Using Cover Crops to Convert to No-till

Article · January 2009

CITATIONS
12

READS
90

4 authors, including:

James J. Hoorman
The Ohio State University
16 PUBLICATIONS **114** CITATIONS
SEE PROFILE

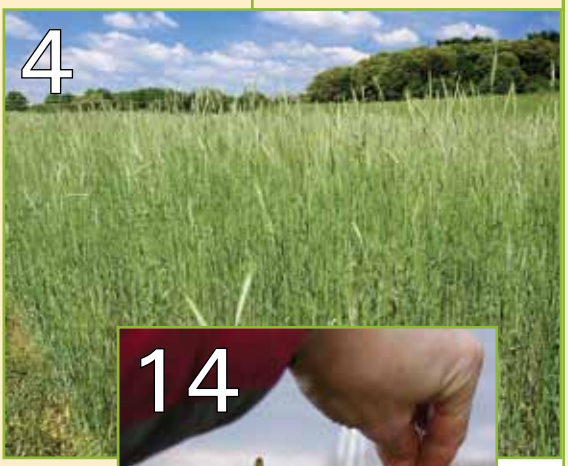
Rafiq Islam
The Ohio State University
126 PUBLICATIONS **2,660** CITATIONS
SEE PROFILE

Randall Reeder
The Ohio State University
27 PUBLICATIONS **944** CITATIONS
SEE PROFILE

Crops & Soils

agronomy for practicing professionals

Volume 42 ■ Issue 6
November–December 2009



Focus Cover Crops

An American Society of Agronomy Publication

PIONEER®
A DuPont Business

Science with Service
Delivering Success™

www.**pioneer**.com/careers

Are you ready to make a positive, global impact?

We have a place for you.

Challenging, cutting-edge career opportunities await you at Pioneer Hi-Bred, a DuPont business. We are the world's leading source of customized solutions for farmers, livestock producers, and grain and oilseed processors. Pioneer provides access to advanced plant genetics in 70 countries worldwide.

Make a difference in our world

Every day our employees make a difference in world agriculture production. At Pioneer, our mission is to help farmers be more productive – and, we go to extraordinary lengths to maximize our customers' success.

At Pioneer, you'll use your skills and passion to do work that has a global impact. We're looking for people who bring a new perspective that expands our view of our industry and our world.

Exciting work, opportunities for advancement

Our employees work in an environment that offers new challenges and recognition for their work. We have talented employees that continually learn from each other, many of whom are leading experts in their field. When you join Pioneer, you'll have numerous possibilities for advancement within your area of expertise and opportunities in different areas of the organization.

Pioneer provides our employees with many development opportunities so you can improve your knowledge and skills. Additionally, our international presence and affiliation with our parent company, DuPont, gives you the chance to expand your career.

Join a growing organization and be part of the team putting the best of science and service to work for farmers worldwide.

DUPONT®
The miracles of science™

Pioneer at a Glance

Pioneer Headquarters
7000 NW 62nd Avenue
Johnston, Iowa 50131-1000

Products and Services
Pioneer provides seed for corn, soybeans, sorghum, sunflower, alfalfa, rice, canola and wheat, as well as forage and grain additives, crop protection products and a variety of services and expertise to help our customers succeed in 70 countries worldwide.

Locations
Operations in 70 countries

Employees
More than 8,500 employees worldwide

Recent Recognition
Named top large company to work for in the life sciences industry by *The Scientist* magazine and named among the top biotechnology employers by *Science Magazine*.

Rewarded for Your Work
Pioneer offers our employees an extensive compensation and benefits package, including training and development opportunities that ranks among the best in our industry.

Positions Available
Full-time, part-time, internship and temporary positions are available in all areas of our business:

- Research & Development
- Production
- Sales & Marketing
- Engineering
- Supply Chain
- Functional support areas such as Information Management, Finance, Communications, Human Resources, Government Affairs, among others

Learn more about available careers and internships at:
www.Pioneer.com/Careers

Crops & Soils

agronomy for practicing professionals

Volume 42 ▪ Issue 6 ▪ November–December 2009

Crops & Soils, the magazine for practicing professionals in agronomy, is published bimonthly (January, March, May, July, September, and November) by the American Society of Agronomy. Visit us online at www.agronomy.org/publications/crops-and-soils.

Contributions/correspondence

Crops & Soils welcomes letters, comments, and contributions, published on a space-available basis and subject to editing. The deadlines are February 15 (March–April issue), April 15 (May–June issue), June 15 (July–August issue), August 15 (September–October issue), October 15 (November–December issue), and December 15 (January–February issue). Email cropsandsoils@agronomy.org or call 608-268-4968. For general inquiries not related to *Crops & Soils*, please email certification@agronomy.org or call 866-359-9161.

Advertising

Contact Alexander Barton (abarton@agronomy.org or 847-698-5069) or visit www.agronomy.org/advertising.

Postage/Subscriptions

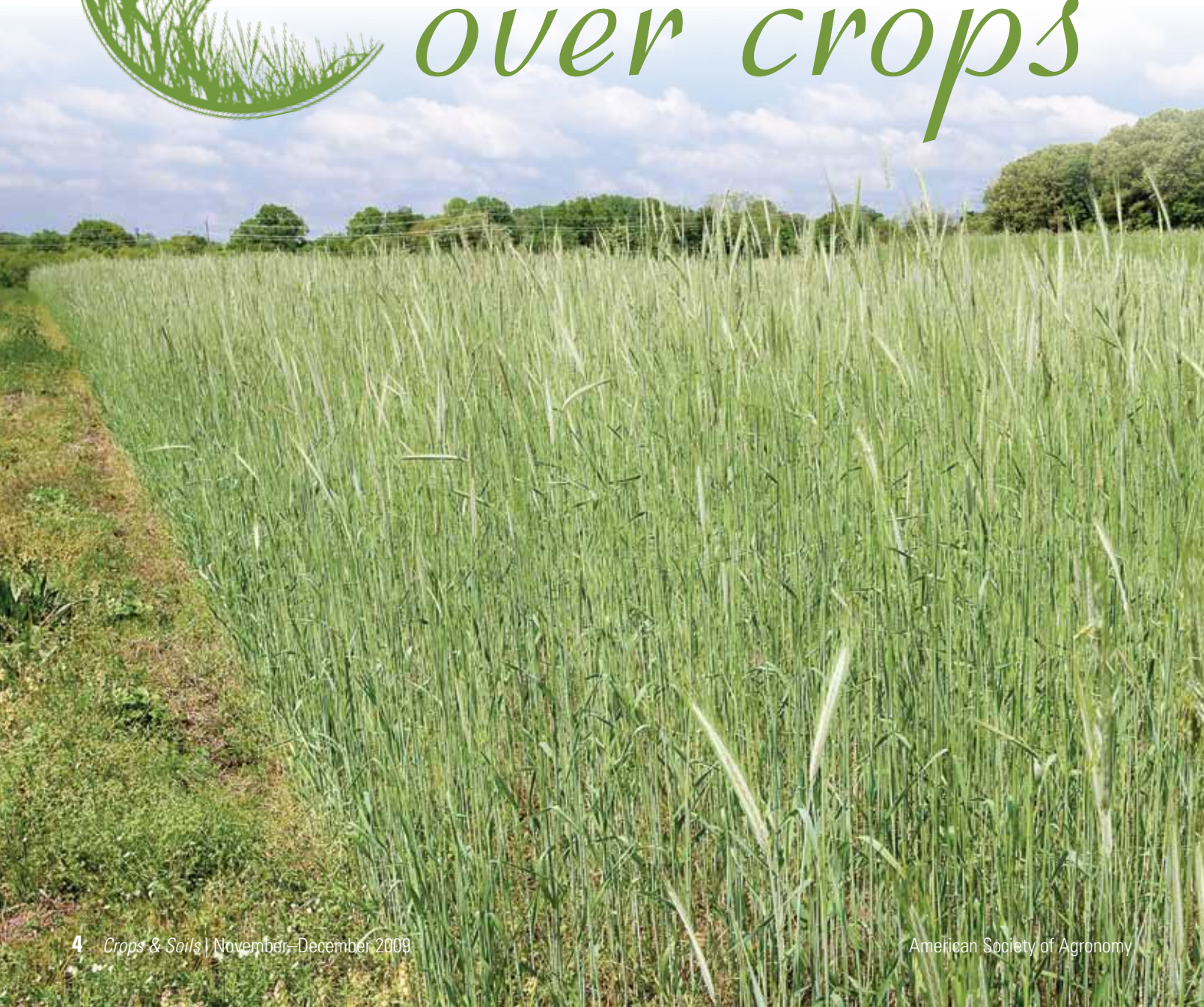
Crops & Soils (ISSN 0162-5098) is published bimonthly by the American Society of Agronomy. Send address change to *Crops & Soils*, 677 S. Segoe Rd., Madison WI 53711-1086. Subscriptions are $20/year (U.S.) and $45/year (international). Visit www.agronomy.org/publications/crops-and-soils, call 608-268-4959, or email journals@agronomy.org.

Focus Cover Crops

The focus of this issue is on cover crops. See pages 4–17, 20–21, and 24–28.

Focus on

cover crops



Cover crops on the edge

cover cropping in marginal production areas could have far-reaching benefits

Rye cover crop. Photo by Stephen Ausmus (USDA-ARS).

The traditional use of cover crops provides a range of benefits, mainly soil fertility improvements, soil erosion management, and weed and insect pressure reduction. Farmers evaluate the economic and ecological aspects of cover crops by measuring the reduction in input costs such as fertilizer, herbicide, and other pesticide costs. Benefits of the practice vary by location and season, but at least two or three usually occur with any cover crop. As an additional measure, combining cover cropping with conservation tillage can also lead to reduced energy use.

Beyond their on-farm use, research conducted over many years indicates that clever cover crop choices have both local and larger-scale ecological benefits.

According to a report by the USDA Economic Research Service titled "Environmental Effects of Agricultural Land-Use Change" (www.ers.usda.gov/publications/err25/err25.pdf), the large-scale production of just a few crops has contributed to the degradation of water quality with sediment, nutrients, and pesticides; hydrologic modifications contributing to flooding and groundwater depletion; disruption of terrestrial and aquatic wildlife habitats; emission of greenhouse gases; and degradation of air quality with odors, pesticides, and particulates.

Ultimately, farmers tend to make strictly economic-based production choices, according to the report. Producers tend to keep highly productive land in crop cultivation regardless of changing economic conditions. But an increase in commodity prices or production input costs encourages farmers to expand production to less productive land or to shift less productive croplands to other uses. Agricultural and conservation policies also affect land use. Beyond the individual farm level, these wider-scale land-use changes have an impact on environmental quality, particularly when affected lower-quality lands are environmentally sensitive.

The USDA report says that almost three-quarters of the cropland that shifted into or out of cultivation between 1982 and 1997 had soil productivity ratings below the average acre of cropland. This suggests that policies that increase incentives for crop cultivation and stimulate production on economically marginal land may ▶

Cover Crop	Erosion Reduction	Increase soil organic matter	Capture, recycle, redistribute nutrients in the soil profile	Promote biological nitrogen fixation	Weed suppression	Provide supplemental hay	Provide supplemental grazing	Rooting Depth / Plant Water Use /1	Minimize / reduce soil compaction	Seed size (Large or Fine)	Crop Type /2	Seeding rate, lbs/acre	Seeding depth, inches	Salinity tolerance	C:N Ratio	Attract Beneficial Insects	Mycorrhizal fungi association
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
alfalfa	G	G	G	Y	G	F	F	DH	G	F	CB	6.5	0.25 - 0.75	P	L	Y	M
alsike clover	G	F	G	Y	G	F	F	SL	P	F	CB	3	0.25 - 0.75	P	L	Y	M
annual oregon ryegrass	F	G	G	N	F	G	G	MM	P	F	CG	15	.5-1.5	F	M	Y	L
barley	G	G	F	N	G	F	F	MM	F	L	CG	60	0.75 - 2	G	M	Y	L
buckwheat	G	F	G	N	G	P	P	SL	P	F	WB	50	0.5 - 1.5	P	L	Y	N
canola	F	F	G	N	P-G**	F	F	MM	G	F	CB	5	0.25 - 0.75	G	L	Y	N
chickling vetch	G	F	G	Y	F	F	F	SL	F	L	CB	70	0.5 - 1.5	P	L	Y	M
corn	G	G	G	N	P-G**	F	F	DH	G	L	WG	12*	1-1.5	P	H	N	H
cowpea	P	P	F	Y	G	F	F	SL	F	L	WB	30	1 - 1.5	P	L	Y	M
flax	F	F	F	N	P	P	P	SM	P	F	CB	20	.25-.75	F	H	Y	H
grain and forage sorghum	G	G	G	N	G	G	F	MM	G	L	WG	10	0.5 - 1.5	F	M	Y	H
hairy vetch	G	F	F	Y	P	F	F	SM	F	L	CB	15	0.5 - 1.5	P	L	Y	M
lentil	P	P	F	Y	P	F	F	SL	P	F	CB	30	1-1.5	P	L	Y	M
millet	G	G	F	N	G	G	F	SL	F	F	WG	30	.25-.75	P	M	N	H
mustard, oriental or brown	F	F	F	N	G	F	F	MH	F	F	CB	6	0.25 - 0.75	P	M	Y	N
mustard, tame yellow	F	F	F	N	G	F	F	MH	F	F	CB	12	0.25 - 0.75	P	L	Y	N
oat	G	G	F	N	F	G	F	MM	F	L	CG	70	0.5 - 1.5	F	M	N	L
pea	P	P	P	Y	F	G	F	SL	P	L	CB	90	1.5 - 3	P	L	Y	M
radish	P	P	G	N	G	P	G	DH	G	F	CB	10	0.25 - 0.5	P	L	Y	N
red clover	G	F	G	Y	G	F	F	SL	P	F	CB	5	0.25 - 0.75	P	L	Y	M
soybean	P	P	F	Y	P-G**	F	F	SM	P	L	WB	40	1-1.5	P	L	Y	M
spring rye or s. wheat	G	G	G	N	G	F	F	MH	F	L	CG	100	0.5 - 1.5	F	M	Y	L
sudangrass, sudan-sorghum hybrid	G	G	G	N	G	G	G	MM	G	L	WG	25*	0.5 - 1.5	F	M	Y	H
sugarbeet	P	P	G	N	F	P	G	DH	G	F	CB	4	0.25 - 0.5	G	L	N	N
sunflower	F	F	G	N	F	P	G	DM	F	L	WB	7	.5-1	F	M	Y	M
sweet clover	G	F	F	Y	F	P	F	MM	F	F	CB	4	0.25 - 1	F	L	Y	M
tall wheatgrass	G	G	G	N	G	G	G	DH	F	L	CG	13	0.25 - 1	G	H	N	L
teff grass	F	G	F	N	F	G	F	SM	P	F	WG	5	.125 - .25	P	M	N	N/A
triticale	G	G	G	N	G	F	F	MH	F	L	CG	100	.5-1.5	G	M	Y	L
turnip	P	P	G	N	G	P	G	DH	G	F	CB	4	.25-.5	P	L	Y	N
white clover	G	F	G	Y	G	F	F	SL	P	F	CB	1.5	0.25 - 0.75	P	L	Y	M
winter rye or w. wheat	G	G	G	N	G	F	F	MH	F	L	CG	100	0.75 - 2	G	M	Y	L

/1 Rooting Depth/Water Use

SL= Shallow rooted/Low water use
SM= Shallow rooted/Medium water use
SH= Shallow rooted/High water use
ML= Medium rooted/Low water use
MM= Medium rooted/Medium water use
MH= Medium rooted/High water use
DL= Deep rooted/Low water use
DM= Deep rooted/Medium water use
DH= Deep rooted/High water use

Shallow 6 - 18 inches
Medium 18 - 24 inches
Deep 24 + inches

/2 Crop types

CG= cool season grass
CB= cool season broadleaf
WB= warm season broadleaf
WG= warm season grass

Ratings

L= Low G= Good
M= Medium F= Fair
H= High P= Poor
N/A= Not Available

*Variable depending on seed size and row spacing.
**Poor weed competitor, but herbicide-tolerant varieties are available.

Common species and properties of cover crops. *Source: USDA-NRCS (see www.sd.nrcs.usda.gov/technical/CoverCrops.html).*

have disproportionately large unintended environmental consequences. On the other hand, large environmental benefits could be achieved at lower cost using targeted conservation programs because owners of low-quality and environmentally sensitive land require less payment to remove land from production than owners of higher quality land.

The USDA Natural Resources Conservation Service (NRCS) through its new Conservation Stewardship Program provides financial and technical assistance to eligible producers to conserve and enhance soil, water, air, and related natural resources on their land. Eligible lands include cropland, grassland, prairie land, improved pastureland, rangeland, nonindustrial private forest lands, agricultural land under the jurisdiction of an Indian tribe, and other private agricultural land (including cropped woodland, marshes, and agricultural land used for the production of livestock) on which resource concerns related to agricultural production could be addressed. Participation in the program is voluntary.

The program encourages land stewards to improve their conservation per-

formance by installing and adopting additional activities and improving, maintaining, and managing existing activities on agricultural land and nonindustrial private forest land. The use of cover crops is one of the activities that the program encourages. The program directly refers to the planting of crops such as grasses, legumes, and forbs to provide seasonal cover that will reduce erosion, improve soil organic matter, promote efficient nutrient cycling, fix nitrogen in the soil, suppress weeds, increase biodiversity, and provide food and cover for wildlife. (For more on the Conservation Stewardship Program, see www.nrcs.usda.gov/Programs/new_csp/csp.html.)

Another group that is working to increase the practice of cover cropping in the Midwest is the Midwest Cover Crops Council (MCCC). The MCCC seeks to significantly increase the amount of continuous living cover on the agricultural landscape of the Upper Midwest. According to the MCCC, in a time when the Mississippi River Basin and Great Lakes watershed suffer from serious environmental degradation, a shift in agricultural systems can play a significant and positive role in revitalizing and restoring lakes, rivers, fields, and communities in the region.

Why cover crops?

Cover crops can provide many different benefits in modern cropping systems, according to ASA–SSSA member Dr. Eileen Kladivko, a founding member of the MCCC and professor of agronomy at Purdue University. However, they require a higher level of management and some experimentation to achieve maximum benefit.

"There are several good reasons to re-evaluate cover crops right now for use in modern cropping systems," said Kladivko during a recent online seminar to crop advisers about the use of cover crops. "These include higher fertilizer prices, higher energy costs, water quality concerns, soil tilth and compaction issues, and concerns about replacing organic matter with increased residue removal practices."

Cover crops are most commonly found in areas with longer growing seasons, Kladivko noted, such as the southeastern U.S. or areas with soils that are steeply sloping, low in organic matter, or sandy and blowing; they are also commonly found on vegetable and melon farms (for sand blasting control), organic farms, mixed farms that use cover crops for grazing, and farms around the Chesapeake Bay that participate in a cost-share program for nutrient management to reduce losses to the bay.

"Traditionally there has been a low level of use of cover crops in the Midwest as compared to a region such as the Southeast," Kladivko said. "However, recently there has been an increased interest in the use of cover crops in the Midwest, especially the eastern part of the Corn Belt region, to prevent nutrient input loss and [improve] water quality."

Cover crops can provide many different benefits in modern cropping systems.

A good fit for using cover crops in the Midwest would be after corn silage and after winter wheat, Kladivko said. "These situations have enough time for seeding and growth and provide significant benefits for soil structure, weed control, and nitrogen production if legumes are used. If corn stover is removed for biomass, cover crops should also be grown to protect soil productivity."

Preventing nutrient loss

According to Kladivko, cover crops are important in nutrient cycling. They trap nutrients that would otherwise "leak out" during fallow periods through leaching, erosion, or runoff and can release those nutrients later—ideally at the time needed by the next crop. Cover crops can translocate nutrients from deeper in the subsoil to near the surface and increase soil biological activity in topsoil, potentially releasing nutrients from soil minerals. Most cover crops do not "create" nutrients in soil; instead they recycle and release. However, leguminous cover crops do add nitrogen to the soil through atmospheric fixation.

A large body of research indicates that losses of nitrate and phosphorus from corn and soybean fields in the Upper Mississippi River Basin contribute to contamination of the Mississippi River and the Gulf of Mexico. For example, the northern portion of the Gulf of Mexico ecosystem, which contains almost half of the nation's coastal wetlands and supports commercial and recreational fisheries, has undergone profound changes due to nutrient enrichment of Mississippi River water from land-based sources. Nutrient over-enrichment can lead to excessive production of algae. When this organic material sinks and becomes decomposed, dissolved oxygen in bottom waters is reduced. Research indicates that this has resulted in seasonal hypoxia (very-low-oxygen water) over the Louisiana continental shelf. Hypoxic waters can cause habitat and marine life loss, affecting commercial harvests and impacting the ecosystem.

Even when farmers carefully manage fertilizers and put on only what is needed by the crop, substantial nutrient losses occur during the fall, winter, and spring when corn and soybean are not growing and the fields are bare. Nutrient loss happens, in part, because there are extended periods during each year when living plants are not removing nutrients from the soil and the nutrients are susceptible to losses. Summer annual grain crops, like corn and soybean, accumulate water and ▶

Cover crop terminology

Brown gap. Nutrient loss happens, in part, because there are extended periods during each year when living plants are not removing nutrients from the soil and the nutrients are susceptible to losses. Summer annual grain crops, like corn and soybean, accumulate water and nutrients only for about four months of the year. The remaining months of the year have been called the "brown gap" because there are no "green" plants that serve to protect the soil and recycle nutrients.

Catch crop. A catch crop is a cover crop established after harvesting the main crop and is used primarily to reduce nutrient leaching from the soil profile. For example, planting cereal rye following corn harvest helps to scavenge residual nitrogen, thus reducing the possibility of groundwater contamination.

Continuous living covers systems. These are agricultural cropping and livestock production systems that maintain continuous living cover throughout the year. This includes those based on perennial plants such as trees, shrubs, grasses, and legumes, as well as annual plants grown in combination, such as the use of cover crops as row crops.

Cover crops. Crops that "cover" the soil and may be used to reduce soil erosion, reduce nitrogen leaching, provide weed and pest suppression, and increase soil organic matter. Winter cover crops are planted shortly before or soon after harvest of the main grain crop and are killed before or soon after planning of the next grain crop.

Forage crop. Short-rotation forage crops function both as cover crops when they occupy land for pasturage or haying and as green manures when they are eventually incorporated or killed for a no-till mulch.

Living mulches. Living mulches are defined as cover crops planted either before or with a main crop and maintained as a living ground cover throughout the growing season. Living mulches are often perennial species and are maintained from year to year.

Perennials. Perennial crops grow for multiple years from a single planting and can replace annual grain crops as the cash crop. For a perennial crop to replace an annual grain crop, a market must be available or the crop must be used on the farm. The most common perennials found in the agricultural systems of the Upper Mississippi River Basin are forages such as grasses and legumes.

nutrients only for about four months of the year. The remaining months of the year have been called the "brown gap" because there are no "green" plants that serve to protect the soil and recycle nutrients.

One way to prevent these losses is to grow plants to take up nutrients and protect the soil surface when the main crops are not present. Cover crops, living mulches, and perennial crops can bridge the gap between harvest and planting of corn and soybean.

Cover crops only grow during the period between harvest and planting of the main crops. Living mulches grow year round between the rows of the main crop but are suppressed with mowing or herbicides during the summer. Perennial crops (e.g., alfalfa) replace the corn and soybean crops altogether. All three of these approaches have advantages, disadvantages, and potential applications. It is generally accepted by scientists that these practices have the potential to reduce nutrient losses, but their adoption is limited by management problems, unfamiliarity of farmers with these practices, and lack of financial incentives. More research is needed, but these practices in conjunction with fertilizer management and other practices can reduce nutrient contamination of the Mississippi River Basin and other surface waters.

Multifunctional agriculture

Advocates of cover crops mention the concept of agricultural multifunctionality, which is defined as the joint production of agricultural commodities and "ecological services." The term, "eco-agriculture" has also been used to describe how land can be managed to sustain a range of ecosystem services, including food and fiber production. Examples of ecosystem services include increased recreational opportunities in agricultural landscapes and protection of biodiversity and water quality.

"Giving up production on just 5% of a producer's most marginal land can pay dividends in terms of overall environmental friendliness," says Dr. Paul Porter, a professor in the Agronomy and Plant Genetics Department at the University of Minnesota.

Overall, these ecosystem services can be highly valuable. For example, the USDA-NRCS Conservation Reserve Program has been estimated to produce $500 million per year in benefits from reduced erosion and $737 million per year in wildlife viewing and hunting benefits at a cost of approximately $1.8 billion.

Continuous living cover crop systems are one component of the agricultural multifunctionality effort. Continuous living cover systems are agricultural cropping and livestock production systems that maintain continuous living cover throughout the year. This includes those based on perennial plants such as trees, shrubs, grasses, and legumes, as well as annual plants grown in combination, such as the use of cover crops as row crops.

The concept of the continuous living cover system has been promoted by the Green Lands, Blue Waters project, a long-term comprehensive effort by midwestern land grant institutions and various nongovernmental organizations to support the development of and transition to a new generation of agricultural systems in the Mississippi River Basin that integrate more perennial plants and other continuous living cover into the agricultural landscape.

"All farming decisions are based on economics, but for some farmers, it may make sense to convert some of their least productive acres into wetlands and open that to hunters or conservation," Porter says.

Individual growers will consider a variety of factors in determining whether a cover crop might be right for their particular situation such as: soil erosion and conservation, soil fertility, pest management, growing season, biomass production to increase organic matter, and the producer's resource-suitable acreage, irrigation capability, available labor, equipment, costs, capital, and personal goals and interests. ■

Using cover crops to convert to no-till

By James J. Hoorman, extension educator; ***Rafiq Islam,*** soil and water specialist; ***Alan Sundermeier,*** extension educator; and ***Randall Reeder,*** extension agricultural engineer, Ohio State University Extension

No-till planting of corn into cover crop of barley. Photo by Jeff Vanuga (USDA-NRCS).

In the Midwest, about three-fourths of all soybeans and wheat are planted without prior tillage. But before corn is planted, at least three-fourths of the fields are tilled in the fall and possibly again in the spring. Farmers are tilling ahead of corn planting because they perceive a yield increase with tillage that is more than enough to cover the added direct costs for machinery, fuel, and labor. Typically, soybeans are no-tilled into corn stalks followed by soybean residue being tilled for corn planting the next year. No-tilling one year (for soybeans) and then tilling the next (for corn) is not a true no-till system.

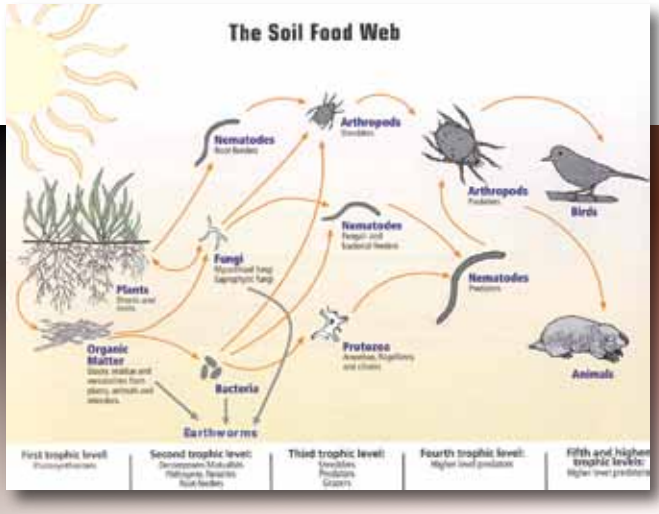
In many situations, corn yields drop slightly after switching to no-till. Farmers typically see a 5 to 10% bu yield decrease for the first five to seven years after they convert from conventional till to no-till. The corn crop benefits from tilled soils due to the release of nutrients from soil organic matter. Tilling the soil injects oxygen into it, which stimulates bacteria and other microbes to decompose the organic residues and releases nutrients. Every 1% of soil organic matter holds 1,000 lb of nitrogen. However, continuous tillage oxidizes soil organic matter and soil productivity declines with time. Thus, tillage results in poor soil structure and declining soil productivity.

Long-term research reveals that seven to nine years of continuous no-till produces higher yields than conventionally tilled fields because it takes seven to nine years to improve soil health by getting the microbes and soil fauna back into balance and to start to restore the nutrients lost by tillage. In those transition years, the soil is converting and storing more nitrogen as microbe numbers, and soil organic matter levels increase in the soil. For the first several years after converting to no-till, there is competition for nitrogen as soil productivity increases and more nitrogen is stored in the soil in the form of organic matter and humus.

Cover crops have the ability to jump-start no-till, perhaps eliminating any yield decrease. They can be an important part of a continuous no-till system designed to maintain short-term yields and eventually increase corn yields in the long run. Cover crops recycle nitrogen in the soil, help to build soil organic matter, and improve soil structure and water infiltration. Long-term cover crops can boost yields while improving soil quality and providing environmental and economic benefits. Growing cover crops is helping farmers adapt faster to a continuous no-till system, one that provides long-term economic and environmental benefits that are impossible to obtain by no-tilling one year.

Ecosystem functionality

Our agricultural landscape is typically green for only about six months during the year with no living cover for the other six months. Most crops are planted annually in the spring and harvested in the fall. Fall tillage prepares the seedbed for the following crop but leaves the soil exposed and fallow. The result is a soil surface devoid of plant life for six months and a decrease in "ecosystem functionality." In a typical corn–soybean rotation, there are active living roots only 32% of the time (Magdoff and van Es, 2001). Typically there are 1,000 to 2,000 times more microbes (especially bacteria and fungi) associated with living roots because the roots provide active carbon and exudates to feed the microbes (Schaetzl and Anderson, 2006). Ecosystem ▶



Left: **Ecosystem functionality depends on a healthy soil food web. Each species has a certain role and function in the soil.** *Graphic from the Ohio State University Fact Sheet "Using Cover Crops to Convert to No-till."* ***Right:*** **Cowpeas may supply 120–150 lb of N to no-till corn. The background of the image shows no-till corn that was planted into cowpeas with no additional commercial fertilizer. Note the dark green color indicating good N fertilization. The foreground shows cowpeas that were drilled into wheat stubble seven days after planting.** *Photo by Dr. Rafiq Islam.*

functionality means that an ecosystem can sustain processes and be resilient enough to return to its previous state after environmental disturbance. Functionality depends on the quantity and quality of a system's biodiversity. An important characteristic of ecosystem functionality is that it develops and responds dynamically to constantly occurring environmental changes. Tillage is a constant disrupter, and biodiversity in the soil decreases as tillage increases.

Tillage releases carbon to the atmosphere by oxidizing the soil organic residues and in the process releases nitrogen. Nitrate leaching typically occurs after the crop is harvested in the fall, winter, and early spring months because after the microbes release the nutrients, there are no live plants to recycle the excess nutrients. Tillage also increases soil erosion and phosphorus losses (phosphorus attaches to clay soil particles) to surface water. Excess nitrogen and phosphorus in the water causes hypoxia and eutrophication in surface waters. Ecosystem functionality decreases because the soil biodiversity decreases and there is less recycling of nutrients in the soil. That explains why the nitrogen use efficiency for commercial fertilizer is only 30 to 40% for N and 50% for P. By improving ecosystem functionality, farmers can increase their N and P nutrient use efficiency, decrease their fertilizer bill, and have a positive effect on the environment by decreasing N and P losses to surface water.

In the last 100 years, tillage has decreased soil organic levels by 60 to 70%. The remaining carbon stocks (30–40%) correlate directly with nitrogen use efficiency (30–40%). To increase nitrogen and other nutrients in the soil, farmers need to increase carbon or organic matter. Carbon is the glue that binds the soil and stores and recycles nutrients. Ecosystem functionality decreases as the soil carbon content decreases because carbon is the food for microbes and the storehouse for many nutrients. Most soil nitrogen (>90%) and available phosphorus (50–75%) is stored in the organic form. Nitrogen use efficiency for corn is directly related to the amount of soil organic carbon in the soil. The soil carbon-holding capacity is 2.5 times the amount of carbon dioxide in the atmosphere, so the soil has a tremendous ability to store carbon.

Continuous living cover and no-till

An agricultural system that combines a continuous living cover (cover crops) with continuous long-term no-till is a system that more closely mimics natural systems and should restore ecosystem functionality. A thick layer of plant residue on the soil surface protects the soil from the impact of rain drops, moderates soil temperatures, and conserves soil moisture. Soil micro-organisms and plants together produce polysaccharides that form glomalin (a glycoprotein), which acts like glue that binds soil particles and improves soil structure. Living roots increase pore space for increased water infiltration, soil permeability, and water-holding capacity and recycle soil nutrients (nitrogen and phosphorus) in the soil profile.

In natural systems, the land is not extensively tilled, and a continuous living cover protects the soil from rain drop impact (less erosion). By growing a cover crop in the winter, carbon inputs are added to the soil, keeping nutrients recycling within the system. Nitrogen is directly linked to carbon, so less carbon losses means more nitrogen stays in the soil rather than being lost through leaching or runoff. Soil nutrients (N and P) are recycled within the natural system. Plant roots and soil residues protect the soil and keep it from eroding, which reduces P losses and results in less hypoxia and eutrophication. Microbial diversity and numbers increase with continuous living covers so that pest (disease, insects,

Left: **No-till soybeans drilled into a cover crop of cereal rye and annual ryegrass.** *Photo by Dr. João Moraes Sá. Graphic from the Ohio State University Fact Sheet "Using Cover Crops to Convert to No-till."* ***Right:*** **A rye and vetch cover crop is mowed down.** *Photo courtesy of USDA-ARS.*

and weeds) pressures can be more effectively moderated. The solution lies in changing agricultural practices to promote greater nutrient efficiency to recycle carbon, nitrogen, and phosphorus in the soil. Improved soil productivity, soil structure, and nutrient efficiency should increase crop yields and farmer profitability.

Nitrogen recycling

Legume cover crops (cowpeas, Austrian winter pea, etc.) can provide nitrogen to the following crop. Legume cover crops fix nitrogen from the air, adding up to 100 to 150 lb/acre of this essential nutrient. Non-legume cover crops recycle leftover nitrogen from the soil, storing it in roots and aboveground plant material, where a portion will be available to the following crop. Every pound of nitrogen stored is a pound of nitrogen prevented from leaching out of the topsoil into streams.

Cover crops can replace nitrogen fertilizer but not in every situation. After cereal rye, there may not be enough nitrogen available early for the new crop; after a legume, the N will likely not be available until later in the growing season depending upon when the crop decomposes. It all depends upon the carbon-to-nitrogen (C/N) ratio. A C/N ratio less then 20 allows the organic materials to decompose quickly while a C/N ratio greater than 30 requires additional nitrogen and slows down decomposition. Microbes will tie up soil nitrogen if a high-carbon-based material with low nitrogen content (cereal rye or wheat straw) is added to the soil. Eventually the soil nitrogen is released, but in the short-term the nitrogen is tied up. A low C/N ratio means more nitrogen is available for microbes and plants to convert nitrogen to amino acids and protein.

Microbes generally take up nitrogen faster than plants, so if nitrogen is limiting, the plant will suffer. No-till corn is often yellow from a lack of nitrogen because as the soil carbon content is increasing, the microbes are using the limited nitrogen stocks before the corn plant. A typical soil C/N ratio is 10 to 12, so nitrogen is available to plant roots. If the soil C/N ratio is too high, adding nitrogen to the soil will allow the microbes to decompose the carbon residues, which will decrease the C/N ratio, and more nitrogen will be available to the plant.

For cereal rye and annual ryegrass before corn, plan to kill it three to four weeks before planting or when it is young and lush when the C/N ratio is lower. If it cannot be killed until about two weeks before planting, apply nitrogen (as liquid fertilizer or dry fertilizer). Cereal rye and annual ryegrass provide good rooting and soil structure and absorb nitrogen, which can be recycled for the following corn crop, but depending upon the C/N ratio, may tie up nitrogen short term, hurting corn yields.

Cereal rye or annual ryegrass management is different for soybeans. Soybeans can be successfully no-till drilled into a standing cereal rye cover, even one that is 7 ft tall. The cereal rye gets flattened, helping to smother potential weed growth, and is fairly easy to kill with herbicides after planting. Annual ryegrass will reach 3 to 4 ft tall but should not be allowed to go to seed. Since soybeans are legumes and make their own nitrogen, the carbon content or C/N ratio of cereal rye ▶

and annual ryegrass does not hurt the soybean growth or yield.

No-till corn generates 14% less CO_2 losses than intensive tillage. The advantages include less fuel used, improved soil quality and structure, and better drainage, which can lead to earlier planting. Potential disadvantages include more weeds, more herbicides (to initially kill the cover crops), slower soil drying in spring (at least initially until soils are better aerated), and more N required in the transitional years until soil compaction is reduced and/or drainage is improved. The nitrogen may be provided, at least in part, by manure or cover crops.

Reduced soil erosion and phosphorus retention

Using a continuous living cover with no-till greatly reduces soil erosion and the loss of phosphorus with runoff. Remember that 50 to 75% of the available P in soil is organic and our P efficiency is only about 50% with tillage. Since the majority of the P in the soil is attached to clay particles and organic matter, protecting the soil from rain drops results in less sediment erosion and keeps the P on the soil, rather than as runoff to surface water. Over 90% of P runoff is associated with P attached to the soil when soil P levels are below

Using a continuous living cover with no-till greatly reduces soil erosion and the loss of phosphorus with runoff.

100 lb/acre Bray P1. Phosphorus in the soil is quickly tied up by clay particles, so tillage incorporates P into the soil and binds it quickly.

In no-till, as the crop residues decompose, they release soluble P, which can flow to surface waters. Growing a living crop with no-till or adding a cover crop allows the soluble P to be absorbed and recycled back into the soil system.

In long-term no-till systems with a continuous living cover (cover crops), P is efficiently recycled on the soil surface, so less P fertilizer is needed. A continuous living cover protects the soil from soil erosion where a majority of the P is lost. With tillage, the P is incorporated into the soil and binds to it, but since the soil is not protected, soil erosion may increase sediment and P losses to surface water. When soil erodes, the nutrient rich portion or the organic matter is the first portion to erode because it is less dense than soil particles, floats, and can easily be washed away from the soil surface into surface water.

Soil temperature

Living cover crops can significantly alter soil temperatures. Cover crops decreased the amplitude of day and night temperatures more than average temperatures, resulting in less variability. Cover crop mulches protect the soil from cold nights and slow down cooling. This may be a benefit in hot regions but may slow growth in cooler regions. Winter cover crops moderate temperatures in the winter. Standing crops have higher soil temperatures than flat crops. Row cleaners can be used to manage residues to improve soil temperatures in no-till fields. Corn responds to warmer soil temperatures, so strip tilling in a 4- to 6-inch band by moving the top soil residue may increase stand establishment and corn growth initially when converting from conventional tillage to no-till.

Long-term no-till farmers who use cover crops say that their soils are not cold. There are three reasons why this occurs.

First, in the transition from conventional tillage to no-till, soils tend to be compacted, keeping the soil wet and saturated. Water holds the heat and cold longer than air, which acts like an insulation. Thus cold soils tend to be wet and insulated from the atmosphere by residue on the soil surface. Cover crops in a no-till rotation allow rainfall and precipitation to infiltrate the soil (soils are more porous) and allow more air into the soil to warm it up faster. Grass cover crops can typically remove about 12 inches of soil compaction per year, so it may take one to three years to remove soil compaction that is several feet deep.

Second, as organic residues are added to the soil surface, the soil color changes from light yellow and brown to dark brown and black as organic residues decompose. Dark brown and black organic residues absorb sunlight and heat, warming the soil. This process may take another one to three years to occur.

Third, as even more organic residues accumulate on the soil surface, the intensity of the biologic activity on the soil surface increases. Biologically active organic matter like compost piles give off heat as the microbial decomposition intensifies, warming the soil. In order for this last sequence to occur, a thick layer of residue needs to accumulate on the soil surface. Long-term no-tillers and no-till farmers using cover crops say that the improved soil porosity and dark organic residues promote soil warming.

Controlled traffic and compaction

Soil compaction is a biological problem. Surface and subsoil tillage may physically break up hard pans and soil compaction temporarily, but they are not a permanent fix. Good soil structure requires the production of glomalin, formed from polysaccharides produced by plants and fungus in the soil. The plant roots provide the sugar and the fungi provide the protein to form glomalin, a glycoprotein. Glomalin coats microaggregate soil particles, forming macroaggregates, which improve soil structure and allow air and water to infiltrate and move through the soil. Tillage destroys macroaggregates by oxidizing the glomalin. Both cover crops and fungus microorganisms are needed to improve soil structure and decrease long-term soil compaction in the soil.

No-till corn (either in rotation or continuous) offers an opportunity for controlled traffic to manage compaction and provide other savings. Using GPS or RTK auto-steering to maintain exact traffic patterns means that earlier planting and more timely harvest are possible because tracks are firm, re-

sulting in higher grain yields. Precise steering means no overlap, which reduces costs of all inputs, including fuel and labor. Using GPS or RTK with a cover crop and no-till in a controlled system offers the opportunity to manage soil compaction so that it does not hurt crop yields.

Water infiltration

As a plant grows, the roots create channels and fissures in the soil called macropores. These macropores allow air and water to infiltrate and move in the soil and water to be stored. A pound of soil organic matter has the ability to hold 18 to 20 lb of water. The organic residues stabilize the soil and hold soil moisture. A bare soil that has been tilled has the ability to hold 1.5 to 1.7 inches of water while a continuously vegetated soil has the ability to hold 4.2 to 4.5 inches of water. Organic matter improves water infiltration, soil structure, and macropores in the soil. Living plants, plant roots, organic matter, and the polysaccharides in the soil (glomalin) stabilize the soil and allow it to retain more water than a tilled soil.

Cover crops produce more vegetative biomass than volunteer plants, transpire water, increase water infiltration, and decrease surface runoff and runoff velocity. If the velocity of runoff water is doubled, the carrying capacity of the water to transport soil sediment and nutrients increases by 64 times. *So 64 times more sediment and nutrients are lost with moving water when the velocity is doubled* (Walker et al., 2006). Cover crops protect soil aggregates from the impact of rain drops by reducing soil aggregate breakdown. By slowing down wind speeds at ground level and decreasing the velocity of water in runoff, cover crops greatly reduce wind and water erosion.

Cover crops decrease soil erosion by 90%, sediment transport by 75%, pathogen loads by 60%, and nutrient and pesticide loads by 50% to our streams, rivers, and lakes. As the price of fuel and fertilizer increases, planting cover crops becomes more and more economical as a way to build soil organic matter and store and recycle nutrients in the soil.

Summary

Agricultural systems that mimic the natural world tend to be more efficient, sustainable, and profitable. Using a continuous long-term no-till system with cover crops or a continuous living cover is an agricultural system that closely mimics the natural world and restores ecosystem functionality. In no-till, a thick layer of residue protects the soil from the impact of raindrops and reduces soil erosion. Soil temperatures are moderated by this residue, and soil moisture is retained in the soil profile. Water infiltration is improved, and runoff is minimized. Soil nutrients are efficiently stored and recycled in the soil by growing plants or cover crops, allowing carbon to be recycled in the soil and storing nitrogen and phosphorus. Soil pests like weeds, insects, and diseases are controlled because there is a biological diversity that generally prevents or moderates large increases in one species over another.

Growing a continuously living cover with no-till promotes healthy growing crops and reduces the problems most farmers have in growing crops with tillage (hard soil, cloddy soils, soil compaction, runoff, soil erosion, nutrient losses, annual weeds, insects, and soil diseases). Tillage creates problems with soil compaction, water infiltration, soil structure, and nutrient recycling.

Converting to no-till, however, requires a transition period because the biological diversity has been diminished with tillage. Natural systems are fragile, and once they have been disturbed, it takes time to restore the ecosystem functionality. As the carbon is decomposed and released to the atmosphere, the capacity to store nutrients in the soil is diminished. The fastest way to build soil organic matter levels is to grow plants continuously using long-term no-till so that the residues are not decomposed.

Continuous no-till plus a cover crop mimics natural cycles and promotes nutrient recycling and improved soil structure to improve crop production. ■

This article has been adapted from an Ohio State University Extension Fact Sheet, "Using Cover Crops to Convert to No-Till," SAG-11-09.

References

Magdoff, F., and H. van Es. 2001. Building soils for better crops. 2nd ed. Sustainable Agriculture Network, Beltsville, MD.

Schaetzl, R., and S. Anderson. 2006. Basic concepts: soil organisms. p. 93–105. *In* Soils: Genesis and morphology. Cambridge University Press, Cambridge, UK.

Sustainable Agriculture Network. 2007. Managing cover crops profitably, 3rd ed. Sustainable Agriculture Network, Beltsville, MD.

Tisdall, J.M., and J.M. Oades. 1982. Organic matter and water-stable aggregates in soils. J. Soil Sci. 33:141–163.

Walker, D., D. Baumgartner, K. Fritzsimmons, and C.P. Gerber. 2006. Surface water pollution. p. 279–311. *In* I.L. Pepper, C.P. Gerber, and M.L. Brusseau (ed.) Environmental and pollution science. Academic Press, New York.

Additional resources

Ohio State University Extension offers several fact sheets related to cover crops on their web site (http://ohioline.osu.edu):

- Crop Rotations with Cover Crops
- Understanding Soil Ecology and Nutrient
- Recycling
- Homegrown Nitrogen
- The Biology of Soil Compaction
- Using Cover Crops to Improve Soil and Water Quality

Radishes: A new cover crop option

Forage radish. Photo courtesy of Sjoerd Duiker, Penn State.

Planting forage or oilseed radishes began to take root several years ago, and their use as cover crops is growing. Both are members of the mustard family (Brassicaceae), which has a long history of being used for cover crops and animal forages. Forage radish (*Raphanus sativus* L. var. *niger* J. Kern.), also known as the daikon radish or Japanese radish, has a very large taproot. Originally developed for oil production, oilseed radish (*R. sativus* L. var. *oleiformis* Pers.) is similar to the forage radish, but its taproot is stubbier and more branched, and it tends to be somewhat more winter hardy than the forage radish.

Forage and oilseed radishes can be helpful in no-till operations where their large roots can help retain soil moisture and reduce erosion. They are excellent at breaking up shallow layers of compacted soils, earning them the nickname "biodrills" or "tillage radishes." Once planted in late summer, the radishes are not harvested but die in the winter, decay, and contribute a nitrogen store for spring planting. Dying off in the winter, the radishes leave root channels so that soil dries and warms up faster in the spring.

As part of a recent Illinois extension telnet series on utilizing cover crops in conventional cropping systems, Joel Gruver, assistant professor of soil science and sustainable agriculture at Western Illinois University, spoke on the benefits and management of brassicas and legumes as cover crops.

"Cover crops are multi-functional," Gruver said. "It is important to remember that capturing multiple benefits takes more management. Cover crops are not idiot proof, but there are few profits in idiot-proof systems!"

If you want to reduce soil compaction, good cover crop choices are radish, canola, turnip (and hybrids), sugarbeet, sunflower, and sorghum-Sudangrass, according to Gruver. For nitrogen fixation, legumes such as clovers, vetches, lentils, cowpeas, soybean, and field peas are best. For nutrient cycling, Gruver recommended sunflower, sugarbeets, brassicas, and small grains.

Brassica cover crops have a number of beneficial attributes, including rapid fall growth, high biomass production, a well-developed taproot, excellent nutrient-scavenging ability, high responsiveness to nitrogen, competitiveness with other plants, and special pest resistance capabilities.

According to Gruver, the large taproot of radishes and other brassicas gives the crops an above-average ability to penetrate compacted layers; this promotes deeper rooting by subsequent crops and increases water infiltration. The residue from brassicas decomposes very quickly, and this means that they immobilize less nitrogen than cereal cover crops and often result in net nitrogen mineralization. They also tolerate cold temperatures very well.

An additional special feature of most brassicas is that they produce compounds, called glucosinolates, which are toxic to soil-borne pests and pathogens. Mustards usually have higher concentrations of these chemicals. More than 100 different glucosinolates are found in brassicas. Breakdown products from glucosinolates are volatile and similar to the active chemical in the fumigant Vapam. Glucosinolate concentrations differ according to plant part, age, health, and nutrition. Despite this complexity, Gruver said there is evidence that brassica cover crops can be used to reduce pests, pathogens, and weeds if the right species/cultivar is planted and managed strategically.

Benefits of radishes

Various research groups have been growing different types of radishes in

different areas to determine their efficiency as a cover crop.

Ray Weil, Charlie White, and Yvonne Lawley at the University of Maryland have studied the use of forage radish. Although it is fairly new to the Mid-Atlantic region, the use of forage radish as a cover crop has some advantages over other cover crops in the region. Mathieu Ngouajio and Dale Mutch at Michigan State University have experimented with the use of oilseed radish. Because of its quick establishment and rapid growth in cool weather, it has been used successfully in Michigan as a cover crop in diverse production systems.

According to the Michigan researchers, the classification of these and other types of radishes is not well defined because they can easily cross-pollinate, and therefore distinctions among subspecies are often blurred. Most of the traits and management recommendations described in this article apply to both forage and oilseed radishes.

One of the great features of forage radish cover crops is that they can be used as a biological tool to reduce the effects of soil compaction, hence the term "tillage radish." The roots of all cover crops can penetrate compacted soils in fall to some extent because they are growing when soils are relatively wet and soft. But the Maryland researchers found that forage radish roots can penetrate plow pans or other layers of compacted soil better than most other cover crops. The thin lower part of the taproot can grow to a depth of 6 ft or more during the fall. The thick, fleshy upper part of the taproot grows 12 to 20 inches long and creates vertical holes and zones of weakness that tend to break up surface soil compaction and improve soil tilth. After the cover crop dies in the winter and its roots decompose, the remaining root channels are used by the growing roots of following crops to penetrate compacted deep soil layers.

In Maryland research, four times as many corn roots penetrated compact subsoil after a forage radish cover crop than after winter fallow, and twice as many as after a rye cover crop.

Data suggests that biodrilling with cover crops like forage radish can substitute for expensive and energy-intensive deep ripping and other mechanical methods to reverse soil compaction. Some farmers plant forage radish in 24- or 30-inch-wide rows (with another cover crop species broadcast in between rows—see "Cover Crop Cocktails" section on page 17) to maximize its root-to-shoot ratio. They then plant the following summer crop in these same wide rows to alleviate restriction of root growth into the subsoil.

In a similar manner, oilseed radish produces large taproots. Upon decomposition, these roots leave large holes in the ground that improve water infiltration and possibly soil microbial activity.

Oilseed radish emerges shortly after planting and provides quick ground cover that smothers weeds. When planted in fall, it prevents weed germination and, consequently, seed production. Early planted forage radish can also produce a dense canopy that all but eliminates weed emergence in the fall and winter. To obtain this near-complete weed suppression, forage radish should be planted by September 15 (in Maryland) with a stand of 5 to 8 plants/ft^2. The near-complete weed suppression can be expected to last until early April but does not extend into the summer cropping season.

Oilseed radish can scavenge nitrate from deeper soil layers after harvest of the cash crop. Upon decomposition, the nitrogen uptake becomes available to the next cash crop. In the Michigan State tests, a cultivar called Renova, for example, was shown to recycle more than 140 lb of nitrogen/acre in a growing season. In muck soil, the common cultivar recycled more than 60 lb of nitrogen/acre in two months. The Maryland group found that, unlike rye and other cereal cover crops whose residues decompose slowly and immobilize nitrogen in the spring, forage radish residue decomposes rapidly and releases its nitrogen early. In fact, on sandy soils, it is important to plant as early as possible, following forage radish cover crops, to take advantage of this flush of nitrogen before it leaches out of the rooting zone. Forage radish recycles large amounts of N taken up from the soil profile in fall and can reduce the need for nitrogen fertilizer in spring.

One of the great features of forage radish cover crops is that they can be used as a biological tool to reduce the effects of soil compaction, hence the term "tillage radish".... After the cover crop dies in the winter and its roots decompose, the remaining root channels are used by the growing roots of following crops to penetrate compacted deep soil layers.

Growing radishes as a cover crop

Oilseed radish cultivars used as cover crops include the common variety, Adagio, Arena, Colonel, Remonta, Revena, Rimbo, and Ultimo. According to the Michigan researchers, most of these cultivars are imported from Europe. The common cultivar is the most readily available in Michigan. ▶

Left: **Oilseed radish taproot compared with 1-ft ruler.** *Photo by Alan Sundermeier.* ***Right:*** **"Tillage radishes" can be used as a biological tool to reduce the effects of soil compaction.** *Photo by Steve Groff (www. tillageradish.com).*

Oilseed radish seed is generally more expensive than seed of other cover crops commonly grown in Michigan.

Whether planted in spring, late summer, or early fall, oilseed radish grows quickly and produces a large amount of biomass in a relatively short time. Four oilseed radish cultivars (Adagio, Arena, Rimbo, and common), seeded in August, were tested in Michigan over two years and produced similar amounts of dry biomass. Total biomass generally exceeds 4 tons/acre. Most cultivars produce more shoot than root biomass, but the common cultivar produces more root biomass and tends to have a better balance of shoot-to-root biomass. Because oilseed radish establishes very fast, even under moderate drought situations, the plants provide good protection against wind and water erosion, which can be particularly helpful for muck or sandy soils.

Oilseed radish seeding rates are typically 10 to 20 lb/acre. Studies conducted in Michigan showed that rates of 10, 15, and 20 lb/acre produced similar amounts of biomass. Low rates are generally recommended because of the high cost of seeds. In some situations, however, high rates may be more beneficial. These include cases where control of weeds, diseases, and nematodes is the primary focus. Oilseed radish leaves low surface residue in the spring, so it is very appropriate for crops that require a well-prepared seedbed. To improve weed and pest management, planting oilseed radish on the same field more than two years in a row is not recommended.

The Maryland researchers recommend seeding at 8 to 10 lb/acre using either a conventional or no-till drill or by broadcasting at 12 to 14 lb/acre to establish a good stand of forage radish. When using a drill, seeds are best planted between 0.25 inches deep (when moisture conditions are good) and 1 inch deep (during dry conditions). When broadcasting, germination will be best if the seeder is followed by a corrugated roller or very light disking to encourage some seed–soil contact.

Aerial seeding has been successful using 14 to 16 lb/acre broadcast into standing corn or soybean canopies that have begun senescence (yellowing of lower leaves). Forage radish usually emerges within just three days if the soil is warm and not too dry. Even unincorporated broadcast seed will achieve rapid germination if seeding is followed by a timely rain or irrigation.

Forage radish has a very flexible and aggressive growth habit and will spread out in a rosette to fill the space it is given. Radish plants—especially their fleshy root—will become much larger when grown at lower plant densities.

In the Mid-Atlantic, forage radish grows best when planted in late August or early September, but significant amounts of N can be captured by this cover crop when planted as late as October 1. Forage radish planted in late September may be less susceptible to frost and more likely to overwinter. When planted in late March as a spring cover crop in Maryland tests, forage radish did not emerge quickly or grow as well as when planted in fall.

Forage radish is tolerant of frost until temperatures dip below 25°F. It takes several nights of temperatures in the low 20's to kill forage radish. If mild temperatures resume and the growing point is intact, green leaves may grow back. Under the freeze–thaw winter conditions of the Mid-Atlantic, forage radish tissues (shoots and roots) decompose rapidly once killed by frost and leave only a thin film of residue by March.

Research indicates that forage radish winter cover crops can fit well into corn silage and vegetable crop rotations that have openings for cover crop planting by the end of August. Forage radish has successfully been aerially seeded in early September into standing corn grain and soybeans on commercial farms. Because forage radish seeding rates are low, the seed may be mixed with other cover crop seed of similar size to bulk it up for more even aerial seeding. If planted in late September, growers may not achieve effective biodrilling and weed suppres-

sion, but significant amounts of nitrogen can still be captured.

Avoiding problems

According to Gruver, the brassicas have some special management concerns. They are not well adapted to poorly drained soils. Forage radish does not tolerate very wet soils, so avoid planting it in low spots that collect standing water.

Some brassicas have proved difficult to kill with glyphosate—requiring rates of at least 1 qt/acre and possibly multiple applications. Gruver recommends adding 1 pt/acre 2,4-D if possible. Also, they are sensitive to a number of herbicide carryovers. Many of the Group 2 herbicides and the triazine herbicides can have soil residuals that may injure oilseed radish seedlings.

In Maryland, researchers found that nitrogen deficiency will limit forage radish growth and may limit its ability to compete with weeds or grow through compacted soil. Nitrogen deficiencies have been observed when planting after silage or grain corn on sandy soils or soils that do not have a history of manure application. Nitrogen-deficient plants have also been observed to be less susceptible to frost and are more likely to overwinter. If they survive the winter, forage radishes may be attacked by harlequin bugs and flea beetles.

Seed production by oilseed radish may lead to volunteer plants in succeeding crops. In Michigan, this is normally not a problem because oilseed radish planted in August or September will be killed by frost before setting seeds.

Purchase oilseed radish seed early because it may be difficult to locate. Also, growers are warned that during warm spells in winter, rotting forage radish residues may produce a rotten egg-like odor.

Cover crop cocktails

Some farmers are experimenting with cover crop mixtures that combine radishes with other cover crops that fix nitrogen or provide nitrogen-immobilizing residues in the spring.

According to Gruver, current research does not indicate a strong advantage in using these mixes, but individual growers can sometimes get good value for a mix of seeds. He believes additional research on cover crop cocktails is needed.

Gruver said radish seeds cost more than most other cover crops—about two to three times more per acre as seeds for cereal rye, for example. Some farmers plant alternating rows of radishes with other cover crops to try to save money.

Spring oats and sorghum-Sudangrass compete well with forage radish, and since they stop growing in the winter in the Mid-Atlantic, they provide longer-lasting residues to immobilize some of the nitrogen released from forage radish residues in the spring. These additional residues may also help maintain soil moisture, reduce weed growth, and reduce erosion during the next growing season. When rye is mixed with forage radish, the rye overwinters and grows into the spring when it can take up the nitrogen released by the decomposing forage radish. Hairy vetch is a nitrogen-fixing cover crop that overwinters and has performed well when mixed with forage radish. Sun hemp fixes nitrogen but will winter kill with the forage radish in the Mid-Atlantic. ■

Portions of this article were adapted from the following sources:

"Forage Radish: New Multi-Purpose Cover Crop for the Mid-Atlantic," published by the University of Maryland Cooperative Extension (http://extension.umd.edu/publications/pdfs/fs824.pdf).

"Oilseed Radish: A New Cover Crop for Michigan," published by Michigan State University Extension (http://fieldcrop.msu.edu/documents/E2907%20Oilseed%20Radish.pdf).

Foodborne pathogens | FROM PAGE 37

production. The centralization and internationalization of food production means that when a problem does occur, it can easily become dispersed. Additionally, new technologies have created gaps in the food safety system, as these improvements come with new requirements for inspection and enforcement, which potentially can lag behind these advancements.

"Why are we seeing so many large multistate foodborne outbreaks? I think better surveillance is part of the answer—it means we're finding some we would've missed before," Tauxe said. "But I also think that large centralized food production means when a problem occurs, it may be widespread. The shift in diet to less cooked and more fresh and raw foods and less processed foods [could be another reason]."

To improve the public health surveillance of foodborne outbreaks, faster processes are needed. The difficulty lies in funding programs on local and state levels in order to do this. At the core of this surveillance is the interview process. Determining the circumstances of one patient of an outbreak can help save many lives, and the development of a core standard of questions can be beneficial to future investigations.

Despite the rigorous efforts of the CDC and other local and state public health agencies, Tauxe warned that future disease outbreaks from foodborne pathogens is likely to occur.

"I think we're going to continue to have problems—I expect the unexpected. New pathogens and new foods arise in new combinations…but with attention to the ecological settings in which we raise the animals and plants, I am sure that there are practical control measures that can be devised. They just need to be explored." ■

How does your salary match up?

Whether you need to fill a position, conduct a performance evaluation, seek a new job opportunity for yourself, or negotiate a new salary, a key factor is the ability to make a competitive analysis based on market factors.

For many years, the American Society of Agronomy (ASA), Crop Science Society of America (CSSA), and Soil Science Society of America (SSSA) have periodically conducted a survey of faculty salaries in departments of agronomic, crop, soil, and environmental sciences. We've gathered data on types of positions as well as minimum, median, and maximum salaries by position, department type, department and institution size, appointment length, and professional focus.

For 2010, we'll be expanding the survey to include all members and certificants in our professions—whether in academia, government, private industry, or consulting. By expanding the survey, we will be able to:

- Compile comprehensive, quantifiable information that is relevant for our members and certificants.
- Demonstrate that the pay in our professions is comparable to other professions, which will be particularly useful in career recruitment.
- Demonstrate that certificants (CCA, CPAg, CPSS, and CPSC) have higher earning power than those not certified.
- Reach out to those beyond the traditional academic departments.

Participate in the survey

Beginning in late November 2009, all members and certificants will be contacted via email, requesting their participation in the survey. Information to be gathered will include type of employer, job title, job functions, salary, and basic benefits. The data will be compiled and reported collectively, based on specific criteria such as job title, region of North America**,** employer type, and more. At no time will individual data be reported (in fact, minimum numbers of participants will be required in order to report information). Survey data collection will be conducted for several months, with reports available in spring 2010.

We are also working to expand the data collection to other organizations and their members to increase the scope of the report.

eNetrix, A Gallup Company with extensive experience in working with professional societies, has been retained to develop and conduct the survey. The company has 30+ years of compensation-consulting expertise with 10+ years of developing and conducting online compensation surveys. All data collection will be done through eNetrix's web application, and all individual salary and benefits information will be collected directly by the company.

Watch for emails requesting your participation. Thank you in advance for your participation. ■

Find your next job, employee at careerplacement.org

Job seekers, are you ready to find your next career opportunity? Employers, are you looking for the next addition to your team? Then check out the new and improved ASA–CSSA–SSSA Career Placement Center at **www.careerplacement.org**.

Certification holders (CCA, CPAg, CPSS, and CPSC) looking for jobs can post resumes free of charge through our easy-access submission site. They can also create more than one resume to target different job opportunities and select categories for employers to conduct resume searches. But that's not all—resumes can be searched based on any criteria in your resume.

Employers can search our resume database to find that qualified practitioner and agronomic, crop, soil, or environmental professional. Resumes can be searched using a wide range of criteria, so you can find the right individual to match your position. You can also browse all the resumes posted by the date submitted.

For more information, go to www.careerplacement.org, email lmalison@agronomy.org, or call 608-268-4949. ■

Canada East

Squeezing more value from manure with cover crops

By Brian Hall, edible beans and canola specialist, Ontario Ministry of Agriculture & Food & Rural Affairs, Stratford, ON, Canada

Establishment of cover crops following manure applied in late summer has been promoted as a means of reducing manure nitrogen (N) losses to the environment through leaching and increasing manure N availability to the following corn crop. Except for red clover, changes in corn N requirements associated with cover cropping have not been extensively evaluated in Ontario. Seventeen on-farm trials were conducted in southern Ontario from 2003–2008 to evaluate the potential of three commonly available cover crops (oats, oilseed radish, and field peas) for (i) their ability to sequester manure N when seeded immediately following manure applied in August on wheat stubble fields and (ii) their impact on corn N requirements the next year.

Shortly after cereal harvest (usually in August), manure was applied and oat, oilseed radish, and field pea cover crops were seeded. Strips where manure was not applied were included in each trial to evaluate the impact of manure on cover crop growth, N uptake, and N transfer to next year's corn. The rate of manure applied was typical for each farm with an overall average manure ammonium N application of 80 lb of N/acre. The cover crops were allowed to grow until the end of the growing season (November) at which time fall tillage was conducted according to the cooperator's discretion. The following spring, plots were split with half of the plots receiving an additional 150 lb of N/acre of fertilizer N side-dressed as urea ammonium nitrate in early to mid-June.

Cover crop growth and N uptake

Both oat and oilseed radish growth and N uptake were clearly higher where manure was applied. Table 1 shows the cover crop and N uptake values averaged across all sites. Applying manure increased oat and oilseed radish growth by about 1,000 lb/acre and N uptake by about 35 lb of N/acre.

Both oat and oilseed radish cover crops resulted in late-fall soil N levels following manure that were similar to those observed when manure was not applied (Table 1). This suggests that establishing either oat or oilseed radish cover crops can reduce the potential for fall N leaching following summer-applied manure to levels that are similar to when manure is not applied.

Field peas often were more difficult to establish and generally did not produce more above-ground growth than oats (Table 1). As a legume, field pea can fix N, resulting in above-ground N content that was about twice that of either oats or oilseed radish when manure was not applied. Following manure, field peas had N contents similar to either oats or oilseed radish. Higher late-fall soil N levels following field peas suggest that oat or oilseed radish are a better choice for reducing fall soil N levels following late-summer manure application.

Corn response

Corn yield response to manure, cover crops, and fertilizer N application averaged across all 17 sites is shown in Table 2. When nitrogen was not applied, corn yields were not significantly increased by either oat or oilseed radish cover crops compared with when a cover crop was not planted. Also, the yield response to applying 150 lb of N/acre following oats or oilseed radish was not less than when a cover crop was not planted. These corn yield responses to oat or oilseed radish cover crops suggest that fertilizer N requirements were not reduced compared with when a cover crop was not planted. The maximum economic rate of nitrogen (MERN) estimates included in Table 2 clearly indicate that oat and oilseed radish cover crops, on average, did not reduce corn fertilizer N requirements when manure was or was not applied the previous summer.

Field peas did slightly increase yields when fertilizer was not applied and did have a slightly smaller yield response to adding fertilizer N when

Table 1. Effect of late-summer manure application on cover crop yield, nitrogen content, and associated soil N levels in surface 12 inches measured in November.

Manure cover crop	Cover crop yield	Cover crop N	Soil N
	lb dry matter/acre	lb N/acre	
No manure			
Oats	1,800	28	29
Oilseed radish	1,360	25	31
Field peas	1,590	53	37
No cover planted†	470	5	40
Manure applied			
Oats	2,620	61	40
Oilseed radish	2,530	65	35
Field peas	1,850	63	50
No cover planted†	650	9	56

† Yield and N content of weeds and volunteer cereal growth.

manure was not applied (Table 2). The field pea credit averaged about 23 lb of N/acre when manure was not applied. When manure was applied, use of field peas did not significantly increase N availability to corn.

Corn yields following any of the cover crops were similar to when a cover crop was not planted (Table 2), suggesting that these cover crops are not consistently associated with a rotation benefit that increases corn yield potential.

Summary

Oat or oilseed radish cover crops usually did successfully establish and grow when seeded into cereal stubble fields in August, especially when manure was applied. Sufficient growth of oats or oilseed radish usually occurred, reducing the risk of soil erosion and soil N leaching losses following manure incorporated in summer. However, fertilizer N requirements of corn planted the next year were not reduced by either oat or oilseed radish cover crops.

Field peas were more difficult to establish and did not significantly reduce the risk of soil N loss following manure application. Field pea credit when manure is not applied averaged about 23 lb of N/acre, a reduction in fertilizer N cost that, even at current N prices, would not cover the seeding cost of a pea cover crop.

Reducing the risk of soil erosion and fall soil N leaching losses on susceptible fields is a sufficient reason to justify establishment of either oat or oilseed radish cover crops following manure incorporated in summer. Field pea cover crops, owing to their ability to fix N, are best suited as a cover crop for fields with low N availability where either oat or oilseed radish cover crop growth would be limited by N availability.

These short-term trials were not designed to evaluate the potential long-term benefits that cover crops may potentially have on corn yield and/or N availability. Unfortunately, it does not appear that August seeding of oat, oilseed radish, or field pea cover crops into cereal stubble fields will reduce corn fertilizer N requirements and/or increase yield sufficiently to cover the cost of seeding the cover crop. ■

▶ **Table 2. Corn yield response to manure application, cover crops, and fertilizer N.**

	Corn yield			
Manure cover crop	**0 lb N/acre**	**150 lb N/acre**	**Response†**	**MERN††**
	bu/acre			lb N/acre
No manure				
Oats	**123**	**167**	**44**	**83**
Oilseed radish	**131**	**170**	**39**	**77**
Field peas	**144**	**174**	**30**	**53**
No cover planted	**136**	**175**	**38**	**76**
Manure applied				
Oats	**157**	**177**	**20**	**40**
Oilseed radish	**161**	**179**	**18**	**37**
Field peas	**162**	**176**	**15**	**29**
No cover planted	**162**	**177**	**18**	**37**

† Yield increase associated with applying 150 lb of N/acre of fertilizer N.
†† Estimate of maximum economic rate of nitrogen predicted by the size of yield response to fertilizer N assuming a corn price of $5.00/bu and a fertilizer N price of $1.00/lb of N.

North Central

Illinois CCA Convention

The Illinois CCA Convention will be held on Dec. 17, 2009 at the Crowne Plaza in Springfield. There'll be great speakers on hot topics, CEU credits, good food, and networking. Registration materials will be available in November. Go to www.illinoiscca.org or contact Lisa Martin at lisam.martin@verizon.net or 815-844-6677 for more information.

Ohio CCAs promote their professionalism

Ohio State University Extension's 47th annual Farm Science Review was held September 22–24 at the Molly Caren Agricultural Center in London, OH. With more than 600 commercial exhibitors and 138,014 attendees over the three-day event, the Ohio CCA board saw this as perfect opportunity to showcase the professionalism of the CCA program. Members of the board distributed CCA signs to all exhibitors employing CCAs. Exhibiting companies were asked to place the sign, listing their CCAs, in a conspicuous location within their exhibit.

South Dakota Agronomy Conference

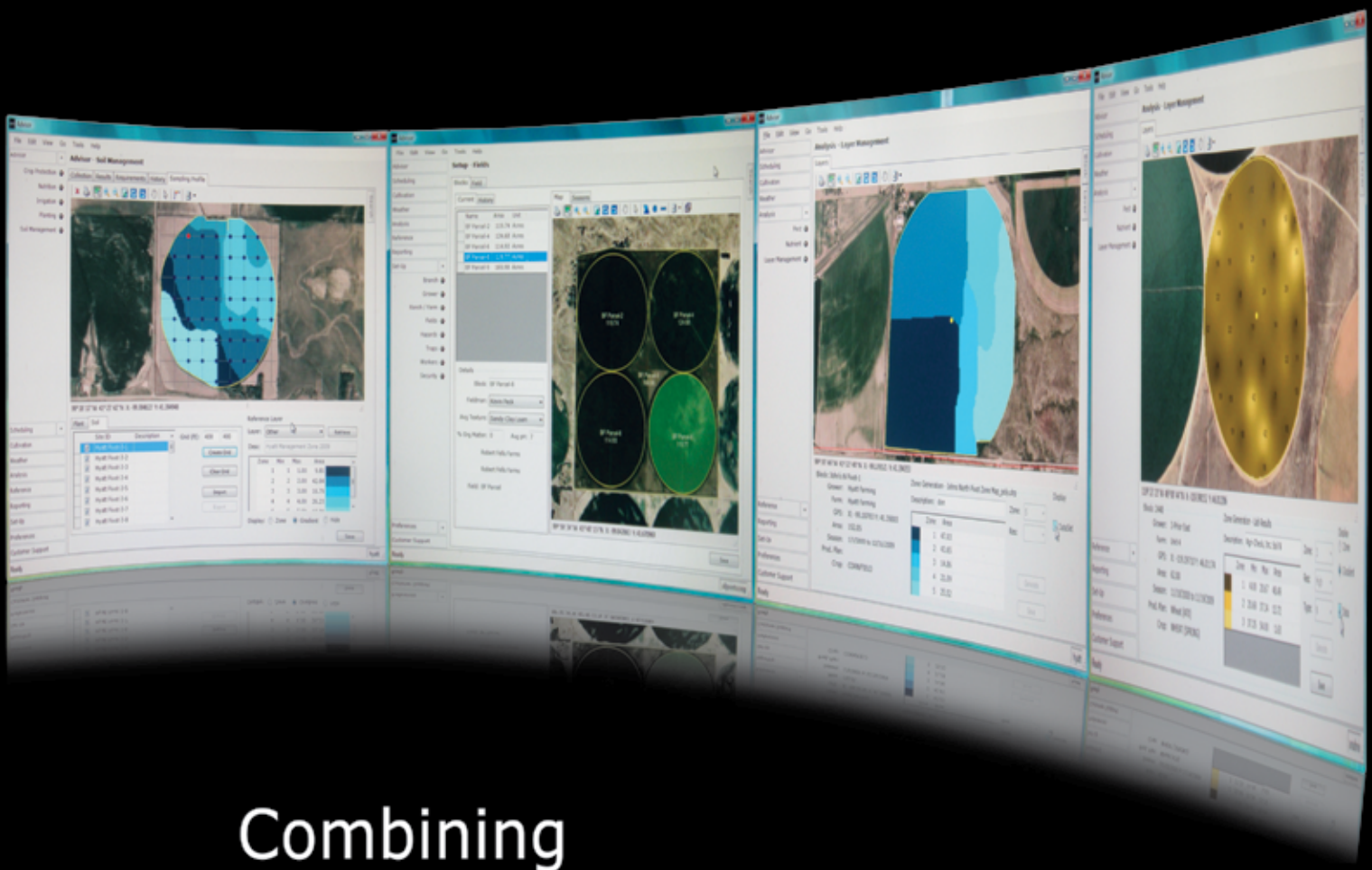
The South Dakota Agri-Business Association's (SDABA) 2009 Agronomy Conference will take place December 15 and 16 in Sioux Falls. This is the eighth year for this two-day conference, which has gained recognition from CCAs for its comprehensive program that keeps them abreast of current agronomic topics. It's also a great way to catch up on CEUs (CCAs can earn up to 20 at this conference—five in each category) before the end of the year. The conference will feature experts from several state universities and national companies covering many different topics. Complete information on the program and how to register can be found online at www.sdaba.org; or you can call 605-224-2445 for more information. ■

ADVISOR | CDMS Applied Intelligence

The Next Generation Agronomy Management System

ADVISOR IS A COMPREHENSIVE WEB-BASED AGRONOMY MANAGEMENT SYSTEM providing decision support for agronomic best practices, GIS based field activity, and connectivity between all participants in the food production continuum.

With its comprehensive approach to crop production, ADVISOR can be applied to virtually any input requirement for optimizing crop production.



Combining Agronomy & Technology

- Web-based for Mobility and Flexibility
- Full GIS/Mapping Features
- Precision Ag and VRA Support
- Planning, Planting, Field Applications and Harvest

CDMS | Data Logic Knowledge

800.237.2367 | sales@cdms.net | www.cdmsadvisor.com

Self-Study Course

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

Organic vegetable systems improved: Optimizing weed suppression and plant growth with legume–oat cover crops

Organic vegetable production has become more common in the central coast of California. For example, in 2007, 111 farms in Monterey County produced $226 million of organic crops. Annual rotations in these systems typically include two or more vegetable crops during the warmer periods, followed by a fallow period, cover crop, or vegetable crop in the cool season.

The benefits of cover crops on soil and water quality include improved N use efficiency in high-input cropping systems. Cover crops are more common on organic than conventional farms and often include mixes of legumes and cereals. It has been reported that in some years, the N content of a rye–vetch mix was more than twice as high as in rye monoculture, presumably because such a mix combines the N-scavenging characteristics of the cereal with the N-fixing ability of the legume.

Weed growth in winter cover crops can be a problem on the central coast of California because many weed species germinate all year and can produce seeds during the winter. To try to reduce weed management costs in subsequent cash crops, a research team looked at how seeding rate and planting arrangement affected cover crop growth and weed suppression. Their study was published in the July–August 2009 issue of *Agronomy Journal* (101:979–988).

The study occurred during two consecutive winters (November to April) from 2003 to 2005 on certified organic farms in Hollister and Salinas, CA. The Hollister site is a diversified organic vegetable and fruit farm, and the soil is a Clear Lake Clay (fine, smectitic, thermic Xeric Endoaquerts). The Salinas site is the USDA-ARS organic research farm, and the soil is a Chualar loamy sand (fine-loamy, mixed, thermic Typic Argixerol). Different fields were used at each site during each winter. The Hollister site has been in an intensive organic vegetable and cover crop rotation since 1990 with annual additions of compost and supplemental organic fertilizers. Bulb onions and melons were grown in 2003 and 2004, respectively, before the Hollister trial. In contrast, the Salinas site was used for oat hay production from 1990 to 1996, followed by frequent fallow periods and occasional organic vegetables and cover crops with minimal additions of compost or supplemental organic fertilizers. Buckwheat cover crop and baby leaf spinach were grown in 2003 and 2004, respectively, before the Salinas trial. Specifics of the trials can be found in the *Agronomy Journal* paper mentioned above.

The study included a cover crop mix containing 90% legumes (35% bell bean, 15% 'Lana' woolypod vetch, 15% purple vetch, and 25% 'Magnus' pea) and 10% oat ('Cayuse' oat) by seed weight. The cover crop seed was inoculated with Rhizo Stick *Rhizobium* inoculant (Becker Underwood, Ames, IA) before planting. Three seeding rates (100, 200, and 300 lb/acre) and two planting arrangements (one-way versus grid pattern) were evaluated; 100 lb/acre is a typical seeding rate in this region.

Rainfall was higher in Year 2 than Year 1 and was below the 13-year average both years in Hollister and in Year 1 in Salinas. Irrigating winter cover crops during dry periods is seldom a cost-effective option because the sprinkler pipes used to germinate the crop are removed early in the fall before they are covered with vegetation. Intermittent irrigation in winter cover crops is possible with linear-move irrigation systems, but these are less common in the area than hand-moved sprinkler systems. Late rainfall, as occurred in Year 2, can be problematic if cover crops produce seed or when excessive soil moisture delays field preparation for spring vegetable plantings that typically occur four to six weeks after mowing and incorporating the cover crop in February or March. The need for early spring vegetable plantings is a major barrier to cover cropping in the region and is why most fields are fallow over the winter and why farms that use cover crops frequently keep some fields fallow over the winter.

Cover crop planting arrangement, density, and ground cover

Planting arrangement had no affect on cover crop or weed dry matter production. This result agrees with a study with a rye cover crop that reported inconsistent effects of planting arrangement on rye and weed dry matter. Studies elsewhere reported improved weed suppression and higher dry matter and grain yield in wheat planted in a grid versus the normal row pattern, but it is assumed that potential benefits from increased spatial uniformity in the grid pattern were cancelled by the increased diversity in canopy and root architectures in the mixed cover crops in our study.

As a percentage of planted seed, total cover crop emergence across seeding rates was 59 and 78% in Salinas and 100 and 65% in Hollister, in Years 1 and 2, respectively. As expected, increasing the seeding rate increased the total cover crop density at both sites; however, proportionally fewer seeds emerged as rate increased during both years in Salinas. The seeding rate did not affect the proportion of planted seeds of each component that emerged. The percentage of plants in the mix averaged across years, sites, and

seeding rate was 26% oat, 9% pea, 60% vetch, and 6% bell bean. The ratio of legume to oat plants was unaffected by rate or year at either site.

Cover crop density and 1,000-kernel weight are seldom reported in cover crop studies but provide useful information to understand differences in cover crop performance between and within sites and may be particularly useful with mixed cover crops. The 95% confidence intervals for cover crop densities indicated more variability in Salinas than in Hollister both years. This greater variability in Salinas than Hollister may be due to biotic differences (predation, germination, emergence) between sites and years as well as the larger subsampling area for each seeding rate in Hollister compared with Salinas. The distribution of larger-seeded components (i.e., pea and bell bean) in the mixed cover crops planted in a single pass tended to be less uniform than that of smaller-seeded, more numerous components, and thus may have required a larger sampling area to accurately determine population densities.

The seeding rate and year had significant effects on percentage ground cover ($P < 0.001$) in Hollister but were not measured in Salinas. Contrary to our hypothesis, percentage ground cover by the cover crops was not greater in the grid than one-way planting arrangement. Ground cover by cover crops increased linearly ($P < 0.001$) and quadratically ($P < 0.05$) with seeding rates from 12 to 28 to 36% in Year 1 and also increased linearly with seeding rate from 7 to 13 to 20% in Year 2 for the 100, 200, and 300 lb/acre rates, respectively. Ground cover was probably greater in Year 1 because of the earlier planting date, warmer fall conditions, and increased age of plants when the ground cover measurements were taken. There was greater weed suppression with the higher seeding rates, which was likely due to the increased early-season ground cover. Increasing planting density and reducing row spacing can reduce the photosynthetic photon flux density at the soil surface and improve crop competitive ability with weeds.

Weed density and species

Early-season weed emergence was unaffected by cover crop planting arrangement or seeding rate in Hollister. Weed emergence in Hollister was probably lower in Year 2 than Year 1 because a shallow cultivation was necessary to remove weeds that germinated after an early fall storm in late October 2004 just before the Year 2 planting. This cultivation created a stale seedbed; however, this scenario is unusual before cover cropping.

Practical implications

It is important to consider whether the benefits of planting a cover crop at higher seeding rates are worth the ▶

Photo courtesy of USDA-NRCS.

increased cost of the seed. Few studies have addressed seeding rate issues with cover crops, but recommended seeding rates for a vetch–rye mix were based on the performance of the cover crop and subsequent corn cash crops as well as seed costs. This approach is appropriate, and the optimal rate would likely differ between regions and production systems due to differences in production costs and profit margins.

In the central coast of California, cover crop seed accounts for a relatively small percentage (i.e., 10–20%) of the total cost of cover cropping, considering all operations involved such as field preparation, irrigation before winter rainfall, land rent, and tillage at the end of the cover cropping period. For example, the estimated cost of cover cropping in the Salinas area is currently about $325 per acre. Tripling the seeding rate with a legume–cereal mix at typical cost would only increase the cost of cover cropping by about 13% to $367 per acre. This cost is minimal compared with the production costs of roughly $7,000 per acre for organic lettuce in this region.

Determining the optimal seeding rate in a mixed cover crop is more complex than with cash crops or with monoculture cover crops. Cash crop seeding rates are usually selected to optimize the yield and quality of the harvested product. The seeding rate choices for cover crops are more complex because it is difficult to assign economic value to dry matter that is used for mulch or soil improvement and for cover crop services such as nitrate scavenging, erosion control, weed suppression, N fixation, and diversity. For example, if the main objective of cover cropping is to maximize biomass production by the end of the winter for soil improvement, the 100 lb/acre rate would be most cost effective because final biomass production was unaffected by rate, while a 300 lb/acre rate would be optimal to suppress weeds that could contribute to the weed seed bank.

A primary reason to include legumes in mixed cover crops in the region where this study occurred is to promote biological N fixation that, in theory, may reduce the need for supplemental N fertilizers in subsequent vegetable crops. The importance of N fixation in the legumes in the study is not known because it was not quantified. However, in legume–grass mixtures, N fixation was inhibited as soil N increased and the grass component became more dominant. The consistent dominance of the oat over the legume component in Hollister suggests that conditions favored the oat and that N fixation by the suppressed legume component was probably minimal. In such cases, using a nonlegume cover crop such as cereal rye, with good weed suppression and N scavenging ability, may be a more cost-effective way to add soil organic matter, suppress weeds, and improve the N budget for the farm.

While N leaching is generally less on organic than conventional systems, it may be an issue in high-value organic vegetable systems that typically use supplemental organic fertilizers.

The results of this study are applicable to both organic and conventional vegetable farms that are trying to maximize cover crop biomass production and minimize weed growth, especially in regions where year-round weed management is important. More research is needed to (i) understand how soil quality, soil moisture, and mixture composition affect the complex competition dynamics in mixed cover crops and (ii) design mixes that consistently suppress weed growth yet improve N use efficiency in high-value vegetable production systems.

It is unclear whether the potential benefits of N fixation by legumes can be achieved in a mix that is planted at a high enough density to provide ample weed suppression. In future studies with legume–cereal mixes, it would be useful to measure soil residual N levels at the cover crop planting date, N fixation, and seasonal changes in N content of the cover crop components. Such information may help to

Pea.

Oat. *Photo courtesy of the Soil and Crop Sciences Department at Texas A&M University.*

explain differences in dry matter production by the legume and cereal components and determine optimal kill dates for the cover crop. ■

Adapted from the July–August Agronomy Journal *article, "Seeding Rate and Planting Arrangement Effects on Growth and Weed Suppression of a Legume-Oat Cover Crop for Organic Vegetable Systems," by E.B. Brennan, N.S. Boyd, R.F. Smith, and P. Foster. Agron. J. 101:979–988.*

November–December 2009 Self-Study Quiz

Organic vegetable systems improved: Optimizing weed suppression and plant growth with legume–oat cover crops (no. SS 03970)

This quiz 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 "Self-Study Quizzes to Earn 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 quiz registration form and evaluation form on the back of this page.**
3. **Clip out this page, place in envelope with a $20 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 Quiz, 677 S. Segoe Road, Madison, WI 53711. You can also complete the quiz and pay online at www.certifiedcropadviser.org ($15 charge).**

1. In the central coast of California, cover crops are more common on

- ❑ a. vegetable farms.
- ❑ b. organic farms.
- ❑ c. corn acreage.
- ❑ d. non-GMO crops.

2. Why is weed growth a particular problem in winter cover crops on the central coast?

- ❑ a. Weed pressure is very high.
- ❑ b. Many weed species germinate all year and produce seed during the winter.
- ❑ c. Weed types grow rapidly in the dry air.
- ❑ d. Long fallow periods give weeds opportunity to grow.

3. Which of the following is NOT true regarding irrigating cover crops in the region discussed in this article?

- ❑ a. Using linear-move irrigation systems in winter cover crops is more common than hand-moved sprinkler in this region.
- ❑ b. Irrigating winter cover crops during dry periods is seldom a cost-effective option.
- ❑ c. Intermittent irrigation in winter cover crops with hand-moved sprinkler systems is common in this region.
- ❑ d. Sprinkler pipes used to germinate the crop are removed early in the fall before they are covered with vegetation.

4. What percent of the total cost of cover cropping does cover crop seed account for in the central coast of California?

- ❑ a. 1–2%.
- ❑ b. 5–10%.
- ❑ c. 10–20%.
- ❑ d. 20–30%.

5. A primary reason to include legumes in mixed cover crops in this region is to promote biological N fixation that, in theory, may

- ❑ a. reduce the need for supplemental N fertilizers in subsequent vegetable crops.
- ❑ b. decrease N runoff during flooding.
- ❑ c. permit faster growth of cover crops.
- ❑ d. improve soil texture.

6. Which was NOT listed as a possible reason for the greater variability in cover crop emergence in Salinas compared with Hollister?

- ❑ a. Differences in predation between sites and years.
- ❑ b. Differences in emergence between sites and years.
- ❑ c. Differences in rainfall between sites and years.
- ❑ d. Larger subsampling area for each seeding rate in Hollister.

Quiz continues next page

DETACH HERE

7. The estimated cost of cover cropping in the Salinas area is currently about $325 per acre. Tripling the seeding rate with a legume–cereal mix at typical cost would only increase the cost of cover cropping by about

- ❑ a. 13% to $367.
- ❑ b. 10% to $358.
- ❑ c. 20% to $390.
- ❑ d. 35% to $439.

8. While N leaching is generally less on organic than conventional systems, leaching may be an issue in high-value organic vegetable systems that typically use

- ❑ a. ammonia.
- ❑ b. supplemental organic fertilizers.
- ❑ c. crop rotation with alfalfa.
- ❑ d. some chemical fertilizers.

9. Using a nonlegume cover crop such as cereal rye can have several cost-effective benefits. Which of the following was NOT mentioned in the article?

- ❑ a. Suppresses weeds.
- ❑ b. Prevents erosion.
- ❑ c. Adds soil organic matter.
- ❑ d. Improves the N budget for the farm.

10. The need for early spring vegetable plantings is a major barrier to cover cropping in the California region, resulting in

- ❑ a. some crops being planted later than would be ideal.
- ❑ b. at least some fields being left fallow during the winter.
- ❑ c. cover crops being incorporated late in winter.
- ❑ d. some crops being planted earlier than would be ideal.

SELF-STUDY QUIZ REGISTRATION FORM

Name: _____

Address: _____ City: _____

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

❑ $20 check payable to the American Society of Agronomy enclosed. ❑ Please charge my credit card (see below)

Credit card no.: _____ Name on card: _____

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

Signature as it appears on the Code of Ethics: _____

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

This quiz issued November 2009 expires November 2012

SELF-STUDY QUIZ EVALUATION FORM

Rating Scale: 1 = Poor 5 = Excellent

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

Information was organized and logical: 1 2 3 4 5

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

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

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

Briefly explain any "1" ratings: _____

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

DETACH HERE

Editor's note: This is the last article in a five-part series from the International Plant Nutrition Institute titled "Know Your Fertilizer Rights," sponsored by The Fertilizer Institute and the Canadian Fertilizer Institute. The series is based on fertilizer best management practices structured around the "4R" nutrient stewardship concept. For more information, visit www.ipni.net.

Know your fertilizer rights: right place

By T.S. Murrell, U.S. Northcentral Director, International Plant Nutrition Institute, West Lafayette, IN; ***G.P. Lafond***, Scientist, Production System Agronomy, Indian Head Research Farm, Indian Head, SK, Canada; and ***T.J. Vyn***, Professor of Agronomy, Department of Agronomy, Purdue University, West Lafayette, IN

Self-Study Course

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

The 4R nutrient stewardship concept defines the right source, rate, time, and place for fertilizer application as those producing the economic, social, and environmental outcomes desired by all stakeholders to the plant ecosystem. This concept was introduced by Bruulsema et al. (2009) in an earlier article in *Crops & Soils* magazine. Following that article, subsequent authors discussed concepts of using the right source (Mikkelsen et al., 2009), the right rate (Phillips et al., 2009), and the right time (Stewart et al., 2009). This article completes the series by discussing agronomic concepts of the right place. Right place involves all nutrients and all application methods, such as broadcasting with or without incorporation, banding at various depths, and foliar applications at various growth stages. It also considers the correct location in the field and landscape.

The focus of this article is on soil applications of P and K, and examples of right place concepts are drawn from studies conducted on corn, soybean, and wheat. For soil-applied nutrients, right place involves matching the location of a nutrient supply to the zone within the soil that is accessible to the plant. As such, it is about managing fertilized soil volume—its concentration and location relative to the plant root system. This is particularly important for P and K since they have limited mobility.

Uptake of nutrients by plant roots

Both P and K move to plant roots primarily through diffusion (Barber, 1984). When a root depletes the supply of nutrients in its immediate vicinity, P and K will move limited distances to replenish this supply, but only if a more concentrated zone exists nearby. Higher concentrations supply nutrients more quickly and for a longer period of time to the depleted zone around the root.

There is a limit, however, to how quickly a root can take up nutrients (Barber, 1984). Once this limit is reached, increasing the nutrient supply does not result in any faster or greater uptake. For this reason, more than just a few plant roots must have access to a nutrient supply in order to meet total uptake requirements, particularly during rapid vegetative growth stages.

The rate at which a plant root takes up nutrients, termed flux or inflow, changes with plant age. Figure 1 (next page) shows that for both corn and soybean, flux is higher earlier in the season than it is later in the season. Uptake rates of corn roots exceed those of soybean in initial crop developmental stages; however, as plants age, soybean fluxes exceed those of corn. Additionally, throughout much of the season, root uptake of K is several times more rapid than that of P for both crops. Similar trends have also been observed for winter wheat (Gregory et al., 1979); however, for this crop, fluxes reach a second, though more diminished peak, at the start of rapid shoot growth following winter. In general, more rapid fluxes tend to occur when root growth rates are slower, allowing the plant's uptake demand to be met.

Plant roots also respond to localized, concentrated supplies of N and P. When corn, soybean, and wheat roots encounter bands of these nutrients in the soil, they initiate more branching, developing more of their root system in ▶

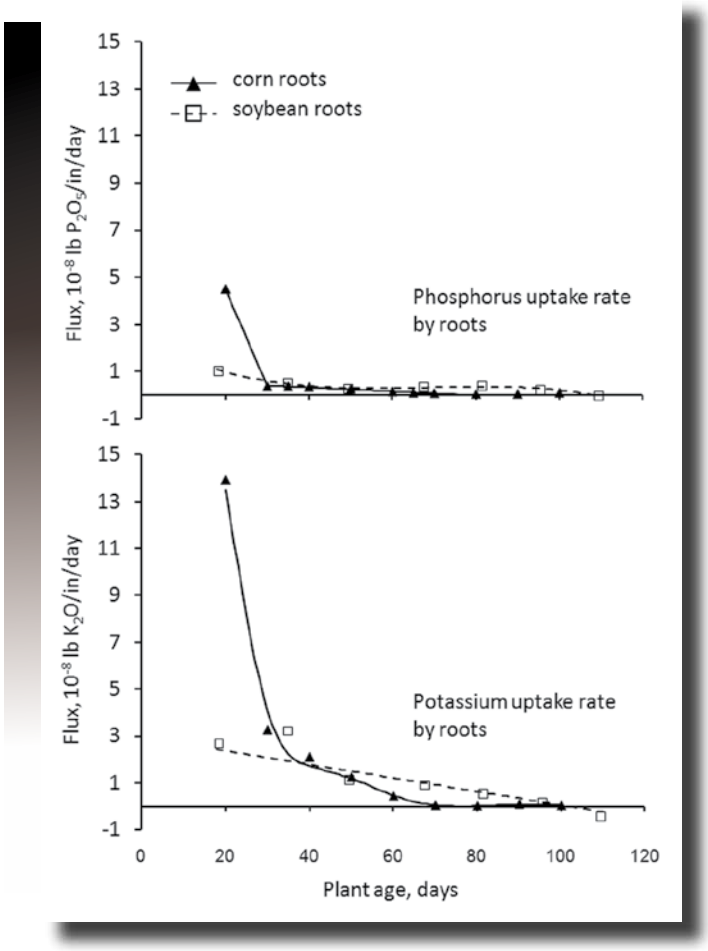


Fig 1. Changes in nutrient flux by corn and soybean roots at different plant ages (Barber, 1978; Mengel and Barber, 1974).

them (McClure, 1972; Passioura and Wetselaar, 1972; Strong and Soper, 1973; Anghinoni and Barber, 1980a; Borkert and Barber, 1985). Such effects have not been observed for K. Additionally, plants benefit from having an ammonium form of N applied in combination with P in these bands. When N is taken up in the ammonium form, the plant root exudes an acid cation to maintain charge balance. As these acid cations accumulate, the soil around the root becomes more acid, increasing the solubility of P and increasing P uptake (Soon and Miller, 1977). Such effects are greatly reduced when ammonium forms of N are applied in a band separated from P (Miller and Ohlrogge, 1958).

The implications of these findings are that a concentrated nutrient supply should be near plant roots early in the season, when root systems are not extensive but root uptake rates are at their highest. High inflow rates rapidly deplete soil nutrient levels around the root and a concentrated supply in close proximity is better able to resupply P and K. If P and K are banded, K should be placed with either P or N to ensure roots proliferate in the K band, since K alone does not promote root branching.

Managing fertilized soil volume

Creating a concentrated supply can be done through banding or increasing the overall fertility throughout the rooting zone. The fundamental dependence of placement upon nutrient rate is demonstrated in a corn study in Fig. 2. When lower rates of P were applied to a soil low in P, maximum uptake and biomass yield were achieved by limiting the fertilized soil fraction to create a concentrated supply that could better keep up with the higher flux rates of the young corn root system. However, because not enough roots could access the supply, overall uptake and biomass yield were lower than those at higher nutrient rates where a greater proportion of the root system was exposed to higher soil P concentrations. This greenhouse study demonstrates the importance of providing a volume of fertilized soil that is adequate for plant nutrient demands.

Extending these concepts to the field is not straightforward because the distribution of nutrients in the soil changes over time and with different management practices. Additionally, the volume and distribution of soil being explored by roots changes during the season as the crop responds to the soil's physical and chemical properties as well as to above-ground environmental conditions.

Increases in fertilized soil volume can be achieved through higher rates of P and K broadcast and then incorporated through tillage. This approach has been followed in much of the eastern Corn Belt. Using this approach generally results in an initial spike in soil fertility that decreases exponentially with time if no further additions are made (Mallarino et al., 1991). Another approach to increasing fertilized soil volume is to make repeated applications of banded nutrients, as is done in much of the western Corn Belt, the Great Plains, and the Canadian Prairies. Such an approach results in soil fertility levels that slowly increase over many years (Zentner and Campbell, 1988; Zentner et al., 1993). The effect of a banded application on fertility levels over time depends greatly on the rate applied and the frequency of the application. Stecker et al. (2001) investigated how P concentrations in a band change over time in a no-till system (Fig. 3). They predicted that increases in fertilized soil volume could only be achieved when a higher rate of P was banded annually in a corn–soybean rotation. The lower rate banded annually or both rates banded biannually kept fertilized soil volume essentially unchanged or decreased it.

In reduced-tillage systems, lack of soil mixing results in higher concentrations of nutrients near the soil surface compared to those deeper in the soil profile—a more limited fertilized soil volume. While the higher concentrations promote greater root proliferation near the surface (Bauder et al., 1985), nutrient distribution may not be adequate, particularly under drier conditions. For instance, positive corn yield responses have been observed under drier situations when K is applied in deep bands that create a higher volume of fertilized soil deeper in the profile (Bordoli and Mallarino, 1998).

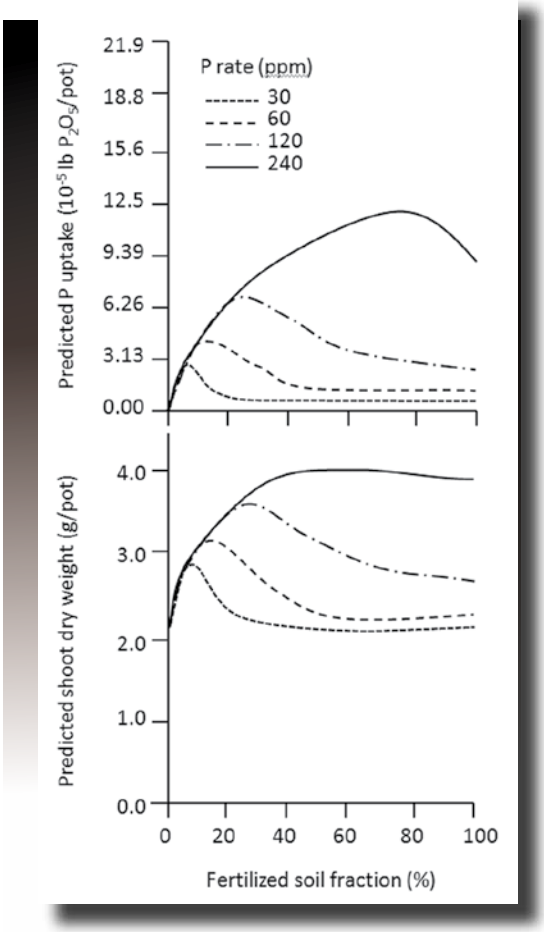


Fig. 2. The influence of P rate on the volume of fertilized soil required to maximize P uptake and dry matter yield of 18-day-old corn grown in greenhouse conditions (Anghinoni and Barber, 1980).

In crops like corn and wheat, many studies have shown the importance of including a band of concentrated nutrients near the seed at planting (termed starter fertilizer). For instance, such a fertilization strategy is common practice for P applied to spring wheat grown in the Canadian Prairies. Placement of P near the seed is important to meet the higher flux rates of wheat roots early in the season. Additionally, proper early-season P nutrition is important for tiller initiation—an important component of final grain yield. Positive wheat responses to starter applications of P have occurred in this area even on soils with a history of broadcast or banded P applications (Wagar et al., 1986).

The need for a starter fertilizer may diminish as nutrient levels in the soil increase. Bundy and Andraski (2001) surveyed 100 farms in Wisconsin, most of which had soils testing high in P. They found no relation between probability of corn response to N-P-K starters and soil test P but did find that when K fertility level was lower, probability of response increased, particularly when longer-season hybrids were planted later. Vyn and Janovicek (2001) also noted that response to starter K was more likely at lower soil test K levels in no-till systems. Such observations demonstrate that

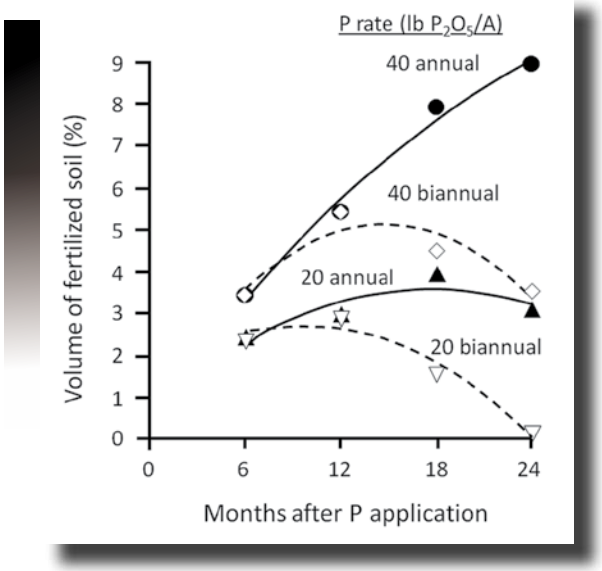


Fig. 3. Predicted volume of P-enriched soil after applications of various P rates banded 2 inches to the side and 2 inches below no-till corn seed planted in 30 in rows (Stecker et al., 2001).

in higher-fertility soils, further increases in fertilized volume through the application of a starter fertilizer may be unnecessary.

Managing limited root access to nutrient supplies

Management practices, both for P and K nutrients as well as others, can affect the plant's ability to access the volume of soil fertilized. As demonstrated above, reduced tillage and the resulting stratification of nutrients is one example. However, there are others.

Row position on fields with a history of banded P and K applications is an important consideration for nutrient access, particularly when the nutrient needs of all crops in a rotation are considered. As an example, Yin and Vyn (2003) compared yields of soybean grown directly over bands of K applied the previous corn season to those growing between the bands. Bands of K were spaced 30 inches apart for the previous corn crop. Soybeans were grown in 15-inch rows or 7.5-inch rows, depending on study location. In the 15-inch row configuration, half of the soybean rows were directly over residual K bands while half were not. In the 7.5-inch row arrangement, one out of every four rows was directly over a residual band. Soybeans grown between fertilizer bands were not as well supplied with K as those growing directly over them, resulting in yield losses. Because soybean roots turn downward when they encounter root systems of other soybeans grown in adjacent rows (presumably to avoid competition for water and nutrients; Raper and Barber, 1970), it is likely that root systems of narrow-row soybeans are oriented more directly under the plant and extend more deeply, rather than outward. Such a change in root distribution may explain why soybean grown between residual fertilizer K bands in the study by Yin and Vyn (2003) had reduced K levels and lower yields.

A final example of management impacts on access to fertilized soil volume comes from a study examining the response by corn to starter K applications on a compacted soil (Wolkowski, 1989). In that study, corn response to starter K increased as compaction increased. Such an observation is consistent with the more limited root volume explored by a plant growing under compacted soil conditions. With less rooting volume, the concentration of K would need to be higher to meet plant uptake requirements throughout the life cycle of the corn plant.

Summary

Right place is an important part of proper nutrient management and must be combined with considerations of right source, rate, and time. It has been shown that right place is a moving target that changes depending on the crop grown, the stage of its development, the overall fertility of the soil, and the accompanying management practices implemented. The overall concept with right place is managing the extent and concentration of fertilized soil volume. To be successful, this must be planned by considering all crops grown in a particular cropping system to ensure each crop can access the nutrients it needs when it needs them. ■

References

Anghinoni, I., and S.A. Barber. 1980a. Phosphorus application rate and distribution in the soil and phosphorus uptake by corn. Soil Sci. Soc. Am. J. 44:1041–1044.

Anghinoni, I., and S.A. Barber. 1980b. Predicting the most efficient phosphorus placement for corn. Soil Sci. Soc. Am. J. 44:1016–1020.

Barber, S.A. 1984. Soil nutrient bioavailability: A mechanistic approach. John Wiley & Sons, New York, NY.

Barber, S.A. 1978. Growth and nutrient uptake of soybean roots under field conditions. Agron. J. 70:457–461.

Bauder, J.W., G.W. Randall, and R.T. Schuler. 1985. Effects of tillage with controlled wheel traffic on soil properties and root growth of corn. J. Soil Water Conserv. 40:382–385.

Bordoli, J.M., and A.P. Mallarino. 1998. Deep and shallow banding of phosphorus and potassium as alternatives to broadcast fertilization of no-till corn. Agron. J. 90:27–33.

Borkert, C.M., and S.A. Barber. 1985. Soybean shoot and root growth and phosphorus concentration as affected by phosphorus placement. Soil Sci. Soc. Am. J. 49:152–155.

Bruulsema, T., J. Lemunyon, and B. Herz. 2009. Know your fertilizer rights. Crops & Soils 42(2):13–18. Available online at www.agronomy.org/publications/crops-and-soils (accessed 13 Sept. 2009; verified 19 Oct. 2009).

Bundy, L.G., and T.W. Andraski. 2001. Starter fertilizer response on high and very high testing soils. Better Crops 85(2):3–5.

Gregory, P.J., D.V. Crawford, and M. McGowan. 1979. Nutrient relations in winter wheat: II. Movement of nutrients to the root and their uptake. J. Agric. Sci. Camb. 93:495–504.

Mallarino, A.P., J.R. Webb, and A.M. Blackmer. 1991. Soil test values and grain yields during 14 years of potassium fertilization of corn and soybean. J. Prod. Agric. 4:560–566.

McClure, G.W. 1972. Nutrient distribution in root zones: III. Further studies of the effects of phosphorus distribution on corn and wheat. Can. J. Bot. 50:2275–2282.

Mengel, D.B., and S.A. Barber. 1974. Rate of nutrient uptake per unit of corn root under field conditions. Agron. J. 66:399–402.

Mikkelsen, R., G. Schwab, and G. Randall. 2009. The four fertilizer rights: Selecting the right source. Crops & Soils 42(3):28–32. Available online at www.agronomy.org/publications/crops-and-soils (accessed 13 Sept. 2009; verified 19 Oct. 2009).

Miller, H.H., and A.J. Ohlrogge. 1958. Principles of nutrient uptake from fertilizer bands: I. Effect of placement of nitrogen fertilizer on the uptake of band-placed phosphorus at different soil phosphorus levels. Agron. J. 50:95–97.

Passioura, J.B., and R. Wetselaar. 1972. Consequences of banding nitrogen fertilizers in soil: II. Effects on the growth of wheat roots. Plant Soil 36:461–473.

Phillips, S.B., J.J. Camberato, and D. Leikam. 2009. Selecting the right fertilizer rate: A component of 4R nutrient stewardship. Crops & Soils 42(4):14–18. Available online at www.agronomy.org/publications/crops-and-soils (accessed 13 Sept. 2009; verified 19 Oct. 2009).

Raper, C.D., Jr., and S.A. Barber. 1970. Rooting systems of soybeans: I. Differences in root morphology among varieties. Agron. J. 62:581–584.

Soon, Y.K., and M.H. Miller. 1977. Changes in the rhizosphere due to NH_4^+ and NO_3^- fertilization and phosphorus uptake by corn seedlings (*Zea mays* L.). Soil Sci. Soc. Am. J. 41:77–80.

Stecker, J.A., J.R. Brown, and N.R. Kitchen. 2001. Residual phosphorus distribution and sorption in starter fertilizer bands applied in no-till culture. Soil Sci. Soc. Am. J. 65:1173–1183.

Stewart, W.M., J.E. Sawyer, and M.M. Alley. 2009. The four fertilizer rights: Timing. Crops & Soils 42(5):24–28. Available online at www.agronomy.org/publications/crops-and-soils (accessed 13 Sept. 2009; verified 19 Oct. 2009).

Strong, W.M., and R.J. Soper. 1973. Utilization of pelleted phosphorus by flax, wheat, rape, and buckwheat from a calcareous soil. Agron. J. 65:18–21.

Vyn, T.J., and K.J. Janovicek. 2001. Potassium placement and tillage system effects on corn response following long-term no till. Agron. J. 93:487–495.

Wagar, B.I., J.W.B. Stewart, and J.L. Henry. 1986. Comparison of single large broadcast and small annual seed-placed phosphorus treatments on yield and phosphorus and zinc contents of wheat on chernozemic soils. Can. J. Soil Sci. 66:237–248.

Wolkowski, R.P. 1989. Soil compaction and soil fertility interactions. Ph.D. diss. Univ. of Wisconsin, Madison.

Yin, X., and T.J. Vyn. 2003. Previous corn row effects on potassium nutrition and yield of subsequent no-till soybeans. J. Plant Nutr. 26:1383–1402.

Zentner, R.P., and C.A. Campbell. 1988. First 18 years of a long-term crop rotation study in Southwestern Saskatchewan—yields, grain protein, and economic performance. Can. J. Plant Sci. 68:1–21.

Zentner, R.P., C.A. Campbell, and F. Selles. 1993. Build-up in soil available P and yield response of spring wheat to seed-placed P in a 24-year study in the Brown soil zone. Can. J. Soil Sci. 73:173–181.

November–December 2009 Self-Study Quiz

Know your fertilizer rights: right place (no. SS 03971)

DETACH HERE

1. Which of the following is NOT a consideration for the right place?

- ❑ a. Landscape position.
- ❑ b. Quantity of nutrients removed in crop harvest.
- ❑ c. Root system extent.
- ❑ d. How far nutrients move in the soil.

2. Phosphorus and potassium move through the soil to the plant root primarily through

- ❑ a. osmosis.
- ❑ b. mass action.
- ❑ c. diffusion.
- ❑ d. cation exchange.

3. The rate at which a plant root takes up nutrients is termed

- ❑ a. flux.
- ❑ b. diffusion.
- ❑ c. adsorption.
- ❑ d. desorption.

4. For corn, inflow rates are highest

- ❑ a. during early vegetative growth stages.
- ❑ b. during late vegetative growth stages.
- ❑ c. during early reproductive growth stages.
- ❑ d. during late reproductive growth stages.

5. When present in a concentrated supply, this macronutrient is known to cause plant root systems to initiate more branching:

- ❑ a. manganese.
- ❑ b. potassium.
- ❑ c. phosphorus.
- ❑ d. zinc.

This quiz is worth 1 CEU in Nutrient 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 "Self-Study Quizzes to Earn 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 quiz registration form and evaluation form on the back of this page.**
3. **Clip out this page, place in envelope with a $20 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 Quiz, 677 S. Segoe Road, Madison, WI 53711. You can also complete the quiz and pay online at www.certifiedcropadviser.org ($15 charge).**

6. When placed together in a band, ammonium forms of nitrogen enhance phosphorus uptake because

- ❑ a. roots take up acid cations and exude ammonium cations.
- ❑ b. roots branch when they encounter zones of concentrated acid cations.
- ❑ c. ammonium nutrition increases the pH of the soil around the root.
- ❑ d. ammonium nutrition acidifies the soil around the root.

7. On a soil deficient in phosphorus, if only a low rate of phosphorus will be applied to either corn or wheat, it should be

- ❑ a. foliar applied.
- ❑ b. banded near the seed at planting.
- ❑ c. broadcast and left unincorporated.
- ❑ d. broadcast and incorporated with tillage.

Quiz continues next page

8. Which of the following is NOT a way to increase fertilized soil volume over time?

- ❑ a. Apply a lower rate in a band every few years.
- ❑ b. Apply a higher rate in a band every year.
- ❑ c. Broadcast a higher rate every year and incorporate with tillage.
- ❑ d. Each year, combine a higher rate that is broadcast and incorporated with a lower rate that is banded.

9. When potassium has been applied in subsurface bands that are 30 inches apart, and soybeans are planted in 7.5-inch rows with one row directly over the band, what percentage of the crop is likely to have adequate access to the banded K?

- ❑ a. 25%.
- ❑ b. 50%.
- ❑ c. 75%.
- ❑ d. 100%.

10. Which of the following is NOT a characteristic of starter fertilizer?

- ❑ a. It provides a supply of nutrients near young, limited root systems.
- ❑ b. It provides a more concentrated supply that helps keep up with higher inflow rates.
- ❑ c. It promotes root branching if N, P, or both are in the fertilizer formulation.
- ❑ d. It is well distributed in the soil and provides nutrients to the entire root system later in the season.

If you would like to order reprints of this five-part series, email cropsandsoils@agronomy.org or call 608-268-4968.

SELF-STUDY QUIZ REGISTRATION FORM

Name: _____

Address: _____ City: _____

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

❑ $20 check payable to the American Society of Agronomy enclosed. ❑ Please charge my credit card (see below)

Credit card no.: _____ Name on card: _____

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

Signature as it appears on the Code of Ethics: _____

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

This quiz issued November 2009 expires November 2012

DETACH HERE

SELF-STUDY QUIZ EVALUATION FORM

Rating Scale: 1 = Poor 5 = Excellent

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

Information was organized and logical: 1 2 3 4 5

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

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

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

Briefly explain any "1" ratings: _____

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

American volunteers in agricultural development

By Gary Alex, Farmer to Farmer Program Manager, USAID, Washington, DC

American volunteers working in international agricultural programs are an important complement to U.S. foreign assistance programs working to improve the lives of small-farm families. Volunteers work under the John Ogonowski and Doug Bereuter Farmer-to-Farmer (FTF) program, providing technical assistance to farmers, farm groups, and agribusinesses in developing and transitional countries. They promote sustainable improvements in food processing, production, and marketing. The program relies on the expertise of volunteers from U.S. farms, land grant universities, cooperatives, private agribusinesses, and nonprofit farm organizations to respond to the local needs of host-country farmers and organizations.

The volunteers provide a people-to-people face to U.S. foreign assistance programs, thus creating an understanding and appreciation of American values and institutions. Volunteers provide practical assistance on agricultural production and marketing technologies and management that magnifies the impact of larger development programs.

The FTF program was initially authorized by Congress in the 1985 farm bill and funded through Title V of Public Law 480. The 2008 farm bill authorized the current fiscal year 2009–2013 phase of the program, designating it as the "John Ogonowski and Doug Bereuter FTF program" in honor of John Ogonowski, one of the pilots killed on Sept. 11, 2001, and former Congressman Bereuter, who initially sponsored the program. The U.S. Agency for International Development (USAID) funds the program.

Hydroponic forage

In 2006, volunteer Phil Pohl, recruited by Winrock International and TechnoServe, worked with farmers in El Salvador on hydroponic forage to improve milk production and reduce costs and water use. During El Salvador's dry season, fodder for dairy cattle is scarce and milk production drops. Between November and April, Salvadoran farmers do not have enough rain to grow grass in their fields, and most lack irrigation. Hydroponic forage was introduced as an alternative to keep milk production steady throughout the year.

Since the first pilot demonstration farm, 15 farmers have built hydroponic corn seed forage units. More than 200 farmers have learned about benefits of using hydroponic forage as a feed alternative. By growing the plants under cover in trays, the hydroponic system focuses all available moisture on the growing plants and minimizes loss from runoff and evaporation. Hydroponic fodder uses one-tenth the water used when growing fodder in the field. Once the low-cost infrastructure is in place, the hydroponic system produces cheaper fodder, costing only about US$0.06/lb compared with US$0.30/lb for field-grown fodder.

In addition to using less water and lowering production costs, the hydroponic system increases productivity. Under a pilot test, milk production averaged 15.4 bottles per cow per day, 10% more than before introduction of hydroponic forage. The Ag Central Coop, an association of six dairy cooperatives, is planning to launch a medium-sized hydroponic forage business for its member farmers and surrounding cattle producers.

The FTF program currently operates in 25 countries, sending about 800 volunteers a year for assignments that average about 21 days in the host country. The major current program areas are: horticulture, dairy and livestock, staple food crops, producer organization development, financial services, marketing and processing, and natural resources management. The program typically covers all travel and support costs. Contact information for the FTF program is available www.usaid.gov/our_work/agriculture/farmer_to_farmer.htm. ■

▶ ***Top:*** **An El Salvadoran cattleman checks hydroponic forage introduced by an American Farmer-to-Farmer (FTF) program volunteer.** ***Middle:*** **FTF volunteer assists host with soil testing.** ***Bottom:*** **FTF volunteer demonstrates sanitary handling for high-value horticulture products.**

The ongoing public challenge of preventing the spread of foodborne pathogens

Each year, the Centers for Disease Control and Prevention (CDC) estimate that one out of every four Americans will suffer from a foodborne disease, causing an estimated 5,000 annual deaths. Since foodborne pathogens can originate from any number of steps in the food delivery process, prevention of disease is a complicated issue, requiring a multitiered approach on local, state, and federal levels. A response to an outbreak of foodborne disease requires an intricate network of diagnoses among public officials, including recognizing a trend among dispersed patients and the ensuing investigation into the source of the outbreak.

At this year's annual meeting of the American Institute of Biological Sciences, held in Arlington, VA in May, Dr. Robert Tauxe, deputy director of the CDC's Division of Foodborne, Bacterial, and Mycotic Diseases, described the public challenge of preventing outbreaks of foodborne diseases. He detailed the ways the CDC coordinates with public health officials in detecting outbreaks and described some of the vulnerabilities that they have been able to identify in the national food production industry. He said just educating consumers to cook their food properly is not enough.

"If only it were that simple," Tauxe said. "We don't have vaccines for these pathogens by and large, and contamination can occur anywhere from farm to table, so the array of possibilities is great. For the really severe problems, our goal is to understand the mechanisms of contamination well enough to prevent it from happening upstream from the consumer, so that the consumer isn't responsible for worrying about it, and that can mean re-engineering food production processes and policy for food safety."

The CDC was established in 1946 in Atlanta, GA, as an agency designed to combat the spread of malaria in the southern regions of the United States. Since then, it has expanded its efforts to a general promotion of public health, including the prevention of foodborne illnesses, such as *Salmonella* and *Escherichia coli* O157:H7, better known as *E. coli*.

Investigations into the causes of foodborne disease outbreaks have relied upon cooperation from health officials at the state and local levels and have typically been prolonged due to the complexity of acquiring the proper information and data about the origin of an outbreak. This tiered method of involvement among jurisdictions allows for a detailed investigation of an

outbreak as well as the ability to detect clusters of individual cases.

PulseNet

In recent years, the CDC has improved its ability to determine certain patterns in the detection of multistate outbreaks. This has been the result of its implementation of PulseNet, a coordinated network of public health laboratories used to detect outbreaks through its national surveillance based on molecular subtypes.

"The number of DNA patterns that are going into PulseNet has been increasing steadily from 1996 when we began it in four states," Tauxe explained. "We reached full national participation in 2001 for *E. coli*, we're about there now for *Salmonella*, and we're getting 50,000 to 60,000 new patterns each year dumped in for a number of different bacteria pathogens."

Determining the sources of foodborne disease is an important goal of the PulseNet program. In recent years, fresh produce has been proven to be a frequent contributor to foodborne disease outbreaks. Produce can be easily contaminated while still in the field and is very difficult to clean once it has been harvested.

"What we're seeing now is not just the ground beef and the chicken and the old animal products scenarios, we're seeing scenarios with fresh produce, leafy greens, peppers, tomatoes, carrots, and cantaloupes," Tauxe said. "Complex ecologies that link the pastures, streams, and produce fields that we really don't understand very well, and I think this is a whole new arena where we're going to need the help of a lot of research to understand what's going on here and how it's going to be addressed."

Recently, some multistate food outbreaks in the United States have been the focus of media attention, leading to some concern about the safety of the nation's food ▶

[continued on page 17]

NRCS CAPs: An opportunity for agriculture, IPM

By *Brenna Wanous*, IPM Institute of North America, Inc., Madison, WI

According to a 2007 report from the Natural Resources Defense Council ("More IPM Please"; see www.nrdc.org/health/pesticides/ipm/contents.asp), just 2.4% of Environmental Quality Incentive Program (EQIP) dollars were applied to pest management from 2003 to 2005. Many state USDA-NRCS programs provided no dollars for Integrated Pest Management (IPM), including those with documented pesticide impacts on water quality and other resources. The report focused on EQIP, which provides more than $1 billion annually to farmers in technical and financial assistance to protect natural resources.

This past year, the NRCS included an IPM option in its new EQIP cost-share program called CAPS (Conservation Activity Plans), which is designed to address on-farm natural resource concerns. CAPs offers up to 75% of the cost for a private-sector technical service provider (TSP) to prepare a CAP for a farm. Approximately $750 million is available in the current farm bill through 2013 for CAPs.

CAPs are designed to identify site-specific resource concerns on the entire farm, such as nutrient or pesticide runoff risk to a nearby water body, high drift potential due to sprayer type or nozzle configuration, inefficient water use, and more. State conservationists, in consultation with state technical committees, can choose from 12 different CAP options, which include IPM, transition to organic, forestry, and aquaculture.

California was one of four states to offer IPM CAPs in fiscal year 2009 and received more than 70 plans. This successful pilot in California is attributed to strong collaboration between the NRCS, cooperative extension services, TSPs, and conservation districts. Three other states that offered the IPM CAP did not receive any plans, largely due to the lack of qualified TSPs able to write the plans in these states. All TSPs must meet new NRCS certification requirements specific to the CAP they will prepare.

To maximize this opportunity for farmers and IPM, a new national working group was formed to develop training curriculum for TSPs and other conservation professionals, create model IPM CAPs and templates, assist in determining realistic financial assistance, and increase awareness of the IPM CAPs opportunity among state conservationists, EQIP program managers, TSPs, and other agriculture IPM professionals and growers.

Crop advisers needed

Crop advisers are needed to prepare IPM CAPs. CCAs and CPAgs qualify for TSP status in pest management; additional CAPs requirements apply. If you are interested in becoming a TSP and/or receiving the additional training to qualify, visit http://techreg.usda.gov and use the right-hand navigation bar to learn more. You can also contact your NRCS state TSP coordinator by clicking on "State TSP Coordinators."

A national training opportunity for crop advisers interested in writing IPM CAPs will be held Jan. 19, 2010 in Orlando, FL, coordinated by the national IPM CAPs working group in conjunction with the National Alliance of Independent Crop Consultants Annual Meeting. This full day of training by extension and IPM specialists and representatives from NRCS will cover the criteria required for IPM CAPs TSP certification. Please contact me (bwanous@ipminstitute.org or 608-232-1410) for additional information and to register.

The national IPM CAPS working group is funded by grants from the Northeastern and North Central IPM Centers. For more information, visit www.ipminstitute.org/IPMCAPs/home.htm or email bwanous@ipminstitute.org. ■

Recap of the ICCA board meeting

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

The International Certified Crop Adviser (ICCA) board had its annual meeting in Kansas City, MO in October. The ICCA program has maintained its numbers with 13,188 CCAs throughout the United States and Canada. That's down 95 CCAs from 2008 but still 173 higher than 2007, so the number of CCAs has been relatively steady over the last three years.

Exam numbers are also very steady with 1,066 international exams given in 2009. That was down by 107 examinees compared with 2008 but was three higher than 2007. Over the last four years, exam numbers have been right around 1,100 examinees per year, so about as many new CCAs who enter the program leave the program. According to past surveys, the top reasons why someone leaves the program are retirement or change of profession. We will be evaluating that over the coming months.

There were no policy changes enacted by the ICCA board, but it did enact some new initiatives for 2010. The self-reported online CEU form will be updated with some new features. More detail will be required about the event being reported and CCAs will be able to attach supporting documents such as the event agenda. The local CCA boards will have 24/7 access to the information being reported for auditing purposes. The CCA CEU application form for vendors will become more interactive, allowing vendors and local reviewers to forward the form electronically without needing to print and mail it. It will also enter the ICCA database without having to be keyed, saving on labor.

The ICCA board approved a Washington, DC based position working in the American Society of Agronomy (ASA) science policy office. This position, if approved and supported by ASA, will focus on agency and legislative issues that impact the certified professionals in agronomy and soils (CCAs, CPAgs, and CPSS/Cs). There are many opportunities coming out of DC activities that could add more value to being certified, so the board felt it was important to invest in this additional resource.

The American National Standards Institute's (ANSI) International Standards Organization (ISO) has an accreditation process for certification programs called ANSI ISO 17024. The ICCA board believed it was important to have the ICCA program accredited by ANSI ISO, so that will be a charge to the staff to accomplish in 2010 and 2011. This accreditation will improve the standards of the program and add more creditability in the eyes of stakeholders. Many of the new initiatives being discussed by policy makers and agency personnel around water quality, climate change, nutrient management, and agriculture production mention ANSI ISO standards and accreditation.

A comprehensive salary survey will be conducted by ASA, the Soil Science Society of America, and the Crop Science Society of America along with the certification programs to better define the professions and their associated compensation packages. The information gathered will be very helpful in promoting the professions to new candidates. Please consider completing the survey when you receive it in the next couple of months.

If your two-year CEU cycle ends this year, this is a reminder that your CEUs need to be earned and reported by December 31. You can check your totals and your ending date on the websites: www.certifiedcropsdviser.org or www.agronomy.org/certifications. You will need to log in to do so. If you are short, there are self-study CEUs found on the websites and in *Crops & Soils* magazine.

The ICCA board meeting wrapped up by honoring two CCAs for their service to the program and passing the gavel. Jim Peck, CCA, served as the Northeast regional representative to the board and on the continuing education committee. He also serves on the Northeast Region CCA board. Kim Polizotto, CCA, served as chair of the ICCA board and on the Indiana CCA board. Norm Flores, CCA, also completed his term on the board but was unable to attend the meeting. Norm served as the Western Canada regional representative and on the continuing education committee. He also served on the Prairie Provinces CCA board.

As is tradition, the gavel was passed to Jim Smith, CCA Northwest Region, and Jim will begin his term as chair of the ICCA board. Howard Brown will rotate to past chair, and Russell Duncan, CCA from South Carolina, will begin his term as vice chair. You will be hearing more from both Jim and Russell in the coming issues of *Crops & Soils* magazine.

We wish you an enjoyable holiday season and hope you have a very prosperous 2010. ■

Howard Brown, chair of the ICCA board (right), honors Kim Polizotto, past chair, for his leadership and service to the ICCA program during the recent ICCA board meeting in Kansas City.

Miles Farm Supply / Big Rivers Agri-Supply

When?

January 12th & 13th

Where?

Casino Aztar Event Center
Evansville, IN

Who Should Attend?

All CCA License holders, and anyone interested in gaining agronomic knowledge from nationally renowned speakers and field specialists.

Credits Available?

Planned 20 hours for CCA
Planned 5 hours for
KY Pesticide CEU & IN CCH

Cost?

$300- 2 Days
$175- 1 Day
Prices include meeting fees, lunches and refreshments throughout the day(s)

How Can I Save $25?

If you choose to prepay for this meeting through cash, check or credit card you will only pay
$275 - 2 Days
$150 - 1 Day




Mark your calendars and plan to join us for the ***Annual Certified Crop Advisor Meeting***. This year we will be holding our meeting at the ***Casino Aztar Event Center in Evansville, IN.***

We have many presenters, including but not limited to:

- Dr. F. William Simmons - Professor of Soil and Water Management (University of Illinois)
- Fred Whitford - Purdue University, Coordinator Purdue Pesticide Program
- Neil Kinsey - Kinsey Agricultural Services, Inc.
- John Hassell - Agronomic Development Manager Agrotain International
- Presentations from BASF, FMC, Syngenta and more!

A block of rooms have been reserved at a discounted rate for attendees. Each individual, however, will be responsible for both reserving and paying for their accommodations by calling 1-800-342-5386 ext.#7 and requesting the "Miles CCA Meeting Group Rate".

Please RSVP to Megan Litkenhus by calling (270)852-7802 or by email meglit@milesnmore.com.

Meet the professional: Doug Bentson

Doug Bentson, a CCA with GRAINCO FS Inc. in Mazon, IL, received the International CCA of the Year Award from the American Society of Agronomy (ASA) during its Annual Meeting in November in Pittsburgh, PA. This award recognizes CCAs who deliver exceptional customer service, show that they are leaders in their field, and contribute substantially to the exchange of ideas and the transfer of agronomic knowledge within the industry. The Illinois CCA board and the Illinois Farm Bureau nominated Bentson for the award. He was an honorary guest at the ASA Annual Meeting and received a one-year membership in the ASA, a commemorative plaque, and a cash award.

After earning an associates degree in agriculture from Joliet Junior College, Bentson began working with the FS Cooperative system in the Grundy–Kendall–LaSalle region of Illinois, where he has spent most of his career. During this time, he has worked in a variety of positions in the organization including operations, management, and sales. From 1990–1995, he went to work for Carroll Service Company in Lanark, IL as the marketing manager. In 1997, he earned his credentials as a CCA and came back to Kendall–Grundy FS to lead the sales and marketing efforts at the Mazon, IL location, where he continues to work today. The decision to come back was easy for him. "I really like walking fields, scouting crops, solving problems, and working with customers to improve their bottom line," Bentson says. "Long term, this is what I really enjoy."

Confidence for the customer

Bentson's commitment to agricultural production in his region showcases the value a CCA can bring to the community. "His many years of experience and service are the epitome of what a CCA is all about," says Bruce Baker, a farmer in Verona, IL, who has worked with Bentson for more than 20 years. "He has become our most trusted agronomic confidant." Bentson is responsible for advising approximately 200,000 acres in the Kendall–Grundy area. Although his clients range in both size and diversity, his enthusiasm for serving each individual does not waver. Bentson has offered support and advice for client Cash Biros, not only for his crop and dairy operation, but also for a smaller pumpkin endeavor Biros is starting. "I've learned to manage weeds and insects without harming my pumpkins and their best friends, the bees," says Biros, who credits his CCA for helping him translate a hobby into a growing business opportunity.

For many farmers, the best service a CCA can provide involves helping to solve problems and increase profitability. Bentson takes a proactive approach in his service by engaging the customer before problems arise. He has sponsored seminars for farmers on timely topics and issues that may affect their crops. He also is a regular contributor to the GRAINCO-FS newsletter, promoting the latest industry news and events. Keeping his clients at the forefront of new agronomic innovations has always been an important aspect of Bentson's job. "I spend a lot of time looking at new ideas and getting them out to my customers to try," he says. Bentson has conducted numerous on-farm discovery trials with his clients to help them see the benefits new innovations and technology can bring to their businesses. He has built a rapport with chemical companies, which allow him to use their products in trials and demonstrations. "They benefit from learning about their product in a field situation," Bentson says, "and knowing that their product increases yields or income gives me the confidence I need to promote it."


Doug Bentson

Bentson was also one of the first CCAs to encourage variable-rate application. "I would tell the customer that we could either save money by not wasting inputs on these [high fertility] spots or take the money they are saving and apply it to building up the low [fertility] spots." Bentson now estimates about 60% of his business deals with variable-rate application. "Quite often, the things we recommend and do end up actually costing the customer more money," explains Bentson, "but in the end, if we can offset that cost and add to it with additional gains, that's ultimately what the customer wants." His ability to convey the economic returns that new ideas and strategies can bring has helped Bentson's territory grow, says Brent Ericson, general manager of GRAINCO-FS. "Doug has been able to balance the needs of the organization while providing a high-value service to the patron."

In addition to service and advice that translates into higher product yields, Bentson also helps his region minimize its ecological footprint. He has shared his knowledge of containment laws with clients and assisted them in updating their facilities to comply with industry regulations. He also helps them understand that sustainable production practices can be good for the bottom line. However, for some clients, it is the little actions that speak volumes for Bentson's environmental concern. Before his operators sprayed an alfalfa crop at Cash Biros' farm, Bentson identified a bee hive also belonging to his client. Although it was not visible from the field, Bentson was concerned that it could still be vulnerable to the treatment. Before proceeding, he made sure the hive was

properly secured both during and after the field application. "This oversight and management, not just with the crop, but also with the customer or operator, makes me even more confident in his abilities as a CCA," Biros says.

Lessons in the field

Learning is a part of the daily process for Bentson. "The more we know, the more we want to know," he asserts. Bentson credits the continuing education component of the CCA program as helping him bring the latest discoveries and advancements to his clients. In addition to the CCA program, he has also participated in GROWMARK, Inc.'s training sessions, which have played a crucial role in his professional success, providing an opportunity to develop sales and service skills as well as technical training.

Bentson enjoys the diversity of his work and the ongoing learning that comes with it. "You really need to enjoy what you do," he explains, "and you need to strive to compete with the best." His enthusiasm extends into the community, where he has participated

> *"I really like walking fields, scouting crops, solving problems, and working with customers to improve their bottom line... You really need to enjoy what you do, and you need to strive to compete with the best."*

in Ag in the Classroom and 4H programs, teaching students about crops and insects. Bentson also works with students in the custom application courses at Joliet Junior College, helping them understand the process of working with customers to keep their fields clean.

His experience and leadership has earned Bentson frequent recognition from GROWMARK, Inc., through its MARC (Marketing Activities Recognition Criteria) of Excellence Program. He has been recognized by the corporation on eight occasions and has earned his annual sales program goal 13 times as well. However, those who know Bentson know that his commitment to his clients and the community far exceeds what any award could measure. "For Doug, what he does isn't just a job; it's his life's work," Biros says. "When Doug is out driving [around our community] and seeing the crop [grow], it not only makes him proud, but he is already anticipating how he can help his customers do even better the next year." ■

Label database app for iPhone

Agrian documented users, a subscription-based service of $500 annually, can now access Agrian's comprehensive and easy-to-use label database on their iPod Touch/iPhone. Users can download the application, called the Agrian Mobile Information Center, from iTunes and have access to Agrian's complete label database offline within their pocket, giving those involved in crop protection the ability to access more than 3,800 manufacturer-approved labels anywhere at anytime.

The powerful application gives users searchable label information while in the field, enabling them to search by product brand name, registered states, pests controlled, and specific product use rates. The application also includes active ingredient, signal word, minimum air/ground diluents, and safety information. When connected to the web via phone service or Wi-Fi, users have the ability to view and maneuver through thousands of product labels and material safety data sheets (MSDS). With the Mobile Information Center, Agrian replaces thousands of pages of documents and out-of-date label books and delivers the most current label information available, all in a device that weighs less than 4.8 oz.

To learn more about Agrian and how to sign up to be an Agrian documented user, please email sales@agrian.com or call 559-437-5700. To visit Agrian's website, go to www.agrian.com.

Tillage radish seeds

Tillage radish seeds are available for purchase from Steve Groff SEEDS, LLC. Mr. Groff says tillage radishes have demonstrated to be "the most versatile and beneficial" cover crop available to farmers. He cites five university studies, which he says have verified an increase of 10 to 20 bu/acre for corn and 7 to 9 bu/acre for soybeans.

In addition, Groff says radishes promote a warmer and dryer seedbed, allowing for earlier planting; fragment soil for better nutrient and water absorption; suppress most winter annuals; protect soil against erosion during the fall and winter months; scavenge nutrients deep in the soil profile and deposit them on or near the soil surface to be used by succeeding crops; add up to 5 tons/acre of organic matter; and absorb excess nutrients in the soil and preserve them for the next season's crop.

For more information, visit www.tillageradish.com or call 717-575-6778. ■

TURNING SCIENCE INTO INNOVATIVE SOLUTIONS.

Dow AgroSciences is rapidly developing revolutionary new advancements in crop protection.
Our breakthrough herbicides are specifically developed for today's trait technology.
Our insecticides are developed using cutting-edge chemistry to deliver effective and efficient insect control.
Our complete portfolio of herbicides, fungicides and insecticides are all supported by knowledgeable field staff.
It's all part of our commitment to turning science into the innovative solutions you need to succeed.

Science. Yield. Success.™ Dow AgroSciences

THE BIGGEST BREAKTHROUGH IN CROP NUTRITION. PERIOD.

MicroEssentials granules, containing N, P, S and Zn (SZ), eliminate component segregation to ensure uniform distribution of nutrients.

MicroEssentials fertilizer is proven to help you increase nutrient uptake and maximize efficiency, from germination to harvest. A patented manufacturing process packs essential nutrients into uniform granules that provide consistent nutrition, all season long.

Each MicroEssentials granule is nutritionally balanced. So nutrients are distributed uniformly, and your crops get what they need to achieve their full yield potential. And only MicroEssentials provides two forms of sulfur: sulfate for immediate uptake, and longer-lasting elemental sulfur. Research shows this balanced crop nutrition helps plants get off to a faster start and stay healthier.

This season, break through to a better harvest with MicroEssentials. For more information, see your local ag retailer, or visit MicroEssentials.com.

MicroEssentials

Performance. Profitability. Peace of mind.

Mosaic

Stevens Hydra Probe Soil Sensor

turn your data into growth

All in one multi-parameter soil sensor

The Stevens Hydra Probe soil sensor is the most robust and unique soil sensor available. Users can select up to 22 parameters, including:

- Soil Moisture
- Soil Temperature
- Soil Electrical Conductivity
- Real and Imaginary Dielectric Permittivity
- and many more!

Features of the Stevens Hydra Probe

- Extensively researched and well-tested, durable design provides quality data over many years without removal or recalibration
- Over 10 years of field use
- Excellent precision and accuracy
- Temperature corrected measurements
- Smart Sensor technology
- No calibration required for most soils
- SDI-12 or RS-485 signal output

Over 100 universities, government agencies (USDA, USGS, NOAA, DOD, NASA), farms, vineyards and other companies use the Hydra Probe for quality data analysis!

The POGO portable multi-parameter soil sensor - just poke and go!

The POGO portable soil sensor enables manual readings to be taken quickly and easily. Simply insert the Hydra Probe into the soil you wish to sample, select the soil type and user defined location, and click "Sample" on the PDA's screen. The soil measurements can be logged to the PDA for further analysis via *MS Excel* or other spreadsheet programs.

The POGO enables immediate understanding of soil conditions for agriculture, greenhouse monitoring, research, golf course greens, ground penetrating radar studies or any other application that requires manual checking of soil conditions at multiple locations.

Data Loggers

Water Level & Quality

Radio Telemetry

Weather Sensors

Tel: 800.452.5272
503.445.8000
Web: www.stevenswater.com/csa

Monitoring the Earth's Water Resources Since 1911

Stevens®
Water Monitoring Systems, Inc.