, Madison, WI 53711. Or you can save $5 by completing the quiz online at www.certifiedcropadviser.org/certifications/self-study.

Quiz continues next page
8. In all economic analyses, the four-year rotation was significantly more efficient in energy use than the two-year rotation, making the incorporation of which crop important?

- a. Oat.
- b. Alfalfa.
- c. Triticale.
- d. Soybean.

9. As compared with the two-year rotation, the three-year rotation required 54% more labor, whereas the four-year rotation required

- a. 75% more labor.
- b. 91% more labor.
- c. 82% more labor.
- d. 60% more labor.

10. For the management practices and economic conditions used for this study, the analysis shows that a conventional two-year rotation system widely used in the central U.S. Corn Belt (corn–soybean) effectively allows

- a. more on-farm jobs.
- b. greater wage rates for the producer.
- c. for the use of less fossil energy.
- d. more acres to be farmed.
Long-term cropping studies have demonstrated the value of extended crop rotations, which include two or more years of a forage legume such as alfalfa in maintaining yields of grain crops in rotations instead of continuous annual grain production. A two-year corn–soybean rotation predominates in much of the Midwest, producing high yields of commodities for marketing and livestock feed, but relies on external inputs of synthetic pesticides and fertilizers to augment the rotation effects. Annual grain production systems have been associated with greater soil loss than longer crop rotations that include perennials such as alfalfa, and increasing input costs for crop production have piqued farmer interest in organic and low-external-input (LEI) cropping systems, which have emerged as profitable alternatives to conventional crop production.

Recent studies have compared crop production in conventional and organic systems. Over seven years on a field with a history of conventional fertilizer and pesticide use in a low-rainfall region of southwestern Minnesota, corn and soybean grain yields were 7 and 16% greater in a conventional high-external-input (HEI) two-year corn–soybean rotation than in an organic input (OI) system with a four-year oat/alfalfa–alfalfa–corn–soybean rotation; however, net returns for the two systems were equal.

Knowledge of how external-input management systems and crop rotation influence crop yields over the long term is critical for providing a solid foundation on which to base adoption of cropping systems that are profitable, high yielding, and environmentally responsible. A recent study published in Agronomy Journal examines how cropping systems with contrasting levels and types of external inputs affect crop yield and stability of crop yield in a two-year soybean–corn rotation and a four-year oat/alfalfa–alfalfa–corn–soybean rotation over 16 years.

A 40-ac field experiment was established in 1989 following soybean at the University of Minnesota Southwest Research and Outreach Center near Lamberton, MN. (For details of the plot management, see the report in Agronomy Journal, volume 103, pages 182–192.) The LEI cropping system involved less aggressive tillage in the fall after corn and soybean harvest than the zero-external-input (ZEI), HEI, and OI cropping systems; had synthetic fertilizers and herbicides for corn and soybean that were applied directly to the crop rows in bands; and used band-applied fertilizers at planting based on realistic crop yield goals. The HEI system included synthetic fertilizers and herbicides broadcast over the full width of the field and was fertilized for yield goals that were 10% higher than expected. The OI cropping system was managed in compliance with the USDA National Organic Program Standards and received applications of manure at rates for yield goals that were 10% higher than expected. Although the two-year crop rotation would not satisfy the requirement for organic certification, the OI cropping system was evaluated within both the two- and four-year crop rotations to balance the experimental design and determine the effects of crop rotation. The crop rotations

**Abbreviations:** HEI, high external input; LEI, low external input; OI, organic input; ZEI, zero external input.
and cropping systems in this study were initiated in 1989 and remained in place through 2007.

Oat was planted about an inch deep while alfalfa seed was placed on the soil surface followed by one pass with a drag and another pass with a culti-packer. Oat and alfalfa planting occurred on the same date for all cropping systems, which typically occurred between mid- to late April (April 24 on average). Corn and soybean were planted 2.0 and 1.5 inches deep, respectively, in rows spaced 30 inches apart. Seeding rates for corn increased steadily over time according to university and industry recommendations while those for soybean were stable. Planting in the LEI and HEI cropping systems occurred on the same date, typically between late April and early May for corn and mid- to late May for soybean. Planting in the ZEI and OI cropping systems occurred on the same date, which was one to two weeks later than the LEI and HEI cropping systems to allow additional flushes of weeds to emerge and be destroyed with tillage prior to planting. Average planting dates in the ZEI and OI cropping systems were May 16 and 28 for corn and soybean, respectively.

The seed used in the ZEI and OI cropping systems was not treated with pesticides. Beginning in 2004, because of changes in conventional farming practices by growers in the region, herbicide-tolerant corn and soybean cultivars were planted in the LEI and HEI cropping systems. From 2004 to 2006, the near-isoline corn hybrids without genetic modification for herbicide tolerance were planted in the ZEI and OI cropping systems. In 2007, organically produced corn hybrids were planted in the ZEI and OI cropping systems. These hybrids had different base genetics than those planted in the LEI and HEI cropping systems. Food-grade soybean cultivars were planted in the ZEI and OI cropping systems from 2004 to 2007, since these were the cultivars commonly planted by organic growers in the region during this time. From 2005 to 2007, soil insecticide was placed in the seed furrow at corn planting within the LEI and HEI cropping systems to control corn rootworm.

Weed management in corn and soybean within the ZEI and OI cropping systems involved delayed planting, postplant rotary hoeing of germinated weeds that had not yet emerged, and interrow cultivation to control escaped weeds as needed. In the LEI cropping system, weeds were controlled in corn and soybean with postplant rotary hoeing, interrow cultivation, and the use of one pre-emergence and zero to two postemergence herbicide applications in bands over the crop rows as needed. Weed management in corn and soybean within the HEI cropping system included interrow cultivation and one pre-emergence and zero to two postemergence herbicide applications that were broadcast.

No herbicides or mechanical weed control methods were used during oat/alfalfa and alfalfa production within any cropping system, and no foliar fungicides were applied to any crop. In late July of 2006, a foliar insecticide was broadcast within the LEI and HEI cropping systems for control of soybean aphid according to recommendations from the North Central Soybean Research Program.

Due to significant interactions among cropping system, four-year cycle, and year for oat and alfalfa yield and significant interactions among crop rotation, cropping system, four-year cycle, and year for corn and soybean yield, regression stability analysis of yield was conducted by cropping system for oat and alfalfa and by crop rotation and cropping system for corn and soybean. The analysis was conducted in order to understand treatment × environment interactions and the stability of crop yields across variable environments for the various combinations of crop rotation and cropping system in this study. A cropping system was considered stable if the slope from the regression stability analysis was equal to a value of 1. In comparison, cropping systems were considered to have a reduced or greater ability to take advantage of enhanced environmental conditions with respect to the other treatments when the slope from the regression stability analysis was less than or greater than a value of 1, respectively.

**Results and discussion**

Oat yield was affected by cropping system, but not by four-year cycle or the interaction between cropping sys-

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Crop yield †</th>
<th>Oat grain yield, bu/ac</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZEI</td>
<td>44 b §</td>
<td></td>
</tr>
<tr>
<td>LEI</td>
<td>66 a</td>
<td></td>
</tr>
<tr>
<td>HEI</td>
<td>69 a</td>
<td></td>
</tr>
<tr>
<td>OI</td>
<td>68 a</td>
<td></td>
</tr>
<tr>
<td>Crop rotation</td>
<td>soybean grain yield, bu/ac</td>
<td></td>
</tr>
<tr>
<td>Two year</td>
<td>34 b</td>
<td></td>
</tr>
<tr>
<td>Four year</td>
<td>36 a</td>
<td></td>
</tr>
</tbody>
</table>

† Oat yield is from the four-year crop rotation, and soybean yield is averaged across cropping systems.
‡ ZEI, zero external input; LEI, low external input; HEI, high external input; OI, organic input.
§ Within a column for a given crop rotation or cropping system, treatment means followed by the same letter are not significantly different (α = 0.05).
tem and four-year cycle. When averaged across four-year cycles, oat yield was similar for the LEI, HEI, and OI cropping systems and averaged 53% greater than that with the ZEI cropping system (Table 1). Lower oat yield with the ZEI cropping system was probably due to insufficient soil fertility. The similarity in oat yield between the OI cropping system and the LEI and HEI systems (Table 1) may have also been due to the limited capacity of the OI system to reduce crop water stress during oat production and oat's ability to complete its life cycle prior to the onset of dry conditions in late summer.

Alfalfa yield with the OI cropping system did not differ among four-year cycles, and there was no relationship between alfalfa yield and environmental index for this cropping system. Alfalfa yield was stable over time with the ZEI cropping system. In comparison, results for the LEI and HEI cropping systems indicated that as environmental conditions for alfalfa production improve, alfalfa yield in these cropping systems increases more rapidly than that in the ZEI and OI cropping systems.

Corn grain yield was affected by the interaction between cropping system and four-year cycle. Averaged across crop rotations, corn grain yield during the first two four-year cycles was highest with the LEI and HEI cropping systems, lowest with the ZEI cropping system, and intermediate with the OI cropping system (Table 2). Low corn grain yield with the OI cropping system during the first two four-year cycles of this study may have been related to less effective mechanical weed control in 1993, 1996, and 1997 resulting from wet soil conditions. During the last two four-year cycles, however, corn grain yield was highest with the HEI and OI cropping systems, lowest with the ZEI cropping system, and intermediate with the LEI cropping system. Corn grain yield was also affected by the interaction between crop rotation and cropping system. Averaged across four-year cycles, corn grain yield was 13, 26, and 41% greater with the four-year crop rotation than the two-year crop rotation in the LEI, OI, and ZEI cropping systems, respectively, but corn grain yield with the HEI cropping system was similar for the two- and four-year rotations (Table 3).

The low corn grain yield that occurred throughout this study with the ZEI cropping system (Tables 2 and 3) was expected since corn has a relatively high requirement for supplemental N applied through fertilizer or manure and a low tolerance for weed competition when compared with other crops such as soybean, small grain, and legume hay. The interaction between crop rotation and cropping system for corn grain yield may be related to differences in weed control. Grass weed density in the two-year rotation was less than 1 plant/mi² in the HEI cropping system compared with 12 to 23 plants/mi² in the other cropping systems. In comparison, grass weed density in corn did not differ among cropping systems within the four-year rotation and averaged 4 plants/mi².

Differences in corn grain yield among cropping systems may be partially due to differences in planting dates, which averaged May 7 for the LEI and HEI cropping systems and May 16 for the ZEI and OI cropping systems. Separate experiments in a HEI two-year soybean–corn

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**Table 2. Annual total alfalfa forage dry matter (DM) yield, corn grain yield, and soybean grain yield as affected by cropping system and four-year cycle.†**

<table>
<thead>
<tr>
<th>Cropping system</th>
<th>Cycle 1</th>
<th>Cycle 2</th>
<th>Cycle 3</th>
<th>Cycle 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>annual total alfalfa forage yield, tons/ac $§$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZEI</td>
<td>4.0 bA ¶</td>
<td>2.6 bAB</td>
<td>2.1 cB</td>
<td>1.9 cB</td>
</tr>
<tr>
<td>LEI</td>
<td>5.2 aA</td>
<td>4.9 aAB</td>
<td>3.4 bC</td>
<td>2.9 bC</td>
</tr>
<tr>
<td>HEI</td>
<td>5.5 aA</td>
<td>5.4 aA</td>
<td>4.0 bB</td>
<td>3.5 bB</td>
</tr>
<tr>
<td>OI</td>
<td>4.9 aA</td>
<td>4.9 aA</td>
<td>5.2 aA</td>
<td>5.5 aA</td>
</tr>
<tr>
<td>corn grain yield, bu/ac</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZEI</td>
<td>54 cA</td>
<td>66 cA</td>
<td>63 cA</td>
<td>80 cA</td>
</tr>
<tr>
<td>LEI</td>
<td>120 aA</td>
<td>143 aA</td>
<td>115 bA</td>
<td>144 bA</td>
</tr>
<tr>
<td>HEI</td>
<td>126 aB</td>
<td>157 aA</td>
<td>140 aAB</td>
<td>168 aA</td>
</tr>
<tr>
<td>OI</td>
<td>98 bB</td>
<td>124 bAB</td>
<td>133 aA</td>
<td>153 abA</td>
</tr>
<tr>
<td>soybean grain yield, bu/ac</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZEI</td>
<td>31 bA</td>
<td>31 bA</td>
<td>25 bA</td>
<td>21 bA</td>
</tr>
<tr>
<td>LEI</td>
<td>37 abAB</td>
<td>44 aA</td>
<td>32 abB</td>
<td>42 aA</td>
</tr>
<tr>
<td>HEI</td>
<td>42 aA</td>
<td>46 aA</td>
<td>38 aA</td>
<td>47 aA</td>
</tr>
<tr>
<td>OI</td>
<td>37 abA</td>
<td>32 bAB</td>
<td>30 bAB</td>
<td>26 bB</td>
</tr>
</tbody>
</table>

† Alfalfa yield is from the four-year crop rotation, while corn and soybean yields are averaged across the two- and four-year crop rotations.
‡ ZEI, zero external input; LEI, low external input; HEI, high external input; OI, organic input.
§ Alfalfa yield in the year after stand establishment.
¶ Within a column, treatment means followed by the same lowercase letter are not significantly different (α = 0.05). Within a row, treatment means followed by the same uppercase letter are not significantly different.
rotation at this location comparing soil-applied insecticide with an untreated control on two and four corn hybrids lacking transgenic resistance to corn rootworm found that grain yield was not affected by soil-applied insecticide in 2005 and 2006. It is unlikely that differences in corn grain yield due to the use of soil-applied insecticide occurred among cropping systems within the four-year crop rotation since corn rootworm in this region lay eggs predominantly in corn and the majority of larvae hatch within two years.

Corn hybrids differed among cropping systems from 2004 to 2007, but it is unlikely that this significantly contributed to the differences in corn grain yield among cropping systems during the last four-year cycle. From 2004 to 2006, corn hybrids planted in the LEI and HEI cropping systems had transgenic herbicide tolerance, while those planted in the ZEI and OI cropping systems were near-isoline corn hybrids without transgenic herbicide tolerance. In the poorest-yielding year, corn grain yield was highest with the LEI, HEI, and OI cropping systems and lowest with the ZEI cropping system for both crop rotations.

Soybean yield was affected by crop rotation and the interaction between cropping system and four-year cycle. Across cropping systems and four-year cycles, soybean yield with the four-year crop rotation was 7% greater than that with the two-year rotation (Table 3). Across crop rotations, soybean yields were among the highest with the LEI and HEI cropping systems in all four-year cycles, while soybean yields with the ZEI and OI cropping systems were among the lowest in all four-year cycles (Table 2).

When compared with the LEI and HEI cropping systems, lower soybean yield with the ZEI cropping system in all four-year cycles and with the OI cropping system in three of the four four-year cycles (Table 2) may be due to differences in planting date. Between 1992 and 2007, soybean planting dates averaged May 19 in the LEI and HEI cropping systems and May 28 in the ZEI and OI cropping systems.

Conclusions

For both corn and soybean, the longer, more complex four-year crop rotation increased grain yield across years, but the synthetic fertilizer and herbicide used in the HEI cropping system were able to offset this rotation effect in corn and allow this cropping system to be better suited to take advantage of favorable environmental conditions. As expected, yields with the ZEI cropping system were among the lowest for all crops and had reduced ability to take advantage of enhanced environmental conditions with respect to the other treatments for oat and corn, regardless of crop rotation. Oat, corn, and soybean yields with the HEI cropping system were among the highest of all systems, but yields with the HEI cropping system were similar to those with the LEI cropping system for oat, alfalfa, corn within the four-year crop rotation, and soybean within the two- and four-year crop rotations.

The high corn grain yield obtained with the LEI and OI cropping systems in the four-year crop rotation but not in the two-year crop rotation indicates that extended crop rotations with forage legumes may be necessary for LEI and OI cropping systems to be competitive with HEI cropping systems for corn production. For soybean, yield was stable for all cropping systems in both crop rotations, but was consistently highest with the LEI and HEI cropping systems. Across crop rotations and four-year cycles, soybean yield was 7% greater with the four-year crop rotation than the two-year crop rotation, but the lack of a significant interaction between crop rotation and cropping system for soybean yield indicates that factors other than crop rotation may be more important for improving the capacity of LEI and OI cropping systems to compete with HEI cropping systems for soybean production.


<table>
<thead>
<tr>
<th>Crop rotation</th>
<th>Two year</th>
<th>Four year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cropping system †</td>
<td>corn grain yield, bu/ac</td>
<td></td>
</tr>
<tr>
<td>ZEI</td>
<td>55 cB‡</td>
<td>77 bA</td>
</tr>
<tr>
<td>LEI</td>
<td>123 bB</td>
<td>139 aA</td>
</tr>
<tr>
<td>HEI</td>
<td>150 aA</td>
<td>145 aA</td>
</tr>
<tr>
<td>OI</td>
<td>112 bB</td>
<td>142 aA</td>
</tr>
</tbody>
</table>

† ZEI, zero external input; LEI, low external input; HEI, high external input; OI, organic input.
‡ Within a column, treatment means followed by the same lowercase letter are not significantly different (α = 0.05). Within a row, treatment means followed by the same uppercase letter are not significantly different.

Table 3. Corn grain yield as affected by cropping system and crop rotation, averaged across all four-year cycles from 1992 to 2007.
1. The articles mentions a study in southwestern Minnesota that compared crop production in conventional vs. an organic system. In the study, corn and soybean grain yields
   a. were about the same in a conventional HEI two-year rotation and an OI system with a four-year rotation, but net returns were greater in the HEI system.
   b. 7 and 16% lower in a conventional LEI two-year rotation than in an OI system with a four-year rotation.
   c. 7 and 16% greater in a conventional HEI two-year rotation than in an OI system with a four-year rotation.
   d. were greater in a conventional HEI two-year rotation than in an OI system with a four-year rotation, but net returns were greater in the OI system.

2. In this study, the LEI cropping system
   a. was fertilized to achieve realistic crop yield goals.
   b. was fertilized to reach minimum crop yields.
   c. involved more aggressive tillage in the fall than the ZEI system.
   d. did not use synthetic fertilizers.

3. Weed management in corn and soybean within the ZEI and OI cropping systems involved
   a. interrow cultivation and one pre-emergence herbicide application.
   b. early planting, preplant rotary hoeing, and intrarow cultivation.
   c. interrow cultivation and one postemergence herbicide application.
   d. delayed planting, postplant rotary hoeing, and interrow cultivation.

4. Beginning in 2004, ___ corn and soybean cultivars were planted in the LEI and HEI cropping systems because of changes in conventional farming practices by growers in the region.
   a. drought-tolerant.
   b. herbicide-tolerant.
   c. cold-tolerant.
   d. heat-resistant.

5. The low corn grain yield that occurred throughout this study with the ZEI cropping system was expected since
   a. herbicide-tolerant varieties were not used.
   b. corn has a relatively high requirement for supplemental N.
   c. corn has a relatively high tolerance for weed competition.
   d. insecticide-tolerant varieties were not used.

6. For both corn and soybean, the longer, more complex four-year crop rotation increased grain yield across years, but the
   a. synthetic fertilizer and herbicide used in the LEI cropping system were able to offset this rotation effect in soybean.
   b. synthetic fertilizer and herbicide used in the HEI cropping system were able to offset this rotation effect in corn.
   c. herbicide used in the HEI cropping system was not as effective as needed.
   d. synthetic fertilizer partially offset the need for the longer rotation.

7. In the poorest-yielding year, corn grain yield was highest with the
   a. LEI, HEI, and OI cropping systems and lowest with the ZEI cropping system for both crop rotations.
   b. LEI, HEI, and ZEI cropping systems and lowest with the OI cropping system for the two-year rotations only.
   c. LEI and OI cropping systems with the four-year rotations and lowest with the HEI cropping system with the two-year rotations.
   d. LEI and OI cropping systems with the two-year rotations and lowest with the HEI cropping system with the four-year rotations.

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

Directions
After carefully reading the article, answer each question by clearly marking an “X” in the box next to the best answer. Complete the self-study quiz registration form and evaluation form on the back of this page. Clip out this page, place in an envelope with a $20 check made out to the American Society of Agronomy (or provide your credit card information on the form), and mail to: ASA c/o CCA Self-Study Quiz, 5585 Guilford Road, Madison, WI 53711. Or you can save $5 by completing the quiz online at www.certifiedcropadviser.org/certifications/self-study.

Quiz continues next page
8. Yields with the ZEI cropping system were among the lowest for all crops and had reduced ability to take advantage of
a. the inherent yield advantages of the hybrid traits.
b. the high pesticide and nutrient applications.
c. enhanced environmental conditions with respect to the other treatments for oat and corn.
d. N boost following soybean in the two-year rotation.

9. Across crop rotations, soybean yields were among the highest with the
a. ZEI and OI cropping systems in all four-year cycles.
b. ZEI and OI cropping systems in all two-year cycles.
c. LEI and HEI cropping systems in all two-year cycles.
d. LEI and HEI cropping systems in all four-year cycles.

10. The high corn grain yield obtained with the LEI and OI cropping systems in the four-year crop rotation but not in the two-year rotation indicates that
a. extended crop rotations with forage legumes may be necessary for LEI and OI cropping systems to be competitive with HEI cropping systems for corn production.
b. extended crop rotations with soybean may be needed for LEI and OI systems to compete with HEI systems for corn production.
c. crop rotation may be the most important factor for improving the capacity of LEI and OI cropping systems to compete with HEI cropping systems for soybean production.
d. fewer external inputs results in higher yields over shorter rotational periods.
Golden Opportunity Scholars Institute Celebrates 5th Anniversary

The 2011 International Annual Meetings of the American Society of Agronomy, Crop Science Society of America and Soil Science Society of America marked the 5th Anniversary of the Golden Opportunity (GO) Scholars Institute. This program matches undergraduates with scientist-mentors during the annual meetings to encourage talented students to enter agronomy, crop and soil sciences, cultivate networks and succeed in their careers.

There are 72 GO Scholar Alumni and the current awardees number 21 in total. For more information on how to get involved with the program please visit:

www.goldenopportunityscholars.org

Celebrating 5 Years
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