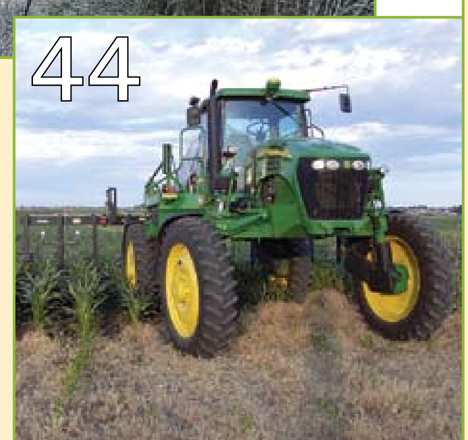
Crops & Soils

agronomy for practicing professionals

Volume 40 ■ Issue 2
Summer 2007



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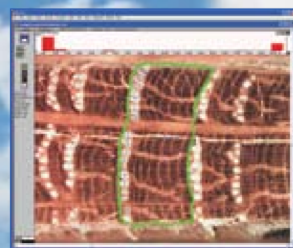

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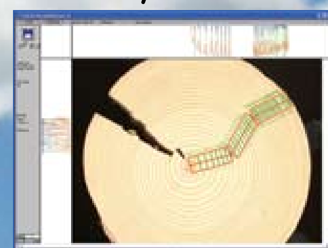

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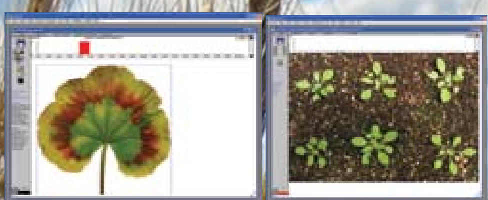

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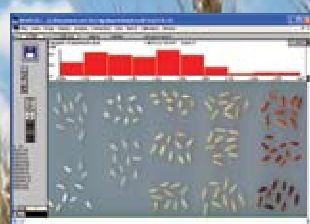

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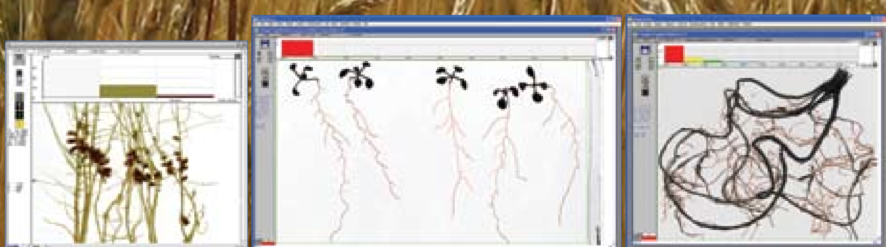

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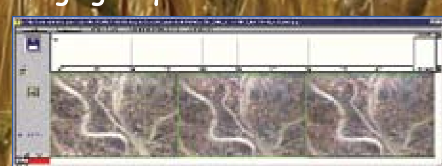

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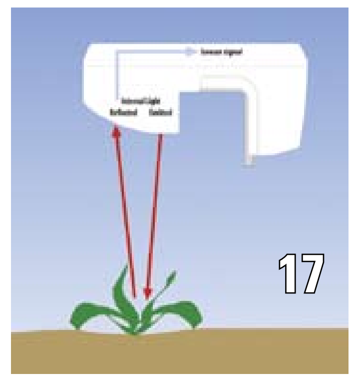


Comparing production practices and costs for continuous corn and corn–soybean cropping systems

By Stan Daberkow and James Payne, agricultural economists, Resource and Rural Economics Division of the USDA Economic Research Service; and ***James Schepers***, soil scientist, USDA Agricultural Research Service

Current projections by the USDA indicate that several million additional acres of corn will be needed over the next several years to meet increased demand for corn by-products, especially ethanol. A large share of the increased corn acreage will likely come at the expense of soybean acres, leading to an increase in continuous corn cropping systems. However, monoculture corn production is often associated with lower and more variable yields, higher costs, and environmental risks. Agronomists often cite yield differences of approximately 10%, nitrogen increases of 30 to 50 lb per acre, and additional insect and weed management. Increased nitrogen and pesticide use may also lead to additional environmental risks.

Despite these risks, continuous corn is grown on a substantial share of acreage in the U.S.—about one-fourth of all corn acreage was planted to corn for at least two consecutive years. Given that continuous corn is fairly widespread and persistent over time, these producers have apparently adopted practices that allow them to profitably grow corn without rotating with other crops. To what extent do current production practices, costs, and yields differ between corn–soybean and continuous corn farmers?

Using data from a 2005 national survey of fields growing corn for grain, we tested for differences between the two major cropping systems used to produce corn, focusing on differences in residue, nutrient, pest, and seed management; expected and actual yields; seed, pesticide, and fertilizer costs; and planting and harvesting machine capacity. The two cropping systems were compared by statistically testing for differences in: (1) the share of planted acres on which a specific practice, input, or technology was used or (2) mean values of selected input rates, yields, or costs.

Data, methods

Data for the analysis come from USDA´s 2005 Agricultural Resource Management Survey (ARMS), which is a multiframe, probability-based sample of corn producers. The ARMS data used in this study are from a field-level survey of farms producing corn for grain in the 19 largest corn-producing states. Information was collected on input use (i.e., seed, fertilizer, and pesticides), production practices (i.e., tillage, pest, and nutrient management), sources of information on nutrient management, field operations and machinery size (i.e., tillage, planting, cultivation, fertilizer and pesticide applications, and harvesting), and biotech and precision agriculture technologies used in the production of corn for grain. Respondents were also asked about costs per acre for three major inputs: seed, fertilizer, and pesticides. In addition, the sampled field's cropping history for the two previous years was recorded, which allowed us to distinguish fields growing continuous corn (for at least three years) from those in a corn–soybean–corn rotation. Restricting the analysis to these two major cropping systems resulted in 1,044 usable observations (fields) of which 223 were in continuous corn and 821 were in a corn–soybean rotation.

Each corn field sampled in the ARMS represents a known number of fields with similar attributes. By appropriately weighting the data for each field, inferences about the entire planted area of the surveyed states is possible. Only fields that were planted for grain and in a continuous corn (C-C-C) or corn–soybean (C-SB-C) cropping system were examined. These two crop rotations were estimated to account for about 50.2 million acres of corn planted for grain in the surveyed states in 2005. About 42 million acres

were planted in a C-SB-C rotation, and 8.2 million acres were in C-C-C.

Yield results

Contrary to much of the research literature, yields reported by corn-for-grain producers in 2005 did not differ significantly between the C-C-C and C-SB-C crop rotations (Table 1). Apparently, at least in 2005, continuous corn producers did not suffer a significant yield penalty compared with corn–soybean producers. Producers who have already switched to C-C-C note that it is difficult to avoid a yield penalty with second-year corn unless they have taken into account differences imposed by the corn residue and differences in nutrient requirements, unless weather conditions are favorable. The likelihood of a third-year yield hit is considerably reduced because the soil–plant system is well on its way to establishing a new equilibrium.

Residue management

Residue management is clearly one of the major challenges associated with continuous corn production. Given the larger amounts of residue, no-till systems are more difficult to manage in C-C-C production than in C-SB-C. As expected, a larger share of the C-SB-C acreage uses a no-till system compared with C-C-C. Likewise, it is more difficult for C-C-C to be conventionally tilled, unless a moldboard plow is used, than a C-SB-C system. In fact, the survey data indicate that a greater share of the acres was conventionally tilled while no acres were moldboard plowed. Continuous corn producers reported significantly more tillage trips (and total field operations) than did the corn–soybean producers.

▶ Table 1. Comparison of mean yields, input use and costs, equipment, and field operations on continuous corn (C–C–C) and corn–soybean (C–SB–C) fields on farms producing corn for grain, 2005.†

Item	Unit	C–C–C	C–SB–C
Actual yield	bu/acre	143	149
N application rate	lb/acre	125	134
P_2O_5 application rate	lb/acre	39_B	53_A
K_2O application rate	lb/acre	45_B	68_A
Seeding rate	seeds/acre	28,500	28,500
Days from state mean planting date	days	-1.5_B	-6.0_A
Planter size	no. rows	7.96_B	10.14_A
Harvester size	no. rows	5.67_B	6.63_A
Field operations: total trips	no.	6.31_B	5.83_A
Tillage trips (prior to and including planting)	no.	3.50_B	2.77_A
Seed input cost	$/acre	41.13	39.14
Pesticides input cost	$/acre	27.74	25.72
Fertilizer input cost	$/acre	58.50	64.12

† Source: 2005 USDA Agricultural Resource Management Survey. A and B subscripts indicate significant differences for that item.

Nutrient management

Because of the implications for crop yields, profitability, and the environment, nutrient use and management are critical aspects of corn production in general. While some research suggests that nutrient management should differ by cropping system, the 2005 survey found only modest differences. Nitrogen application rates, soil testing, and most application timing indictors were not significantly different between C-C-C and C-SB-C production. When the previous crop was soybeans, a higher share of acres received all commercial nitrogen in the fall ▶

whereas, when the previous crop was corn, a higher share was applied in the spring before planting—which may be related to the higher residue associated with continuous corn. Phosphate and potassium use did vary by cropping system with higher applications of both nutrients reported for C-SB-C production. With the exception of the use of crop consultants for nitrogen recommendations, information often used for nutrient recommendations, such as soil and tissue testing, was no different between the two systems. Manure use was more probable on C-C-C acres, which likely reflects proximity to local livestock production rather than the choice of cropping system.

Regardless of the cropping system, the use of most nutrient management practices is limited and remained similar between the two cropping systems.

Pest management

Weed and insect management in a continuous corn cropping system is typically considered more challenging because of increased residues, which may lead to loss of efficacy of soil applied pesticides, an increase in certain weed species, and greater populations of insects, especially corn rootworm and European corn borer. In 2005, there was little difference between the two cropping systems in terms of herbicide or fungicide use, herbicide timing, or in the share of acreage planted to herbicide-tolerant seed varieties. However, insect management did vary by cropping system with C-C-C producers more likely to use insecticides and C-SB-C producers utilizing Bt seed varieties. Also, weed control through cultivation was more prevalent in continuous corn production. Pest scouting is more critical for monoculture systems, and C-C-C producers did report using paid scouting on a larger share of acreage than the C-SB-C producers.

Seeding and equipment

Agronomists suggest that residue levels and related soil temperature should have an impact on seeding rates and dates. Relative to C-SB-C producers, C-C-C farmers did plant several days later based on our measure of both national and state adjusted planting dates. However, the seeding rate did not differ between the two cropping systems.

One of the benefits of a corn–soybean rotation is the possibility of spreading out the planting and harvesting seasons and possibly utilizing smaller equipment. Continuous corn producers reported using significantly smaller planters and harvesters than the C-SB-C farmers. However, machine capacity may not be so much a function of cropping system as size of farm, climate considerations, or other enterprises on the farm. Based on data from the entire farm, we tested for differences in both the type of farm and acres planted to corn and soybeans on the farm. Total soybean plus corn acreage on farms with continuous corn averaged 436 acres compared with 709 acres for farms with a corn–soybean rotation. Furthermore, only 68% of the farms with a continuous corn system were classified as a crop farm (vs. livestock farm) compared with 87% of farms with a corn–soybean system.

Photo courtesy of Syngenta

Input cost comparisons

For individual producers, differences in input costs between C-C-C and C-SB-C are a critical economic consideration in the choice of cropping system. At the national level, 2005 per-acre costs for seed, pesticides, and fertilizer were not significantly different between the two cropping systems. Despite concerns in the literature about higher production costs for continuous corn compared with corn–soybean rotations, the 2005 survey data did not reveal consistent cost differences.

Conclusions

Significant differences between the two cropping systems for many production practices implies that, as continuous corn production increases, corn–soybean producers may want to consider adopting practices commonly used by continuous corn producers in order to maintain yields and profits. For example, no-till systems, early planting, and fall nitrogen fertilization are much more prevalent in corn–soybean systems than in continuous corn, which has to deal with large crop residues after harvest. Other practices or technologies associated with a particular cropping system, such as irrigation, use of crop consultants, manure use, and adjustments in equipment size, are less common in corn–soybean production and would not likely change, at least in the short run, with the increase in continuous corn since these characteristics are likely linked to such factors as region, availability of crop consultant services, livestock production, and farm size. Some of the ambiguity about the impact of changing cropping systems is related to the assumptions underlying the statistical technique employed in this analysis, which does not control for the wide variety of factors associated with the decision to adopt a particular cropping system or practice.

One of the most striking findings of this analysis is that there are many similarities between these two major cropping systems. The share of acres using the most common nitrogen and weed management practices was not significantly different across the two systems. At the national level, the use of precision technologies, reduced and conservation tillage, input costs, or seeding rates did not vary by cropping system. Perhaps the most surprising result from the survey was the finding that none of our yield indicators or nitrogen application rates varied by system, which is contrary to much of the literature and extension recommendations. Without additional analysis, we cannot fully explain these results. One possibility is that continuous corn producers, over time, have learned to manage production risks associated with monoculture corn and avoided yield reductions, at least in 2005. For example, producers who have used the C-C-C system for a number of years manage crop residues by cutting the stalks, cleaning residues from the area where the seed will be placed, and planting. Based on this survey data, concerns about increased nitrogen application rates and input costs or yield penalties due to increased continuous corn may not be as serious as reported in the literature. ■

Education…

in the end, it's the beginning that counts

by Janet Braun
Program Coordinator
CropLife Ambassador Network
janet@maca.org or 800-625-2767

▶ Certified Crop Adviser Kevin Kilgus, Helena Chemical Co., teaches school children in Strawn, IL.

Education—agronomy's future depends on it. ASA, CSSA, and SSSA are in agreement on that fact and support strengthening the education programs for undergraduate and graduate students and professionals. But first, they need to get to that point. When is the seed for soil science planted? I propose that the love of science begins long before high school or college. Have you ever observed elementary school children dig in the dirt or check their science project every day to see if their seed has sprouted yet? Catch them at that time in life and show them agronomy CAN be in their future. When they enter the doors to undergraduate studies and beyond, agronomy will be a known option.

The CropLife Ambassador Network (CAN) offers a free service for the agricultural industry to connect with these students. CAN, the educational outreach program of the Mid America CropLife Association, takes the leg work out of public education. Using our network allows your time to be dedicated to actual teaching, not coordination. Marketing, school coordination, and material development is provided for you. Adding your individual expertise makes each program different. Our programs are aligned with the National Education Standards and are geared towards fourth- to sixth-grade students. Teachers are provided with lessons that reinforce the information presented.

▶ Retired agronomist Ray Sullivan at Lakeview Elementary in Bloomington, IN.

Our program has been approved by our Educator Advisory Committee consisting of fourth- to sixth-grade teachers across the Midwest. It has been well received by participating teachers, and many invite ambassadors back to their classrooms every year. As a teacher in Independence, MO relates, "My students were quiet for the first time this week! Really, they were very interested and enthralled by the presentation. Rarely do our urban students find out about lives away from their own."

Our mission is to provide scientifically based, accurate information to the public regarding the safety and value of American agricultural food production. Plant and soil sciences are the roots of a safe and abundant food supply. This is your opportunity to promote plant science for a better world.

Getting involved is easy. Visit http://ambassador.maca.org to register, review our orientation page, and view our presentations. Current presentations cover topics such as America's agricultural abundance, stewardship, meeting the food and fiber needs for a growing population, and biofuels. While you're online, check out the results of our first Essay & Art Contest to see the insight these students gain about agriculture.

Ray Sullivan, an agronomist in Indiana, and April Borders and Kevin Kilgus, Certified Crop Advisers in South Dakota and Illinois, respectively, are all active ambassadors. Their involvement teaches students much more than any textbook could. Through a personal connection, they allow students to see what it means to work in agronomy, what challenges we face, and how it adds value to our lives. That's information that shapes future decisions.

Last year, over 6,500 students in 150 schools heard our message, but there are so many more to reach. In the end, it's the beginning that counts. Let's ensure these students know they can study plant and soil sciences in higher education. If you don't, who will? ■

Field photography for an agronomist

By ***Dale Softley***, CPAg, forensic agronomist, Lincoln, NE; dale@softley.com

So many times an expert is requested to look at a problem weeks or months after it was initially observed and finds no one had photographs to document what it looked like. The first symptoms of crop damage are important when determining what actually happened. Often when examining the photos in the office, points are observed that were not seen during the field visit.

As part of our normal work as forensic agronomists, my wife and I carry both film and digital cameras all the time. We take about 5,000 digital photos per year. There have been discussions about the use of digital cameras not being acceptable in court because photos are easily manipulated. If one expects a case could end up in court, take part of the photos with film, so the negatives can be presented if necessary. Point-and-shoot cameras are very common and survive riding in a pickup. A two- or three-year life span is about the most we get out of the less expensive units. Fancy equipment is not necessary—simple disposable cameras take excellent pictures. Some insurance companies purchase disposables by case lots to provide to their field adjusters. Experience has shown one seldom takes too many photos, and the actual cost of film and developing is minor when something has gone wrong.

Three sets of photos need to be taken at each problem spot. The first group establishes the general field location, showing identifiable landmarks such as trees, power lines, or buildings. If a stranger could take the photo in hand and come fairly close to the same spot you were standing in at the time of taking the photo, you have done it correctly. We frequently take panoramic shots showing all directions from the damaged area. A photo of the GPS showing latitude and longitude helps establish time and location.

The second group of photos are closer observations of the problem area—they don't concentrate on individual plants, but show a general view of the damage area. The last group are close-ups of individual plants or plant parts, taken at quality that allows an untrained person to see the damage and a trained person to identify the damage and its cause. The use of the macro setting is good for these sets of shots. Using a set of macro lenses is better still, but not everyone is comfortable with them.

Practice makes perfect

Practice is very important in photography—take field photos when no one is breathing down your neck to solve a problem. Close-up photos are the most difficult to take, as the focus becomes critical. Taking a copy of your camera instruction book with you until you are comfortable with the variables of your specific camera helps greatly. More than once I have needed to look up a setting or problem in the field and called my staff to get the instruction book to look up something.

Photo resolution is an ongoing problem—we maintain one should use the best resolution your camera will take; once you have them downloaded, you can make copies at a lower resolution to send with a report. The ability to zoom in on a specific spot in a photo is invaluable if you see something you did not see in the field. We take all photographs at or above 6 megapixels. This give greater flexibility once back in the office and on the computer.

Carry your equipment in an insulated container to protect it from summer heat and keep the dust to a minimum. There are some soft-sided coolers that work well. Heat can mess up film color and do odd things to digitals.

Developing your film

Where film is developed is important—with all the one-hour developers, some do a better job that others. The skill of the operator and the age of the developing solutions make a huge difference in negative and print development. The quality of CDs made by the developer has a large variability. We have given up on most CDs made by developers and use our own scanners. Experience is the only way to determine what local photo store will do a good job on your film and prints.

Complete documentation is the best defense if a crop goes bad, and the farmer looks to you for solutions. ■

▶ Three sets of photos need to be taken at each problem spot. *From left to right:* The first group establishes the general field location, the second are closer observations of the problem area, and the third are close-ups of individual plants or plant parts.

Agritourism: more than just farm visits!

By Ross Ament, MA, CAE
Ament Associates Inc., President
Agriculture Tourism Partners of Illinois, Vice President
630-466-8024 or rament1@aol.com

A growing (pardon the pun) market for two of our country's leading industries, agriculture and tourism, is agritourism or agritainment. This exciting, interactive area can mean enhanced economic impact to rural communities if coordinated successfully.

But first, just what do I mean by agritourism? One of the definitions that I use is: "The act of visiting a working farm or an agricultural, horticultural, or agribusiness operation for the purpose of enjoyment, education, or active involvement in the activities of the farm or operation." For the farmer, that means an alternative revenue stream where visitors will pay for the experience of being on the farm.

Agriculture as a whole has realized the importance of teaching today's consumers where their food and fiber originates and how it is produced. That is the purpose of the Agriculture In the Classroom initiatives (www.agclassroom.org). Agritourism enhances that effort. The goal of tourism is to attract visitors from over 50 miles away from a destination, creating overnight hotel stays and thus additional room tax for the destination and state. When visitors stay longer at a destination, the revenue generated benefits many diverse businesses, not just the usual tourism ones.

Selling the ag 'experience'

The essence of agritourism is to not only sell an agricultural product to the consumer, but also to sell the "experience." To maximize the experience and to add value to the products that are sold, an agritourism business should strive to fulfill the four components of the experience:

- entertain,
- educate,
- escape, and
- esthetic.

Produce farms, U-pick operations, orchards, corn mazes, pumpkin patches, wineries, elk farms, alpaca farms, and organic farms are all examples of agritourism businesses. Related businesses can also be a part of this sector, such as breweries, food-processing plants, nurseries, fisheries, and fiber arts studios, to name a few.

Creating a critical mass of related experiences can really maximize the economic impact that a destination can achieve through agritourism. Agritourism is really selling the "good life" that the consumers from metropolitan areas remember from their childhood. They want to share that experience with their children and grandchildren. But to entice a visitor from over 50 miles away, the tourism attractions need to be packaged with other agricultural experiences. That is where cooperation and coordination become very important. In order to attract new and additional visitors, farmers and agribusinesses need to meet with their convention and visitors bureaus, chambers of commerce, and farm bureaus to build agritourism destinations. Create a local agritourism task force. Through these collaborative efforts, value-added marketing can be realized, such as high-impact websites, agritourism trails, directed signage, and group packages.

Jimmy Cheek, Professor and Dean of Agricultural Education at the University of Florida, stomps on grapes at Lake Ridge Winery's open house in Clermont, FL. Photo by Milt Putnam.

Today's consumers are looking for genuine, educational, and fun experiences. What better way to grow the local agricultural success (and enhance your community's economic health) than through agritourism!

The Fertilizer Institute, Nutrients for Life Foundation to be Lead Sponsors of Smithsonian Soils Exhibit

The Fertilizer Institute (TFI) recently announced a $1 million commitment in the name of the Nutrients for Life Foundation (Nutrients for Life) to the Smithsonian Institution for an exhibition about soils at the Smithsonian's National Museum of Natural History in Washington, DC. Through this donation, TFI and Nutrients for Life will be the designated lead sponsors of this exhibit, scheduled to open in July of 2008, at the Natural History Museum, the most visited natural history museum in the world. The 5,000-ft^2 soils exhibit is being developed by the Smithsonian in partnership with the Soil Science Society of America (SSSA) and is designed to increase the level of public awareness about the important role of soils in our world by educating visitors about the many ways soil is essential to human life.

The Fertilizer Institute
Nourish, Replenish, Grow

Bin washers

Food safety is an integral part of the produce industry, including the cleanliness of equipment used at packing house facilities. Washing out packing house bins after use can prevent cross-contamination of produce—a key consideration for today's food safety requirements.

Cleaning of packing line equipment is critical. Just one source of pathogen introduction, at any point, can infect all fruit that pass through the line. Any sorting, grading, and packing equipment that makes contact with fresh produce may serve as a vehicle for spreading contamination from bacteria and micro-organisms. Therefore, mud and debris should be removed from processing equipment daily.

Durand-Wayland, a fruit and vegetable handling equipment manufacturer, offers a complete line of high-capacity bin-washing equipment, which the company says provide an automated solution to the need to continually and effectively clean packing house bins. By removing dirt, leaves, and other trash from inside and outside of bins, the bin washers not only eliminate one source for the spread of bacteria in the packing house, but also prevent cross-contamination in orchards and groves.

"Keeping packing house equipment clean is one of several steps necessary to control the spread of disease in produce," says Ray Perry, Durand-Wayland vice president of sales. "We've designed our bin washers to provide packing facilities with a simple, yet highly effective process to ensure the cleanliness of their bins."

Visit www.durand-wayland.com or call 800-241-2308.

▶ **Durand-Wayland bin washer.**

In-line filters

Industrial Specialties Manufacturing recently introduced a new line of in-line filters for fast, easy serviceability.

The filter cartridge is visible through the clear, polycarbonate housing, and a quick twist of the bayonet-style fastener separates the housing components for cleaning or replacing the cartridge. Cartridges are available in a wide range of filter microns in both porous and plastic cone design.

3/16-inch I.D. barbs are the standard ends, but optional threaded fittings are available. Ends can also be provided in male and female luers and elbows. The filters will operate in air, vacuum, and some fluid applications.

Detailed product literature and free samples are available upon request.

For more detailed information or free samples, call 303-781-8486 or email sales@industrialspec.com. Or, visit www.industrialspec.com.

▶ **In-line filters.**

No-till, conventional-till drills

Adding to its growing line of seeding equipment, Frontier Equipment has announced the addition of the new BD1307 No-Till Drill and the BD11 Series Grain Drills.

"The new drills will complement the extensive lineup of John Deere seeding equipment," says Mike Horrell, marketing manager of Frontier Equipment. "These economical drills will be offered exclusively by John Deere dealers and are designed to meet the needs of conventional and no-till producers throughout the U.S. and Canada."

The BD1307 No-Till Drill is an all-purpose 7-ft drill that is adjustable for conventional, minimum, and no-till applications. With the tractor hydraulic controls, the operator can adjust the opener down pressure from 135 to 300 lb of pressure, depending on soil conditions in the field.

"This versatile drill has 12 offset dual-disk openers that are staggered to allow excellent residue and soil flow," Horrell explains. "It is designed with a 23.5-bu large-capacity dual seed box and infinitely adjustable seed meters. Customers can order an optional swivel hitch for use on sidehills and rolling terrain."

Other features include cast iron seed boots, steel press wheels, a standard acremeter, and a spring-loaded drive wheel. This drill also features an optional native grass kit and small grass seed box, adding to its versatility.

The new BD11 Series Grain Drills—the BD1108, BD1110, and BD1113—are available in 8-, 10-, and 13-ft sizes, respectively. They are conventional drills capable of seeding cereal grains, legumes, and forage crops.

"These drills will be manufactured with the John Deere brand in the traditional green and yellow colors," Horrell says. "They have been designed with staggered dual-disk furrow openers on various spacings to match an operator's desired residue flow."

A heavy duty steel platform allows easy access to the high-capacity seed and fertilizer boxes, and aluminum or cast iron seed boots are available depending on field conditions.

Visit www.BuyFrontier.com or contact your local John Deere dealer.

▶ **BD11 Series Grain Drill (*top*) and BD1307 No-Till Drill (*bottom*).**

Soil moisture sensor

Stevens Water Monitoring Systems has announced that its Hydra Probe soil moisture sensor now comes with a new loam-setting feature that covers more of the soil triangle spectrum.

The new firmware calibration model is based on the work of Mark Seyfried from the USDA-ARS and Keren Humes from the University of Idaho. The new loam setting is a calibration model now programmed into the Hydra Probe that was determined from a variety of different soils taken from different depths. Loam is a term used to describe a soil that contains mixtures of sand, silt, and clay. The company says the new calibration curve will make the Hydra Probe even more accurate over a wider range of soil types.

The loam setting has also been shown to work well in some clays and in soils with high organic matter contents such as an A horizon. Information about this new loam calibration was also published in *Vadose Zone Journal*, a peer-reviewed scientific publication.

For more information on the Hydra Probe and Stevens Water Monitoring Systems, see www.stevenswater.com.

▶ **Hydra Probe soil moisture sensor .**

Temperature/RH sensor, water level logger

Onset Computer, a supplier of battery-operated data loggers and weather stations, has introduced a new Temperature/RH Smart Sensor for the company's HOBO Weather Station products and a new data logger, the HOBO Water Level Logger, designed for measuring water levels and temperature at shallow depths up to 13 ft.

Offering high-accuracy measurements, the new Temperature/RH Smart Sensor is suitable for use in a wide range of applications, from agricultural and ecological research to greenhouse growing. According to Onset, the sensor features extended reliability in humid environments and is over three times more accurate compared with previous models. Users can replace sensors by simply plugging in a replacement sensor, and the Smart Sensor design enables plug-and-play connection to HOBO Weather Stations and Micro Stations, which can automatically recognize the sensor without extensive user setup, programming, or calibration.

Designed for use in groundwater wells, streams, and wetlands, the shallow-depth HOBO Water Level Logger is suitable for a wide range of water-monitoring applications, from estuary research to irrigation studies. It features a maintenance-free pressure sensor and fully sealed housing and is available in stainless steel and titanium versions to ensure trouble-free operation in fresh or salt water applications.

The water level logger offloads data to a computer via a USB-based optical interface, which provides high-speed, reliable data offload in wet environments. Onset says its optical design eliminates the need for failure-prone mechanical connectors found in many traditional water logger products.

See www.onsetcomp.com or call 1-800-564-4377 for more information.

▶ **Temperature/RH Smart Sensor (*top*) and HOBO Water Level Logger (*bottom*).**

Yield-optimizing system

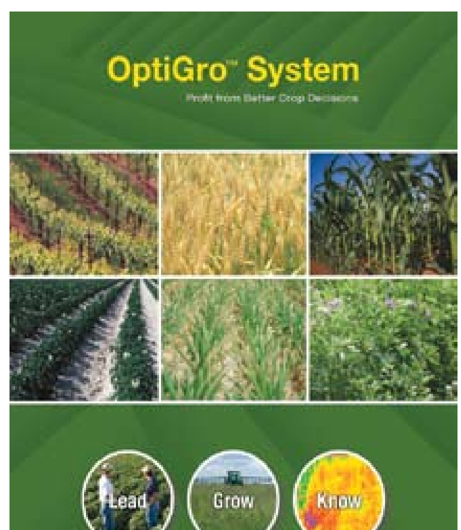
John Deere recently introduced its new OptiGro System for corn and wheat to help optimize yields while improving use efficiency of nitrogen and other inputs.

"This field-proven system will help growers improve efficiency of inputs in corn and wheat," says John Mann, Vice President of Strategic Marketing with John Deere Agri-Services. "The OptiGro system helps to maximize nitrogen investments in corn, helping to put nitrogen only where it is needed at the optimal time to efficiently nourish the corn plants. This means that a producer can optimize corn yields while saving on fertilizer costs."

Research in seven states over the past four years has shown that corn plants indicate nitrogen needs throughout the growing stage. The company says using the OptiGro system to identify those needs in season could save growers between \$5 and \$20 dollars per acre in nitrogen costs.

"Not only that, the OptiGro system reduces overall costs, optimizes yields, and helps growers minimize the chance for nitrogen runoff," says Mann. "The system is a useful tool in helping to better manage fertilizer, and it ultimately helps growers become more efficient with overall inputs in their fields."

For more information, visit www.JohnDeereAgriServices.com or contact your authorized OptiGro reseller.



CCA appointed to EPA hypoxia advisory panel

Dr. Clifford S. Snyder, Nitrogen Program Director of the International Plant Nutrition Institute (IPNI), was appointed to the U.S. Environmental Protection Agency (EPA) Science Advisory Board (SAB) Hypoxia Advisory Panel late last summer. The SAB consists of 23 scientists who have expertise in the science and management of hypoxic conditions. The panel members were selected from a group of 91 highly qualified nominees.

"As the only panel member who is a CCA, I consider this a great opportunity to share a perspective of agronomic science and production agriculture," Snyder says.

The SAB panel has the responsibility of preparing a "state-of-the-science" evaluation that identifies scientific advances and management options for hypoxia in the Gulf of Mexico in three general areas:

1. Characterization of the causes of hypoxia;
2. Characterization of nutrient fate, transport, and sources; and
3. Scientific basis for goals and management options.

The SAB panel has been active since last August and recently completed the first draft of its science report, which is available for public viewing at www.epa.gov/sab/panels/hypoxia_adv_panel.htm. The report will be considered by the EPA and its state, tribal, and federal partners on the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force.

Snyder, based in Conway, AK, is a CCA and serves as a southern region representative to the International Certified Crop Adviser Board. He earned his B.S. and M.S. degrees at the University of Arkansas and his Ph.D. from North Carolina State University. Before joining the staff of the Potash & Phosphate Institute in 1995, Snyder was state Extension Soils Specialist with the University of Arkansas. He was elected Fellow of the American Society of Agronomy (ASA) in 2002 and was the 2006 A-9 Division (Professional Practitioners) Chair of ASA. He has served as a co-chair of the Southern Plant Nutrient Management Conference since 1995 and also served on the EPA Gulf of Mexico Nutrient Enrichment Focus Team since 1997.


Clifford Snyder

More information about the hypoxia SAB activities, as well as the names and biosketches of the hypoxia SAB panel, can be found at: www.epa.gov/sab/panels/hypoxia_adv_panel.htm. Public comments on the science report may be submitted to the EPA during the public comment period that will be posted. ■

Readers respond to 'Going Organic,' published in the Spring 2007 *Crops & Soils*

While we are pleased to see the return of *Crops & Soils* magazine, we are disappointed that the inaugural issue featured an article that overlooks important details about organic history and provides a selected summary of recent research that creates a negative slant toward organic agriculture. For example, it is misleading for Alex Avery to seemingly suggest that Rudolf Steiner was the key figure in the development of organic agricultural principles and concepts, while ignoring Sir Albert Howard, along with his influence on Jerome Rodale. Although Steiner's biodynamic agriculture had an early influence on the origin of organic farming, scholars of organic agricultural history would give due credit to Sir Albert Howard as the foremost pioneer of organic methods. It was the publications of Sir Albert Howard that inspired Jerome Rodale to launch *Organic Farming and Gardening* magazine in 1942 (Howard served as associate editor).

It was not Rodale who coined the term "organic" as a method of farming. The word organic in application to farming was apparently first used by Walter Northbourne in an influential book, *Look to the Land*, published in 1940. Howard's inspiration for developing organic farming concepts and principles was rooted in his years of agricultural research experiences in India as well as his observations of natural ecosystems. As an example of Howard's perceptive ecological/organic thinking, he strongly advocated that farming systems include a mix of crops and livestock. Interestingly, the symposium papers on integrated crop–livestock systems in the March–April 2007 *Agronomy Journal* highlight the negative environmental consequences from neglecting this long-standing principle of organic agriculture.

Further, in the article by Alex Avery, a short quote from Lady Balfour is used to dismiss her work on organic farming research without giving much context for the reader to understand the real meaning of her statement that is at odds with the findings she presents in her book entitled *The Living Soil and the Haughley Experiment*. It would be more instructive for the interested to read Lady Balfour's book, which is regarded as classic work in organic agriculture, to fully comprehend the findings and contributions of her long-term experiment in the study of organic agriculture.

The statement by Avery that "there have been a sizable number of studies over the past 50 years that have found no evidence for organic food being more nutritious" is not congruent with the findings from a review of UK farming systems (Shades of Green, 2003) comparing organic and nonorganic in animal feeding trials. Thus, on "the nutrition question" it is prudent to conclude that this is an area in science where the question remains unsettled.

What is impressive about organic agriculture is how remarkably well it performs in terms of food production given the very limited research funding and attention it has received from agricultural institutions and scientists. While the article by Avery states that crop yields are sometimes similar, he fails to mention an important finding in the long-term Rodale farming systems trial. Grain yields were significantly better with organic methods in drought years. He also fails to mention the recent study from Kathleen Delate's group in Iowa, which found that organic methods sometimes achieve corn and soybean yields that are better than those under conventional agricultural methods (Agron. J. 96:1288–1298).

Nevertheless, organic agriculture has always been about more than a single-minded focus on yield. Not only has it been shown that organic foods are less likely to have pesticide residues, the organic farming methods employed also can achieve other benefits. For example, a study by Michelle Wander's group showed that organic management improved soil quality and increased soil organic carbon levels 14% above values found in conventional systems (Soil Sci. Soc. Am. J. 70:950–959).

With the rapid expansion of organic farming across the USA, *Crops & Soils* magazine can become an effective vehicle for communicating with today's professionals in agronomy that are increasingly called upon to provide objective and practical advice to their organic clientele. We would hope that *Crops & Soils* will publish additional articles that will provide practical information of value to both organic and conventional agriculture. There is ample opportunity to invite the increasing number of agricultural scientists working in organics to write articles useful to organic agriculture.

We recommend that when *Crops & Soils* publishes articles on controversial topics that they be subjected to careful external peer review. Our letter here was subjected to review by members of the ASA Committee on Organic and Sustainable Agriculture.

—Heather Darby, University of Vermont Extension Agronomist and Nutrient Management Specialist, St. Albans, VT

Julie Dawson, Graduate Research Assistant, Department of Crop and Soil Sciences, Washington State University, Pullman, WA

Kathleen Delate, Associate Professor, Departments of Agronomy and Horticulture, Iowa State University, Ames, IA

Walter Goldstein, Research Director at Michael Fields Agricultural Institute, East Troy, WI

Joseph Heckman, Department of Plant Biology and Pathology, Rutgers, The State University of New Jersey, New Brunswick, NJ

Kim Leval, Eugene, OR

Stefan Seiter, Agricultural Sciences Faculty, Linn-Benton Community College, Albany, OR

The new *Crops & Soils* magazine is a great idea, and as a CCA and a long-time member of the American Society of Agronomy (ASA), I look forward to future editions. However, I do have a concern regarding an article in your first issue.

As a Wisconsin Agriculture Department employee charged with providing technical assistance for organic farmers, I was at first pleased that you chose to feature organic foods in your first issue. ASA has a reputation for providing science-based information, and I was looking forward to reading a balanced, unbiased review of what is known about organics.

So, I was surprised and disappointed that you selected Alex Avery to write this feature article for your premier edition. Alex Avery is many things, but he is not, by anyone's definition, unbiased. Perhaps you were unaware of his history of anti-organic publications and his association with the Hudson Institute, a think tank that receives substantial support from the agricultural chemical industry? Both Alex Avery and his father Dennis Avery have been outspoken enough in this arena that, regardless of the content of this particular article, their name alone suggests a bias to many people working in organic and alternative agriculture.

In reality, I can think of no think tank that does not have an agenda—by definition, they are entities that promote a particular position. Because few of them do research themselves, it can never be clear to the reader whether they're fairly characterizing the available research or selecting studies that support their views.

As a matter of principle, I don't think that it is appropriate for ASA publications to utilize a think tank (no matter what its political leaning) for material if your goal is to report unbiased information. With the dearth of research on organic agriculture, there are a lot of misrepresentations on all sides of the organic food issue. The only way to get to the truth is to encourage more research and summarize the breadth of research results in a clear, balanced way, leaving aside any agendas. I hope that *Crops & Soils* intends to uphold this standard that has served ASA's other publications so well. I encourage you to consider publishing an alternative view in a future issue to provide some balance to Mr. Avery's views.

—Laura Paine, Grazing & Organic Agriculture Specialist, Division of Agricultural Development, Wisconsin Department of Agriculture Trade and Consumer Protection, Madison, WI

WHILE I APPRECIATE *Crops & Soils* contributing to the discussion on organic agriculture, the featured article by Alex Avery was decidedly lacking in breadth and was not-so-subtly biased against organic production. Although consumers are certainly driving the rapid growth in organic production, as the author points out, they are not doing so merely because of perceived health benefits from the food grown. Many savvy consumers are buying organic because of the perceived environmental benefits over conventional agriculture. The author failed completely to address the last point in the article. The overuse of synthetic pesticides and mineral fertilizers in this country and around the world is a major contributor to ground and surface water contamination; eutrophication of streams, lakes, estuaries, and bays; and increased greenhouse gas emissions through their life cycle of production, transport, and application. The substitution of organic amendments and practices can and usually does significantly reduce ▶

these environmental impacts through crop rotation, diversification, recycling of organic residues, use of locally adapted varieties of crops, and application of organic-approved fertilizers and pesticides. Given the massive investment of time, energy, research, and money that modern agriculture has put into combating weeds, pests, and diseases and trying to reverse the loss of soil fertility due to nutrient depletion and erosion, I would think Mr. Avery would be more excited to report that organic production of staple crops can produce “similar” yields to conventional production methods. Finally, many consumers of organic production also appreciate the support it provides for small, diversified, family farms. In fact, there is a strong and growing movement to support local agriculture at state and community levels, rather than focusing on organic production alone. The real fear among the organic food “movement” is that as the market grows, the same large-scale, fossil fuel-intensive, monocultural farming operations that characterize modern agriculture will begin to switch over to organic agriculture production, leading to some of the same environmental and social problems.

—Travis Idol, University of Hawaii-Manoa, Honolulu, HI

Congratulations on relaunching *Crops & Soils*. In the first issue, ASA President Jerry Hatfield identifies this venture as one means of meeting ASA’s goal of providing “educational, research, and scientific information for professionals.” This is an important goal indeed. In the same issue, ICCA Chair Tom Kemp concurs, saying, “*Crops & Soils* can be a valuable resource” for “good, sound advice” CCAs need for their growers. However, the publication’s first feature article falls short of meeting these standards.

In “Going Organic,” Alex Avery purports to assess whether organic agriculture provides benefits to consumers or the environment. We share the author’s hope that the debate over organic agriculture “leads all farmers—and their consumers—toward a more productive, sustainable, and healthy future.” But rather than contributing to this important debate, Avery’s article muddles it. Instead of presenting a scientific assessment of the human health or environmental effects of certified organic practices backed by appropriate references, Avery casts aspersions and spreads disinformation.

For example, Avery conflates Rudolf Steiner’s biodynamics with organic agriculture though the two are distinct, with completely different certification criteria and agencies. He also ignores the historical progression of organic agriculture from 1946 to the present, failing to acknowledge the growth of organics in university research and extension. While early statements by organic proponents may have been “unacceptable to both the scientist and the practical farmer,” researchers from land grant universities and other institutions as well as the USDA are publishing high-quality organic-focused studies in peer-reviewed journals and distributing their findings to crop advisers and growers. In the last two years, CCAs have been able to earn CEUs for workshops on organic production or certification methods sponsored by North Carolina State University’s Center for Environmental Farming Systems, California Polytechnic State University, the Pennsylvania State University, and the Rodale Institute. This indicates much more than a consumer-driven, unscientific organic food movement.

Avery’s section on nutrition is geared to dismissing organic foods, not evaluating them. He includes an unrelated study of vitamins and smoking that seems to have little purpose aside from frightening the reader. Moreover, citation information for this study and the other sources used is conspicuously absent. Similarly, the food safety section contributes little to our understanding of how to improve food safety, nor whether organic agriculture can do so more or less effectively than conventional agriculture. He discusses last fall’s *E. coli* O157:H7 outbreak in spinach though the means of transmission to the field (wild pigs or contaminated irrigation water) are unrelated to pest or fertility management practices that would classify the farm as organic or conventional. Avery also mentions a single study on *Salmonella* that showed no significant difference between organic and conventional green peppers and lettuce but does so in such a way as to make it appear that organic produce is more likely to contain the bacteria. A fuller examination of current research on the relationship between pathogen load and composting time would be of use for all growers—both conventional and organic—that use manure as part of their fertility management program.

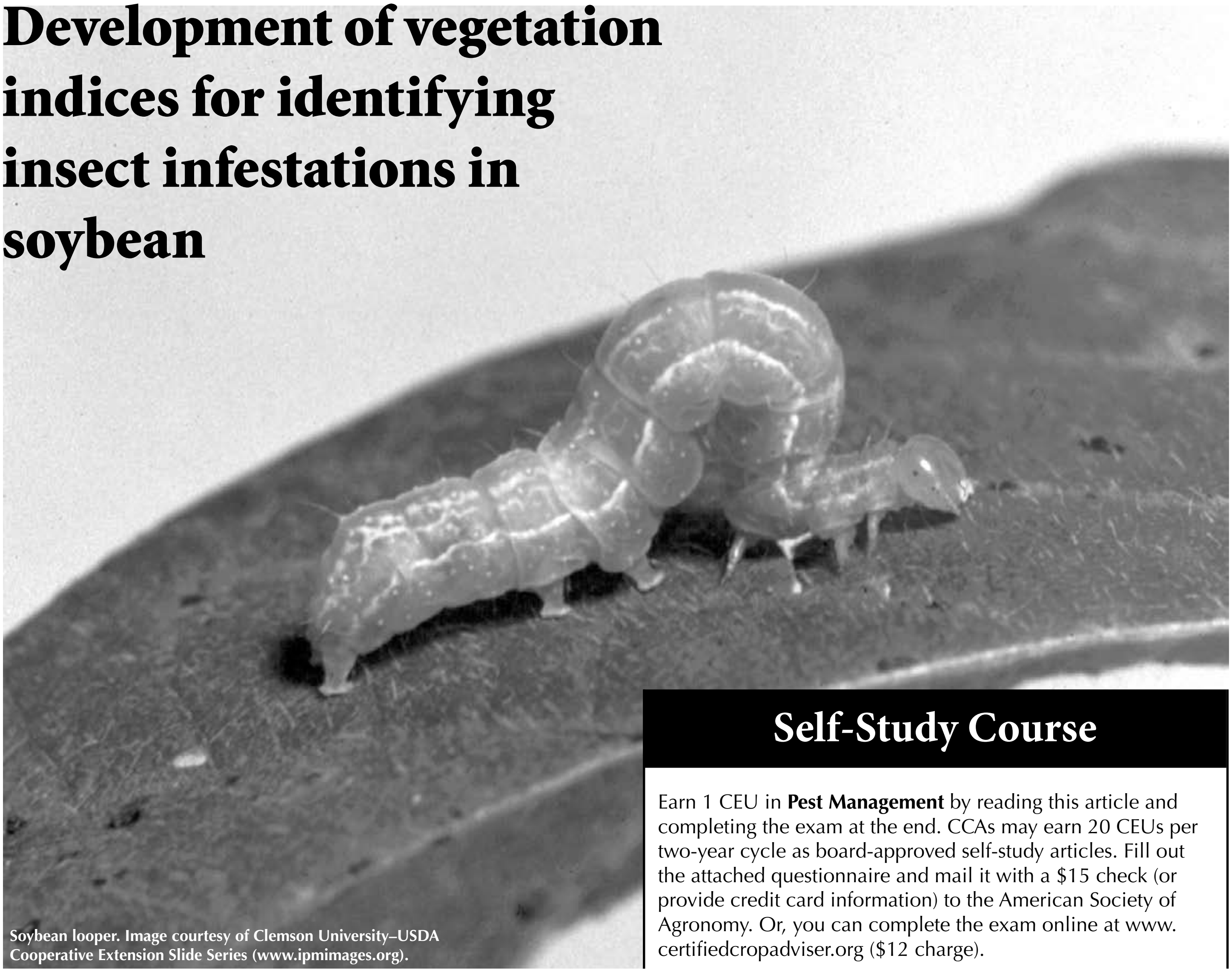
To produce food, fiber, and fuel while protecting the environment, we need to examine the human health and environmental effects of all cropping systems carefully, especially those expanding rapidly in response to consumer demand, grower interest, or government incentives. We need accurate representations of the current findings on organic production methods, including pest and fertility management as well as social aspects such as labor, economics, and human health, so we can determine where the methods are working and where they need change. Avery’s article does not provide this service.

We realize *Crops & Soils* is not a peer-reviewed publication, yet it should meet the standards of good extension and certified consulting. The three CEU self-study courses in the same issue are adaptations of peer-reviewed studies. “Going Organic” should have been held to a similar standard. This would have been appropriate to Kemp’s call to “respond to these challenges [facing the agricultural industry] with scientific facts, not hysteria.” As it stands, Avery’s article does a disservice to *Crops & Soils* readers. ■

—Anna Zivian, Katie Monsen, and Timothy J. Krupnik, Department of Environmental Studies, University of California, Santa Cruz, CA

Crops & Soils welcomes letters, published on a space-available basis and subject to editing. Letters should be 500 words or less and emailed to cropsandsoils@agronomy.org.

Development of vegetation indices for identifying insect infestations in soybean



Soybean looper. Image courtesy of Clemson University–USDA Cooperative Extension Slide Series (www.ipmimages.org).

Self-Study Course

Earn 1 CEU in **Pest Management** by reading this article and completing the exam at the end. CCAs may earn 20 CEUs per two-year cycle as board-approved self-study articles. Fill out the attached questionnaire and mail it with a $15 check (or provide credit card information) to the American Society of Agronomy. Or, you can complete the exam online at www.certifiedcropadviser.org ($12 charge).

Defoliating insect pests are a major stress to soybean production in the southeastern USA. The three major defoliating insects of soybean are the soybean looper, velvetbean caterpillar, and green cloverworm, usually invading soybean fields during the seed-filling period. Previous defoliation studies have indicated that yield response is affected not only by the severity of insect infestation, but also the timing of the attacks. In one study, 100% defoliation at the midpoint and three-quarter point of seed filling resulted in yield reductions of 40 and 20%, respectively. Additional studies showed that 40 and 60% defoliation at the midpoint of seed filling resulted in yield losses of 8 and 17%, respectively; whereas another study showed the same defoliation at the three-quarter point of seed filling caused no yield reduction.

Estimates of insect numbers are determined by scouting selected areas of a field with a sweep net that is brushed against the side of the canopy to collect insects. Ideally, soybean fields should be sampled at weekly intervals starting at first flower (R1) and continuing into the seed-filling period. The large amount of labor involved in collecting insect populations has stimulated research into alternative methods for identifying insect-infested areas. Because insect defoliation reduces yield through reducing canopy photosynthetic activity, light interception and leaf area index (LAI) have been proposed as possible tools for identifying such infested areas.

Defoliation studies conducted during the first half of the seed-filling period demonstrated that yield was reduced only when defoliation was severe enough to reduce LAI below about 3.5, a level at which light interception started falling below the optimal 95% level. It was therefore concluded that either maintenance of an LAI of 3.5 to 4.0 and/or light interception of 95% could be used as criteria for identifying areas experiencing injury by defoliating pests.

Remote sensing techniques that determine canopy reflectance ratios (vegetation indices) may be useful in ▶

▶ **Abbreviations:** GNDVI, Green Normalized Difference Vegetation Index; LAI, leaf area index; NDVI, Normalized Difference Vegetation Index; SR, Simple Ratio.

determining critical levels of LAI and/or light interception for identifying areas in a field experiencing injury by defoliating insects. Because green leaf surfaces reflect a much smaller amount of incident red light compared with infrared light, spectral reflectance ratios calculated from reflected red and infrared light can indicate leaf area indices between 0 and 100% canopy cover. Possible spectral reflectance ratios (spectral reflectance ratios from crop canopies are referred to as vegetation indices) to consider as a method for identifying areas experiencing injury are the Normalized Difference Vegetation Index (NDVI), Green Normalized Difference Vegetation Index (GNDVI), and Simple Ratio (SR), defined as:

$$NDVI = (NIR - R)/(NIR + R)$$
$$GNDVI = (NIR - G)/(NIR + G)$$
$$SR = NIR/R$$

where R = canopy reflectance of red light, NIR = canopy reflectance of near-infrared light, and G = canopy reflectance of green light.

These vegetation indices have demonstrated useful agronomic applications in soybean and other crops. Some studies have demonstrated a highly significant correlation in corn and soybeans between NDVI and light interception and that corn yield could be accurately predicted from the GNDVI. However, other researchers have reported poor relationships between LAI and NDVI when LAI levels approach canopy closure. Since soybean LAI frequently reaches levels greater than this during seed filling, these reports suggest that vegetation indices may not be useful for predicting canopy parameters under these conditions.

The purpose of this research was to determine the feasibility of using vegetation indices derived from digital photography to identify areas in a soybean field experiencing injury by defoliating insects. Vegetation indices tested were the NDVI, SR, and GNDVI. Specific objectives were to determine the relative accuracy of these three vegetation indices for predicting LAI and light interception across canopies ranging from very low LAI to canopy cover and to develop a system for using vegetation indices to identify insect infestations based on the normal progression of LAI and light interception during the seed-filling period.

Materials and methods

Experimental design. Field studies were done on a research farm near Baton Rouge, LA in 2004 and 2005. Row width was 38 inches, and seeds were sown to create a plant population of 90,000 plants/acre. Experimental units were 20 ft long by 40 ft wide and consisted of 12 contiguous rows. Experimental design was a randomized complete block with four replications in a split-plot arrangement. Weeds, diseases, and insects were suppressed by recommended pesticides.

An array of varieties was used to study possible interactions of Maturity Group (III, IV, and V) and growth habit (determinate and indeterminate) on relationships between LAI/light interception and vegetation indices. Differences in LAI and light interception were created by manual defoliation in 2004, two weeks after the start of seed filling (R5). Previous studies indicated that for nonstressed soybean canopies, LAI reaches a maximum near R5, and no further leaf production occurs after this point. This optimal LAI level remains constant during the first two to three weeks of the seed-filling period. Thus, defoliation occurred for both cultivars when seasonal LAI levels were optimal for both and regrowth could not occur after defoliation. Treatments were to create the following LAI levels: 0, 33, 50, 66, and 100% defoliation. During the second year of the study, differences in LAI and light interception were created by planting date and cultivar. Main plots were three planting dates: an optimal planting on May 5, 2005; a moderately late planting on June 14, 2005; and a late planting on July 25, 2006. Plant size generally declines as planting date is delayed from the normal period and cultivar maturity group declines. Our purpose was to use these two factors to create a wide range of canopy sizes to determine the predictive use of NDVI, GNDVI, and SR.

After completion of defoliation treatments, all plots were sampled for LAI and light interception. Light interception was determined at randomly selected areas within the defoliated areas of each plot with a LI-COR line quantum sensor connected to a data logger. Photosynthetic irradiance was measured at ground level as the average of three measurements made with the sensor placed diagonally between two contiguous rows. Irradiance was then measured at the top of the canopy and the light interception percentage determined. All recordings were made parallel to the rows between 12:00 and 1:00 p.m. under full-sun conditions. Leaf area index was based on sampling a 5-ft^2 interior plot area and placing 50% (by fresh weight) of the leaf blades through a LI-3100 leaf-area meter.

Digital images of the plots were recorded using a camera system mounted on a pole truck. The pole truck system consisted of a multispectral camera with a superwide angle lens mounted on a 40-ft telescoping mast. The collected images were converted into NDVI, GNDVI, and SR using Leica Geosystems ERDAS software to process the digital imagery. Red values were centered at a 670-nm wavelength with a 40-nm bandpass, NIR was centered at 800 nm with a 60-nm bandpass, and green was centered at a 500-nm wavelength with a 40-nm bandpass.

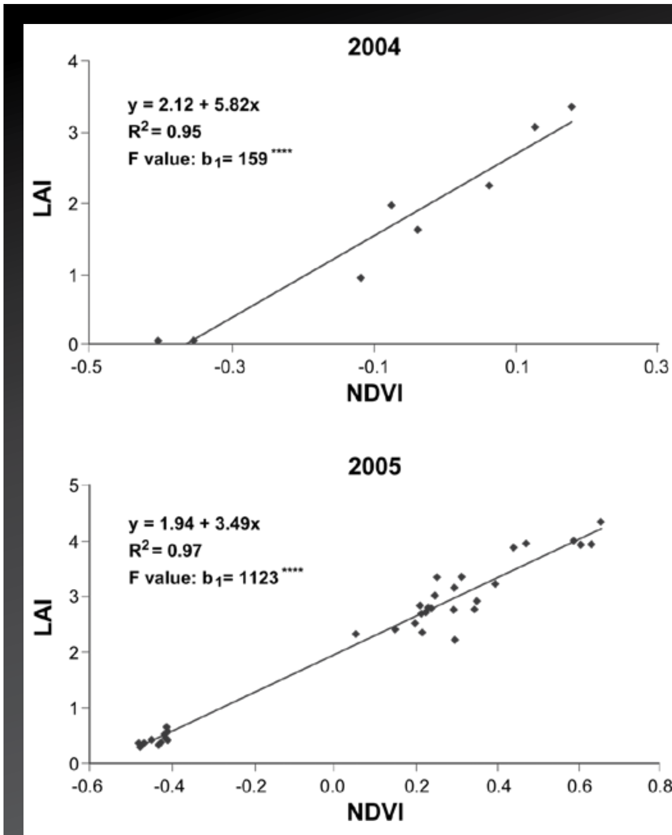
Data analyses. Within both years, correlation and regression analyses between vegetation indices (NDVI, GNDVI, and SR) and canopy parameters (LAI and light interception) were conducted. Analyses were done for treatment combinations averaged across replications: defoliation x cultivar treatment combinations in 2004 and planting date x cultivar treatment combinations in 2005. Regression analyses were done using SAS PROC GLM in which linear, quadratic, and cubic components were successively tested for significance and included if the residual sum of squares was significantly reduced ($p < 0.05$). No procedure was employed to identify and remove outlier data points. Homogeneity of regression equations across years for specific vegetation index/canopy parameter relationships was accomplished with SAS PROC GLM. Homogenous regression equations were pooled across years.

Results and discussion

Regression relationships between vegetation indices and LAI/light interception. Regression relationships between LAI and light interception with NDVI, GNDVI, and SR varied from linear to quadratic to cubic. Regression relationships between specific vegetation indices with either LAI or light interception were not homogenous across years. Simple linear relationships were shown for LAI and light interception regressed on NDVI in both years. Green NDVI showed linear relationships with LAI and light interception in 2004 but not 2005 (relationships were quadratic). The SR showed the most complicated relationships with LAI and light interception, having quadratic and cubic relationships in 2004 and 2005, respectively. An example regression relationship set is shown in Figure 1.

Leaf area indices ranged from 0 to 3.5 in 2004 and 0.5 to 4.5 in 2005, producing a wide LAI spectrum for testing the predictability of NDVI. Regression of LAI on NDVI showed similar linear patterns in both years, although the regression coefficient was greater in 2004 compared with 2005. Thus, specific NDVI levels did not predict similar LAI levels across years. Data for regression of GNDVI and SR with LAI and light interception were less consistent across years compared with NDVI regressed against these two canopy parameters.

Data in the current study demonstrate the feasibility of using vegetation indices for making management decisions about defoliating insects. Such methods have potential use for models using LAI levels as economic injury levels for defoliating pests. Important advantages for this are improved prediction of defoliation levels requiring insecticide application, greater accuracy for insecticide application, and reduced sampling costs for defoliating insects. For purposes of identifying canopies where light interception falls below 95% (indicating the possible presence of defoliating pests), the NDVI was the ▶



▶ **Fig. 1. Relationships for leaf area index (LAI) regressed on Normalized Difference Vegetation Index (NDVI), 2004 and 2005.**

most appropriate vegetation index to use. The strong linear regressions of NDVI with LAI and light interception levels ranging from near total defoliation to canopy closure (95% light interception, LAI > 4.3) demonstrate that this reflectance ratio accurately predicts LAI and light interception as these parameters fall from optimal to suboptimal levels. The GNDVI and SR did not maintain linear relationships up to canopy closure as shown by NDVI. For both vegetation indices in 2004 and 2005, relationships with LAI and light interception were linear up to an LAI of 3.0 and 70% light interception. However, above this level, both canopy parameters showed plateau responses to further increases in either GNDVI or SR. Consequently, neither vegetation index could distinguish between optimal LAI/light interception levels (3.5–4.0, 95%) and the suboptimal levels below this, which may indicate infestations of defoliating insects.

The level of precision shown by NDVI for predicting LAI/light interception makes it an ideal criterion for identifying insect-infested areas of a soybean field during the seed-filling period. Although linear relationships have been reported in previous research between NDVI and LAI at LAI levels below 3.0, data points typically cluster at LAI levels above this, resulting in either quadratic or exponential relationships. In contrast, the linear relationships between LAI/light interception and NDVI in our study were maintained up to an LAI of 4.5 and light interception of 95%. Based on previous work, it is expected that if LAI in the current study had risen above 4.5 to the 5.0 to 6.0 range (levels supraoptimal for 95% light interception), a similar clustering of points would have occurred. Although NDVI would not be expected to accurately predict LAI and light interception in this range, its ability to identify these parameters up to canopy closure demonstrates its usefulness for identifying areas experiencing defoliating pests.

Multivariate analyses for LAI and light interception. A major consideration in development of vegetation indices for use in identifying insect-infested areas is the consistency of vegetation index/canopy parameter regression models across cultivars. Differences in canopy architecture exhibited by determinate and indeterminate cultivars are an area of particular concern. Results of the multivariate analysis demonstrated that cultivars significantly affected regression relationships between LAI vs. NDVI and light interception vs. NDVI, although the interaction was greater in the former compared with the latter. Use of a given LAI level to identify potential insect infestations as predicted by NDVI would require regression models tailored to specific Maturity Groups and growth habits. In contrast, regression models between light interception and NDVI would be more broadly applicable across cultivars. In either case, the inconsistency of LAI and light interception relationships with NDVI across cultivars presents a major barrier to their adoption.

NDVI as an identifier of insect infestations. Regression relationships of NDVI with LAI and light interception were not homogenous across years. For example, NDVI indicating 95% light interception differed from 0.33 in 2004 to 0.68 in 2005. A number of factors could have accounted for this: percentage canopy cover, soil color, crop developmental stage, crop condition, and atmospheric characteristics. Use of NDVI for identifying insect infestations would be more consistent if regression models were site/cultivar specific and not extrapolated to other locations, years, and cultivars. Greater consistency could also be achieved with newer technology in which NDVI is based on light emitted from the instrument and reflected from the canopy back to the sensor, such as GreenSeeker (Fig. 2).

Regression models relating NDVI to light interception, rather than to LAI, would be more effective for identifying insect infestations. Based on the multivariate analysis, the effect of NDVI on light interception was less affected by cultivar differences than was the NDVI effect on LAI. Also, reduced light interception directly affects yield, while LAI indirectly influences yield through its effect on light interception. Although the two parameters are closely linked, LAI effects on light interception can be confounded by factors such as row spacing. A farmer or agricultural consultant could calculate the NDVI used to identify insect infestations by first determining the NDVI associated with 95% light interception (canopy closure) for a particular field. Canopy closure usually occurs by R5, but can occur earlier at narrow row spacings or with larger plants. Recordings should be taken as soon as canopy closure is recognized. Since 95% light interception is maintained throughout early and midseed filling, any decrease in NDVI below the level associated with optimal light interception would indicate the possible presence of insect damage. The rate of NDVI reduction from the initial optimal level would indicate the severity of suspected insect attacks. Once a problem area is identified, the cause of the reduced light interception would require on-site investigation. Insect sampling would still be required in these areas to ensure that insecticide application was warranted—insects causing the

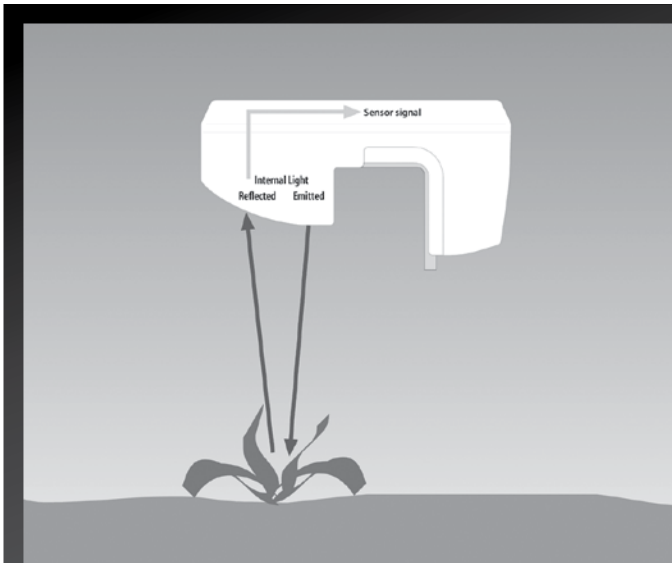


Fig. 2. With newer technology like GreenSeeker, Normalized Difference Vegetation Index (NDVI) is based on light emitted from the instrument and reflected from the canopy back to the sensor. (For more on GreenSeeker, see page 44.)

original damage may not be present. Also, other agents (e.g., diseases and animal defoliation) may have been responsible for the damage. In crop situations where canopy closure was not achieved, maximal light interception would occur near R5. The NDVI associated with this level would then be used as a benchmark to assess canopy damage at subsequent periods.

Conclusions

Because of its strong linear relationships with LAI and light interception across a broad range of canopy cover, NDVI demonstrated potential use for identification of areas experiencing insect-induced defoliation. Thus, NDVI could be used to increase the accuracy and efficiency for detecting defoliating pests of soybean and determination of pesticide application. Regression models relating light interception to NDVI appeared more useful for this purpose than those between LAI and NDVI, mainly because of greater applicability across cultivars and more direct effect on limiting yield. Based on remote sensing methods used in this study, regression models between NDVI and light interception would need to be time and site specific. However, recent technological advances may result in more robust models having wider applicability across location and time. ■

Adapted from "Development of Vegetation Indices for Identifying Insect Infestations in Soybean" by J.E. Board, V. Maka, R. Price, D. Knight, and M.E. Baur. Agron. J. 99:650–656.

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Summer 2007 Self-Study Exam

Development of vegetation indices for identifying insect infestations in soybean (no. SS 03730)

This exam is worth 1 CEU in Pest Management. A score of 70% or higher will earn CEU credit. The International CCA program has approved self-study CEUs for 20 of the 40 CEUs required in the two-year cycle. An electronic version of this test is also available at www.certifiedcropadviser.org. Click on "Continuing Education" and then "Self-Study CEUs."

Directions

1. **After carefully reading the article, answer each question by clearly marking an "X" in the box next to the best answer.**
2. **Complete the self-study exam registration form and evaluation form on the back of this page.**
3. **Clip out this page, place in envelope with a $15 check made payable to the American Society of Agronomy (or provide your credit card information on the form), and mail to: ASA c/o CCA Self-Study Exam, 677 S. Segoe Road, Madison, WI 53711. You can also complete the exam and pay online at www.certifiedcropadviser.org ($12 charge).**

1. Major soybean defoliating pests in the southeastern USA include

- ❑ a. green cloverworm.
- ❑ b. soybean cyst nematode.
- ❑ c. bean chlorotic mottle.
- ❑ d. southern corn rootworm beetle.

2. The correctly defined spectral reflectance ratio is

- ❑ a. GNDVI = (NIR – R)/(NIR + R).
- ❑ b. GNDVI = (NIR – G)/(NIR + G).
- ❑ c. SR = R/NIR.
- ❑ d. NDVI = (NIR + R)/(NIR – R).

3. A goal of this research was to

- ❑ a. determine the ability of distinguishing various insect pests through remote sensing.
- ❑ b. rate the relative yield penalties of different varieties to defoliating insects.
- ❑ c. test the relative accuracy of NDVI, SR, and GNDVI for predicting LAI and light interception.
- ❑ d. develop spectral signatures for combinations of insects and varieties at various levels of defoliation.

4. A characteristic of the experimental setup was

- ❑ a. manual defoliation each year to create differences in LAI and light interception.
- ❑ b. a seeding rate of 150,000 seeds/acre.
- ❑ c. satellite imagery to calculate vegetation indexes.
- ❑ d. camera system on a pole truck.

5. The vegetation index most consistent across years for correlating with LAI and light interception was

- ❑ a. GNDVI.
- ❑ b. NDVI.
- ❑ c. SR.
- ❑ d. EVI.

6. Factors affecting the relationship between NDVI and LAI in different years could be any of the following EXCEPT

- ❑ a. variations in NDVI calculations.
- ❑ b. crop condition.
- ❑ c. soil color.
- ❑ d. developmental stage.

Exam Continues Next Page

7. LAI in soybeans reaches a maximum usually at growth stage

❑ a. V10.
❑ b. V12.
❑ c. R3.
❑ d. R5.

8. The level of precision of NDVI for predicting LAI and light interception was shown to decrease

❑ a. at higher LAI levels.
❑ b. during early growth stages.
❑ c. in narrow rows.
❑ d. with indeterminate varieties.

9. The multivariate analyses indicated that

❑ a. cultivars did not influence regression relationships between LAI or light interception and NDVI.
❑ b. using NDVI to predict LAI would require soybean maturity group and growth habit-specific models.
❑ c. extreme insect defoliation caused more yield loss in the determinate varieties.
❑ d. the covariates for LAI and light interception were similar across sampling dates.

10. A farmer or adviser could best use NDVI for identifying areas experiencing insect defoliation by

❑ a. comparing to the NDVI associated with canopy closure for a particular field.
❑ b. using vegetation indexes to distinguish among insects and diseases.
❑ c. leaving a bare soil check area for calibration.
❑ d. utilizing readings before the R3 stage.

SELF-STUDY EXAM REGISTRATION FORM

Name: ____________________

Address: ____________________ City: ____________________

State/province: ____________ Zip: ____________ CCA certification no.: ____________

❑ $15 check payable to the American Society of Agronomy enclosed. ❑ Please charge my credit card (see below)

Credit card no.: ____________________ Name on card: ____________________

Type of card: ❑ Mastercard ❑ Visa ❑ Discover ❑ Am. Express Expiration date: ____________

Signature as it appears on the Code of Ethics: ____________________

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

This exam issued June 2007 expires June 2010

SELF-STUDY EXAM EVALUATION FORM

Rating Scale: 1 = Poor 5 = Excellent

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

Information was organized and logical: 1 2 3 4 5

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

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

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

Briefly explain any “1” ratings: ____________________

Topics you would like to see addressed in future self-study materials: ____________________

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Soft red winter wheat is improved by proper timing of nitrogen application

Self-Study Course

Earn 1 CEU in **Crop Management** by reading this article and completing the exam at the end. CCAs may earn 20 CEUs per two-year cycle as board-approved self-study articles. Fill out the attached questionnaire and mail it with a $15 check (or provide credit card information) to the American Society of Agronomy. Or, you can complete the exam online at www.certifiedcropadviser.org ($12 charge).

The quantity and quality of protein content in soft red winter wheat grown in the southeastern USA varies from year to year and across environments. The amount of grain protein in "all-purpose" flour is in the range of 8 to 11%, but for special uses such as cookies or pastry, the amount and kind of protein is more specific. Grain protein content in North Carolina (where this study was performed) has been reported to range from 8.6 to 13.5% across cultivars and environments over the last several years. This variation makes regional wheat less desirable to southeastern millers, who currently import about half of their soft red winter wheat from the midwestern USA, where grain protein content is generally more consistent; it prevents southeastern soft red winter wheat from achieving premiums; and it also reduces its value to the export market.

Why the variation?

Variation in grain protein across a region can be caused by many environmental factors including differences in temperature, humidity, soil moisture content, and soil type. Cultivar genetic potential and management decisions, such as nitrogen (N) fertilizer rate and application timing can also result in different grain protein levels. Increasing N fertilizer rates often increase grain protein content. Nitrogen fertilizer rate recommendations in the southeastern USA generally call for N to be applied at growth stage (GS) 25 and/or 30, with total amounts at these two growth stages not to exceed 120 lb N/acre, but soft red winter wheat producers may apply spring N fertilizer at rates that range from as low as 40 lb N/acre when the price of N is high or the crop appears to have low yield potential to as high as 180 lb N/acre. This wide range in N fertilizer rates may contribute to regional variability in wheat protein content.

The high variability in protein content that exists from year to year, and within years from one farm to another, makes it harder to market soft red winter wheat effectively at a premium price. This group of scientists studied and compared different N fertilizer rates and the timing of N application and its effect on protein variation. They also compared the proportion of protein variation caused by environmental effects and sought to develop N fertilizer recommendations that would minimize the protein variation in the southeastern USA.

▶ **Abbreviations:** CV, coefficient of variation; GS, growth stage; SD, standard deviation.

Agronomics

To encompass the range of soil and environmental variability representative of the region, experiments were conducted in the North Carolina Piedmont, Coastal Plain, and Tidewater in 2001–2002 and 2002–2003 (C2001, C2002, L2001, P2001, P2001$_{nt}$, P2002, and T2002; see Table 1). In each environment, a split-plot randomized complete block design with five replications was used. The main plot treatment consisted of N fertilizer rates applied at GS 25 (N_{25}). The subplot treatments consisted of five N rates applied at GS 30 (N_{30}). This resulted in 25 N treatments consisting of different N fertilizer application rates and times of application.

Environments C2001 and C2002 received a preplant N application of approximately 27 lb/acre as N–P–K: 10–13.2–24.9% (N–P_2O_5–K_2O: 10–30–30%), N source unknown. At P2001, P2001$_{nt}$, and P2002, N_{25} and N_{30} treatments ▶

▶ **Table 1. Environment, planting date, tillage system used, seeding rate, subplot size, and soft red winter wheat row spacing used in this split-plot design in a study of the effects of N fertilizer timing and rate on wheat grain protein variability.**

Environment	Planting date	Tillage	Seeding rate	Subplot size	Row spacing
			seeds/ft^2	ft	inches
C2001	October 17, 2001	conventional	44.6	7.9 by 11.8	7.0
C2002	October 22, 2002	conventional	44.6	7.9 by 24	7.0
L2001	October 17, 2001	conventional	44.6	7.9 by 11.8	7.0
P2001	October 10, 2001	conventional	41.6	7.9 by 10.2	7.5
P2001$_{nt}$	October 10, 2001	no-till	41.6	7.9 by 10.2	7.5
P2002	November 25, 2002	conventional	64.0	7.9 by 20	7.5
T2002	October 25, 2002	conventional	46.8	7.9 by 14.1	6.7

were applied as ammonium nitrate (NH_4NO_3: 34% N). At all other locations, these treatments were applied as aqueous urea–ammonium nitrate [$CO(NH_2)_2$–NH_4NO_3; 30% N]. Lime and fertilizer rates other than N followed standard recommendations for North Carolina based on annual soil tests. Pre- and postemergence herbicides were applied as needed, and weed management was excellent for all site-years except L2001, where weed populations at GS 25 were rated at approximately 22% cover.

Data collection

The number of tillers with a minimum of three leaves in a 39-inch section of row was determined at two random locations in each subplot before N_{25} application. This resulted in 10 samples per main plot, and main plot tiller density was then estimated as the average of these samples. Subplots were harvested with a small plot combine and grain yields adjusted to a moisture content of 13.5%. From each harvested subplot, samples of grain were taken for protein and test weight analysis.

Statistical analysis

The N_{25} and N_{30} fertilizer treatments differed in terms of how much and when N was applied. To evaluate the impact of how much N fertilizer was applied, the effect of total spring N rate (rate applied at GS 25 plus that applied at GS 30) on the grain protein treatment means and the variance, computed as the standard deviation (SD) and coefficient of variation (CV), respectively, across all seven environments were considered. Additionally, relationships between treatment grain protein means, SD, CV, and total spring N fertilizer rates were explored using regression analysis.

To learn more about how grain protein variability was affected by N fertilizer treatment, and the environment, a method similar to that described by Eberhart and Russell (1966; Crop Sci. 6:36–40) for estimating a genotype's comparative yield performance across multiple environments was used. Over multiple environments, they regressed a genotype's yield at an environment against the mean yield of all genotypes at that environment to obtain a regression coefficient usually referred to as a "*b* value." For this research, the approach was modified to use N treatments instead of genotypes and grain protein instead of yield, with the criteria that a desirable N treatment should have low protein variability across environments. For this purpose, *b* values closer to zero combined with low deviations from the regression were assumed to indicate N treatments that fostered grain protein stability across environments.

To identify the most stable N treatments, the deviations from the regression were plotted against the *b* values for each N treatment. This graph was divided into quadrants based on the median values of the *X* and *Y* axes. In this graph, the stable grain protein treatments, that is, those with the lowest deviations from the regression and with *b* values closest to zero, fall in the lower left quadrant.

Results

Grain yield and test weight. Yield response to N_{25} and N_{30} was complex, but overall environment had the strongest influence on yield variability. The highest mean yields were at P2001 and P2001$_{nt}$. These two environments had the highest mean GS 25 tiller densities and a relatively dry spring. P2002 had the lowest mean yield, the lowest mean GS 25 tiller density, and an extremely wet spring. Across all environments, mean grain yield was positively correlated with mean GS 25 tiller density, indicating that at any given environment, mean grain yield was related to the number of tillers that had developed by GS 25. Also, yield was negatively correlated to total spring precipitation, indicating that wetter environments had lower yields. Overall, GS-25 tiller density and spring precipitation appeared to be the primary environmental factors influencing yield variability.

Most of the variability in test weight was also attributable to environment. Environments P2002 and T2002 had the lowest mean test weights and the highest spring precipitation. This was consistent with reduced test weights being associated with environments that had an increased chance of grain wetting (from dew or rain) during the grain formation or filling process, as has been reported by other researchers.

Stabilizing grain protein content. In contrast to grain yield and test weight, the majority of protein variability (51.4%) was attributable to N treatments. Grain protein content increased as the total amount of spring-applied N fertilizer increased. This increase in grain protein at higher N rates is consistent with findings by researchers in other wheat production regions. If producers within a region use different N rates, that fact alone will result in variability in grain protein content.

Grain protein content variability across environments also increased at higher N rates. At low total spring N rates, the protein SD was about 0.6%. At the higher N rates, the SD doubled to approximately 1.2%. As growers apply higher rates of spring N fertilizer, they can expect the average grain protein content across the region to increase, but at the cost of higher protein variability from field to field or farm to farm.

Why would increased N fertilizer rates result in higher protein variability? In this study, all the interaction terms that included environment and N treatment were significant for grain protein. Low N rates resulted in low grain protein levels that were relatively stable across environments. But high N rates had different effects on grain protein dependent on the environment. At environments with low protein potential, higher N rates had a relatively small effect on protein, but high N rates applied in responsive environments resulted in large increases in grain protein and high regional protein variability. Based on work in other wheat production areas, it would seem that grain protein content might be higher when N is delayed until GS 30, but in this study, when application was delayed to GS 30, there was a small decrease in grain protein content. There also was a difference in protein stability between treatments that applied ≥80% of spring N at GS 25 instead of GS 30. The *b* values associated with the early N treatments were lower than those associated with the late

CCA TOOLBOX

New to Certified Crop Advisers (CCA) is the CCA Toolbox, a brainstorming idea of the American Society of Agronomy and ICCA leadership to develop both electronic and hard copy "tools" that CCAs can use in their every day work. We tested some early ideas with the CCA technology team to evaluate their usefulness.

The first of these tools are the conversion charts below. They are a collection of commonly used conversion tables, formulas, and reference charts. The hard copy version here is meant for easy retrieval when in the field, but you can also access the same information plus more (e.g., a conversion calculator) on the CCA website (www.certifiedcropadviser.org). The electronic toolbox is only available to CCAs—to access it, you will need to log in with your email address and password (your certification number followed by the first initial of your first name unless you changed it).

We will be adding more tools as they are discovered and will announce their arrival in *Crops & Soils*. Please feel free to let us know if you have ideas for new tools that would be helpful to CCAs by emailing Luther Smith at lsmith@agronomy.org.

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▶ Yield

		Conversion chart						
Unit of measure	**Symbol**	**kg/ha**	**t/ha**	**cwt/acre**	**bu/acre (60 lb)**	**bu/acre (56 lb)**	**bu/acre (48 lb)**	**bu/acre (32 lb)**
Kilogram/hectare	kg/ha	1	0.001	0.0089	0.0149	0.0159	0.0186	0.0279
Metric ton/hectare	t/ha	1,000	1	8.9215	14.870	15.932	18.587	27.881
Hundred weight/acre	cwt/acre	112.08	0.1121	1	1.6667	1.7857	2.0833	3.1250
Bushel/acre, 60 lb	bu/acre	67.249	0.0672	0.60				
Bushel/acre, 56 lb	bu/acre	62.723	0.0627	0.56				
Bushel/acre, 48 lb	bu/acre	53.801	0.0538	0.48				
Bushel/acre, 32 lb	bu/acre	35.867	0.0359	0.32				

▶ Volume, liquid measure†

		Conversion chart						
Unit of measure	**Symbol**	**mL**	**L**	**hL**	**oz**	**qt**	**gal**	**ft^3**
Milliliter	mL	1	0.001	1.0×10^5	0.0338	1.1×10^3	2.6×10^4	3.5×10^5
Liter	L	1,000	1	1.0×10^2	33.829	1.0567	0.2642	0.0353
Hectoliter	hL	1.0×10^5	100	1	3382.9	105.67	26.418	3.5315
Ounce	oz	29.563	0.0296	3.0×10^4	1	0.0312	7.8×10^3	1.0×10^3
Quart	qt	946.4	0.9464	0.0095	32	1	0.25	0.3342
Gallon	gal	3,785	3.7854	0.0379	128	4	1	0.1337
Cubic foot	ft^3	28,317	28.317	0.2832	977.5	29.922	7.4805	1

† 3 teaspoons = 1 tablespoon = 14.8 mL • 2 tablespoons = 1 fluid oz = 29.6 mL • 1 fluid pint = 0.473 L • 1 qt/acre = 2.3386 L/ha • 1 gal/acre = 9.3541 L/ha • 1 ft^3 = 2.83×10^{-2} m^3 • 1 in^3 = 1.64×10^{-5} m^3 • 1 acre-inch = 102.8 m^3

For additional charts, calculators, and information, check out the CCA Toolbox online at www.certifiedcropadviser.org (log in with your email address and password).

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▶ Volume, dry measure†

Unit of measure	Symbol	Conversion chart: L	pt	qt	pk	bu	ft^3	yd^3
Liter	L	1	1.8162	0.9081	0.1135	0.0284	0.0358	0.0013
Pint	pt	0.5506	1	0.5000	0.0667	0.0156	0.0194	7.2×10^4
Quart	qt	1.1012	2	1	0.1250	0.0312	0.0389	1.4×10^3
Peck	pk	8.8096	16	8	1	0.2500	0.3110	0.0115
Bushel	bu	35.238	64	32	4	1	1.2502	0.0461
Cubic foot	ft^3	28.317	51.428	25.714	3.2142	0.8035	1	0.0370
Cubic yard	yd^3	764.53	1388.4	694.22	86.778	21.694	27	1

† 1 $ft^3 = 2.83 \times 10^{-2}$ m^3 • 1 $in^3 = 1.64 \times 10^{-5}$ m^3 • 1 acre-inch = 102.8 m^3

▶ Bushel weights of various crops

Crop	Unit	Crop	Unit
Grains	lb	Fruits/vegetables	lb
Corn (shelled)	56	apples	48
Corn (ear)	70	peaches	48
Wheat	60	pears	50
Soybeans	60	beans (dried)	60
Oats	32	beets	55
Barley	48	cabbage	52
Rye	56	carrots	50
Sorghum	56	cucumbers	48
Peanuts	22	onions	57
		peas (dried)	60
Grasses		peppers	25
Bluegrass	14	potatoes	60
Bromegrass	14	sweet potatoes	55
Redtop	14	tomatoes	53
Ryegrass	25		
Timothy	45	Miscellaneous	
Meadow fescue	14	alfalfa	60
Bermudagrass	40	rape (canola)	50
Sudangrass	40	vetch	60
Orchardgrass	14	flaxseed	56
		hemp	44
		buckwheat	48
		cotton	33

▶ Temperature

°C	°F
100	212
90	194
80	176
70	158
60	140
50	122
40	104
37	98.6
30	86
20	68
10	50
5	41
0	32
–5	23
–10	14
–20	–4
–30	–22
–40	–40

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Area

Unit of measure	Symbol	Conversion chart: m^2	ha	km^2	in^2	ft^2	yd^2	acre	mi^2
Square meter	m^2	1	0.0001	1.0×10^{-6}	1,550	10.764	1.196	2.5×10^{-4}	3.9×10^{-7}
Hectare	ha	10,000	1	0.01	1.6×10^{7}	1.1×10^{6}	1.2×10^{4}	2.4711	0.0039
Square kilometer	km^2	1.0×10^{6}	100	1	1.6×10^{9}	1.1×10^{8}	1.2×10^{6}	247.1	0.3861
Square inch	in^2	6.4×10^{-4}	6.4×10^{-8}	6.4×10^{-10}	1	6.9×10^{-3}	7.7×10^{-4}	7.6×10^{-7}	2.5×10^{-10}
Square foot	ft^2	0.0929	9.3×10^{-6}	9.3×10^{-8}	144	1	0.1111	2.3×10^{-5}	3.6×10^{-8}
Square yard	yd^2	0.8361	8.4×10^{-5}	8.4×10^{-7}	1,296	9	1	2.1×10^{-4}	3.2×10^{-7}
Acre	acre	4,047	0.4047	0.0040	6.3×10^{6}	43,560	4,840	1	0.0016
Square mile	mi^2	2.6×10^{6}	259	2.5899	4.0×10^{9}	2.8×10^{7}	3.1×10^{6}	640	1

Length

Unit of measure	Symbol	Conversion chart: mm	cm	m	km	in	ft	yd	mi
Millimeter	mm	1	0.1	0.001	1.0×10^{-6}	0.0394	0.0033	0.0011	6.2×10^{-7}
Centimeter	cm	10	1	0.01	1.0×10^{-5}	0.3937	0.0328	0.0109	6.2×10^{-6}
Meter	m	1,000	100	1	0.001	39.37	3.2808	1.0936	0.0006
Kilometer	km	1.0×10^{6}	1.0×10^{5}	1,000	1	39,370	3280.8	1093.6	0.6214
Inch	in	25.40	2.54	0.0254	2.5×10^{-5}	1	0.0833	0.0277	1.6×10^{-5}
Foot	ft	304.8	30.48	0.3048	3.0×10^{-4}	12	1	0.3333	1.9×10^{-4}
Yard	yd	914.4	91.44	0.9144	9.1×10^{-4}	36	3	1	5.7×10^{-4}
Mile	mi	1.6×10^{6}	1.6×10^{5}	1,609.3	1.6093	63,360	5,280	1,760	1

Weight

Unit of measure	Symbol	Conversion chart: mg	g	kg	t	lb	short ton	long ton
Milligram	mg	1	0.001	1.0×10^{-6}	1.0×10^{-9}	2.2×10^{-6}	1.1×10^{-9}	9.8×10^{-10}
Gram	g	1,000	1	0.001	1.0×10^{-6}	2.2×10^{-3}	1.1×10^{-6}	9.8×10^{-7}
Kilogram	kg	1.0×10^{6}	1,000	1	0.0010	2.2046	1.1×10^{-3}	9.8×10^{-4}
Metric ton	t	1.0×10^{9}	1.0×10^{4}	1,000	1	2,204.6	1.1023	0.9842
Pound	lb	4.5×10^{5}	453.9	0.4536	4.5×10^{-4}	1	0.0005	4.4×10^{-4}
Short ton	short ton	9.1×10^{8}	9.1×10^{5}	907.18	0.9072	2,000	1	0.8928
Long ton	long ton	10.2×10^{8}	10.2×10^{4}	1,016.0	1.0160	2,240	1.1200	1

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▶ Pressure

Unit of measure	Symbol	Conversion chart: g/cm²	kg/cm²	lb/in²	atm
Gram/square centimeter	g/cm²	1	0.001	0.0142	9.7×10^{-4}
Kilogram/square centimeter	kg/cm²	1,000	1	14.233	0.9678
Pound/square inch	lb/in²	70.308	0.0703	1	0.0680
Atmosphere	atm	1,033.3	1.0333	14.696	1

▶ Seedbed density

Unit of measure (symbol)

English	Metric
Lineal bed foot (bed ft)†	Lineal bed meter (bed m)†
Square foot (ft²)	Square meter (m²)

Conversion chart

42-inch usable bed space‡

English to English	Metric to metric
1 bed ft = 3.5 ft²	1 bed m = 1.067 m²
English to metric	**Metric to English**
1 bed ft = 0.3252 m²	1 bed m = 11.48 ft²
1 ft² = 0.09290 m²	1 m² = 10.76 ft²
1 ft² = 0.08709 bed m	1 m² = 3.075 bed ft

48-inch usable bed space‡

English to English	Metric to metric
1 bed ft = 4 ft²	1 bed m = 1.219 m²
English to metric	**Metric to English**
1 bed ft = 0.3716 m²	1 bed m = 13.12 ft²
1 ft² = 0.09290 m²	1 m² = 10.76 ft²
1 ft² = 0.07620 bed m	1 m² = 2.691 bed ft

† One lineal bed ft (or 1 lineal bed m) equals an area of seedbed 1 ft (or 1 m) long times the width of the bed.

‡ Usable bed space is the area of seedbed actually occupied by seedlings.

▶ Fertilizer

Unit of measure (symbol)

English	Metric
Ounces per square foot (oz/ft²)	Grams per square meter (g/m²)
Pounds per acre (lb/acre)	Kilograms per hectare (kg/ha)
Parts per million (ppm)	

Phosphorus (P)

Phosphoric acid (P_2O_5)

Potassium (K)

Potash (K_2O)

Conversion chart

English to English	Metric to metric
1 oz/ft² = 2,722 lb/acre	1 g/m² = 10 kg/ha
1 ppm = 3 lb/acre	
English to metric	**Metric to English**
1 lb/acre = 1.121 kg/ha	1 kg/ha = 0.8921 lb/acre

$P = P_2O_5 \times 0.4364$

$P_2O_5 = P \times 2.291$

$K = K_2O \times 0.8301$

$K_2O = K \times 1.205$

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treatments. When the early and late treatments were pooled into two groups, this trend was statistically significant, which is perhaps the most interesting and important of the findings. At a given N rate, applying the majority of that N at GS 25 resulted in a slightly higher grain protein content but a lower *b* value, and consequently a protein content that was less sensitive to environmental differences and more regionally stable.

The secondary objective was to determine if there were N fertilizer recommendations that might minimize regional grain protein variation for soft red winter wheat intended for the baking industry. Some of the 25 treatments explored in this study did result in lower protein variability. Based on the criteria of low deviations from the regression and a low *b* value, seven $N_{25} + N_{30}$ treatment combinations (30 + 0, 60 + 0, 120 + 0, 60 + 30, 60 + 60, 30 + 90, and 0 + 90 lb N/acre) were identified as the most stable. These treatment combinations also had relatively low SDs and CVs. Of these N treatments, those that apply 60 lb N/acre or less would most likely not be agronomically feasible, but the remaining five treatments represent N rates that would generally optimize yield while minimizing regional protein variability.

The results suggest some general recommendations that might lead to lower regional grain protein variability. The first recommendation is to reduce the range (40–180 lb N/acre) of N fertilizer rates used across the region. One of the biggest contributors to high protein variability in this study was high N fertilizer rates. The second recommendation is to avoid over application of N beyond what is required to optimize yield and economic return. Limiting N application rates to 90 to 120 lb N/acre would reduce the regional protein variability compared with the range in rates currently used. This technique may optimize wheat yields and minimize the use of excessively high or low N fertilizer rates. The third recommendation to reduce protein variability is to apply spring N at GS 25 and avoid waiting until later in the season. Five of the seven treatment combinations identified as most stable for grain protein had at least 50% of the total spring N applied at GS 25, and "early" N applications increased stability compared with "late" ones. Regional interest would be served well by reducing the range of N rates applied, realistically applying N based on yield potentials or an in-season tissue test, and avoiding later N applications. ■

Adapted from "Minimizing Protein Variability in Soft Red Winter Wheat: Impact of Nitrogen Application Timing and Rate," by D.C. Farrer, R. Weisz, R. Heiniger, J.P. Murphy, and J.G. White. Agron. J. 98:1137–1145.

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Summer 2007 Self-Study Exam

Soft red winter wheat is improved by proper timing of nitrogen application (no. SS 03731)

This exam is worth 1 CEU in Crop Management. A score of 70% or higher will earn CEU credit. The International CCA program has approved self-study CEUs for 20 of the 40 CEUs required in the two-year cycle. An electronic version of this test is also available at www.certifiedcropadviser.org. Click on "Continuing Education" and then "Self-Study CEUs."

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1. Why is protein content in red winter wheat of concern to farmers?

- ❑ a. A wide range of protein content permits better sales.
- ❑ b. The range is broader than the requirements for protein of all-purpose flour, restricting its sales.
- ❑ c. Low protein content is better for the soil.
- ❑ d. High protein content requires higher fertilizer use.

2. What additional factor favors restricting the variability of protein in winter wheat?

- ❑ a. Export/import requirements favor a narrow range of protein contents.
- ❑ b. It's easier to process.
- ❑ c. It maximizes the use of nitrogen fertilizers.
- ❑ d. It's easier to store.

3. Why is midwestern grain considered preferable by millers?

- ❑ a. It's easier to ship to processors.
- ❑ b. It has less protein variability.
- ❑ c. It's harvested earlier.
- ❑ d. It's harvested later.

4. For southeastern wheat growers, the authors recommend applying spring nitrogen fertilizer

- ❑ a. earlier instead of later.
- ❑ b. later instead of earlier.
- ❑ c. only if necessary.
- ❑ d. at least half at GS 25.

5. Which treatments were found to be most stable regarding protein variability in southeastern fields?

- ❑ a. Seven $N_{25} + N_{30}$ treatment combinations were identified as the most stable.
- ❑ b. Treatment combinations that emphasized late N treatments.
- ❑ c. Variable planting times.
- ❑ d. Earlier planting times plus heavy N treatment at N_{25} and N_{30}.

Exam Continues Next Page

6. In order to maximize protein content in a variety of environments, farmers should

- ❑ a. decrease N fertilizer content.
- ❑ b. increase fertilizer contents in all environments.
- ❑ c. treat wheat plants with N fertilizer after growth has begun.
- ❑ d. pretreat soil with low amounts of N.

7. Which condition is not noted as producing low test weights?

- ❑ a. Environments with an increased chance of grain wetting during the formation or filling process.
- ❑ b. Late planting.
- ❑ c. Excessive weeds in fields.
- ❑ d. Nitrogen fertilization early in the growth cycle.

8. These results were produced in fields that were

- ❑ a. not tilled.
- ❑ b. not treated with weed preventers.
- ❑ c. rotated with corn.
- ❑ d. rotated with soybeans.

9. What characteristic was not considered as part of the environmental condition?

- ❑ a. tillering and weed competition.
- ❑ b. unseasonable cool weather.
- ❑ c. rainfall.
- ❑ d. insect pressure.

10. *b* value is used to define a regression factor that describes

- ❑ a. the desirability of a genotype.
- ❑ b. the value of wheat when sold on the commodities market.
- ❑ c. the value of no-till cultivation in wheat.
- ❑ d. the value of wheat protein.

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

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

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

Briefly explain any “1” ratings: ______________________________

Topics you would like to see addressed in future self-study materials: ______________________________

Turfgrass irrigated with recycled water: environmental impact

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As population increases and water supplies become sparser, the use of Type 1 recycled water (treated municipal water that contains some minerals and nutrients, but no major contamination) has become part of the agricultural water supply. The withdrawal of water from lakes, streams, and aquifers is carefully controlled in some areas, making knowledge about what and how much materials are in recycled water essential. Every year, the rate of withdrawal of water from these sources increases, largely because of the constantly increasing demand for potable water supplies. One such area, the city of San Antonio, TX, is heavily dependent on the Edwards Aquifer as its major water source; however, pumping from this aquifer has reached the estimated maximum rate of withdrawal without causing environmental damage. The aquifer is the source for natural spring flows, and reduced flow caused by excessive water removal can threaten endangered species that depend on these springs for their habitat.

The Edwards Aquifer Authority (EAA) regulates the amount of water that can be withdrawn from the Edwards Aquifer by well owners. Pumping limits have been established by the EAA for the wells operated by the San Antonio Water System (SAWS). Reuse of treated municipal wastewater for irrigation is an essential element of the SAWS Conservation and Reuse Plan designed to reduce the use of potable groundwater for nonpotable applications. The plan is designed to virtually eliminate the use of groundwater for irrigation and stream augmentation while preserving the integrity of the Edwards Aquifer, which underlies much of south-central Texas. The dropping water table makes it essential that the use of the aquifer water be primarily for potable needs, and lower-quality water should be used for nonpotable applications, including irrigation of large turf areas.

Wastewater treatment facilities and a distribution pipeline have been constructed that are capable of producing and distributing large quantities of Type I recycled water suitable for nonpotable uses. (Note that the terms recycled, reclaimed, and reuse can be used interchangeably.) Since large irrigators located on the Edwards Aquifer Recharge Zone (EARZ) have expressed interest in the use of SAWS' recycled water, SAWS needed the technical data on the fate of certain constituents found in the water before deciding whether or not to provide this service to these potential customers. The overall concern is that chemical constituents of the recycled water may migrate into and pollute the aquifer, thus damaging its usefulness as a long-term potable water source.

Previous studies have indicated that the major constituents of concern within leachate include total salts, calcium, chloride, magnesium, nitrogen (particularly the NO_3 form), potassium, phosphorus, and sodium. The high total salt content and high sodium level may require special management, including the use of a leaching fraction of 10% and periodic gypsum applications to prevent the accumulation of too much salt in the soil. The use of specified leaching fractions (the leaching fraction is the amount of extra irrigation water that must be applied above the amount required by the crop in order to maintain an acceptable root zone salinity depending on the salinity of the water it is being irrigated with) appeared to control the total salt concentration and the associated risk to plant growth.

▶ **Abbreviations:** SAWS, San Antonio Water System.

The present study was conducted to provide information regarding the environmental fate of nutrients contained in Type I recycled water used to irrigate turf areas and the effect of this recycled water on turf quality. The study used 18 plots, planted with 'Tifway' bermudagrass and 'Jamur' zoysiagrass. These warm-season grasses are commonly used in the San Antonio area. All plots were equipped to collect leachate from three depths, and one replication of each treatment was equipped to collect runoff. All plots were irrigated with either Edwards Aquifer water or recycled water with or without a leaching fraction. Leachate and runoff samples were collected monthly. Unscheduled leachate and runoff samples were collected immediately after rainfall events that produced 1.5 inches or more precipitation within a 24-hour period at the study site.

After experimenting with nitrogen application methods, the N nutritional program was changed for 2003 to more closely approximate best management practices for a facility using recycled water in which the target N goal includes the N from the water sources, thereby minimizing spikes in turf growth. Target N goals were established for zoysiagrass and bermudagrass. These were divided into six equal applications and were reduced by the estimated amount of N from the irrigation water applied during that period. Applications were made in April, May, June, August, September, and October 2003. To ensure that all plots contained adequate fertility, soil samples were collected from the upper levels of the soil in plots every three months and tested for macro- and micronutrients. The analysis consistently showed that all plant nutrients other than N remained in the adequate to high range.

Mineral content

It should be noted that three major rainfall events, each in excess of about 8 inches, occurred in July, September, and October of 2002. During the summer of 2002, the site experienced an unusually high amount of rainfall. In addition ▶

to generating a large amount of runoff, such intense storms likely caused leaching of salts and other soluble constituents deep into the soil profile. Rainfall during 2003 and 2004 was much more typical of an "average year" in the San Antonio area. However, even in 2003, there was in excess of 4 inches of rain in the months of June, July, and September. The calcium concentration showed a slight overall decrease throughout the study and ended with a slightly lower concentration than at the onset.

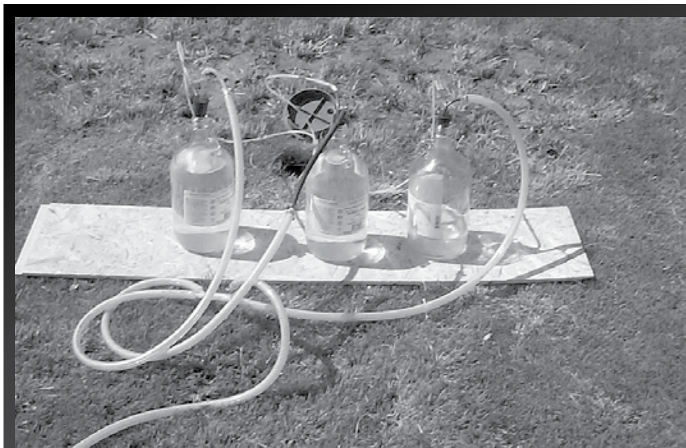
The sodium concentration in the runoff from the zoysiagrass plots also showed a slight overall decrease throughout the time period. The nitrate (NO_3) concentration in the runoff from the zoysiagrass plots showed a large spike in concentration, but then dropped, so that of all the runoff samples for this plot, only one exceeded the drinking water standard of 10 ppm. The manganese concentration in the runoff from the zoysiagrass plots showed a rapid decrease in concentration with a slight spike near the end of the project. Concentrations of all other elements measured in the runoff water showed no trends due to irrigation treatment.

Soil samples from the treatment characterized as the replacement of evapotranspiration with recycled water plus 10% treatment contained significantly more calcium than either the replacement of evapotranspiration with recycled water or replacement of evapotranspiration with Edwards Aquifer water. Plots planted with bermudagrass had significantly lower soil concentrations of iron, magnesium, manganese, and potassium, which indicated that the bermudagrass was more efficient than zoysiagrass at removing these nutrients. Irrigation treatments produced no significant differences in soil concentrations of these minerals.

Turf quality

In June 2002, the turf quality for both bermudagrass and zoysiagrass was 7.0 or greater and increased to 8.0 or above in July. The turf quality for both grasses remained at 8 or above through August and increased to nearly 9 in September. Following September, turf quality declined as turf growth slowed, and color waned because of suboptimal growth temperatures. By January 2003, both grasses had gone into winter dormancy. Although the color was poor, turf density and uniformity remained high. As green-up was reached in March 2003, the cycle of turf quality repeated itself. Except for one date (March 2003) during an outbreak of take-all patch, there were no significant differences in turf quality due to grass or irrigation treatments.

Grass species had no significant effect on the total salts in the soil, but irrigation treatments did. The soil from the replacement of evapotranspiration with Edwards Aquifer water had significantly lower total salts than either of the recycled water treatments. This is in general agreement with previous research, which measured increased salts in fairway soils on golf courses that had been irrigated for many years with recycled water. As expected, the grass species had no significant effect on the calcium content of the soil.



▶ **Leachate samples were collected monthly from lysimeters buried at depths of 6, 18, and 30 inches by drawing a vacuum on glass collection bottles. Accumulated leachate flowed into the bottles via a nylon tube that was normally housed in a buried irrigation valve box to protect the tubes from physical damage and sunlight.**

Leachate concentration

There were no significant interactions in the leachate regarding the total salts, pH, potassium, magnesium, manganese, sodium, or calcium. Leachate from the bermudagrass treatment had a higher total salt concentration. Part or all of this difference may be due to the higher N fertilization requirement of the bermudagrass. Although the difference was significant, the total salt concentration of both grass treatments was well within the safe range for turf production. Turfgrass species had no effect on the pH of the leachate or the concentrations of magnesium, manganese, or sodium. Leachate from bermudagrass contained higher concentrations of calcium and lower concentrations of potassium than did the leachate from zoysiagrass.

Leachate tended to show reduced total salts as it was measured deeper in the soil. When evaluated as a function of depth, the leachate from about the 6-inch-deep lysimeters had greater total salts and higher pH than did leachate from greater depths. In addition, leachate samples from the 6-inch lysimeters had higher concentrations of potassium, magnesium, and sodium. This is likely a result of some of the water soluble nutrients being transported to this depth before being adsorbed to soil cation exchange sites. Under the conditions of this study, it appears that a depth of 18 inches was sufficient to lower the concentration of these elements to near background levels.

The study showed that under these conditions, turf quality and environmental conditions would not be damaged by the use of recycled water typical of that produced and distributed by the SAWS. Testing was done on two popular warm-season turf species, bermudagrass and zoysiagrass. Using a leaching fraction of 10% did not improve turf quality or environmental parameters, given the environmental conditions and rainfall in this test. However, the use of recycled water did result in a significant increase in soil total salt content and calcium content compared with using water from the Edwards Aquifer for irrigation, which indicates the potential for a long-term problem of salt accumulation. In addition, the use of recycled water resulted in increased total salts, sodium, and nitrate concentrations of the leachate passing a depth of 18 inches. However, nitrate concentrations in leachate from areas irrigated with recycled water exceeded the drinking water standard on only 6 of the 27 sampling dates and occurred primarily during periods of inactive turfgrass growth. Runoff water from plots irrigated with recycled water also exhibited a trend of increased total salts, calcium, manganese, and sodium compared with using aquifer water for irrigation. The results of this study indicated that Type I recycled water may be used for irrigation of actively growing warm-season turf with minimal environmental impact on groundwater quality provided that turf areas are irrigated responsibly using a portion of the evapotranspiration as the basis for irrigation and a judicious nutrient management program is employed. ■

Adapted from "Environmental Impact of Irrigating Turf with Type I Recycled Water," by J.C. Thomas, R.H. White, J.T. Vorheis, H.G. Harris, and K. Diehl. Agron. J. 98:951–961.

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Summer 2007 Self-Study Exam

Turfgrass irrigated with recycled water: environmental impact (no. SS 03729)

This exam is worth 1 CEU in Soil & Water Management. A score of 70% or higher will earn CEU credit. The International CCA program has approved self-study CEUs for 20 of the 40 CEUs required in the two-year cycle. An electronic version of this test is also available at www.certifiedcropadviser.org. Click on "Continuing Education" and then "Self-Study CEUs."

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1. Reuse of treated municipal wastewater for irrigation is an essential element of the SAWS Conservation and Reuse Plan designed to reduce the use of potable groundwater for nonpotable applications. The plan is designed to change the amount of groundwater used for irrigation of turfgrass in what way?

- ☐ a. Reduce the added groundwater by 50%.
- ☐ b. Reduce the amount of groundwater by 80%.
- ☐ c. Virtually eliminate the use of groundwater for irrigation.
- ☐ d. Use only fresh water on turfgrass.

2. This study was done to measure the level of chemical constituents of recycled water that could migrate to the aquifer, polluting the potable water source. Which chemical constituent was not measured in the Type 1 recycled water?

- ☐ a. Total salts.
- ☐ b. Calcium.
- ☐ c. Nitrate.
- ☐ d. Arsenic.

3. It should be noted that three major rainfall events, each in excess of about 8 inches, occurred in July, September, and October of 2002 during the tests. What was the effect of these events?

- ☐ a. The large amount of runoff carried salts deeply into the soil profile.
- ☐ b. Excess water caused loss of plant growth in the turf.
- ☐ c. There was no discernible difference.
- ☐ d. The turf was washed out.

4. Treatments for the turfgrass were calculated to replace or increase the total amount of water lost by evapotranspiration. Which irrigation treatment increased the calcium in the soil?

- ☐ a. Replacing evapotranspiration with recycled water.
- ☐ b. Replacing evapotranspiration with Edwards Aquifer water.
- ☐ c. Adding 10% additional water from the aquifer.
- ☐ d. Reducing irrigation water by the amount of evapotranspiration.

5. One of the questions asked of the study was the depth of soil necessary to return the chemical concentrations to near background (not necessarily potable) levels. Which of the following did the study find?

- ☐ a. Under the conditions of this study, it appears that a depth of 18 inches was sufficient to lower the concentration of these elements to near background levels.
- ☐ b. A depth of 12 inches of soil would return the salts and mineral levels to less than background levels.
- ☐ c. It would require 22 inches of soil to prevent chemical increases in runoff.
- ☐ d. Four to six inches of soil would be adequate to prevent high levels of chemical leaching.

6. The use of recycled water resulted in increased total salts, sodium, and nitrate concentrations of the leachate. However, nitrate concentrations in leachate from areas irrigated with recycled water exceeded the drinking water standard under what conditions?

- ☐ a. Only occasionally during periods of inactive turfgrass growth.
- ☐ b. During initial planting.
- ☐ c. Only occasionally during periods of rapid growth.
- ☐ d. When the turfgrass was becoming established.

Exam Continues Next Page

7. Why was the city of San Antonio studying the use of recycled water in its general area?

- ❑ a. The Edwards Aquifer is the source for local springs, and the water flow has been reduced by overuse, causing other sources to be studied.
- ❑ b. The city wants to shut down industry to prevent contamination.
- ❑ c. So that the city can use large quantities of recycled water.
- ❑ d. The aquifer is drying up.

8. Two types of turfgrass were studied. A recommendation that could not be made is

- ❑ a. Plots planted with bermudagrass had significantly lower soil concentrations of iron, magnesium, manganese, and potassium, which indicated that the bermudagrass was more efficient than zoysiagrass at removing these nutrients.
- ❑ b. Irrigation treatments produced no significant differences in soil concentrations of these minerals, so either turfgrass may be used under these conditions.
- ❑ c. Turfgrass of either type would not be damaged by these irrigation plans.
- ❑ d. Neither turfgrass should be watered with recycled water.

9. The present study was conducted to provide information regarding the environmental fate of nutrients contained in Type I recycled water used to irrigate turf areas and the effect of this recycled water on turf quality. What were some of the parameters of the study?

- ❑ a. Concentrations of minerals were studied in the soil, leachate, and runoff to identify potential problems resulting from the use of recycled water.
- ❑ b. Volume of grass was measured to determine whether additional mowing would be required.
- ❑ c. Numerous (10) different turfgrasses were compared.
- ❑ d. Studies were done on several different irrigation methodologies.

10. Which statement does not describe the condition of turfgrasses watered with recycled water?

- ❑ a. Both grasses were well grown and in good condition most of the time.
- ❑ b. Turf quality reached 9 by September of the first year.
- ❑ c. Both grasses went into winter dormancy.
- ❑ d. Neither variety showed any sign of disease at any time.

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Long-term soil experiments: keys to managing earth's rapidly changing ecosystems

Self-Study Course

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With human population doubling to about 10 billion people in 50 years, a number of society's most important scientific questions concern the future of the earth's soil—questions about how food production can be doubled in the next several decades and about how humanity is transforming soils and soils' interactions with the wider environment. In this article, we review how long-term soil experiments (LTSEs) help address these questions, specifically in quantifying decade-scale transformations in soil physics, chemistry, and biology.

Long-term soil experiments are field experiments with permanent plots that are periodically sampled to quantify soil change across time scales of decades. They are especially valuable if their time-series data are accompanied by a sample archive that can be analyzed long after sample collection. Management treatments are experimentally controlled, and ideally, sampling, archiving, and analyses are well documented and statistically rigorous.

▶ **Abbreviations:** LTSEs, long-term soil experiments; NUE, nitrogen use efficiency.

Long-running observations of environmental change are proving to be extremely useful to environmental management and education. Long-term records help predict the weather, air and water pollution, river flows, tectonic activity, wildlife populations, and changes in vegetation. Although not many soils are studied for more than several years, our scientific understanding of the soil is greatly influenced by a few, highly productive, long-running field experiments (Table 1).

Soils are nonlinear systems resulting from high-order interactions of physics, chemistry, and biology. As such, the details of soil change are not readily predictable as they play out ▶

▶ Table 1. Selection of long-term soil experiments demonstrating a global interest in quantifying the sustainability of managed systems.

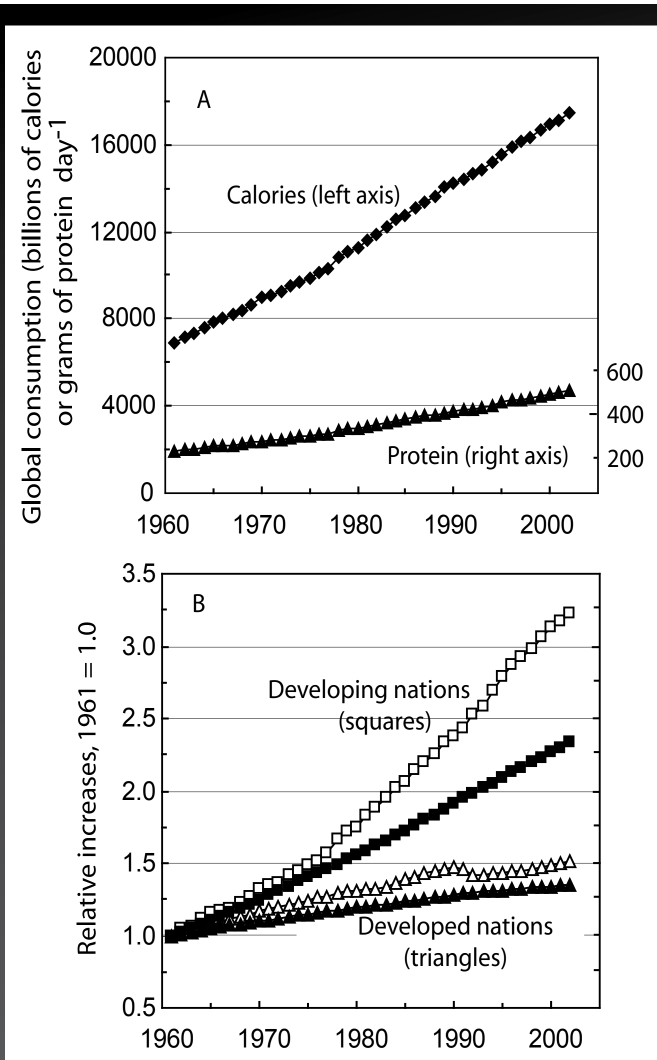
Research site	Location	Soil taxa	Management	Date originated
Park Grass	Rothamsted Research, Harpenden, UK	Paleudalfs	grass cut for hay	1856
Sanborn Field	Columbia, MO	Ochraqualfs	corn, wheat, crop rotations	1888
Askov	Askov Exp. Stn., Denmark	Ochrepts, Hapludalfs	various rotations	1893
Old Rotation	Auburn, AL	Kanhapludults	cotton and rotations	1896
Bad Lauchstädt	Bad Lauchstädt, Germany	Inceptisols	various crops and fertilizers	1902
Bretton Plots	Alberta, Canada	Boralfs	wheat–legume rotations	1930
Calhoun Exp. Forest	Union, SC	Kanhapludults	pine trees on old cotton fields	1957
Wooster Tillage Exp.	Wooster, OH	Fragiudalfs	tillage treatments	1962
Tamworth Rotation	Tamworth, Australia	Chromic and Pellic Vertisols	legume–cereal rotations	1966
Haryana	Hisar, India	Ustochrepts	millet–wheat rotation	1967
Yurimaguas	Yurimaguas, Peru	Paleudults	corn–bean rotations	1972†
KwaZulu–Natal acidity trials	Natal, South Africa	Plinthic Paleudult	corn	1982†
Long-Term Soil Productivity study	25 North American forests	Entisols, Inceptisols, Alfisols, Ultisols, Spodosols, Vertisols	compaction and organic matter effects	1990–1994
Grassland Afforestation	Argentina	Hapludols	eucalyptus on grassland	2000

† Experiment terminated.

over decades, and temporal dynamics are studied with several approaches, including short-term studies in the lab or field, space-for-time substitutions, repeated soil surveys, computer modeling, and LTSEs. The objective of this study was to evaluate how LTSEs address three questions that fundamentally challenge modern society: how soils can sustain a doubling of food production in the coming decades, how soils interact with the global carbon cycle, and how soil management can establish greater control over nutrient cycling.

Can food production be doubled while minimizing adverse effects on soil?

When the Green Revolution was born in Mexico in the 1940s, crop yields in the developing world were low and stagnant, and the potential productivity of earth's soils was not well understood. The specter of famine drove several teams of scientists, governmental agencies, and private foundations to accelerate yields and production of wheat, corn, and rice in the developing world. The agricultural intensification focused narrowly on "moving up the yield curve," developing and disseminating high-yielding varieties of wheat, corn, and rice, along with management packages of fertilizers, pesticides, and irrigation.



▶ **Fig. 1. *Top:* Global consumption of calories and protein by humanity. *Bottom:* Relative increases in protein production (open triangles and squares) compared with relative growth in human population (solid triangles or squares).**

The resulting increases in crop yields are human achievements among the most impressive in history. In the second half of the 20th century, human population more than doubled, and food production in the developing world more than tripled. Diets across the developing world improved greatly, particularly in East Asia, but also in Latin America and South Asia (Fig. 1). The Nobel Peace Prize of 1970 was awarded to a researcher and exponent of the Green Revolution, Dr. Norman Borlaug.

Field experiments were instrumental to the Green Revolution to test crop growth and yields across soils, climates, and management regimes. The experiments continued for more than a few years, and although most are now abandoned, a number of rice studies have matured into some of the world's most important field experiments. These experiments now test sustainability of intensive rice management across two to four decades, results of which have implications not only for several billion Asians, but also for the environmental externalities of >370 million acres of rice fields.

Although rice yield declines may not be widespread in long-running rice experiments, both meta-analysis and random regression coefficient analysis indicate that rice declines are significant in a number of experiments in South Asia and China, despite high levels of management. In rice–wheat rotations, declines occur in rice but not wheat, and these declines are attributed to changes in soil physical properties; soil toxicities; diminished soil availability of P, S, B, Mn, and Zn; and changes in nighttime temperatures. Much remains to be learned about the sustainability of rice management, and long-term rice experiments present an enormous potential for LTSE research in the years ahead.

LTSEs and future revolutions of food production

Most impressive are suggestions that earth's soils now produce food in such abundance that feeding humanity has more to do with food distribution than with the soil's ability to produce food. In fact, recent approaches to combat malnutrition appear to deemphasize food production in favor of improving access to food, health care, sanitation, education, hygiene, and nutritional practices.

Such approaches to combating malnutrition make important assumptions about the soil and its sustainability under intensive management. We are, after all, already working earth's soil at an intensity and geographic scale never before attempted. Of the world's 30 billion acres of soil, which includes vast deserts, mountain lands, and high latitudes, nearly 12 billion are cultivated and managed in permanent crops or pastures, with about 5 billion more periodically logged for wood. To suggest that food production be deemphasized underestimates the demands that doubling world food production by 2050 will place on soils and the environmental change that will certainly follow.

Long-term soil experiments have three key roles to play in improving food production and soil management in the coming decades. First, LTSEs can help test new cropping systems that minimize adverse effects on the wider environment. Second, they can provide early warning capabilities to detect threats to future crop production. Third, LTSEs can be aimed squarely at boosting soil productivity in regions where hunger is pervasive and soil fertility is in demonstrable decline.

Improved soil management in hunger-prone regions

Although the Green Revolution impressively increased crop yields across the developing world, decreasing human malnourishment from 33 to 18% in about 40 years, the harsh reality is that nearly 900 million people remain significantly undernourished in Africa, Latin America, the Caribbean, and Asia. Our gravest concerns are with sub-Saharan Africa, a region where soil fertility is degraded across enormous areas.

Soil fertility and water management are now recognized as major factors limiting food production in sub-Saharan Africa. Nutrient amendments are not used by many farmers, and continued harvests of grains and residues are primary causes for fertility depletions. Because organic matter is also diminished by soil use, the sub-Sahara's sparse and variable rainfall challenges soil management with infertility and drought stress. To help reverse current trends, LTSEs can test and promote simultaneous improvement of yields and soil fertility and contribute to a larger strategy of agricultural development in the sub-Sahara.

Many LTSEs have historically operated in Africa, and the recognition that degraded soil fertility is a main factor limiting agriculture in the sub-Sahara has increased interest in African LTSEs. Even today, however, productive African LTSEs are unfortunately being abandoned. Novel agroforestry and water-harvesting techniques might provide a focus to help catalyze a regional network of LTSEs that addresses the twin needs of crop yields and soil fertility. Although the task is complex, a network of efficiently run LTSEs could help demonstrate and facilitate agricultural development. Across a range of sub-Saharan management systems, soils, climates, and human–soil interactions, LTSEs could promote what these experiments have long been designed to do: sustainably increase crop yields and quality and serve as leading indicators of crop, soil, and environmental sustainability.

Effects of rising atmospheric carbon dioxide (CO_2) and a warming environment

For most of the last 1,000 years, atmospheric CO_2 varied little and averaged about 280 ppm. In about 1800, however, atmospheric CO_2 started increasing—slowly at first and then progressively faster, surpassing about 370 ppm in 2000. The increase is caused by the growing pace of industrial activity, deforestation, and soil cultivation, which together transfer enormous amounts of CO_2 to the global atmosphere. This fundamental shift in the global C cycle is important to scientists and policy analysts alike, as atmospheric CO_2 affects plant photosynthesis, ecosystem C cycling, and the biosphere's radiation balance as well.

How rising CO_2 and temperature interact with soil C and biogeochemical processes is rapidly evolving as a major environmental issue, which remains remarkably unresolved. Dozens of experiments worldwide, not a few of which can be considered LTSEs, are testing the responses of ecosystems to elevated atmospheric CO_2 and soil warming. Given the large content of C stored in global soils, even small C exchanges between the soil and the atmosphere can impact atmospheric CO_2 and mitigate or exacerbate global warming. These issues require resolution if we are to advance global-change science and predict future concentrations of atmospheric CO_2.

The effects of elevated CO_2 on ecosystems are tested with chamberless Free-Air Carbon Dioxide Exchange experiments, known as FACE studies. The longest-running FACE studies were initiated in the late 1980s, and the gradual accumulation of FACE data is greatly increasing our understanding of soil, ecosystem, and global-change sciences.

Because temperature is a primary driver of decomposition, global warming's effects on soil C might seem straightforward, especially compared with the interaction of elevated CO_2 and soil C. Indeed, soil-warming LTSEs indicate that elevated temperature accelerates soil respiration, and such results create concerns about a positive feedback between temperature and soil C loss of global significance. A meta-analysis of >12 warming experiments indicates that warming of <5°F increased soil respiration by 20%, net N mineralization by 46%, and plant productivity by 19% in temperate forests, grasslands, and tundra.

Soil nitrogen

Nitrogen use efficiency (NUE), the fraction of fertilizer N taken up by crops and removed in harvest, averages about 33% for the world's cereals. In many river basins, N not taken up by plants or retained by the soil leaches into drainage waters, runs off with sediments, volatilizes to the atmosphere, and contributes to eutrophication or hypoxia in aquatic systems.

Because NUE has a large interannual variability due to the weather, LTSEs are well suited to the task of quantifying and increasing NUE on time scales of decades. Many LTSEs can estimate and help increase NUE, and such data are particularly important because sustainably doubling food production in the coming decades will require increasing N uptake and NUE. While the Green Revolution relied heavily on increasing crop N uptake by increasing N inputs, future doubling of crop production is challenged to boost both N uptake and NUE, reducing N released to the environment.

Soil phosphorus

The cycling and management of P contrasts with that of N, as P and N cycle through soil with different rates and ▶

reactions. Whereas N is associated mainly with organic matter, P is associated with organic matter, Fe- and Al-oxides, and Ca compounds as well. While N has a prominent atmospheric cycle via biological fixation and air pollution, P is largely a terrestrial element, although with notable exceptions. If oxidized to NO_3, N readily enters soil water as a solute, whereas P is generally considered relatively immobile, except when erosion transports particulate-bound P.

Long-term soil experiments are making two major contributions to advancing the understanding and management of soil P. First, LTSEs are demonstrating the ecologic significance of slowly cycling fractions of P, and second, LTSEs are documenting that P may be much more mobile within soils than we have suspected, specifically in soils receiving long-term or heavy inputs of P in fertilizers or organic matter.

Atmospheric sulfur

Throughout the 1950s to the 1980s, S oxide pollutants greatly affected European and North American atmospheres, as industrial emissions grew more rapidly than their control. Similar phenomena occur in industrializing regions of the developing world today. Pollutant SO_2 is transported hundreds to thousands of miles downwind of industrial emissions, where S is deposited and oxidized to H_2SO_4, potentially effecting substantial acidification in poorly buffered soils.

The rate at which air pollutants acidified nonagricultural soil proved difficult to quantify, due in part to a notable absence of LTSEs. Acidification models, semiquantitative concepts, and short-term experiments were not able to be compared with direct observations of soil acidification from LTSEs. Ironically, the intimacy with which soils are associated with atmospheric processes has been well demonstrated by a number of LTSEs.

Conclusions

To meet economic and environmental demands for about 10 billion people by the mid-21st century, humanity will be challenged to double food production from the earth's soil and diminish adverse effects of soil management on the wider environment. To meet these challenges, an array of scientific approaches is being used to increase understanding of long-term soil trends and soil–environment interactions. One of these approaches, that of LTSEs, provides direct observations of soil change and functioning across time scales of decades, data critical for biological, biogeochemical, and environmental assessments of sustainability; predictions of soil productivity and soil–environment interactions; and developing models at a wide range of scales. Although LTSEs take years to mature, are vulnerable to loss, and have yet to be comprehensively inventoried or networked, they address a number of contemporary issues and yield data of special significance to soil management.

Although it may be understandable why some scientists are reluctant to initiate new LTSEs, it can hardly be denied that during the next 50 to 100 years, an understanding of long-term soil trends is required if soils are to be managed in ways that sustain their full range of functions. In the past, LTSEs have demonstrated their ability to provide important data and guidance to improve soil management. In the future, they can expand our understanding of interactions between soil management and the wider environment and enlighten policy and regulatory frameworks. A key to achieving these goals is to comprehensively inventory and review the long-term soil research base and establish an international network to scientifically address the many critical issues that involve soil management and global soil change.

And the winners are...

Congratulations to Jim Perkins from Waterman, IL, winner of our random drawing for an iPod Shuffle. Jim was one of many readers who participated in the *Crops & Soils* advertising survey. Participants selected the three "most memorable" ads in the spring issue, and the top vote-getters were:

1. Dow AgroSciences (71%)
2. Mosaic (59%)
3. John Deere (46%)

We thank everyone involved with this exciting contest. All of the ads were creative and made for a spectacular issue of *Crops & Soils*.

For more information about LTSEs and to view the global long-term soil-ecosystem experiments inventory, see http://ltse.env.duke.edu. The first of five annual workshops on LTSEs and space-for-time studies as essential tools to improve soil management and better understand human-caused changes with soils worldwide will be held this December in Durham and Goldsboro, NC. ■

Adapted from "Long-Term Soil Experiments: Keys to Managing Earth's Rapidly Changing Ecosystems," by D. Richter, Jr. and M. Hofmockel. Soil Sci. Soc. Am. J. 71:266–279.

Summer 2007 Self-Study Exam

Long-term soil experiments: keys to managing earth's rapidly changing ecosystems (no. SS 03728)

This exam is worth 1 CEU in Soil & Water Management. A score of 70% or higher will earn CEU credit. The International CCA program has approved self-study CEUs for 20 of the 40 CEUs required in the two-year cycle. An electronic version of this test is also available at www.certifiedcropadviser.org. Click on "Continuing Education" and then "Self-Study CEUs."

Directions

1. After carefully reading the article, answer each question by clearly marking an "X" in the box next to the best answer.
2. Complete the self-study exam registration form and evaluation form on the back of this page.
3. Clip out this page, place in envelope with a $15 check made payable to the American Society of Agronomy (or provide your credit card information on the form), and mail to: ASA c/o CCA Self-Study Exam, 677 S. Segoe Road, Madison, WI 53711. You can also complete the exam and pay online at www.certifiedcropadviser.org ($12 charge).

1. A goal of this study was to evaluate how long-term soil experiments can address

❑ a. how soils can sustain a doubling of food production in the coming years.
❑ b. the negative effects of soil erosion.
❑ c. how soils can serve as a closed loop for nutrient systems.
❑ d. the increasing need for biosecurity worldwide.

2. A characteristic of long-term soil experiments is that they

❑ a. are left undisturbed.
❑ b. need to include a mix of soil taxonomic classifications.
❑ c. do not provide statistically valid information for at least 20 years.
❑ d. are periodically sampled.

3. The individual most associated with the Green Revolution is

❑ a. Norman Borlaug.
❑ b. Henry A. Wallace.
❑ c. Franklin D. Roosevelt.
❑ d. Rachel Carson.

4. A role of long-term soil experiments includes all of the following EXCEPT

❑ a. providing an early warning to threats of soil productivity.
❑ b. boosting productivity in regions where there is hunger and soils are in decline.
❑ c. providing valuable plot space for crop breeding work.
❑ d. testing new cropping systems aimed at minimizing adverse environmental effects.

5. Factors that may be affecting the long-term sustainability of rice production include

❑ a. associated declines in rotational wheat yields.
❑ b. soil toxicities.
❑ c. decreasing solar radiance.
❑ d. declining crop genetics.

6. A region of the world with some of the most severe concerns for soil fertility degradation is

❑ a. sub-Saharan Africa.
❑ b. Amazon River basin.
❑ c. Australia.
❑ d. Bangladesh.

7. Compared to most of the past 1,000 years, CO_2 levels today are about

❑ a. 5% higher.
❑ b. 10% higher.
❑ c. 30% higher.
❑ d. 50% higher.

Exam Continues Next Page

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8. Soil phosphorus differs from nitrogen in its association in the soil with

- ❑ a. bauxite.
- ❑ b. iron and aluminum oxides.
- ❑ c. cation exchange sites.
- ❑ d. organic matter.

9. A consequence of pollutant S is

- ❑ a. acidification of soils.
- ❑ b. degradation of organic matter.
- ❑ c. high concentrations close to industrial sites.
- ❑ d. decreasing availability of micronutrients.

10. The oldest and most well-known long-term soil experiment is located at

- ❑ a. Wooster, OH.
- ❑ b. Rothamsted, UK.
- ❑ c. Natal, South Africa.
- ❑ d. Hisar, India.

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SELF-STUDY EXAM REGISTRATION FORM

Name: ____________________

Address: ____________________ City: ____________________

State/province: ____________ Zip: ____________ CCA certification no.: ____________

❑ $15 check payable to the American Society of Agronomy enclosed. ❑ Please charge my credit card (see below)

Credit card no.: ____________________ Name on card: ____________________

Type of card: ❑ Mastercard ❑ Visa ❑ Discover ❑ Am. Express Expiration date: ____________

Signature as it appears on the Code of Ethics: ____________________

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

This exam issued June 2007 expires June 2010

SELF-STUDY EXAM EVALUATION FORM

Rating Scale: 1 = Poor 5 = Excellent

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

Information was organized and logical: 1 2 3 4 5

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

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

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

Briefly explain any “1” ratings: ____________________

Topics you would like to see addressed in future self-study materials: ____________________

Canada East

Preventing moldy hay using propionic acid

By Joel Bagg, forage specialist, Ontario Ministry of Agriculture, Food, and Rural Affairs; joel.bagg@ ontario.ca

Trying to make dry hay between rainstorms can be frustrating. When haymaking periods without rain are short, we frequently get into a no-win situation. Either the hay isn't dry enough to bale before the next rain and it gets rain damaged, or it gets baled "tough" before it is quite dry enough and becomes moldy, poor-quality, dusty hay. Propionic acid can be used as a dry hay preservative to prevent mold when baling hay at moistures that would otherwise be too high.

Mold damage. Moulds greatly reduce the value of dry hay, particularly when targeting the "quality" horse hay or dairy hay markets. Moulds consume hay nutrients and cause dry matter losses, as well as produce toxins that are detrimental to animal health. Moldy, dusty hay contains spores that can cause respiratory problems, particularly with horses. Mould growth can even result in hay fires from spontaneous combustion.

Propionic acid preservatives. Propionic acid is an organic acid that acts as a fungicide, inhibiting the growth of aerobic micro-organisms that can cause heating and molding. Other organic acids, such as acetic and citric acids are sometimes also included, but propionic acid is the most effective as a mold inhibitor.

The propionic acid inhibits mold growth while the bales "sweat" and "cure" down to safe moisture levels by dissipation and evaporation. Do not confuse organic acid hay preservatives with enzyme, bacterial inoculant, or nutritive additive products, which differ in modes of action and effectiveness. Propionic acid is sprayed onto hay as it enters the baler. Equipment includes a baler-mounted applicator with a pump, nozzles, and tank.

Hay treated with buffered propionic and other organic acid products is safe to feed to livestock. Propionic and acetic acids are organic acids that are produced by microbes in the rumen (and the cecum and colon of horses) and then used by the animal as part of the digestion process.

The hay-drying curve. A standing crop of forage is about 70 to 80% moisture. Initially the drying rate is quite rapid, but slows considerably when it gets to the low 20s. Getting the moisture down those last few percentage points before baling can take a lot of drying time.

Inevitably, there will be situations when the storm clouds are moving in, but the hay isn't quite ready to bale. Rain on almost-dry raked hay is much more damaging than rain on hay that has just been cut. Using propionic acid enables us to bale considerably earlier. This is especially true with poor, slow-drying conditions, such as high relative humidity and low wind speed. With large square balers, propionic acid is almost a necessity because the moisture must be very low to avoid spoilage.

Buffered acid products. The original propionic acid products were unbuffered, which meant they were highly corrosive, very volatile, and difficult to work with. Products now marketed are buffered to a pH of 5.8 to 6.0 with ammonium hydroxide. Buffered products are much less volatile and corrosive, making them much easier to use. Other ingredients sometimes included are surfactants and green coloring. Products differ in concentration of propionic acid, so purchase decisions should be based on the price per pound of active ingredient.

Follow label directions. Read and follow label directions. Enough acid must be applied using the correct rate of active ingredient at various moisture levels for it to work properly. Different products have different concentrations of active ingredient. Using very dilute products provides greater coverage, but requires more water to be applied on the hay you are trying to dry.

Recommended moisture levels. Optimum moisture levels for safe storage vary according to bale type and density. Dry hay storage moisture guidelines **without** propionic acid for various bale types are:

- Small square 15–18%
- Large round (soft core) 13–16%
- Large square and large round (hard core) 12–15%

Specific acid application rates at various moisture levels are detailed on the product labels. At lower moisture levels, product costs are typically in the $7 to $14 per ton range. If targeting quality hay, these costs are easily recoverable. While some product labels indicate acid can be added to hay up to 35% moisture, this would be at a much higher risk of heating and spoilage, as well as significantly increasing the amount and cost of the product per ton of hay, making this less practical. When using propionic acid, most hay producers seldom exceed 25% moisture.

Using electronic moisture testers. An accurate measure of hay moisture is required to determine the proper application rate. Electronic moisture testers estimate percent moisture by measuring the resistance of electricity to move through a hay sample. The wetter the hay, the more electricity flows through. There are two basic types—hand-held probes and in-baler sensors. In-baler moisture sensors enable the operator to monitor moisture on the go from the tractor seat. Sensors can be located in chamber on square balers and on the sidewalls of large round balers. In-baler sensors have the advantage of giving numerous, continuous readings. Application rates can then be adjusted either manually or automatically according to the moisture. In-baler moisture sensors with automatic applicators are ▶

▶ **Hay probe. Photo courtesy of the Soil and Crop Sciences Department of Texas A&M University.**

virtually standard on large square balers and are also available for large round and small square balers.

Electronic moisture testers are an excellent tool, but keep in mind that they cannot guarantee there will be no errors in application rates. Hay can gain or lose 3 to 5 percentage points of moisture in an hour, and there can easily be 5 percentage points of variation in a windrow. Accuracy is affected by bale density, whether it is grass or alfalfa, whether it is plant or dew moisture, and whether acid has already been applied. Electronic moisture testers need to be calibrated to the conditions and well maintained. Make sure digital readings do not give you a false sense of accuracy. Moisture testers should be used to supplement personal experience.

Applicator capital costs. Basic acid applicators, including a small tank, pump, and nozzles, start for about \$1,000. Probe-type hand-held moisture testers can be purchased for about \$300. Of course, adding bigger tanks, in-line moisture sensors, and automatic flow regulators can add a few thousand dollars more to the cost.

When is using acid most economical? The main advantages to using propionic acid to preserve hay are less mold, reduced drying time, less potential rain damage, and more weather suitable for baling. Using propionic acid provides baling flexibility. You can start earlier, quit later in the day, and keep the baler baling when the weather isn't perfect.

There are three situations when propionic acid application to dry hay is most economical:

- used strategically to avoid rain damage on "almost-dry hay" when the weather doesn't co-operate,
- large dense bales that are difficult to dry to low enough moistures to avoid mold, and
- custom operators and producers baling large volumes that can pass the costs onto customers that demand mold- and dust-free hay.

Baling at higher moisture also reduces mechanical harvest loss from leaf shattering and should increase forage quality. So, does it pay to use propionic acid all the time and bale at higher moistures to prevent leaf loss, or only strategically when the weather doesn't co-operate? This will depend on the expected amount of raking and leaf loss, the final value of the hay product, and the nutritional requirements of what it will be fed to. Routine acid application to reduce leaf loss would be more economical on alfalfa hay than on mixed or grass hay and more beneficial when targeting higher-value, well-stored, high-quality hay.

Cautions. There is a "learning curve" for a high batting average when making "no rain, mold-free" hay. Although a useful and successful tool, using propionic acid will add to that learning curve. Errors can result in moldy hay, or even worse, a dangerously heating mow.

Application at the correct and uniform rate is key. Uneven windrows or fields with wet spots will not have uniform moisture. Use the highest reading on a moisture tester to determine application rate. If you use the average reading, you won't get enough acid on much of the hay to prevent spoilage. Spraying should be as uniform as possible to ensure good coverage.

Hay can still heat and become moldy and discolored if inadequate acid is applied. Tightly stacked bales in a confined area don't allow the bales to "sweat" and cure. The acid can dissipate in four to six months, which may be before hay moisture is low enough if conditions are unfavorable. Long periods of high humidity will extend the curing time. Don't store treated and untreated dry hay in direct contact with each other as the moisture will migrate to the dry hay.

Some horse owners aren't comfortable feeding acid-treated hay and prefer not to purchase it. There may initially be some propionic odor in the hay until it has dissipated. Be sure to inform hay buyers that propionic acid has been used.

Conclusions. Propionic acid is most economical when used strategically to avoid rain damage and mold with poor weather conditions. It is very effective with higher-density bales, such as large squares, that need to be drier at baling to avoid mold growth.

Canada West

Pesticide resistance management workshops for Prairie CCAs

All Canadian pesticide labels contain a section on pesticide resistance management. Most labels state a number of strategies to delay resistance; one being for growers to contact local extension specialists or CCAs for any additional pesticide resistance management and/or integrated weed management or IPM recommendations for specific crops and weed biotypes, diseases, or insects in your area.

CCAs are expected to be aware of resistant pest populations in their advising area and their proper management. Recognition on the pesticide label brings a measure of responsibility in handling these technical issues. To meet this need, a formal full-day workshop was developed and delivered by pest management extension specialists with Manitoba Agriculture, Food, and Rural Initiatives. The workshop was delivered to some 70 participants at two locations in the province. Based on the favorable feedback, workshops will be delivered again this fall and in the other Prairie Provinces.

For information on the workshop and materials, contact John Heard, CEU Chair, at John.Heard@gov.mb.ca.

▶ **A formal full-day workshop was developed and delivered by pest management extension specialists with Manitoba Agriculture, Food, and Rural Initiatives to some 70 participants at two locations in the province.**

North Central

Giant ragweed a threat to Indiana crops

Hoosier farmers should take extra steps this year to manage a giant menace in Indiana fields that has the potential to cause great yield losses, according to a Purdue University weed expert.

Glyphosate-resistant giant ragweed was found in one Indiana county last year, but as of this spring, resistant varieties are now located in at least 10 counties. The rapid-growing weed has the ability to significantly reduce yields, and because varieties resistant to glyphosate are becoming more common, it's going to become increasingly difficult to manage.

Bill Johnson, Purdue extension weed specialist, said the threat from giant ragweed is greater than from other glyphosate-resistant weeds because giant ragweed could cause a farmer to lose up to 50% or more of his yield in an infested field if densities are high.

"One of the reasons why Roundup Ready technology is so popular is because when glyphosate—the active ingredient in Roundup—was developed, it was very effective against giant ragweed and the only economical tool for managing ALS-resistant giant ragweed," he says. "Now that the weed is developing resistance to glyphosate, we currently have very few options to deal with it."

Johnson said no new herbicide modes of action have been introduced in the last 25 years, and there are no new ones in the pipeline. That means producers are going to have to rely on better management of glyphosate and a combination of herbicides with different modes of action to control weeds.

In studies conducted last summer by Purdue and Ohio State University researchers, glyphosate-resistant ragweed was controlled with measures that included using a nonselective herbicide to burn down weeds prior to planting, very timely glyphosate applications and higher glyphosate rates, and combining glyphosate with other herbicides.

"We suggest using at least two tactics or herbicides for dealing with the most troublesome weeds," Johnson says. "Reliance on one chemical helps weeds develop resistance and also lessons the odds that your weed-management efforts will be effective for the entire season."

Ninety percent of the soybeans planted this year in Indiana and about 50% of the corn will be in Roundup Ready varieties, Johnson says. Farmers like these varieties because glyphosate is a low-cost and very effective way to combat weeds. However, frequent and exclusive use of the herbicide increases the likelihood that more weed species will develop resistance to it.

Johnson lists some good rules of thumb regarding glyphosate use for weed control, which include:

- Using appropriate soil-applied residual herbicides in both Roundup Ready soybeans and corn.
- Applying the correct rate of glyphosate based on weed size. Glyphosate should not be expected to routinely control weeds that are 18 inches or more in height.
- Starting with a clean field. No-till producers should control all vegetation prior to planting.

Johnson says just because a weed does not seem to be affected by glyphosate does not mean that it's resistant. Factors that affect glyphosate effectiveness including application rates, weather conditions, weed size, and the timing of applications.

More information can be found at www.btny.purdue.edu/weedscience or www.glyphosateweedscrops.org/.

—Source: Purdue Agriculture Report, published by Purdue University. See www.agriculture.purdue.edu/agcomm/news/agresearch/index.html

No additional evidence of Asian soybean rust found in Iowa

How and why a single leaf infected with Asian soybean rust was found in Iowa in March are questions that continue to be addressed by federal investigators. Officials with the Iowa Department of Agriculture and Land Stewardship (IDALS) and Iowa State University (ISU) have found no further evidence of Asian soybean rust in the field where the leaf was reported to have come from or in neighboring fields.

"We did verify that one leaf submitted in a plant sample was infected with Asian soybean rust, but how it got into Iowa still needs to be determined," says Bill Northey, Iowa Secretary of Agriculture. "After careful examination of the materials collected to date, we believe no Asian soybean rust infection occurred during the 2006 growing season in Iowa."

In March, a sample reported to have been taken from a bin of soybeans harvested in Mahaska County in 2006 was submitted to ISU's Plant Disease Clinic. ISU's testing revealed infection by Asian soybean rust. The USDA confirmed that the single leaf in the sample was infected with the disease.

Personnel from IDALS and ISU collected additional samples of seed and plant materials from bins at the location where the sample was allegedly collected. They analyzed the samples and found no symptoms or signs of Asian soybean rust. When the infected leaf was first discovered, the Iowa Soybean Rust Team pointed out that it did not pose a risk for the 2007 growing season. The fungus and spores that cause the disease cannot survive an Iowa winter, plus they require green leaf tissue to sustain themselves. As in previous years, producers need to continue to be vigilant and monitor conditions that favor rust.

Asian soybean rust was first reported in the continental United States in 2004. So far, the disease has mostly affected southern states, although it has been found as far north as Illinois and Indiana.

—Source: Integrated Crop Management 498(11):155–156, published by Iowa State University Extension. See www.ipm.iastate.edu/ipm/icm/

West

Estimated yield of some alternative crops under varying irrigation in northeast Colorado

By David C. Nielsen, research agronomist, USDA-ARS, Central Great Plains Research Station; david.nielsen@ars.usda.gov

Much of the irrigated acres in northeastern Colorado are devoted to corn grain production. Diversifying irrigated agricultural production in this region could result in water savings if alternative crops were grown that have lower water requirements than corn. Making such crop choice decisions initially requires knowledge of how yields of new crops respond to water.

Over a number of years, water use/yield production functions have been developed at the Central Great Plains Research Station near Akron, CO. Such functions predict yield based on a linear relationship between total water use and crop yield. Water use is considered to be the sum of soil water extracted from the soil by the crop, growing season precipitation, and irrigation applied during the growing season. Production functions for three oilseeds, four legumes, three forages, and corn grain are shown in Table 1. These 11 production functions (along with six others) are available for easy use in a simple Excel spreadsheet (the Central Great Plains Yield Calculator, available from the author) that also includes average growing season precipitation for 15 locations in eastern Colorado, western Nebraska, and western Kansas. The calculator assumes that water is the controlling factor for yield and that other factors (such as date of planting, fertility, weed control, insect control, timing of precipitation and irrigation, and harvest efficiency) are optimal. The calculator also assumes that there are no significant weather influences such as hail, frosts, or excessive wind that would adversely affect yield.

Oilseed response to irrigation. Of the three oilseed crops shown in Table 1, canola exhibits the largest response to water (175 lb/acre/inch) while safflower shows the smallest response (121 lb/acre/inch). Predicted yields at Briggsdale range from 1,568 lb/acre with 3 inches of irrigation to 3,145 lb/acre with 12 inches of irrigation.

Yields at all irrigation levels are lower for safflower and sunflower compared with canola and greater in Limon and Wray compared with Briggsdale as precipitation increases moving west to east. The highest predicted yield (3,548 lb/acre) comes from canola grown at Wray with 12 inches of irrigation.

Legume response to irrigation. Legume seed response to water ranges from 148 lb/acre/inch for soybean to 240 lb/acre/inch for chickpea (Table 1). With 3 inches of irrigation, the greatest legume seed yield at Briggsdale was predicted for pea (2598 lb/acre) and the least from dry bean (1823 lb/acre). With 12 inches of irrigation, the greatest seed yield was predicted for chickpea (4,645 lb/acre). As with predicted oilseed yield, predicted yields of legumes are greater at Limon and Wray because of greater average growing season precipitation. Soybean yield at Wray with 12 inches of irrigation is predicted to be 4,142 lb/acre (69 bu/acre).

Forage response to irrigation. Forage dry matter response to water ranges from 549 lb/acre/inch for corn to 748 lb/acre/inch for triticale (Table 1). Predicted dry matter yields range from 3.10 tons/acre for corn grown at Briggsdale with 3 inches of irrigation to 9.28 tons/acre for triticale grown at Wray with 12 inches of irrigation.

Comparisons with corn grain predictions. Corn grain yields were predicted using the Central Great Plains Yield Calculator with four irrigation levels assuming 6 inches of soil water use and average growing season precipitation at three northeastern Colorado locations. Corn grain yields at all irrigation levels and all three locations are predicted to be much greater than oilseed or legume seed yields because of the much greater production function response of grain yield to water use for corn (582 lb/acre/inch) compared with the other crops (Table 1). This is due to the much more efficient photosynthetic mechanism in corn that turns carbon dioxide, water, and sunlight into carbohydrates compared with oilseeds and legumes. Much more energy is required to produce the proteins and oils in legumes and oilseeds than the starches in corn. ■

—Source: From the Ground Up: Agronomy News 26(1):8–9, published by Colorado State University Cooperative Extension. See www.extsoilcrop.colostate.edu/Newsletters/

Table 1. Production functions used in the Central Great Plains Yield Calculator for three oilseed crops, four legumes, three forage crops, and corn.

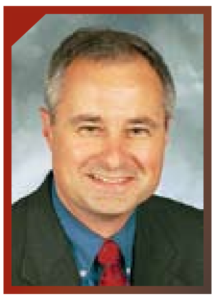
Crop	Production function
Oilseeds	
canola	lb/acre = 175.2 × (inches water use − 6.22)
safflower	lb/acre = 121.4 × (inches water use − 3.02)
sunflower	lb/acre = 150.6 × (inches water use − 6.88)
Legumes	
pea	lb/acre = 181.4 × (inches water use − 0.85)
chickpea	lb/acre = 240.4 × (inches water use − 5.80)
soybean	lb/acre = 148.1 × (inches water use − 0.68)
dry bean	lb/acre = 193.0 × (inches water use − 5.50)
Forages	
forage triticale	lb/acre = 748.4 × (inches water use − 3.39)
foxtail millet	lb/acre = 664.4 × (inches water use − 3.07)
corn silage	lb/acre = 548.8 × (inches water use − 5.31)
Starchy grain	
corn	lb/acre = 582.2 × (inches water use − 9.13)

Promoting your credentials

By ***Luther Smith***, Director of Certification Programs, 608-268-4977 or lsmith@agronomy.org

Tom just presented the features and benefits to Fred on the latest seed variety that Tom believes is the right choice for Fred's business plans. Fred's response: "The price is too high!" Tom smiles and says, "Too high for what?", hoping to draw out the real reason why Fred is objecting to the plan.

Sales training 101 taught us that price objection is really not about the "price" but about the value. The price is a reflection of the value, perceived or real. What is the value of being certified? Fame and fortune? Not really. It is a professional standard leading to professionalism. It is a risk management tool for the client or customer to know someone is qualified. It is a benchmark to establish a profession or professional conduct. It is a hiring tool for employers. It is a professional development track through the continuing education requirements that leads to lifelong learning. It builds confidence and ability in the individual. It leads to more employment or advancement opportunities. It is a mechanism that government agencies (e.g., NRCS, EPA, and RMA) or other groups can identify as a qualified resource. I'll stop there, but you could probably add more.



No one likes someone who brags, and most people don't like to talk about themselves, especially in agriculture for some reason. We are a humble bunch for the most part, and there is nothing wrong with that, but the farmer needs to hear the importance from you of being certified. You are the CCA, CPAg, or CPSS/C program to your client or customer. What you do or say determines what that person thinks a certified person is or does.

This issue of *Crops & Soils* features a new section: the CCA Toolbox (Editor's note: this section is only being sent out to those who are certified.) The purpose of this toolbox is to provide tools that help you do your job every day. We are striving to do the same thing with promotional tools like logos, stickers, signs, power points, hats, articles, and advertisements. A simple explanation at the appropriate time might be all it takes to increase the awareness to your clients that you are certified and that it is important to you and to them that you are. Use the "four E's" approach to guide the talk without over doing it. Think of it as a 30-second commercial. In many cases, they may ask you if you have the logo on your window or on your business cards.

Fred (farmer) asks Tom (CCA) after seeing the CCA logo on his truck, "What's that logo on your truck"?

"That means I'm a certified crop adviser and that I care about your business," Tom responds.

"What's that all about?" Fred asks.

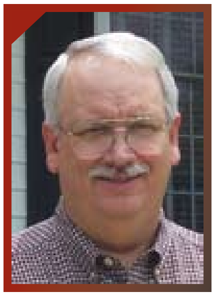
[continued on page 42]

ASA and ICCA: A win /win relationship

By ***Tom Kemp***, ICCA Chair, 843-493-2811 or tkemp@sc.rr.com

What exactly does "win/win" really mean? And does it work? Win/win means exactly what it says, both sides and all parties of a negotiation win! Otherwise, you would have a win/lose result and, in most cases, an unhappy segment. In win/win, both sides benefit from the decisions or the relationship that is formed. And does it work? Yes, it truly does.

The American Society of Agronomy (ASA) and its International Certified Crop Adviser (ICCA) Program are a win/win relationship. Though they have different priorities, they are one family working together to serve the profession of agronomy. At times it may appear they are heading in opposite directions, but they are not independent of each other, and both end up serving agronomy.



Serving all agronomists

The certification programs have attracted more of the industry agronomists, while ASA membership seems to attract more of the academic or research agronomist. Together, they serve industry, academic, and government agronomists. It is similar to a three-legged stool. Take away one leg, and you have a useless stool. Take away one segment of ASA, and you have a weaker organization; but capitalize on having all three working together, and you have a much stronger organization. You also have the opportunity to represent all agronomists regardless of their focus or where they are employed.

Industry agronomists have felt left out of ASA at times, but the certification programs of ASA have been a great service to them—though the programs are open to all agronomists, and all are invited to become certified. Industry, academia, and government agronomists have a lot to gain by implementing the opportunities of working together through ASA.

Another recent example comes from the Soil Science Society of America (SSSA) and its Smithsonian project. The Fertilizer Institute (TFI)—predominantly an industry-oriented organization—through their Nutrients for Life Foundation, made a million dollar commitment towards the soils exhibit that will be opening in 2008 at the National Museum of Natural History. You can learn more about this gift on page 10 of this issue of *Crops & Soils*. This exhibit will educate the general public about soils. Several other industry partners have also contributed towards this effort along with government agencies and members who work in all three areas. What a great example of working together for the good of the whole profession!

There are opportunities before us in agronomy. Whether working at research, teaching, or advising as a CCA, we need to focus on the win/win opportunities to benefit the agronomy profession through ASA. ■

Certification and the Farm Bill

By the time you read the fall issue of *Crops & Soils*, the 2007 Farm Bill might be finalized. August/September is the latest time frame that's being talked about in Washington, DC, but no one is holding their breath. Activity has increased in recent months along with the number of "marker" bills. At the time of this writing, the ag committees had not released anything yet but were expected to by the end of May. The marker bills are typically circulated by members to let others know what they would like to see included in the bill.

When the 2007 Farm Bill process started, conservation, energy, and rural economic development were the key buzz words. Money, or the shortage thereof, quickly became a driving factor. Five years ago, there was an excess of funds, and we saw some of the highest levels of ag program funding in recent history. The direct opposite is now the case to the point that any new, proposed spending needs to have an associated offset (reduced spending) in another area. The lack of funds doesn't seem to stop members of Congress or organizations from asking for more or trying to shift from one area to another. For awhile there was a lot of talk about shifting commodity program funds to the conservation programs. The thought was that it would be more trade friendly, and in an era of higher prices with stronger demand, the time seemed right for a major policy change. This approach was supported more by conservation or environmentally focused groups and not so much by the ag or commodity-oriented groups.

Many organizations circulate their list of what is important to them in hopes that at least some of it will be included in the final legislation. The certification programs are focused on issues that directly impact or could affect what someone does in their daily work practicing the professions of agronomy and soil science. One could argue that nearly all aspects of the Farm Bill could impact directly or indirectly what a certified person is doing since many of the programs impact farmers to some degree. That's true, but the certification programs are not involved in lobbying, and there are many other related groups based in DC that are lobbying. The certification programs and ASA and SSSA maintain close working relationships with like-minded groups to share in their Farm Bill efforts. It is very much a communications and educational effort. Many groups appreciate this approach including staff members on the Hill, who need to cover every aspect of the Farm Bill and cannot reasonably know or understand every issue. When groups that are very focused on a specific issue, like the certification programs, can provide materials to represent the views of those most involved, it helps move the process forward.

Technical service provider priorities

The certification programs were recently asked to indicate what was important to them. This same information was also included in a Farm Bill position paper distributed by ASA and SSSA. The primary focus of the certification programs is the Technical Service Provider (TSP) program:

A. Farmers should be allowed to make the decision on which TSP they use for technical assistance whether government or nongovernment qualified individuals.

B. The current pilot test project that USDA-NRCS is working on with ASA and SSSA through their certification programs, i.e., CCA, CPAg, and CPSS, should continue with the results implemented. This process will streamline the certification and renewal of TSPs in nutrient management, pest management, and irrigation management while incorporating the new performance criteria developed by USDA. These certification programs are recognized through MOUs with USDA and set the standard of their respective professions of agronomy and soil science.

C. USDA should eliminate the not-to-exceed rates (NTE) and should utilize the farmers current service providers, where appropriate, to save resources by engaging the farm's current agronomist or soil scientist who already understands the resource conditions of the farm.

D. USDA should eliminate the self-certifying option to avoid the potential of certifying unqualified individuals and eliminate a double standard where professionally certified individuals like CCAs, CPAgs, and CPSS's are certified at a higher standard.

E. USDA should only utilize established certification and licensing programs to avoid unnecessary redundancy.

The certification programs provide an unbiased resource of people who have met an established standard for the profession. They do not distinguish between public or private employment. The focus is on qualifications. TSPs provide an avenue for the government to utilize additional resources who are already engaged on the farm where and when needed. ■

Promoting your credentials | FROM PAGE 41

"That means I'm a certified crop adviser, and that I care about your business," Tom responds. "I passed two comprehensive exams in nutrient management, soil and water management, integrated pest management, and crop management; have had at least two years of experience along with my B.S. degree; earned 40 hours of continuing education every two years; and signed a code of ethics—and I did this all for you," Tom says.

"For me, what's that suppose to mean?" Fred asks.

"CCA is a professional development certification, so I continually enhance my knowledge and skills to better serve my clients and customers, so in essence, I am doing it for you," says Tom smiling, "now let's go see how that cotton is doing."

Agriculture, especially at the farm level, is still very much a relationship business. You have established relationships with your clients that are more valuable than the products and services that you provide. Don't take them for granted, but also, don't underestimate the value that the farmer places on you. They may not say it, but they do value you or they wouldn't do business with you. Certification enhances that value. It says you are doing more than required to serve them to the best of your ability. Enjoy the summer! ■

Earn CEUs at ASA's Annual Meeting this November in New Orleans

...and celebrate a century of integrating crops, soils, and the environment!

Certified professionals can earn Continuing Education Units (CEUs) by attending paper sessions November 4–8 in New Orleans at the Annual Meetings of the American Society of Agronomy (ASA), Crop Science Society of America (CSSA), and Soil Science Society of America (SSSA). The meetings honor ASA for 100 years of service to the agricultural and scientific communities, beginning on Sunday evening November 4 with a Mardi Gras style parade followed by a ticketed riverboat dessert cruise. The celebrations continue during the meetings with invited speakers, special events, and a historical display and timeline. The celebration culminates on Wednesday evening November 7 with a Centennial Reception.

Earn CEUs

Individuals certified through ASA and SSSA (CCAs, CPAgs, and CPSS/Cs) have the opportunity to earn CEUs during the meetings. In addition, ASA's A-9 Professional Practitioners Division features sessions specifically targeted towards certified individuals. All states and provinces now allow CCAs to self-report up to 20 CEUs, while CPAgs and CPSS/Cs can self-report all 40 CEUs.

Nearly 3,000 poster and oral papers will be presented in sessions throughout the week, covering such topics as nutrient management, soil and water management, pest management, crop management, and professional development, among others. CCAs may only receive CEUs for structured oral presentations. Open poster sessions do not qualify for CCA CEUs.

To self-report CEUs following the meetings, click on these links for the self-reporting forms:

- CCA: www.agronomy.org/cca/ceu_reporting_form.html
- CPAg: www.agronomy.org/certification/ceu_reporting_form.html
- CPSS/C: www.soils.org/certification/ceu_reporting_form.html

For more information, go to: www.acsmeetings.org.

Career opportunities

If you are looking to hire and want to gain exposure to hundreds of agronomy, crop, and soil science professionals or students, then tap into the services of the Annual Meetings' on-site Career Placement Center.

As an employer, you can post your job announcements and also host job interviews on site at no charge. As a meeting attendee, you can use the services of the Career Placement Center free of charge throughout the week. These services include: searchable resumes, job and internship postings, and on-site interviews with potential candidates. In addition, there is a special afternoon devoted to undergraduate internship interviews. For more information, visit: www.careerplacement.org, or contact Leann Malison at 608-268-4948 or lmalison@agronomy.org.

'Green Zone' debuts at this year's meetings

ASA, CSSA, and SSSA are launching a new pavilion at their Annual Meetings, which will be dedicated to renewable energy, biofuels, and organic farming. This new pavilion will be known as the Green Zone.

The Green Zone will debut at the ASA–CSSA–SSSA International Annual Meetings, November 4–8, 2007 in New Orleans, LA. The unveiling of the Green Zone coincides with ASA's centennial. Attendees can expect to meet exhibiting companies who specialize in ethanol/biodiesel fuel production, wind and solar energy technologies, and organic farming methods.

The new pavilion will present the facts behind the science. The Societies believe it is important to give these new areas a platform to present the exciting technology behind this movement.

The ASA–CSSA–SSSA International Annual Meetings bring together more than 3,500 people from over 50 countries representing academia, government, and private industry, including a large contingent of undergraduate and graduate students.

For more information, visit **www.acsmeetings.org** or contact Alexander Barton at 847-698-5069.

Meeting registration

Registration for the Annual Meetings will be available in late June. Register by September 24 to receive the extra early discount or by October 10 to receive the preregistration discount. Early preregistration by September 24 is $395 for ASA–CSSA–SSSA members and $565 for nonmembers. After October 10, the registration fee increases to $460 for members and $630 for nonmembers. Both one- and two-day rates are available. Members receive substantial registration discounts. In most cases, it costs less to join or renew and register for the Annual Meetings than it does to attend at the nonmember fee. For more information, visit: www.acsmeetings.org. ■

New equipment puts the Precise in precision farming

Things have changed since the Native Americans placed a fish alongside a corn seed to provide a shot of fertility to ensure grain yield. Equipment now uses phrases like coefficient of variation (CV) and normalized difference vegetation index (NDVI) to describe how the instruments identify and measure the amount of fertilizer to provide to plants in different parts of the field. New equipment, manufactured by NTech Industries, Ukiah, CA, is the result of cross-licensing and joint development by the firm and Oklahoma State University (OSU). It resulted from interest in the use of algorithms that identify plant tissue in need of extra nitrogen fertilizer, or in the case of cotton, the use of plant growth regulators and defoliants. The technology, placed in conventional spraying systems, is used in a number of countries including the Czech Republic, China, the Netherlands, Argentina, Mexico, Canada, and Australia. It's now in use in several Midwestern U.S. corn and soybean fields.

An earlier technology produced the WeedSeeker for finding and routing weeds. It is particularly of interest in managing fields either where glyphosate-ready crops are planted and "volunteer" the next year and need to be removed to avoid contaminating other crops or where glyphosate-resistant weeds show up unannounced and unappreciated. Further refinement, both by university personnel and NTech, resulted in a major joint venture, developing the optical scanning techniques to new uses for identifying fertilizer shortage in plants. At a signing ceremony on October 15, 2001, in Stillwater, OK, Patchen, Inc. (now NTech Industries) and OSU formalized their working partnership. They signed a license and master research agreement, which resulted in manufacturing the smart sprayer, a new generation of agricultural spray systems.

The GreenSeeker uses some of the basic technology as the WeedSeeker, employing advanced optics and computer circuitry taken to a new level of precision by also detecting the health of the plant. For years, agricultural production in the U.S. and around the world has been based on fertilizing crops by taking several soil samples in a field and then applying a single rate over the entire field. This new technology allows real-time plant assessments and corresponding fertilizer or other crop input rate changes. The optical sensor emits and captures red and near-infrared light that measures the color and health of crop plants and then delivers the precise amount of fertilizer needed for maximum yield. The system works equally well day or night when reduced wind drift eliminates overspraying. A usual way of designing the equipment is to mount a number of sensors on a sidedress nitrogen applicator to assess plant biomass and health as the rig moves across the field. Fertilizer rates are adjusted on the go, depending on the sensor's assessment of the crop's yield potential.

Variants of the system were first tested in 2002, and by 2004, Midwest corn farmers produced an average increase in gross profit of $18.26 per acre by using optical sensor technology to guide the application of nitrogen. In seven Iowa corn fields totaling 800 acres and two additional corn fields in Illinois and Minnesota, nine farmers recorded an average 34.7 lb/acre decrease in nitrogen fertilizer use, from 180 to 145.3 lb/acre, using the GreenSeeker RT200 Variable Rate Application and Mapping System. Jerry Hatfield, designer of the corn field trials, says farmers used less fertilizer with the GreenSeeker to produce the same or better yields.

"In some cases, the farmers had improved yields and in some cases they didn't," says Hatfield, director of the National Soil Tilth Laboratory in Ames, IA and president of the American Society of Agronomy. "But in all cases, using the system reduced the use of nitrogen and improved the efficiency of the nitrogen that was used. While field trial revenue gains resulted primarily from nitrogen use reductions, yield (on average) also increased, from 190.1 to 193 bushels per acre."

Ted Mayfield, chief operating officer of NTech Industries, says nitrogen use was reduced 58% on one 77-acre plot in Illinois, increasing the grower's profit more than $40 per acre over conventional practices for that year.

"The important point is using nitrogen more efficiently, at a rate that gives farmers the best return on their input dollars," Mayfield adds.

The improvement in technology has led to a number of new patents, some held by OSU personnel and some by NTech. The patents build on each other and are still issuing (the most recent is USPTO 7,188,450, March 13, 2007, assigned to the Board of Regents of OSU by Raun et al.). The technology is also used in a hand-held sensor by other research groups such as Agri-Food Canada for developing additional algorithms for other crops such as canola and CIMMYT for corn and wheat.

California vineyards look for improvements

Experiments began in 2004 for use in vineyards when Jack Neal & Son, Inc. (JNS) reported "encouraging results" as it became the first vineyard management company in the U.S. to use proven ground-based optical scanning technology to assist with decision making for precision farming practices.

"We used GreenSeeker in four Napa Valley vineyards last spring to evaluate its potential," explains JNS Geographical Information Systems Manager Walden Grindle. "It can be mounted to a tractor and used in conjunction with other farming activities to dramatically reduce cost; it isn't impeded by clouds, fog, or sunlight; and it produces superior, real-time data."

The equipment, whether mounted on huge machines to cover a field in minutes or as a hand-held mapping device for determining the fertility of fields, reduces excess fertilizer use, preventing runoff and contamination of streams and groundwater. While this is very important to environmentalists, its attraction to farmers is enhanced by the savings in fertilizer costs.

Interest continues to grow

It's taken awhile, but the system is gaining traction.

"Just last month, Agrium, one of the world's largest nitrogen fertilizer suppliers, announced a $21 million third quarter North American wholesale revenue gain from a 44% increase in average realized selling price over last year," said OSU agronomist Bill Raun, one of the inventors of technology, in 2003. "It's bad news for farmers, but I believe they can find financial relief in new precision application systems."

Raun is a member of OSU's agricultural research station team that has developed a sensor-based variable-rate fertilizer system, which last year won the USDA Secretary's award "as the most revolutionary method for fertilizing crops in a century." Most recently (May 22, 2007), it was announced that The Iowa Soybean Association On-Farm Network will incorporate the GreenSeeker optical sensing and variable-rate application system in nitrogen management studies as part of its 2007 replicated strip trial research program.

Further greening the revolution

While the technology can save lots of money in the U.S. and other developed countries, its use in nutrition-poor fields captured the attention of Norman Borlaug in a recent trip to the Yaqui Valley, the cradle of the Green Revolution in Mexico. One of the reasons for his recent visits to Obregón this time was to see and learn about the technology developed by OSU and further developed at CIMMYT. The approach allows farmers to easily and cheaply determine the optimum application of fertilizer for a developing wheat or maize crop. Fertilizer resources are scarce in much of Africa, so timely application of the correct amounts can save farmers money and help produce a better crop. A hand-held computer, programmed with the data about the crop and location, can calculate the nitrogen status of the plant. Ivan Ortiz-Monasterio, who leads CIMMYT's research in nitrogen efficiency, says many Yaqui Valley farmers can recover the cost of the sensor in a single season through savings in fertilizer use, but acknowledges the economics on smallholder farms in Africa are quite different. OSU researchers are now taking on the challenge of producing a less expensive model that will work for the rural poor in Africa. ■

▶ **Dr. Norman Borlaug visits with reporters in a farmer field near Ciudad Obregon, Sonora, Mexico concerning the GreenSeeker nitrogen management approach that has now been used in the Yaqui Valley since 2002. Photo courtesy of Oklahoma State University's NUEweb (www.nue.okstate.edu).**

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Did you know CCAs can earn and self-report up to 20 CEUs by attending sessions at the ASA-CSSA-SSSA 2007 International Annual Meetings? CPAgs, CPSS, and CPSC holders may self-report up to 40 CEUs.
Nearly 3,000 poster and oral papers will be presented in sessions throughout the week, covering such topics as nutrient management, soil and water management, pest management, and crop management and professional development. **Division A09: Professional Practitioners** features sessions specifically targeted towards certified individuals. Check the online Annual Meetings Program for an updated list of sessions.
Take advantage of this great opportunity to earn half—or all—of the CEUs required! For more information, visit **www.acsmeetings.org**
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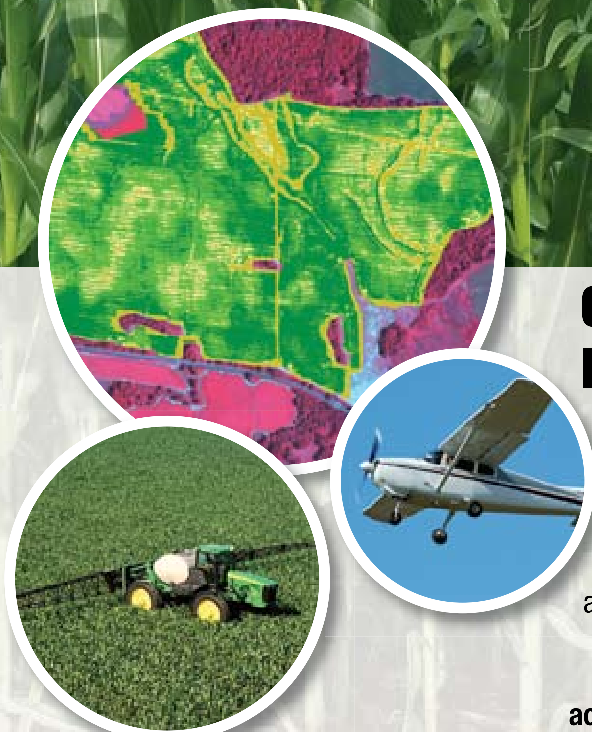

Research in seven states over the past four years shows corn growers could save between $5 and $20 per acre in nitrogen costs.

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The OptiGro system from John Deere Agri Services can help you do both — optimize your corn yields and apply only the nitrogen your plants really need. By translating aerial crop imagery into timely crop knowledge, the OptiGro system lets you apply the right amount of nitrogen in the right place at the right time.

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