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No-till agriculture can reduce costs, improve soil quality, and benefit the environment. However, if manure is applied to the surface of no-till fields, the nutrients can be lost to volatilization or runoff. Therefore, incorporating the manure into the soil may be the best practice. This month’s feature highlights technologies that can incorporate manure into no-till fields, while retaining most of the benefits of no-till practices.

11 Self-Study CEUs | Earn 1 CEU in Crop Management and 1 CEU in Soil and Water Management.

23 Regulatory News | Heading off double-permit requirements for pesticide spraying.

24 Regional Roundup | News from the Canada East region.

26 Certification | Certification update: Restructuring, promotions, and international expansion. Plus, explaining the decision to discontinue the CPSC certification.

32 Tales from the Pits | The tale of the ‘sputter’ question.

34 New Research | Deficit irrigation of alfalfa for water savings in the western U.S.

38 Career Center | Life can be a balancing act.
Manure incorporation in no-till systems
No-till agriculture can reduce costs, improve soil quality, and benefit the environment. However, if manure is applied to the surface of no-till fields, the nutrients can be lost to volatilization or runoff. Therefore, incorporating the manure into the soil may be the best practice. This month's feature highlights technologies that can incorporate manure into no-till fields, while retaining most of the benefits of no-till practices.

It’s hard to argue with the benefits of no-till agriculture: In addition to reducing the fuel costs and time associated with tilling, the practice can reduce erosion, increase organic matter, and improve water retention in soils. But no-till farming also presents a dilemma that Doug Beegle, Distinguished Professor of Agronomy at Pennsylvania State University, knows well. As an extension agronomist, Beegle has trained farmers for years to write nutrient management plans that include incorporating manure, rather than leaving it on the soil surface, to conserve nutrients that might otherwise be lost through volatilization or runoff. At the same time, roughly half the cropland in Pennsylvania is now no-till, says Beegle, who is a Fellow of both the American Society of Agronomy (ASA) and the Soil Science Society of America (SSSA).

“So, we’ve always had this conflict when we’re doing nutrient management planning. How do we deal with manure in no-till systems?”

That question sent him and a group of collaborators searching for technologies that can incorporate manure into no-till fields, while retaining most of the benefits of no-till practices. They’ve since studied a range of methods, including shallow disk injection, which uses familiar equipment, and a sophisticated, high-pressure injector from Norway. Overall, the technologies do offer environmental benefits over surface application of manure, Beegle reports; for example, they’ve been found to reduce nuisance odors and nutrient losses, while causing minimal soil disturbance.

But, just as important, they’ve also proven practical and economical to use, although some more so than others. The team is now working to get the equipment out to farmers. “That’s the next step,” Beegle says. “People need to see these in action in the real world, not just in a research plot.”

What drives the work is Pennsylvania’s role in the water quality of the Chesapeake Bay—the United States’ largest estuary—whose watershed also stretches over parts of Delaware, Maryland, New York, Virginia, West Virginia, and the District of Columbia. No part of Pennsylvania actually abuts the bay; however, the state still contributes more than...
half of the Chesapeake’s water via the Susquehanna River, Beegle says. As a result, sediments, nitrogen, and phosphorus from Pennsylvania farms also wind up in the bay, helping to fuel a dead zone of oxygen-starved water that extends for hundreds of square miles each summer.

That reality makes better manure management a top concern, says ASA and SSSA member Peter Kleinman, who leads watershed research in the USDA-ARS Pasture Systems and Watershed Management Research Unit at Penn State. “Working manure into the ground is a needed step in order to ensure that the nutrients in manure serve as a resource and not a liability.”

Manure incorporation is nothing new, he adds, and some techniques that the team evaluated have been around for quite awhile. But the practice is new to many Pennsylvania farmers, in part, because older incorporation methods are mostly suited to flat, even soils, like those in the Midwest, rather than the steep, rocky farmlands of Pennsylvania.

“So Doug and I went after a number of grants to buy different applicators that could inject manure, but not too deeply, and could handle the steep and stony soils,” Kleinman says. They also resolved to examine not just one or two variables, such as crop response or phosphorus runoff, but an entire suite of factors, with “an emphasis on tradeoffs,” he says. “It really involves trying to come up with the ‘sweet spot.’ Where is the optimal usage? Because inevitably, you end up having a benefit in one area, and a cost in another.”

In Virginia, too, most farmers still surface-apply manure because “historically it has been the cheapest, fastest thing to do,” adds SSSA member Rory Maguire, an associate professor of nutrient management at Virginia Tech University who collaborates frequently with Kleinman and Beegle. But, as Kleinman points out, there is also a major cost to surface application, which the scientists are now targeting: Typically, 30 to 50% of ammonia nitrogen volatilizes from manure within 24 hours.

“With dairy manure, you can actually lose half your plant-available nitrogen with surface application through loss of ammonia into the air,” Maguire says. And because some of this volatilized nitrogen eventually returns earthward in rainfall, the Chesapeake Bay loses, as well, Beegle adds. Atmospheric deposition is, in fact, a major source of nitrogen to the bay that manure incorporation could also help curb.

Five main approaches to manure incorporation

Although there are many variations in actual equipment, five main approaches exist today for incorporating liquid manure into the ground with minor soil disturbance: disk injection, chisel injection, high-pressure injection, aeration, and surface banding, the last of which is sometimes performed with a “sleigh foot” or traveling shoe on standing forages.

Disk injectors typically include a set of coulters that cut crop residues and make furrows in the soil; drop hoses for placing manure in the furrows; and an implement, such as a pressing wheel, to close the furrows afterward. The method is often called “shallow” disk injection because it typically injects manure into just the top 4 to 6 inches of soil. Chisel injectors are similarly configured, except that they drag C-type shanks through the soil to create furrows, usually causing more disturbance. They can also be set to inject manure over a wider range of depths.

A higher-tech variation on the same theme is high-pressure injection. Developed in Scandinavia to incorporate liquid manure into stony soils used for pasture or sod farming, these injectors employ a specialized pump that pressurizes manure slurry. The pressure is then used to

create discrete, manure-filled cavities under the soil surface that resemble upside down mushrooms. Aeration, in contrast, takes a very different approach. Rather than introducing manure directly into the ground, aerators produce holes or pits in the soil. Manure is then applied to the soil surface afterward.

Aeration is thought to help manure infiltrate soils by creating holes into which it can seep. But much of the manure remains exposed to air, rather than being covered by a layer of soil as with injection. The same holds for surface banding. In this approach, farmers surface-apply manure in strips rather than covering the entire soil surface. On forage crops, a sleigh foot or other equipment is used to apply the strips under the plant canopy.

Research indicates that chisel and disk injection can reduce ammonia losses by 40 to nearly 100% compared with surface application, while high-pressure injection in one study cut ammonia emissions by 60%. Results with surface banding and aeration, meanwhile, have been more variable, and aeration so far isn’t well studied. Surface banding of manure in forages is known to decrease ammonia volatilization in cases where the plant canopy lowers wind speeds over the manure. But, in general, Maguire says, injection does a better job of conserving nitrogen than techniques that leave manure exposed to air.

“We find that if you get manure onto the soil and then close the slit where you put the manure, that’s very good at capturing nitrogen and stopping your ammonia loss,” he says. “And it’s also very good at stopping odor.” A study led by Robin Brandt, director of the Penn State Odor Assessment Laboratory, for example, found that the shallow disk and high-pressure injection cut odor emissions by 50 to 70% compared with surface application.

### Shallow disk holds most promise for Chesapeake Bay

These two technologies have also performed similarly in other tests by the researchers. Still, the high-pressure injector has become less of a focus over time, mainly because it suffers from some “practical problems” in Pennsylvania cornfields, Beegle says. Originally designed to pump manure into grasslands, high-pressure injection tends to “blow out” soils not covered by heavy thatch, for example, and is apt to gather up corn stover, creating piles of residue in front of the machine. As a “fairly sophisticated” device, Beegle adds,
it’s also prone to mechanical problems, making the simpler shallow disk injector a clear winner—at least in the Chesapeake Bay region.

“Based on our research, the shallow disk injection systems seem to be the most promising,” he says. “They do a good job getting the manure incorporated with very minimal disturbance. The disturbance we get from our injector is pretty similar to what you’d get from a no-till planter.”

But as the scientists have started demonstrating the technique, a lot of farmers have expressed concern that it’s too slow. Farmers who surface-apply manure can broadcast it across a 50-ft width of field, Maguire says, while shallow disk injection covers about half that width, suggesting it could be roughly two times slower. However, some commercial manure applicators who perform injection in Pennsylvania have found it’s usually not as slow as people assume, Beegle says. Besides, many farmers are already taking a second look at injection now that fuel prices have spiked—taking fertilizer prices with them.

“That increased interest among farmers a lot,” Maguire says, “in terms of being able to capture the extra value of the nitrogen that’s in the manure.”

Along these lines, a study led by Al Rotz, an agricultural engineer with the USDA-ARS unit at Penn State, weighed the environmental benefits of four liquid manure application methods (surface application, shallow disk injection, aeration followed by surface banding, and traditional tillage) against the economics of using them. The research tool he employed was the Integrated Farm System Model, a program that simulates farm processes—such as growth of crops, harvesting processes, and feeding of animals—and how they vary through time given the vagaries of weather. The idea is to extrapolate results obtained under highly controlled experimental conditions to the complex and changeable circumstances found on real farms.

“What happens in a research plot is one thing,” says Rotz, who did the work with Beegle, Kleinman, and others. “But how does that really apply when you’re applying the manure in an actual farming system?”

Using 25 years of weather data, Rotz simulated manure application on three very different farm types in Pennsylvania: a swine and beef cattle farm under grass production, a mixed confinement and grazing dairy farm, and a full-confinement dairy farm where cows were fed corn silage and alfalfa. Not surprisingly, manure incorporation reduced phosphorus and ammonia losses compared with surface application on all three farms. It also cost more. But the scientists were pleasantly surprised to find that nitrogen conservation offset the added cost when shallow disk injection was used, Beegle says.

On the grass-based beef and swine farm, for example, shallow disk injection increased production expenses by 4% over surface application because it took longer and the equipment was more expensive. But disk injection also improved the yield and nutritive content of the forage, yielding a 5% increase in farm income. In other words, “our study found that shallow disk injection and surface application were pretty close economically—a few dollars either way, but they were close,” Beegle says. “And if it’s close to a break-even, I’ve found that farmers will try things.”

The researchers got similar results when they modeled disk injection on the dairy farm where cows grazed grass part of the year and ate corn silage the rest. However, the group...
Quantifying odor reduction of manure incorporation methods

For those hoping to control nuisance odors from surface-applied manure, integrating manure into the soil rather than leaving it exposed seems like a matter of common sense. At the same time, practitioners and scientists need to confirm that manure incorporation actually curbs odors. Robin Brandt is helping to do just that.

As director of the Pennsylvania State University Odor Assessment Lab, Brandt studies ways to quantify agricultural odors—a surprisingly complex task, given how easily the human nose detects these aromas in the first place. The “gold standard” technique involves collecting large bags of malodorous air in the field, bringing them back to the lab, and using a sophisticated machine to dilute the samples with pure, odorless air.

A panel of expert “odor assessors” are then given whiffs of the diluted samples—starting with the most dilute and working toward the least—reporting each time whether they smell a difference between the diluted sample and two samples of purified air. The trial ends when an assessor first detects a difference, yielding the detection threshold.

The method does a good job of quantifying differences in odor concentration that would otherwise be very subjective; for example, a smell that’s detectable when diluted 1,000-fold (1 part odor sample to 1,000 parts pure air) is four times stronger than one that’s only detectable at a 250-fold dilution. But the technique is also expensive, time consuming, and uses whole-air samples that can become tainted by the sample bag itself. So, when Brandt began working with Doug Beegle and Peter Kleinman at Penn State on manure incorporation, he used a less costly field technique and a device called a Nasal Ranger Field Olfactometer.

Although it’s used in the field, the Nasal Ranger allows odor assessors to evaluate serial dilutions of air samples through the device, just as they do with the laboratory machine. Similar to the lab method, too, the assessors report when they can first smell a difference between a diluted ambient sample and a purified puff of air, producing a detection value called dilutions-to-threshold (D/T).

Where field olfactometry differs substantially from the lab technique, though, is in its efficiency. In his manure incorporation study, for example, Brandt collected many more data points by employing multiple assessors equipped with Nasal Ranger units than he did with the laboratory method. And those extra data gave him the statistical power to identify subtle variations in the performance of four incorporation techniques: aeration, chisel injection, shallow disk injection, and high-pressure injection.

For instance, although aeration cut manure odors significantly over surface application (as did all the incorporation methods), it was significantly outper-
didn’t see the same economic benefit in the full-confinement system because alfalfa grown in rotation with corn already boosted soil nitrogen, making the added nitrogen from manure less important.

This suggests that those who are thinking of adopting manure injection need to consider the whole farm system, Rotz says. “It’s really hard to make a blanket statement, saying, ‘If you use this technology, this is what you’re going to get from it,’” he says. “It’s going to vary with the crops grown and how [manure injection] fits with the other parts of the farm.”

Making injection equipment available to farmers

In the meantime, he and Kleinman have been bringing manure injection to farmers in a different way. Individual farmers, they reasoned, might not be willing to invest in manure injection equipment. But they might be willing to pay for the practice if someone else carried it out. So in a project led by ASA member Heather Karsten, an associate professor of crop production at Penn State, and funded by an NRCS Conservation Innovation Grant, the team bought four shallow disk injectors and gave them to a group of commercial manure haulers to try out.

The strategy has so far been working much as planned. In using the equipment on a range of farms, commercial haulers have not only demonstrated the technique widely, but have also been discovering what works and what doesn’t, Beegle says. Moreover, the injectors seem to be creating new business opportunities for haulers, Kleinman adds. Because shallow disk injection reduces phosphorus runoff, for example, the method allows haulers to specialize in applying manure in landscapes sensitive to phosphorus pollution.

But even more important is the reduction in nuisance odors, Kleinman adds. “The custom haulers are developing a niche where they use manure injection on fields near neighbors who might otherwise be offended by the odors.”

In Virginia, Maguire, too, has been working on a grant to bring injection equipment to farmers so that they can “play around with the practicalities.” For example, rather than driving the injector off the field to get new loads of manure, his group has been experimenting with “nursing”: ferrying manure out to the injector in regular tanker trucks that are cheaper and easier to drive and maneuver.

A number of other practical issues remain to be solved before manure injection becomes a well-established practice, Maguire says. Still, like Kleinman and Beegle, he’s optimistic about the approach, especially compared with other conservation practices, such as riparian buffers and stream-bank fencing.

“The great thing about manure injection is that many best management practices cost money, whereas with this, you can get manure off the soil surface and you may help the farmer’s financing because he’s capturing a lot more nitrogen,” Maguire says. “So this is something that will pay off for the environment and will hopefully pay off for the farmer, too.”

Kleinman agrees, adding that questions also remain about site-specific environmental performance. Most research on manure injection has been performed so far in well-drained systems, but at least one study suggests the practice doesn’t curb nutrient losses nearly as well in poorly drained soils. Evidence also suggests that while injecting manure cuts ammonia losses, it may boost denitrification rates and nitrate leaching, although so far the benefits of conserving ammonia appear to outweigh these possible downsides.

Another complexity has to do with no-till standards, which can vary at the state and federal levels and from state to state. The NRCS, for example, offers funds through its Environmental Quality Incentives Program (EQIP) to purchase no-till machinery, and since shallow disk injectors meet the NRCS no-till standard, they can be bought with EQIP money. But aerators aren’t eligible for the same funds because they can perform full-width tillage in addition to aeration. All the manure injection technologies meet NRCS conservation tillage standards, on the other hand, and can be purchased through that program, Beegle says.

Further reading

For more on this topic, see the special section that was published in the March–April 2011 issue of the Journal of Environmental Quality. Visit www.agronomy.org/publications/jeq/tocs/40/2.
Changes in alfalfa yield and nutritive value within individual harvest periods

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Alfalfa is widely used in ruminant livestock diets, impacting the performance of beef and dairy animals as well as the cost of production. The decline in forage nutritive value with increasing harvest interval is a consequence of progressing maturity, along with the associated effects of increasing stem growth and decreasing leaf proportion, and decreasing stem nutritive value. The implications of greater maturity for animal performance are generally negative. Past research has shown that when fed at a 55:45 alfalfa/concentrate ratio, feed intake and digestion along with milk production of dairy cows declined as the maturity at which the alfalfa was harvested increased from mid-bud to early flower to full flower. Other research reported similar results in beef cows fed a diet consisting entirely of cubed alfalfa; average daily gain declined as the maturity of the alfalfa fed to the cows increased.

While studies have documented the general effects of harvest interval and maturity on alfalfa yield and nutritive value across the whole growing season, they have not determined how yield changes relative to nutritive value within the periods of a growing season in which alfalfa is typically harvested. These harvest periods within a growing season are unique due to changing environmental conditions and present the producer with distinct harvest management considerations. Research has shown that alfalfa forage nutritive value declines at different rates during the spring, early-summer, late-summer, and fall growth periods and that nutritive value of the first cutting at the bud and flower stage differs from that of the third cutting. However, commensurate yield changes have not been reported in these studies.

Whether produced for commercial sale or for livestock consumption on the farm, alfalfa producers need specific information about yield and nutritive value relationships within the environmentally distinct periods of the growing season to make informed harvest management decisions. Knowledge of these relationships is also needed for the different regions where alfalfa is typically grown, primarily the northeastern, midwestern, and western United States. A recent study published in *Agronomy Journal* was conducted to determine the rate at which alfalfa yield changes relative to nutritive value during each of the periods in which it is typically harvested at three representative locations.

The study was conducted in central Pennsylvania near Pine Grove Mills on a Hagerstown silt loam (fine, mixed, semiactive, mesic Typic Hapludalf), in south-central Wisconsin near Prairie du Sac on a Richwood silt loam (fine-silty, mixed, superactive, mesic Typic Argiudoll), and in south-central Idaho near Kimberly on a Portneuf silt

**Abbreviations:** DM, dry matter; NDF, neutral detergent fiber; NDFD, neutral detergent fiber digestibility.
loam (coarse-silty, mixed, superactive, mesic Durinodic Xeric Haplocalcid). Monthly temperature and precipitation were recorded at each location. Soil fertility at each site was amended annually to meet recommendations for alfalfa hay production.

In August 2003 (Pennsylvania and Wisconsin) and May 2004 (Idaho), 'Affinity + Z' (Land O’Lakes, Inc., St. Paul, MN), ‘Standfast’ (Cal/West Seeds, Woodland, CA), and ‘WL 346 LH’ (W-L Research, Inc., Madison, WI) alfalfa were drilled (8-inch row spacing) into a prepared seedbed at 20 lb/ac of pure live seed in plots measuring 6 by 15 ft (Pennsylvania), 5 by 16 ft (Wisconsin), or 5 by 18 ft (Idaho). All cultivars have a fall dormancy rating of 4 and the following traits distinctive to each cultivar: multiple pest resistance and enhanced seedling resistance to *Phytophthora* and *Aphanomyces* root rot (Affinity + Z), reduced lodging and fast recovery after harvest (Standfast), and multiple pest resistance with enhanced leaf hopper resistance and fast recovery after harvest (WL 346 LH).

The experimental design was a split-split-plot arrangement of a randomized complete block with the harvest period in which alfalfa growth was measured (spring, early summer, late summer, and fall) as the whole plot, alfalfa cultivar as the subplot, and harvest date based on the number of days (0, 5, 10, 15, and 20) after each cultivar reached Stage 2 of morphological development (stem length >30 cm with no buds, flowers, or seedpods) as the sub-subplot in four replicates. Potato leafhoppers were controlled as necessary at all locations with Warrior insecticide, and plots at Idaho were irrigated on May 13, June 27, and Aug. 4, 2005.

Harvest treatments were imposed in 2004 (Pennsylvania and Wisconsin) and 2005 (all locations). During each of the periods in which the first harvest (spring, mid-May to early June), second harvest (early summer, mid-June to mid-July), third harvest (late summer, late July to mid-August), and fourth harvest (fall, late August to late September) typically occurs at these locations, each cultivar was initially harvested between 9:00 and 11:00 am on the day when Stage 2 was attained, which was considered Day 0 (Table 1). Additional sub-subplots of each cultivar were cut 5, 10, 15, and 20 days after Stage 2 was reached. Alfalfa maturity after Day 0 was not noted since time governed subsequent harvest dates. Because there were no differences in the date on which Affinity + Z, Standfast, and WL346 reached Stage 2 during each of the four harvest periods at any location, all cultivars were harvested on the same date at Day 0.

Environmental conditions at Pennsylvania and Wisconsin, which have humid continental climates, differed considerably during 2004 and 2005. The 2005 growing season at Pennsylvania and Wisconsin was generally warmer and drier than the 2004 growing season. These conditions likely accelerated the rate at which alfalfa reached Stage 2, or first flower, during the spring and shifted the initial cutting date of subsequent harvest periods to earlier dates. At Idaho, where irrigation is required for alfalfa production after the spring due to a semiarid climate, mean monthly temperatures in 2005 were above normal every month of the growing season except June. At all locations, mean monthly temperature increased to a maximum in July before declining.

### Statistical analysis

There was no interaction ($P \leq 0.05$) between alfalfa cultivar and days of growth, harvest period, location, and year for dry matter (DM) yield, neutral detergent fiber (NDF), and neutral detergent fiber digestibility (NDFD) concentration. The similarity in growth among the cultivars was consistent with respect to their fall dormancy ratings and suggested regions of adaptation. The days × year × location × harvest period interaction for DM yield, NDF, and NDFD was significant ($P \leq 0.05$) due primarily to the environmental differences within and between years at each location.

The relationship between each response (DM yield, NDF, and NDFD) and days of growth was usually linear ($P \leq 0.05$) during every harvest period. The only exceptions were a quadratic trend for DM yield during the spring harvest period at Pennsylvania in 2004 and 2005 and quadratic trends for NDFD during the early-summer and late-summer harvest periods in Wisconsin in 2004 and 2005. The linear components of these quadratic regression equations were used in statist-

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**Table 1. Date of initial harvest (Day 0) when alfalfa cultivars reached Stage 2 at each of three locations.**

<table>
<thead>
<tr>
<th>Harvest period</th>
<th>Pennsylvania</th>
<th>Wisconsin</th>
<th>Idaho</th>
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<tbody>
<tr>
<td>Spring</td>
<td>2004</td>
<td>2004</td>
<td>2005</td>
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<tr>
<td></td>
<td>May 20</td>
<td>May 12</td>
<td>May 20</td>
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<tr>
<td>Early summer</td>
<td>July 1</td>
<td>June 13</td>
<td>June 28</td>
</tr>
<tr>
<td>Late summer</td>
<td>July 29</td>
<td>July 12</td>
<td>August 4</td>
</tr>
<tr>
<td>Fall</td>
<td>September 1</td>
<td>August 12</td>
<td>September 8</td>
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<td></td>
<td></td>
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<td>September 1†</td>
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† Plots not harvested.
cal comparisons of the rate of change in DM yield, NDF, and NDFD for these harvest periods with other harvest periods.

**Dry matter yield**

Although environmental conditions at Pennsylvania and Wisconsin differed considerably in 2004 and 2005, differences in the rate of alfalfa DM yield production among harvest periods were relatively consistent over the two-year period. The rate of DM production was lowest both years at Pennsylvania and Wisconsin during the fall harvest period \( (P \leq 0.05) \), except in 2005 at Pennsylvania for early summer vs. fall. Similar results have been reported by others, who found that regardless of harvest frequency, alfalfa yield was lowest during the fall.

At Idaho, the rate of DM production was similar during the early- and late-summer harvest periods and greater than that during the spring harvest period. Other researchers also found that while DM yield was greatest in the spring, the rate of alfalfa growth was greatest from June 17 to August 7, a period similar to the early- and late-summer harvest periods of the current study.

**Neutral detergent fiber concentration**

Among the four harvest periods, alfalfa NDF concentration increased with time more rapidly during the spring than during any other harvest period in Pennsylvania in 2004 and in Wisconsin in 2004 and 2005. Above-normal temperature during the late-summer and fall harvest periods in Pennsylvania in 2005 likely contributed to accelerated maturation and greater rate of NDF increase relative to the spring. Some researchers found that herbage crude fiber increased more rapidly during the first cutting (late May to late June) than during the second cutting (early July to mid-August). In a comparison of high quality and traditional alfalfa cultivars, one researcher found that herbage NDF increased more rapidly during the first growth period (mid-May–early June) compared with the second (mid-June to early July), third (mid-July to early August), or fourth (early to mid-September) growth periods. Some researchers attributed differences in alfalfa nutritive value between the spring and subsequent growth periods to the proportion of leaves in the total forage, with the proportion of high quality leaves being less in the herbage of spring growth than in regrowth herbage for a given age or stage of development.
In contrast to Pennsylvania and Wisconsin, the increase in alfalfa NDF in Idaho during the early-summer harvest period was almost twofold greater than both the spring and late-summer harvest periods. In a northern California environment similar to that of southern Idaho, it was also found that NDF of alfalfa harvested at the prebud to full-bloom stage increased more rapidly in the early summer (0.38% DM per day) compared with the spring (0.3% DM per day), probably because the stem fraction had greater NDF during the summer than the spring.

Neutral detergent fiber digestibility concentration

The NDFD of the diet is an indicator of potential DM intake and milk yield in dairy cows. Summarizing data from a range of studies, the authors found that a one-unit increase in herbage in vitro or in situ NDFD was associated with a moderate increase in DM intake and a moderate increase in 4% fat-corrected milk per day. In this study, alfalfa NDFD declined with days of growth within harvest periods and was often negatively correlated ($P \leq 0.05$) with NDF ($R^2$ ranging from $-0.77$ to $-0.97$), with correlations occasionally being not significant ($P > 0.05$) during the early- and late-summer harvest periods.

The decline in NDFD with days of growth was most rapid during the early-summer harvest period at all locations except Pennsylvania in 2004. A more rapid decline in NDFD during the early-summer harvest period compared with other regrowth periods can be attributed to higher temperatures, which accelerate alfalfa maturation and lignification of the stem cell wall fraction, resulting in lower cell wall digestibility. Because of the positive association between temperature and cell wall lignin concentration and the degree to which temperature varies during the summer, consistently predicting how rapidly NDFD will change during these harvests periods may be difficult.

Conclusions

Economic incentives dictate that alfalfa producers carefully consider the impact of harvest management on yield and nutritive value. Although yield is negatively associated with herbage NDF, acid detergent fiber, and crude protein, the environmental conditions that influence alfalfa growth are not constant throughout the growing season. A better understanding of the relationship between yield and nutritive value, particularly fiber content and digestibility, and the difference among harvest periods will permit producers to tailor harvest management to optimize yield and nutritive value.

The results of the study presented here suggest that the timing of cuttings made in humid regions during the spring and early summer has greater importance than those made during the remainder of the growing season. During the spring and early summer, DM is being produced, and nutritive value is generally declining more rapidly (NDF increases in spring, and NDFD decreases in early summer) than during the late summer or fall. For example, it was determined that harvesting alfalfa initially in early spring with subsequent harvest intervals of <30 days produced less annual DM that had greater nutritive value than that obtained by harvesting later in the spring with longer subsequent intervals. The results, however, indicate that only spring and early-summer harvests need to occur early and more frequently to attain forage with high nutritive value in humid regions. The slower rate of change in nutritive value later in the growing season suggests that the timing of these harvests can be delayed to capture additional DM. In contrast, timing of the spring harvest in more arid environments appears to be less critical due to the slower rate of change in nutritive value compared with the early and late summer, thus allowing producers to delay harvest to obtain maximum DM yield.

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Changes in alfalfa yield and nutritive value within individual harvest periods (no. SS 04146)

1. The decline in forage nutritive value with increasing harvest interval is a consequence of progressing maturity, along with the associated effects of increasing stem growth and decreasing leaf proportion, and
   a. decreasing chlorophyll production.
   b. decreasing root size.
   c. increasing seed production.
   d. decreasing stem nutritive value.

2. In Pennsylvania and Wisconsin, alfalfa NDF concentration increased with time more rapidly during the
   a. spring.
   b. fall.
   c. early summer.
   d. late summer.

3. The 2005 growing season at Pennsylvania and Wisconsin was generally warmer and drier than the 2004 growing season. These conditions likely
   a. slowed the rate at which alfalfa reached Stage 2, or first flower, during the spring and shifted the initial cutting date of subsequent harvest periods to later dates.
   b. accelerated the rate at which alfalfa reached Stage 3, or full bloom, during the spring and shifted the initial cutting date of later harvest periods to later dates.
   c. accelerated the rate at which alfalfa reached Stage 3, or full bloom, during the spring and shifted the initial cutting date of earlier harvest periods to earlier dates.
   d. accelerated the rate at which alfalfa reached Stage 2, or first flower, during the spring and shifted the initial cutting date of subsequent harvest periods to earlier dates.

4. Above-normal temperature during the late-summer and fall harvest periods in Pennsylvania in 2005 likely contributed to a greater rate of
   a. NDF increase relative to the spring.
   b. NDF reduction later in the fall.
   c. reduction in herbage crude fiber.
   d. NDF increase by the next year.

5. The timing of cuttings made during the spring and early summer
   a. has greater importance than those made during the remainder of the growing season in humid regions.
   b. has less importance than those made during the remainder of the growing season in humid regions.
   c. has greater importance than those made during the remainder of the growing season in arid regions.
   d. has less importance than those made during the remainder of the growing season in arid regions.

6. Some researchers attributed differences in alfalfa nutritive value between the spring and subsequent growth periods to the proportion of leaves in the total forage, with the proportion of high quality leaves being
   a. higher in spring growth than in subsequent periods.
   b. about the same across the whole year.
   c. less in the spring growth than in regrowth herbage.
   d. higher in summer growth than in the fall.

7. The authors found that a one-unit increase in herbage in vitro or in situ NDFD was associated with a moderate increase in DM intake and a
   a. significant increase in 10% fat-corrected milk per day.
   b. slight increase in <2% fat-corrected milk per day.
   c. moderate increase in 4% fat-corrected milk per day.
   d. slight decrease in 2% fat-corrected milk per day.

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

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

Quiz continues next page
8. Although yield is negatively associated with herbage NDF, acid detergent fiber, and crude protein,
   - a. the rate of yield decline is site-specific, with steeper declines typically in arid climates.
   - b. the environmental conditions that influence alfalfa growth are not constant throughout the growing season.
   - c. the rate of yield decline is site-specific, with steeper declines typically in humid continental climates.
   - d. year-to-year variations in environmental conditions can actually result in a positive correlation on average over time.

9. The slower rate of change in nutritive value later in the growing season suggests that
   - a. harvest frequency should be increased to capture additional DM.
   - b. the timing of these harvests can be delayed to capture additional DM.
   - c. NDFD is greater earlier in the season.
   - d. the timing of the spring harvest is less critical.

10. A more rapid decline in NDFD during the early-summer harvest period compared with other regrowth periods can be attributed to
    - a. higher temperatures, which accelerate alfalfa maturation and lignification of the stem cell wall fraction, resulting in lower cell wall digestibility.
    - b. higher temperatures, which increase alfalfa transpiration and lignification in leaves, resulting in lower cell wall digestibility.
    - c. a greater proportion of leaves, which decrease total NDF and cell wall digestibility.
    - d. flowering, which increases lignification of the stem cell wall fraction, resulting in lower cell wall digestibility.
Continuous cropping systems under no-till (NT) systems are recognized as an important alternative to crop–fallow systems in the central Great Plains of the United States. Intensified cropping systems have greater benefits than crop–fallow systems for conserving soil and water, improving soil properties, and increasing soil organic carbon (SOC) concentration while improving crop production. Diverse crop rotations and continuous cropping systems return more above- and below-ground biomass to soil than cropping systems with extended fallow periods. Annual return of crop residues in NT systems is essential to protect the soil surface from water and wind erosion, reduce water evaporation, increase soil macroaggregation, and enhance C accumulation.

The Proctor test is a useful approach to determine soil's susceptibility to compaction and allows the determination of relative soil bulk density at different soil water contents under standardized compactive forces. The Proctor maximum bulk density is equivalent to the maximum compatibility of a soil. The soil water content at which Proctor maximum bulk density is reached is known as the critical water content. The Proctor test has important agronomic uses, but it has not been widely used for assessing differences in soil compatibility among diverse crop rotations managed under NT.

A recent report in Agronomy Journal studied the differences in Proctor maximum bulk density, critical water content, and bulk density and the influence of SOC concentration on these compaction parameters for various cropping systems managed under NT in the central Great Plains. The study hypotheses were that: (i) cropping systems differ in their susceptibility to compaction and (ii) changes in SOC concentration due to differential biomass C input by different cropping systems are responsible for changes in maximum bulk density, critical water content, and bulk density. This study differs from others in that it compares (i) differences in soil compatibility among long-term cropping systems within the same tillage system (NT) as well as (ii) the relative differences in maximum bulk density against those of bulk density.

This study was conducted across three soils under long-term (>11 years) cropping systems managed under NT in the central Great Plains. The cropping systems represented common dryland practices in the region. The experiments were at Hays and Tribune in Kansas and Akron in Colorado. These experiments have been in place for 33 years at Hays, 11 years at Tribune, and 19 years at Akron. The soils were Crete silty clay loam (fine, smectitic, mesic Pachic Argiustolls) in Hays, Richfield silt loam (fine, smectitic, mesic Aridic Argiustoll) in Tribune, and Weld loam (fine, smectitic, mesic Aridic Argiustoll) in Tribune.

**Abbreviations:** GRASS, perennial grass; NT, no-till; SF, grain sorghum–fallow rotation; SOC, soil organic carbon; SS, continuous sorghum; WCF, wheat–corn–fallow rotation; WCM, wheat–corn–millet rotation; WF, winter wheat–fallow rotation; WSF, wheat–sorghum–fallow rotation; WW, continuous wheat; WWSF, wheat–wheat–sorghum–fallow rotation.
Akron. The soils at Tribune and Akron are deep and well drained, while the soil at Hays is also deep but moderately slowly permeable. The soil slope at the three sites is <1%. Average annual precipitation is 23 inches in Hays, 17 inches in Tribune, and 16 inches in Akron. At Hays, there were five cropping systems: grain sorghum–fallow (SF), continuous sorghum (SS), wheat–sorghum–fallow (WSF), winter wheat–fallow (WF), and continuous wheat (WW). At Tribune, there were three cropping systems: wheat–sorghum–fallow (WSSF), wheat–wheat–sorghum–fallow (WWSF), and WW. At Akron, there were four crop rotations: WF, wheat–corn–fallow (WCF), wheat–corn–millet (WCM), and perennial grass (GRASS).

**Maximum bulk density and critical water content**

Proctor bulk density curves show that bulk density among the cropping systems differed at soil water contents below the critical water content level in a shallow-depth testing area. Differences were larger for the silty clay loam and loam than for the silt loam. On the silty clay loam, mean Proctor bulk density below the critical water content in SF and WF was 5 to 15% greater than in WW and SS. On the loam, mean Proctor bulk density below the critical water content was about 8% greater in WF and WCF than in WCM and GRASS. The silt loam showed that WSSF had greater bulk density than WW, but there were no differences at greater water contents. For deeper soil depths, differences in Proctor bulk density were not significant.

Changes in Proctor bulk density in the silt loam were small or nonexistent, but larger differences in the silty clay loam and loam were found. This might be due to the following reasons: First, the experiment in the silt loam at Tribune has been in place for shorter time period (11 years) than the experiments at Hays (33 years) and Akron (19 years). Since changes in soil properties in this climate are often detected after long periods of experimentation, the researchers hypothesized that significant differences in maximum bulk density and SOC concentration in the silt loam may surface in the longer term. Second, cropping systems differed among the three soils. The experiment in the silty clay loam and loam included more contrasting cropping systems (crop–fallow vs. continuous cropping systems) than that in the silt loam with only three systems (WSSF, WWSF, and WW). Fallow periods occurred every two years for WF and SF in the silty clay loam and WF in the loam, whereas in the silt loam, they occurred every four years. Thus, the less contrasting differences in cropping systems in the silt loam than in other soils probably reduced differences in soil compatibility due to smaller differences in surface residue cover, biomass C input, and soil properties.

Similar to maximum bulk density, cropping systems also altered critical water content in the silty clay loam and loam but not in the silt loam. The critical water content in the silty clay loam differed only at the shallow depth (0 to 5 cm), but in the loam, it differed at both depth intervals (0 to 5 cm and 5 to 15 cm). On the silty clay loam, the critical water content in WW and SS was greater than in WF and WCF. On the loam, the critical water content in WCM was greater than in GRASS, WF, and WCF at the shallow depth. At the same depth, the critical water content in GRASS was greater than in WF and WCF. The maximum bulk density was very strongly and negatively correlated ($r > -0.8; P < 0.001$) with critical water content in all soils and decreased with an increase in critical water content. The critical water content explained 64, 74, and 75% of the variability in the maximum bulk density in the silty clay loam, silt loam, and loam, respectively. Across all soils, the critical water content explained 88% of the variations in maximum bulk density.

The results of this study showed that the relative maximum soil compaction in continuously cropped systems occurred at a greater soil water content than in crop–fallow systems. This suggests that soils in continuously cropped systems may be trafficked at greater soil water contents than those in crop–fallow systems without causing excessive compaction. It is also clear from the results that differences in near-surface Proctor bulk density occurred only below the critical water content, which indicates that continuous cropping systems can alleviate some of the risks of excessive compaction at low rather than high soil water contents. Above the critical water content, all soils were equally compacted regardless of differences in cropping systems.

Cropping systems altered bulk density only in the silty clay loam and loam. Differences in bulk density were similar to those of maximum bulk density and critical water content. On the silty clay loam, mean bulk density averaged across SF, WF, WSF, and SS was greater than in WW by about 22% at the shallow depth (0 to 5 cm). At the deeper depth (5 to 15 cm), there were no statistical differences in bulk density. On the loam, mean bulk density averaged across WF and WCF was greater than that averaged across WCM and GRASS by 14% in the shallow depth. There were no differences in sand, silt, and clay content among the cropping systems in any of the soils.

**Relationships between soil compaction parameters and soil organic carbon**

The reduction in maximum bulk density by continuous cropping systems is largely attributed to the near-surface accumulation of SOC. The maximum bulk density was highly and negatively correlated with SOC concentration for the shallow depth in all soils, supporting the second
hypothesis. The maximum bulk density decreased in a linear function with an increase in SOC concentration and was less strongly correlated with SOC concentration for the silty clay loam than for the silt loam and loam. Changes in SOC concentration explained 28, 43, and 72% of the variations in maximum bulk density for the silty clay loam, silt loam, and loam, respectively. Across the three soils, changes in SOC concentration explained 71% of the variations in maximum bulk density. It is important to note that while the maximum bulk density and SOC concentration among crop rotations did not statistically differ in the silt loam, maximum bulk density significantly decreased with an increase in SOC concentration as a result of lower, although not statistically significant, maximum bulk density and greater SOC concentration in WW than in WWSF and WSSF.

The bulk density was also significantly correlated with SOC concentration. Similar to maximum bulk density, the bulk density decreased with an increase in SOC concentration in all soils. Changes in SOC concentration explained 23, 39, and 66% of the variations in maximum bulk density for the silty clay loam, silt loam, and loam, respectively. Across the three soils, changes in SOC concentration explained 32% of the variations in maximum bulk density. The relationship between bulk density and SOC concentration was, however, weaker than that between maximum bulk density and SOC concentration. Across all soils, changes in SOC concentration explained 71% of the variability in maximum bulk density, but they explained only 32% of the variability in bulk density. The maximum bulk density and bulk density were significantly related. Changes in bulk density explained about 30% of the variability in maximum bulk density.

The increase in critical water content was also attributed to an increase in SOC concentration with continuous cropping systems as the critical water content was strongly correlated with SOC concentration. The critical water content increased with an increase in SOC concentration, but the magnitude of the relationships varied with soil. Changes in SOC concentration explained 16, 44, and 45% of the variability in critical water content in the silty clay loam, silt loam, and loam, respectively. Across the three soils, SOC concentration accounted for 65% of the variations in critical water content. The sand, silt, and clay content were not correlated with maximum bulk density, critical water content, and SOC concentration in any soil.

The soil’s reduced susceptibility to compaction and compression with increased SOC concentration is attributed to the following mechanisms induced by soil organic matter. First, soil organic matter increases the soil’s
resistance to deformation by improving the elasticity and rebounding capacity of the soil matrix. Soil organic materials are more elastic and looser than mineral particles. Second, soil organic matter lowers the bulk density of the whole soil by the “dilution effect” as it has a lower bulk and particle density than mineral particles. Third, organic compounds of high molecular weight contribute to the bonding of organic and mineral particles at the contact points inside the macro- and microaggregates, improving the resilience against soil consolidation and compaction. Fourth, soil organic matter may alter the electrical charge of organomineral contact points and increase friction between organic and mineral particles, which would reduce consolidation of aggregates.

Results of this study also indicate that the relative maximum compactive force that these soils can resist without being compacted depends on the SOC concentration. These results may have large implications because they suggest that near-surface excessive maximum compaction may be somewhat managed by adopting continuous cropping systems, which increase SOC concentration. Crop–fallow systems had lower SOC concentration than continuous cropping systems and thus were more prone to compaction than cropping systems without fallow periods. The confinement of the beneficial impacts of increased SOC concentration on reducing soil compaction to the upper 0- to 5-cm soil depth is attributed to the stratification of the SOC concentration in these NT soils.

Soil water content, particle-size distribution, and SOC concentration are among the soil factors influencing soil compatibility. Among these factors, SOC concentration is probably the only factor that can be altered by cropping systems as soil water content changes dynamically with precipitation. Improved management strategies that increase SOC concentration at lower depths and reduce SOC stratification are needed. Growing deep-rooted plant species such as forage grass and manure application may be alternatives to increase SOC concentration with depth in cultivated soils and offset some of the risks of soil compaction in deeper soil depths. Data for the loam from Akron indicate that growing perennial grass in cultivated soils increased SOC concentration and reduced the risks of soil compaction.

It is important that the results from this study should be interpreted cautiously. The Proctor test provides information on the relative differences in soil compatibility because it uses homogenized soil samples, which do not fully reflect in situ field conditions. The Proctor bulk density is determined using large and disturbed soil samples, whereas field bulk density is determined on small and undisturbed soil cores. These differences in size and disturbance in soil samples may partly explain the relatively weak relationship between maximum bulk density and bulk density ($r^2 = 0.30; P < 0.001$) in the study.

Characterization of relative bulk density using the Proctor test provides the following additional information over bulk density determinations. First, the Proctor test permits the identification of maximum bulk density of a soil under a systematic, uniform, and repeatable application of compactive forces, simulating the pressure exerted by field equipment. Second, it permits the determination of the critical water content for maximum soil compaction so that the soil can be trafficked below this critical water content level without causing excessive compaction. Third, it allows the breakdown of soil compaction risks at various soil water contents, simulating the effects of field soil water dynamics on soil compaction. For example, in this study, the Proctor test allowed the determination that continuous cropping systems had a greater effect on reducing bulk density at low rather than at high soil water contents. Both maximum bulk density and bulk density decreased linearly with an increase in SOC concentration, but maximum bulk density was more strongly correlated with SOC concentration than with bulk density.

Conclusions

This regional study across three contrasting soils in the central Great Plains shows that long-term continuous cropping systems may alleviate some of the risk of excessive near-surface soil compaction over crop–fallow systems under no-till management. The near-surface maximum bulk density, a parameter of soil compatibility, under continuous cropping systems was significantly lower than under crop–fallow systems in two of the three soils studied. These results indicate that reduction or elimination of fallow periods may reduce some of the risks of soil compaction near the soil surface layers. Continuous cropping systems also increased the soil water content at which a soil can be trafficked without significantly inducing excessive compaction. For the same compactive force, soils under crop–fallow systems become compacted at lower water content than those under continuous cropping systems. Continuous cropping systems increased SOC concentration over crop–fallow systems, and the maximum bulk density decreased and critical water content increased with an increase in the SOC concentration. The increase in SOC concentration was primarily responsible for the reduced relative compatibility in these no-till soils. The data suggest that increasing the SOC concentration through appropriate management practices such as continuous cropping systems may be a potential way to manage compaction within the surface layers.

May–June 2011
self-study quiz

Effect of continuous cropping systems on compaction in no-till soils (no. SS 04147)

1. Which of the following is NOT one of the benefits of intensified cropping systems over crop–fallow systems?
   a. increasing SOC concentration.
   b. improving crop production.
   c. increasing near-surface maximum bulk density.
   d. conserving soil and water.

2. Results of this study showed that the relative maximum soil compaction in continuously cropped systems occurred
   a. at a lower SOC concentration than in crop–fallow systems.
   b. at a lower soil water content than in crop–fallow systems.
   c. at a greater SOC concentration than in crop–fallow systems.
   d. at greater soil water content than in crop–fallow systems.

3. The reduction in maximum bulk density by continuous cropping systems is largely attributed to the
   a. near-surface accumulation of SOC.
   b. accumulation of SOC at greater depths.
   c. near-surface accumulation of soil moisture.
   d. accumulation of soil moisture at greater depths.

4. Which of the following is true of soil organic materials?
   a. They are less elastic and looser than mineral particles.
   b. They are more elastic and looser than mineral particles.
   c. They are more elastic and compact than mineral particles.
   d. They tend to displace mineral particles.

5. Across all soils, the critical water content explained
   a. 88% of the variations in maximum bulk density.
   b. 82% of the variations in SOC.
   c. 92% of the variations in SOC.
   d. a small proportion of the variations in maximum bulk density.

6. Soil organic matter ___ the bulk density of the whole soil by ___
   a. increases/the density effect.
   b. increases/increasing organomineral fractionation.
   c. lowers/decreasing friction between organic and mineral particles.
   d. lowers/the dilution effect.

7. Continuous cropping systems induced an increase in SOC concentration that was primarily responsible for the
   a. increased relative compatibility in these no-till soils.
   b. improved relative nutrient absorption in these no-till soils.
   c. reduced relative compatibility in these no-till soils.
   d. reduced relative water permeability in these no-till soils.

Quiz continues next page
8. The Proctor test  
- a. helps identify minimum bulk density of a soil, simulating the effects of weather.  
- b. helps determine the critical water content for maximum soil compaction.  
- c. simulates the effects of soil breakdown on field soil water dynamics.  
- d. helps determine water permeability of compacted soils.  

9. Organic compounds  
- a. improve the resilience against soil consolidation and compaction.  
- b. contribute to the bonding of mineral particles with other mineral particles.  
- c. contribute to the bonding of macroaggregates with microaggregates.  
- d. lower the molecular weight of mineral particles.

10. According to the article, reduction or elimination of fallow periods  
- a. may reduce some of the risks of soil compaction near the soil surface.  
- b. may increase some of the risks of soil compaction near the soil surface.  
- c. may reduce some of the risks of soil compaction in the deep layers of soil.  
- d. eliminates the risk of soil compaction in the middle soil layers.

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**Self-Study Quiz Registration Form**

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

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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 May 2011 expires May 2014

**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:__________________________
Do farmers need to apply for a second pesticide permit if they are spraying pesticides over water? Not today. And not in the future if Congress enacts legislation before the end of October to eliminate a court-mandated requirement for a National Pollutant Discharge Elimination System (NPDES) permit.

With the House of Representatives taking the lead, Congress is working to forestall requirements for duplicative pesticide requirements that arise under two separate environmental protection laws. This is good news. It means that farmers who use pesticides will not need to seek an NPDES permit in addition to pesticide permits required under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). Only the FIFRA permit will be needed.

The requirement for a separate permit for pesticides sprayed over water resulted from a January 2009 ruling from the Sixth Circuit Court of Appeals in National Cotton Council v. U.S. Environmental Protection Agency (USEPA). The USEPA had developed a regulation in 2006 to clarify requirements under FIFRA and the Clean Water Act (CWA) specifying situations where FIFRA permits would be sufficient and additional permits under CWA would not be necessary. However, this rule was challenged by a number of parties and ultimately vacated by the court.

The court mandate sent the USEPA back to write a rule that would require an NPDES permit for any pesticides sprayed near waterways, including irrigation ditches, regardless of whether or not pesticide users had permits issued under FIFRA that covered the application. Net result: two permits could be necessary for the same pesticide spraying. Farmers, crop advisers, and agriculture organizations have made it clear that this makes no sense.

At the same time that the USEPA was developing regulations to implement the court ruling, the agency worked with Congress to draft the legislative language amending FIFRA to make that law primary and the NPDES permits unnecessary. This reflects the USEPA’s original position, which the court overruled. Should the double-permit requirements go into effect, the USEPA estimates that 35,000 pesticide applicators who perform some 500,000 pesticide applications annually nationwide would need to get NPDES permits in addition to FIFRA permits. Getting a second permit is expected to cost applicators an additional $50 million, plus lead to $2 million in increased costs for the USEPA to process the permits.

While helping with a legislative fix, the USEPA requested and received from the Sixth Circuit Court a delay in implementing the NPDES permitting requirements from Apr. 9, 2011 to Oct. 31, 2011. This extension gives some breathing room for Congress to enact a legislative remedy to correct the duplicative requirements.

That remedy is closer to becoming reality. Specifically, the House of Representatives voted 292–130 on March 31 for H.R. 872, “Reducing Regulatory Burdens Act of 2011,” which was introduced by Rep. Bob Gibbs (R-OH) with 137 co-sponsors. The legislation passed despite opposition by environmental groups such as the Sierra Club, the Natural Resources Defense Council, and Earthjustice.

In the Senate, Sen. Pat Roberts of Kansas, the Agriculture Committee’s ranking Republican, introduced similar legislation on April 4. His bill, S. 718, is titled “A Bill to Amend the Federal Insecticide, Fungicide, and Rodenticide Act to Improve the Use of Certain Registered Pesticides.” It has 12 co-sponsors and has been referred to the Agriculture Committee. Passage of that bill before October 31, and signature by President Obama, will remove the requirement for a second permit.

A second permit for pesticide spraying provides no additional environmental protection. Striking the requirement for it is a common sense solution that will cut costs, eliminate redundancy, and reduce unnecessary burdens for farmers. It’s a simple fix that just makes sense.

By Bruce I. Knight
Consultant for the ASA and
ICCA programs
Washington, DC
A 1,800 lb/ac dry bean crop uptakes about 125 lb/ac of nitrogen and removes about 80 lb/ac in the seed. The rhizobia associated with dry beans are a different strain than those for soybeans and are more sensitive to environmental factors. Dry beans obtain less than half of their nitrogen requirement through fixation. Ontario nitrogen research has not demonstrated an economic response to applied nitrogen. However, it is common practice for dry bean growers to apply between 30 and 60 lb/ac of nitrogen.

On-farm trials were established in fields without a history of manure or forage plow down. Four nitrogen rates (0, 40, 80, and 120 lb/ac) were used at each location, which included two or three replications. Types of beans tested included white pea beans, kidney beans, and cranberry beans. Nitrogen was applied at the time of planting, except for one kidney bean site at Thorndale, where nitrogen was sidedressed prior to flowering using 28% nitrogen behind a coulter. Soil nitrate and ammonium were measured at planting and at maturity. A standard soil test was collected at each site.

Visually there was a large increase in vegetative growth between nitrogen rates, especially between the check (0 N) and the other treatments. There was little to no increase in yield from added nitrogen at the white bean sites (Fig. 1, opposite page). White beans were seeded in 15-inch rows using conventional tillage at all but one site (no-till)

The colored beans produced a positive yield increase to nitrogen application (Table 1). Nitrogen application increased the yield of kidney beans only slightly, but with only three locations over two years, no conclusions could be drawn. Cranberry beans showed the largest yield increase to nitrogen application—more than 300 lb/ac when averaged across the six sites in 2009–2010.

### Table 1. 2009–2010 kidney and cranberry bean nitrogen response trials.

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#### Kidney beans

<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
<th>Soil</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>Thorndale</td>
<td>sandy loam</td>
<td>3,392</td>
</tr>
<tr>
<td>2010</td>
<td>Thorndale</td>
<td>clay loam</td>
<td>3,420</td>
</tr>
<tr>
<td></td>
<td>Thorndale</td>
<td>2010 average</td>
<td>3,406</td>
</tr>
<tr>
<td>2009</td>
<td>Thorndale</td>
<td>clay loam</td>
<td>2,544</td>
</tr>
<tr>
<td>2009</td>
<td>Thorndale</td>
<td>2009–2010</td>
<td>3,119</td>
</tr>
</tbody>
</table>

#### Cranberry beans

<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
<th>Soil</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>Seaforth</td>
<td>clay loam</td>
<td>2,231</td>
</tr>
<tr>
<td>2010</td>
<td>Denfield</td>
<td>clay loam</td>
<td>1,795</td>
</tr>
<tr>
<td>2010</td>
<td>Thorndale</td>
<td>clay loam</td>
<td>1,851</td>
</tr>
<tr>
<td>2010</td>
<td>Dorchester</td>
<td>sandy loam</td>
<td>2,734</td>
</tr>
<tr>
<td></td>
<td>Thorndale</td>
<td>2010 average</td>
<td>2,153</td>
</tr>
<tr>
<td>2009</td>
<td>Thorndale</td>
<td>sandy loam</td>
<td>2,559</td>
</tr>
<tr>
<td>2009</td>
<td>Denfield</td>
<td>clay loam</td>
<td>1,883</td>
</tr>
<tr>
<td></td>
<td>Thorndale</td>
<td>2009 average</td>
<td>2,221</td>
</tr>
<tr>
<td></td>
<td>Thorndale</td>
<td>2009–2010</td>
<td>2,175</td>
</tr>
</tbody>
</table>
This increase was the same at all three nitrogen rates, and thus there was no further yield gain over the first 40 lb/ac of nitrogen. In 2010, the Denfield cranberry site showed excellent growth, but severe dry weather from flowering to maturity resulted in poor pod fill and small seeds. This site showed no increase to nitrogen application.

The positive yield response in cranberry beans may be related to their difference in growth habit compared with the other bean types tested. Cranberry beans have a determinate growth habit and a shorter flowering period and growing season relative to the white and kidney beans. The nitrogen applied to the cranberry beans would help stimulate production of a large plant (i.e., seed factory) prior to flower on which to set pods. The indeterminate and vine nature of kidney and white beans along with the longer growing season allows them to continue to grow and produce flowers once flowering begins.

Fall soil nitrate values collected from each nitrogen rate showed only a slight increase in levels with higher N rates. There were no noticeable delays in maturity from the higher nitrogen rates. This would agree with research results. There was an increase in white mold versus the check, particularly with the 80 and 120 lb/ac nitrogen rate. At higher nitrogen rates at the white bean sites, the greater amount of vine and top growth resulted in more lodging.

Fig. 1. 2009–2010 white bean nitrogen response trials at seven locations over two years.
Certification update:
Restructuring, promotions, and international expansion

By Luther Smith
Director of Certification Programs
ASA and SSSA
lsmith@sciencesocieties.org

The Certified Professional Agronomist (CPAg) board and the International Certified Crop Adviser (ICCA) board have been discussing over the past two years how to bring the two programs under one administrative structure. Earlier this year, they agreed to move the CPAg program into the ICCA program infrastructure. The change will take effect Jan. 1, 2012 and will in essence make CPAg a specialty certification within the ICCA program.

Both ICCA and CPAg are certification programs of the American Society of Agronomy (ASA). Both focus on the agronomy profession with slightly different requirements. The ICCA program currently certifies about 13,000 individuals and is established in the U.S., Canada, and India, with programs under development in Argentina and Mexico. CPAg is a U.S. program and currently certifies about 650 individuals, about half of which have both CCA and CPAg credentials.

The change was necessary to unify the agronomy certification process and eliminate any unnecessary competition between the two programs. The new structure will create a seamless process for a CCA to add a CPAg certification and will capitalize on a coordinated marketing effort and unified financial support.

From an operational perspective, CCA will be the base certification with no changes to requirements or renewals. CPAg will become a specialty certification, meaning that an individual must meet the CCA requirements first or simultaneously to meeting the CPAg requirements. This will apply to all new applications for CPAg after Dec. 31, 2011. Currently, the CPAg application includes passing the same ICCA exam that CCAs must pass. The change will now require also passing the local board exam that CCAs are currently required to complete. The local CCA board will review both CCA and CPAg applications as they are received.

You will not see any changes if you are currently a CCA. If you are a CPAg, you will see some change in the fee structure and CEU requirements. The amount of the change in fees will depend on whether you are both a CCA and CPAg or just a CPAg. CCAs typically pay between $55 and $95 in their annual renewal. The range exists because the local CCA boards do not charge the same amount. Individuals with both certifications will likely see a decrease in their total certification fees while those who only have a CPAg certification will likely see an increase.

The new fee structure will include paying the CCA annual fee plus the specialty fee of $30 on top of it for CPAg. CEU requirements will not change for CCAs, but they will be changing for CPAgs. Those details will be refined in the coming months by the ICCA Continuing Education Committee. We will be sending each CPAg the details of the
changes so that they will know what to expect when the changes are implemented next year.

**Promoting CCA certification**

The ICCA Promotions and Communications Committee will be working with WOW Marketing out of Des Moines, IA to develop and implement a more comprehensive promotional plan in 2011. WOW Marketing has worked with many agriculturally oriented organizations and not-for-profit groups to expand their market penetration. The committee will be developing their plans in the coming weeks and announcing those projects in future issues of Crops & Soils magazine.

**ICCA board global restructuring**

The ICCA board decided to reorganize its structure to better represent the participation of other countries in the program. The new structure will separate what are “national” issues from those that are “international.” The involvement of the local CCA boards will not change, but the involvement of the ICCA board will. There will now be a National CCA Board for each country and an International CCA Council. The council will focus on standards or policies of the program that apply across country boundaries. Each national board will have one seat on the international council. The national boards will ratify any decisions of the council before they are enacted, focus on issues that pertain to their country, and work with the local boards to implement the policies and procedures of the program. This new structure will not change the requirements to become or be certified. It only impacts the organizational structure and duties of the ICCA board.

**Argentina**

The Argentina CCA program began the process of developing the exam performance objectives and organizing its board. The goal of this program is to have the exam ready for an August 2012 offering. At this point, the group is gaining support from private companies, institutions, universities, and government agencies and projects 1,000 CCAs in Argentina over the next three to five years.

Argentina will be the first country in South America to join the ICCA program, and there is a great potential for other countries to follow. It will have all CCA documents translated to Spanish—another first for the program.

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**AMS Soil Probes**

AMS soil probes are the most basic sampling tools for farmers, agricultural consultants, and soil scientists. Soil probes provide a simple, fast, and economic method of collecting small diameter soil samples for soil profiling, moisture determination, or chemical analysis.

- All soil probes are made of nickel-plated or unplated chromoly, or they are all stainless steel.
- All probes feature a heat-treated tip that create holes larger than the outer diameter of the body for easy removal.
- All probes may be used with AMS extensions, handles, and slide hammers.
- Samples may be collected directly in the probe or with certain models, into a liner.
- On replacable tip models four tip options are available for varying soil conditions.
- AMS slide hammers, hammer-head cross handles, and adjustable footsteps are also available for additional downforce.

[www.ams-samplers.com/soilprobes](http://www.ams-samplers.com/soilprobes)
As many of you have likely read or heard by now, the Soil Science Certification Board and the Soil Science Society of America are in the process of bringing the Certified Professional Soil Scientist (CPSS) and Certified Professional Soil Classifier (CPSC) certifications into the single designation of CPSS. The certification board is made up of professionals in private practice, government agencies, and universities and is unified and unanimous in the need for this change. We believe that a singular certification will aid in bettering our science and our industry as a whole.

For years, the soil science profession has been misunderstood by the public and many other professional industries. The confusion as to what a soil scientist is, and what we are qualified to do, is likely in part due to the complexity of our science, which includes the disciplines of chemistry, physics, geology, biology, ecology, hydrology, and climatology. The two certifications within our system give the impression that soil science consists of two distinct areas—classification and non-classification; this has greatly contributed to, and magnified the level of, confusion both inside and outside of our industry. It has become increasingly obvious over the last few years that this division within the certification program was the root of much of the confusion about the soil science profession.

We have received a few letters from concerned certified individuals who are opposed to discontinuing the CPSC. In these letters, the individuals have stated their interpretation of what a CPSC is compared with a CPSS, but each describes what a CPSC is very differently. The board and the Society greatly appreciate this input, as it

Explaining the decision
to discontinue the CPSC certification

By Matthew M. Duncan, CPSS, CPAg, and PSS-MN
Chair of the Soil Science Certification Board
Macomb, IL; mduncan@keyaginc.com

CEU applications now online

Are you a vendor or sponsor of a meeting, workshop, or seminar and looking to apply for CEUs? The CEU application is now online. As many of you have been requesting, we have put the application online to make it easier to fill out the forms and start the approval process. No more pen and paper—and it’s more environmentally friendly than printing and mailing/faxing in the old forms.

Here’s an overview of how it works. Anyone requesting CEUs can access the online form at:

www.certifiedcropadviser.org/continuing-education

The applicant will complete three steps:

1. Enter meeting information
2. Enter session information
3. Submit application

When the application is submitted, the primary CEU reviewer for the board will automatically receive an email with the meeting information. The reviewer will either review it directly or forward to another reviewer. Once the review process has been completed and the meeting has been approved or denied, an email will be sent back to the person who submitted the application. Complete instructions for reviewers are also provided on the website above.

We have also compiled, from the Policies and Procedures manual, additional details to provide both applicants and reviewers with as much information as possible on the process. This new program will help speed up the submission and review process. If you have any suggestions for improvements to the application, reviewer process, and/or instructions, we would appreciate your feedback—simply contact your representative.
has made the issue very clear; it is not only outsiders to our field, but also our own certified individuals, who are confused by having two certifications.

When other industries or the public at large are confused by the system, we could rationalize the issue as one of poor outreach or lack of communication from our industry to others. But when certified individuals within the soil science certification system can’t understand the differences, how can we expect others to understand when a situation is appropriate to call on the services of a soil scientist as opposed to a professional in a different discipline?

Some have argued that to be a CPSC, one must have five years of in-field soil-mapping experience. The experience requirement for the soil classifier does not specify that the experience must be in-field mapping or direct field applications, nor does it exclude the areas of laboratory, research, or teaching as some individuals had thought. What the current CPSC certification does guarantee is that the individual has five semester hours of a soil classification class, which many to most CPSS’s have, and five years of professional experience doing something that is related to classification.

If you teach or conduct research or laboratory work that has to do with soil formation, morphology, etc., it too would be counted as classification experience toward a CPSC. A soil scientist working in an office with GIS to identify locations that are mapped as having hydric soils for construction limitations for the private sector may never be in the field, but that does not mean that experience would not count toward a CPSC.

If the CPSC were only for people who conduct in-field soil series mapping, as some have stated as their interpretation, then this brings the topic to an even more interesting question. What qualifies as field classification of soils? If a scientist’s only experience in the field is to site septic-leaching fields, does that qualify that person to conduct an Order 1 or Order 2 soil survey? So is that person a soil classifier or not?

What about the individual who is in the field evaluating soil profiles for salts, free carbonates, structure and textural changes with depth, and hydraulic conductivity to determine whether the site is feasible for a restoration project? This person is not “classifying” the soil to the series level, nor are they creating a USDA-NRCS style
Newly certified

The following list includes newly certified individuals and those who have added additional certifications in February and March 2011. The list is alphabetized by surname within each state/province.

**Canada**

**Alberta**

Fletcher, Lindsay Meagan, Taber, AB (CCA-PP)
Maze, Ryley Bennett, Red Deer, AB (CCA-PP)
Thiel, Gerald K., Legal, AB (CCA-PP)

**British Columbia**

Funk, Brandon Edward James, Rolla, BC (CCA-PP)

**Manitoba**

Waddell, Kristine April, St. Adolphe, MB (CCA-PP)

**Ontario**

Benjamins, Ryan Evan, Forest, ON (CCA-ON)

**Saskatchewan**

Bohn, Thomas R., Yorkton, SK (CCA-PP)
Bolton, Kyle James, Simmle, SK (CCA-PP)
Court, Tracy Lynn, Norquay, SK (CCA-PP)
Jordet, Kyle L., Moose Jaw, SK (CCA-PP)
McKerchar, David Hugh, Yorkton, SK (CCA-PP)

**United States**

**Arizona**

Miller, Jerry L., Tucson, AZ (CPSS)

**Arkansas**

Frankenberger, Jeremy David, Paragould, AR (CCA-AR)

**California**

Atkins, Michael B., Santa Maria, CA (CCA-CA)
Cerri, Celso Francisco, Somis, CA (CCA-CA)
Dullam, Thomas Glen, Ventura, CA (CCA-CA)
Hansen, Seth M., Kingsburg, CA (CCA-CA)
Johnson, Kenneth Lee, Dixon, CA (CCA-CA)
Overeem, Eric Wilhelm, Aptos, CA (CCA-CA)
Quist, Matthew Elliot, Fresno, CA (CCA-CA, CPAg)
Scurich, Justin Jasper, Watsonville, CA (CCA-CA)
Walgenbach, Paul J., El Dorado Hills, CA (CCA-CA)

**Colorado**

Lang, Joshua Ray, Forrest City, AR (CCA-AR)

**Georgia**

Coyle, David Clayton, Douglasville, GA (CPSS)

**Idaho**

Doperalski, Matt J., Eagle, ID (CPAg)
Young, Allyson, Moscow, ID (CPSS, CPSC)

**Illinois**

Dexter, Adam Lee, Bishop Hill, IL (CCA-IL)

**Indiana**

Maruszewski, Jennifer Marie, Lisbon, IN (CCA-IN)

**Kansas**

Bunck, Brice Eugene, Everest, KS (CCA-KS)
Hampel, Michael Eugene, Beloit, KS (CCA-KS)

**Michigan**

Maust, Jason Earl, Bay Port, MI (CCA-MI)
Montney, Russell Walter, Ray Township, MI (CCA-MI)
Southworth, Kameron Lee, Pigeon, MI (CCA-MI)
Turner, Scott T., Williamston, MI (CCA-MI)

**Minnesota**

Grandstrand, Evan Roman, Stephen, MN (CCA-ND)
Johnson, Margaret Ann, Fountain, MN (CCA-MN)
Kaysor, Adam Francis, Wells, MN (CCA-MN)
Kragenbring, Michael Scott, Alexandria, MN (CCA-MN)
LaVois, Craig R., Battle Lake, MN (CCA-MN)
Rastede, Kelli Ann, Morgan, MN (CCA-MN)
Schmidt, Allen William, Buffalo Lake, MN (CCA-MN)
Scott, Mark Allan, Rochester, MN (CCA-MN)
Sorenson, Jeffrey J., Morgan, MN (CCA-MN)
Tiegen, Gregory David, Byron, MN (CCA-MN)
Wiebers, Matt A., Plymouth, MN (CCA-MN)

**New Mexico**

Stinson, Dex Michael, Clayton, NM (CCA-TX)

**New York**

Niblock, Daniel J., Hoxie, KS (CCA-KS)
Rowan, Justin Ross, Larned, KS (CCA-KS)
Shive, Allen Ray, Mt. Hope, KS (CCA-KS)
Thomas, Tristan Niles, Edson, KS (CCA-KS)
Zweygardt, Andy Austin, Montezuma, KS (CCA-KS)
map of the soils, but they are experienced in applied soil morphology, genesis, and formation and how to interpret those characteristics. Some of you may say, yes, that person should definitely qualify as a CPSC, and others may disagree. The interesting thing about this example is the individual whom this example is about more than meets the education requirements to become a CPSC, yet does not consider himself a soil classifier. Examples like this can go on and on.

The fact is a soil scientist, no matter what area of specialty they may practice, must have an understanding of many of the “specialty” areas of the entire science in order to practice good soil science. Hopefully this makes it more clear that not only is it likely impossible to correctly define an individual as being specialized in a singular specialty area of soil science, it is also not accurate to attempt such a specific designation due to the nature of the science.

Role of the Code of Ethics in preventing unqualified practice

One might ask, then how do we prevent a CPSS who is not qualified to conduct soil mapping from mapping soils, or how do we prevent any soil scientist who is not qualified to practice in a specific specialty area from practicing in that area? The answer is simple—the same way we always have, through the Code of Ethics. If you haven’t re-read our Code of Ethics in a while, I suggest you do as it is a great refresher on what is expected of all of us as certified professionals. You will notice in Article 2, Number 2, it states:

“A Registrant shall not give professional opinion or make a recommendation without being as thoroughly informed as might reasonably be expected considering the purpose for which the opinion or recommendation is desired, and the degree of completeness of information upon which the opinion is based should be made clear.”

In other words, you cannot practice outside of your area of expertise. Also note that Article 5 states that it is the duty of all certified professionals to report unethical activities of other certified professionals. Each of us abiding to the rules set forth within the Code of Ethics has been, and remains to be, the best means for all soil scientists to ensure for ourselves and those we serve a highly respected and trusted scientific profession made up of highly respected individuals.

Change is never easy, and there will never be 100% agreement within any group to a change. What I and the Soil Science Certification Board hope is that all soil science practitioners, no matter what part of the industry you practice in or in what area you specialize, can understand that the purpose of this change is to better position the entire soil science industry to retain and capture the jobs that are best suited for soil scientists. More and better soil science jobs will attract the interest of high quality students to the soils industry. New soil scientists coming into the profession ensures the future of the science to which we have dedicated our careers and reputations.

The certification board and I appreciate your input and hope you now have a better understanding of the time and thought that has gone into this decision as well as the purpose and need for the change. &

[Discontinuing CPSC (continued from p. 29)]

North Carolina
Snyder, Douglas E., Cary, NC (CPAg)

North Dakota
Bowman, Charles Brett, LaMoure, ND (CCA-ND)
Crockett, James Marcus, Langdon, ND (CCA-ND)
Dahl, Lee Kenneth, Lakota, ND (CCA-ND)
Huso, Mark D., Lakota, ND (CCA-ND)
Kyllo, Kaelin Harvey, Hillsboro, ND (CCA-MN)
Plain, Andrew Jay, Edmore, ND (CCA-ND)
Ressler, Bryan L., Cando, ND (CCA-ND)
Spitzer, Tim Todd, Ellendale, ND (CCA-ND)
Stafslien, Jason Derris, Fargo, ND (CCA-MN)

Pennsylvania
Moorhead, Benjamin, State College, PA (APSS, APSC)

South Dakota
Heyne, Brad E., Roscoe, SD (CCA-SD)

Tennessee
Hinrichs, Laura Katherine, Memphis, TN (CCA-AR)

Texas
Jung, Ryan Wade, El Campo, TX (CCA-TX)
Kinnibrugh, Cliff Aaron, Wall, TX (CCA-TX)
Sosebee, Mark Daniel, McAllen, TX (CCA-TX)
Turnbough, Larry Brent, Balmorhea, TX (CCA-TX)
Underwood, Brandt Lee, Lubbock, TX (CCA-TX)
This is a story of soil research and extension from the province of Saskatchewan in Western Canada.

In the 1970s and early 1980s, soil salinity was a serious problem to production agriculture in the northern Great Plains of North America (North Dakota, Montana, Saskatchewan, and Alberta). The problem was perceived to be growing at an alarming rate, estimated by some to be 10% per year. Action was needed or there would soon be no land left to farm.

At that time, the University of Saskatchewan had a series of joint appointments between the campus-wide extension division and subject matter departments in agriculture. I was privileged to have the Extension Chair in the Soil Science Department. The job was 50% extension with the other 50% split between teaching and research. The extension function was used to define research priorities. I called it the “sputter” index. If I sputtered to answer a question at a farm meeting, it was time to look for the answer in the literature. If no answer came from the literature, it was time for research. Soil salinity was a “sputter” question.

The soil salinity question had been the subject of much research, but little of it seemed to explain what we saw in farm fields of Saskatchewan. Conventional wisdom from Montana and Alberta suggested that “side-hill seep” was the dominant process. That meant that water from the nearest hill was encountering an impermeable layer and went sideways instead of down, causing the high water table and consequently soil salinity. The problem with this idea was that many situations in Saskatchewan had no hill to pin it on. Historical air photos and individual quarter-section inspection sheets for municipal assessment showed that soil salinity had been around for a long time.

Enter the Salt Patrol

It took some time to convince bureaucrats with access to the money that a new approach was needed, but we persevered and funding was established to set up the “Salt Patrol.” The project was to take place on actual farms over a wide geographic area (Saskatchewan has 45 million cultivated acres). Auger drilling was used to determine stratigraphy; soil and water pH, electrical conductivity, and selected ions were determined in a field lab. We were committed to finding an answer to the cause(s) of salinity at one farm before another was tackled.

Before field work began, background data was collected and evaluated, which included air photos, soil surveys, topographic and geologic maps, and individual inspection sheets prepared by the assessors (mostly soil scientists) who completed land assessment for taxation purposes. The assessor sheets were the most valuable as they were subject to exam by the farmer. If the assessor didn't report soil salinity, the farmer would appeal and stuff his/her nose in the problem to lower land taxes.

For field work, we had a mobile auger rig and crew with the capability to drill to a depth of 45 ft. The first job near Saskatoon was easy—the soil salinity was caused by a nearby gravel pit, not much was going to be done about it, and more land would not be affected in the future.

The second job was at Shaunavon—a four-hour drive south-west of Saskatoon—and it was difficult. We drilled our 45-ft hole and learned precisely nothing. It was our great fortune that renowned geologist Earl Christiansen and renowned hydrogeologist Bill Meneley had become disgusted with bureaucracy at the Saskatchewan Research Council and were then private consultants. We engaged Earl to review our Shaunavon situation. He said we had the wrong equipment and the wrong
The problem, and we knew what caused that the problem was much the same far-flung sites, it became obvious as the work went on at dozens of over five years to expand the work. A lion ($2 million in current dollars) to further the work. The project was awarded $1 million ($2 million in current dollars) to further the work. The project was awarded $1 million ($2 million in current dollars) to further the work. When I was done, the main question on with farming the rest of the land. The Shaunavon aquifer came in at 52 ft, and a piezometer was installed to measure the piezometric surface of that aquifer. Imagine the excitement when the water level in that piezometer was only inches below the soil surface. The conclusion was easy—the high water table was maintained by the slow but constant upward flow from the aquifer. The Shaunavon aquifer had already been defined as a regional aquifer, so it was obvious that the nearest hill and shelterbelts had little to do with the problem.

The project progressed rapidly after that initial discovery, and soil salinity investigations soon turned into aquifer mapping. The practical application on the farm was to plant the affected acres to grass and carry on with farming the rest of the land.

That fall I was giving extension talks on the work, and the deputy minister of agriculture for Saskatchewan was at one of the meetings. He invited me down to tell the story to the caucus of the party in power in the Saskatchewan government. When I was done, the main question they had was “If we give you more money, can you do it faster?” Not long after that meeting, the minister of agriculture came to the president’s office at the University of Saskatchewan and presented us with a check for $100,000 ($200,000 in today’s dollars) to further the work.

So, the work continued for a number of years, and at one point, the project was awarded $1 million ($2 million in current dollars) over five years to expand the work. As the work went on at dozens of far-flung sites, it became obvious that the problem was much the same everywhere, so there was little point in continuing. We knew what caused the problem, and we knew what it would take to fix it (drainage + leaching), but economics and environmental constraints meant it would not happen. It was not a knowledge problem any longer—it was a money problem and an environmental problem: if you install tile drains, where do you dump the salty water?

So, I shut the program down and returned $100,000 of unused funds to the provincial treasury, which was not very popular with administrators, but the right thing to do.

Take home message

The take home message from this “Tale from the Pits” is:

1. Soil scientists must learn to dig a little deeper and think a little broader. The deepest “pit” we dug was 610 ft. The principle was based on a geologic base of exploration, and we never compromised that principle.

2. Interdisciplinary approaches are required to make gains in applying science to practical problems. The research must be driven by a problem, and the lead researcher should have the option to access other disciplines in the private sector. When we hired private consultants Earl Christiansen and Bill Meneley, many wondered why we did not use geologists from the public sector. My response was easy: “Because when I ask Earl or Bill a question, I get an answer, and they apply their knowledge to my problem.”

3. When science solves real problems for real people, our elected officials respond in spades with the funds to proceed. I often counsel graduate students that to succeed, they need to look around and see where society has a “burr under the saddle.” Then figure out a way to reach in and remove the burr—and money will flow like water.

4. If soil science is to survive and prosper, we must apply the pedologic knowledge base to practical problems. Soil is a natural body and deserves respect and study in its own right, but the funds to do that will not be forthcoming unless we apply that knowledge to real world problems. The public does not care if a soil is called a Degraded Eutric Brunisol (Canadian) or a Typic Argiaquoll (U.S.). Current soil classification systems serve only as internal communication; in essence, we are talking to ourselves. We need to talk to the public in their language.

5. The interaction between groundwater and soil is paramount in understanding soil formation, function, and environmental interpretations. In our glaciated environment, the 10,000-year record of water flux at the soil surface is written in the soil profile. Only soil scientists can read that record. We must make sure we get a chance to utilize that skill to interpret the environment and our use of it.

6. The emerging science of hydropedology is well on the way to realizing the above scientific goals. Thanks to Henry Lin (Penn State) for his work in fathering that science and nurturing it to the present state. The next step is to make sure it is communicated to the public we serve.

Do you have a tale you’d like to share?

If so, email Dawn Ferris at dferris@sciencesocieties.org. Please make the stories generic enough so as not to identify a specific person or place, but still get the point across. Authors may remain anonymous if they wish.
Deficit irrigation of alfalfa for water savings in the western U.S.

Diversions of water from irrigated agriculture are occurring in the western U.S. to address increasing municipal and industrial demands. Deficit irrigation of alfalfa could be a way for farmers to maximize crop water productivity. A new report in *Agronomy Journal* reviews alfalfa plant–water relations in the Great Plains and Intermountain West to understand potential water savings through deficit irrigation and to identify management practices that maximize water use efficiency.

In water-scarce environments, demand for water exceeds the available supply, creating competition among users for this limited resource. Population growth in the western United States drives water scarcity, and the problem is magnified by drought conditions and declining groundwater levels. As an example, it has been projected that Colorado’s population will grow by 65% within the next 25 years, resulting in a likely dry-up of 420,079 acres of irrigated farmland to meet the urban demand for water. Similar water reallocation from agriculture to municipalities has the potential to dry up irrigated agriculture throughout much of the western United States. Solutions that meet water demands of growing populations and industry without loss of irrigated land are needed to preserve food production and regional economies that depend on irrigated agriculture.

Because alfalfa is a high water-use crop grown on 12% of the irrigated land in the United States, controlled deficit irrigation of the crop has been proposed as a way to save water. Controlled deficit irrigation is an approach that supplies water at a rate below the full crop water requirement and usually results in lower biomass yields than full irrigation. In regions where water resources are restrictive, it can be more profitable for farmers to maximize crop water productivity instead of yields.

In the January–February 2011 issue of *Agronomy Journal*, researchers review irrigated alfalfa studies in the Great Plains and Intermountain West to evaluate differences in evapotranspiration (ET), biomass yield, water use efficiency (WUE), and the potential for water savings from controlled deficit irrigation. Their analysis revealed that growing season ET averaged 91 cm over full-irrigation treatments, 80 cm for deficit-irrigation treatments, and 39 cm for dryland treatments. Average annual biomass yield was 7.4 tons/ac under full irrigation, 5.0 tons/ac under a variety of deficit-irrigation treatments, and 2.7 tons/ac under dryland conditions. Although the irrigation treatments are pooled over a wide range of climatic conditions, the comparison illustrates the magnitude of water use by irrigated alfalfa, the potential water savings from converting full-irrigation alfalfa to deficit irrigation or dryland, and the extent of yield reduction that would accompany the reduced irrigation levels.

A regional average WUE for alfalfa was estimated from aggregated results of the reviewed studies. Alfalfa biomass yield responds in a positive, linear relationship to increasing ET, with an average WUE of 0.07 tons/ac/cm. Relative biomass yield declines at a greater rate than relative ET, indicating that WUE will decrease with decreasing ET under either deficit irrigation or dryland conditions.
Several individual studies confirm decreasing WUE with deficit irrigation over a wide range of environmental conditions. Researchers in Utah used line source irrigation in an alfalfa study and found that WUE ranged from 0.08 tons/ac/cm under deficit irrigation to 0.09 tons/ac/cm for full irrigation. In New Mexico, WUE ranged from 0.04 tons/ac/cm in the driest conditions to 0.07 tons/ac/cm in the wettest conditions under line source irrigation. A similar observation of declining WUE with ET was observed in a more humid environment in Minnesota, where average WUE values were 0.10, 0.10, 0.09, and 0.05 tons/ac/cm for high, medium-high, medium-low, and rainfed irrigation treatments. Thus, over a wide range of environmental conditions, there is a consistent trend of decreased WUE with decreasing ET under deficit irrigation.

Seasonal differences in water use efficiency

Water use efficiency varies with harvest interval due to differences in environmental conditions and plant carbohydrate partitioning. A study comparing biomass yield and transpiration over harvest interval found that the greatest WUE was measured during the first harvest of each season and the remaining harvests had lesser WUE. Another study in Texas also found that the greatest WUE was observed for the first harvest.

Variation in solar irradiance helps explain seasonal differences in WUE. The results of an experiment comparing biomass yield per unit of transpiration with level of solar irradiance over time showed that biomass yield increased with increasing average daily solar irradiance during the growing period. Based on a plant growth simulation model, the increase in biomass yield per unit of transpiration was explained by increasing solar irradiance due to increased light penetration into the canopy rather than an increase in heat energy. Both conditions, high light and relatively low temperatures, only occur in the spring, whereas, light levels are limiting in the fall. Thus, harvest intervals corresponding to the greatest WUE occur when solar irradiance is high enough to induce high levels of photosynthesis and temperatures are low enough to keep evaporation at a minimum, such as the first harvest in the spring.

The seasonal variation in WUE also relates to carbohydrate reserve flux in the alfalfa plant. Biomass development early in the season depends on carbohydrate reserves accumulated during the fall of the previous season and results in the highest WUE of the season. After the first harvest, carbohydrates for growth and restoration of root reserves come from photosynthesis in new leaves, and transpiration is correlated with leaf surface area. As daylength shortens and temperatures decline in the late summer and early fall, greater amounts of photosynthate are partitioned into root reserves, resulting in lower levels of aboveground biomass, yield, and WUE.

These observations suggest an approach to saving water from irrigated alfalfa may be to concentrate irrigation during periods of the growing season that have the greatest WUE, such as the first harvest interval, followed by deficit or no irrigation during periods of the growing season with the least WUE, such as mid-summer harvest.
Management factors affecting alfalfa water use efficiency

Variety

While it is expected that alfalfa varieties would vary widely in WUE, there is little evidence to support this. Studies in Utah, Texas, Washington, and California indicate that alfalfa varieties with varying dormancy traits and genetic backgrounds do not differ greatly in total-season WUE. Varieties with different fall dormancy may not relate to the suitability of the variety under deficit irrigation.

Less is known about the potential role of alfalfa varieties on partial-season irrigation. It has been reported that alfalfa varieties that have cold tolerance and winter hardiness also have drought tolerance because both conditions desiccate plant cells. Drought and cold tolerance may be linked to small cell size. If advantages in WUE during particular periods of the growing season do exist, selecting varieties that possess drought tolerance and are more dormant may be best for stand survival during dry periods in a partial-season irrigation system. More studies are needed to evaluate alfalfa varieties under partial-season irrigation in different environments. It is thought that a more fibrous root system may be more efficient in extracting soil water than a dominant tap root system. However, it should be noted that numerically high fall dormancy ratings tend to be correlated with tap-rooted alfalfa varieties and low fall dormancy ratings are correlated with fibrous-rooted alfalfa varieties.

Harvest timing

Harvest timing has been found to influence alfalfa WUE. A study conducted in New Mexico evaluated the WUE response of alfalfa in relation to the accumulation of growing degree days within each growth cycle. The study compared biomass yield per harvest to transpiration and growing degree days with all other variables held constant. The aboveground biomass yield to transpiration ratio decreased as growing degree day accumulation increased between the levels of 450 (bud initiation) and 700 (full bloom) in a very linear fashion. This reduction in biomass yield per unit of transpiration may have been due to partitioning of dry matter into crowns, roots, and reproductive structures rather than new leaves and stems. The accumulation of aboveground growth follows a sigmoid pattern, with growth rates declining after about the bud stage. The canopy achieves full cover by the time ET has reached a maximum and continues at a near-constant level until the bloom state, suggesting that the WUE of alfalfa may be increased by harvesting on a 400 to 450 growing degree schedule. However, harvesting alfalfa at the prebud stage (400 growing degree days) for any period of time will reduce plant vigor and decrease stand longevity. Growing degree-day accumulation for each harvest certainly has some impact on alfalfa WUE, but it is likely that the risk of reduced stand longevity would not justify harvesting at an early growth stage to improve WUE.

Stand age

Stand density and vigor decline over time in alfalfa. Stand density is important for production and is linked to WUE in alfalfa. When comparing WUE over time, it was found that WUE was least in the establishment year, maximized at year 5, and remained constant afterward. This may be due to a difference in CO₂ partitioning as the plant matures. One researcher concluded that the amount of water transpired to produce a given amount of total above- and below-ground biomass remained constant over the study period, but the amount of water transpired to produce a given aboveground biomass decreased until year 5 or 6 when the root system was fully developed. However, consideration of the evaporative portion of ET also affects the WUE and is subject to change as the stand ages. A relatively low WUE occurs during the establishment year due to evaporation from low ground cover. After the establishment year, full ground cover increases transpiration but reduces evaporative loss. In older, thinning stands, ground cover decreases, and more water loss to evaporation can lead to reduced WUE.

When considering adopting deficit irrigation as a water conservation approach, the implications of stand age on alfalfa WUE should be considered. Since WUE was not maximized until year 5 and remained constant afterward, an alfalfa producer may improve WUE by leaving a stand of alfalfa in production for longer than the typical four- to five-year production period. Lengthening the life of the stand will reduce the frequency of lower WUE found during establishment and the first few production years. However, as stands age, they decline in density and are at risk for encroachment by weeds. Therefore, a balance
between increasing WUE and a thinning stand must be found.

**Water table contribution to alfalfa evapotranspiration**

Alfalfa has an extensive root system with the ability to extract water from deep within the soil profile. Alfalfa roots commonly grow 6 to 13 ft long and, under the right conditions, can grow as deep as 29 ft. In the presence of a shallow water table, the contribution to ET from the water table can be significant. Documenting water uptake from shallow groundwater may be important if controlled deficit or partial-season irrigation of alfalfa is promoted as a water-savings approach. Additionally, water uptake from groundwater may have an effect on nearby streamflows, which can impact other water users.

Research that quantifies the water-table contribution to alfalfa ET is very limited, especially under conditions of deficit irrigation; however, a relationship between ET contribution from the water table and depth to the water table can be estimated for alfalfa based on results of published data. The ET contribution declines rapidly as water table depth increases to about 3 ft and then levels off to about 20% for depths up to 20 ft. There is also a strong negative relationship between contribution to ET from the water table and the amount of irrigation and precipitation, suggesting that the potential of significant ET contribution from a water table would increase under controlled deficit or partial-season irrigation. Evapotranspiration determined on the basis of applied irrigation will underestimate actual crop ET where a deficit irrigation system is being considered and shallow water table conditions exist.

**Conclusions**

A review of studies across the Great Plains and Intermountain West regions of the United States revealed a positive, linear response of alfalfa biomass yield to ET and suggested several management techniques that could improve that relationship. Total seasonal ET of alfalfa ranged from 18 cm under dryland to 152 cm under full irrigation with an average total seasonal ET of 88 cm. The irrigation strategy used to reduce ET in most reported studies was deficit irrigation, with a reduced amount of irrigation water applied throughout the entire crop growing season. When managing irrigation to reduce ET, yield declines from its local maximum 25% faster than ET.

For environmental conditions in the Great Plains and Intermountain West, alfalfa WUE is greatest during the first harvest interval when plants are using carbohydrates stored in roots, solar irradiance is high, and temperatures are relatively low. Thus, partial-season irrigation is a potential management approach to saving irrigation water that combines full irrigation during the earliest growth cycle with no irrigation during subsequent growth cycles. Irrigation termination during hot, dry summers can be detrimental to alfalfa stands in arid environments and sandy soils, but evidence suggests minimal stand loss in semiarid environments with finer soil textures. Partial-season irrigation may improve total seasonal WUE for alfalfa compared with deficit irrigation and may be a better approach for conservation of agricultural water compared with deficit irrigation or conversion to dryland production.

In every aspect of our lives, consciously or unconsciously, we are always working to maintain balance among personal time, family time, and work time. It can be a complex issue with a constant shifting of priorities depending on what needs to be done first at a certain time. Maintaining balance requires practice, usually by trial and error, and can come with some frustration and disappointment.

Fabian Fernandez, a member of the Early Career Members Committee of the American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America, offers his opinion on the subject in the May issue of CSA News magazine. He says one way to look at the issue is to break it down into manageable components: time and choice. In one plate of the balance, we have life, and in the other, we have different weights that represent various fractions of time or activities. What we choose to do with our time will determine whether or not we can maintain balance in our lives. Obtaining perfect harmony among all components at the same time is not the goal. Rather, it is keeping them all moving, but at different speeds depending on the situation. Sometimes career comes first, sometimes family or other important relations come first, and sometimes personal time must come first.

Suggestions for success

Following are some suggestions Dr. Fernandez gives for maintaining balance

- **Prioritize time with goals.** It is critical to understand that time is a limited resource that needs prioritization. Long-term perspective on life and clear identification of over-arching goals along with the smaller goals that will get us where we want to be are essential to effectively prioritize our activities. Having clear goals implies taking time to meditate on what is truly important in life. It takes effort to be proactive rather than reactive, but unless one takes a proactive approach in life, the tree is always going to be hiding the forest. Taking time to write a list of tasks that you want to accomplish on a given day in order of importance can do wonders to help you accomplish what is most important, and it greatly boosts your self-esteem as you realize your progress.

- **Have a plan of attack and take time to celebrate.** As long as everything that is important receives proper attention, maintaining balance does not mean giving everything that is important the same amount of time each day. When you have a demanding project at work, consider talking with your family about special activities that you will do to enjoy time together during the busy time or after the project is finished. Having something to look forward to can really make a positive difference in making the long days more bearable and maintaining balance in our lives.

- **Give yourself a break from your professional work.** If you enjoy your work, it is easy to be thinking about work, checking email, or working on the computer virtually every waking moment of the day. To help maintain balance, consider making the conscious effort to schedule time to completely “unplug” yourself from work and use that time to fully devote it to your family or to yourself. By doing so, you’ll find yourself enjoying life a lot more and being more productive at work.

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