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4 Feature
Soil testing: Looking back on the early days of soil testing in the United States, getting a good soil sample, and selecting a reliable testing lab.

11 Special Section
Directory of Participating NAPT Soil-Testing Laboratories | p. 11

15 Certification
Newly Certified. Plus, Meet the Professional.

18 Technology
Using sensors for on-the-go soil sampling.

20 Company Strategies
When foliar fertilization makes sense.

22 Career Center
Prepare for your job search, discover the value of mentoring, and more.

26 Continuing Education
Earn up to 2.5 CEUs in Soil & Water Management.

45 Regional Roundup
North Dakota and Wisconsin CCAs recognized.

46 New Products
Looking back on the early days of soil testing in the United States

It’s hard to imagine what the world would be like without the yield increases we’ve seen over the last several decades. A 50- or 60-year period where yields are flat seems unthinkable, yet this was the case from the latter half of the 19th century into the early 20th century before agronomy organized itself as a scientific discipline and soil-testing methods were developed. During the year’s Leo M. Walsh Soil Fertility Distinguished Lecture at the November 2009 Annual Meetings of the American Society of Agronomy (ASA), Crop Science Society of America (CSSA), and Soil Science Society of America (SSSA) in Pittsburgh, David Mengel, a professor of agronomy at Kansas State University and an ASA–SSSA Fellow, talked about the period around 1920 through World War II, which he characterized as the “soil testing/problem solving era.”

“I grew up in the whole era of surpluses and concerns about how do we get rid of all this stuff we can produce, but that wasn’t the case at the turn of the 20th century,” Mengel said. “Erosion and nutrient depletion were really
reducing both productivity and productive acres in the U.S. The Great Depression, Dust Bowl, and urbanization would all accelerate that trend as we went on into the 1930s and 1940s, so the situation was much different.”

Another thing that was different was the state of the science at the time. ASA was first organized in 1907, and so the discipline of agronomy was just getting started. Two years later, the concept of pH was first introduced. It would be another 20 years until working pH meters and glass electrodes became available and another 20 years after that before flame photometers were widely used in the United States.

The test kit years

“By the early 1900s, agronomists and soil scientists were beginning to look for ways to increase yields and restore productivity to what they termed ‘exhausted’ soils,” Mengel said. “Soil testing addressed some of those important issues, particularly acidity and phosphorus and potassium concentrations. The availability of soil testing was a tool that was chosen to really make a difference in many of these places. Simple ‘do it yourself’ soil test kits were the starting point for this effort.”

The soil test kits used very simple chemistry that still exists. “We’re currently working with a bunch of National Guard soldiers from Kansas in Afghanistan, and we’re using this same technology,” Mengel said. “And I’ve learned over the last six months that Afghanistan has very high phosphorus levels because they were tested with a LaMotte test kit.”

In 1914, Emil Truog, from the University of Wisconsin, developed one of the first soil tests—a zinc sulfide acidity test for farmers and county agents.

“It was a simple little test where you put soil in a little crucible, added a liquid, boiled it, and with zinc sulfide added, fumes came off that turned a lead acetate paper black,” Mengel explained. “So it was sort of semi-quantitative—the blacker it got, the more lime you needed. But it was a very important tool that was used very widely.”

In the 1920s and 1930s, Truog and others, such as Roger Bray from the University of Illinois, C.H. Spurway from Michigan State University, Michael Pech from Cornell, and M.F. Morgan from University of Connecticut, developed field test kit procedures to measure pH, phosphorus, and potassium.

“Most of the kits used either some sort of a pH by indicator dye, the Truog test, or a thiocyanate test to measure pH or acidity,” Mengel said. “Phosphorus was measured using various dilute acids, and… potassium was measured turbidimetrically by cobaltinitrate application.”

Many states began equipping their county agents and specialists with some of these kits to do field- and farm-based soil testing, Mengel said.

Illinois promoted soil testing as a “do it yourself” project where its county agents encouraged farmers to bring samples in and then taught them how to do the tests themselves.

Soil fertility trains soon began traveling the Midwest testing soils for farmers. In addition to “soil doctors,” the trains featured exhibits, labs, lectures, and even motion pictures. They later evolved into lime trains in Indiana and rock phosphate trains in Illinois in the 1930s and 1940s, transporting these materials throughout the state for farmers to load into their trucks.

Instrumentation and labs

Small labs also began to develop during this time, particularly at universities but also at state agencies and even some businesses, Mengel said. Most continued to use soil test kit type technology until the mid-1930s. Advances in  

[continued on page 15]
Oil sampling can help producers gauge the relative nutrient status of their soils and apply the right amount of fertilizer to meet the needs of their crops. It’s the basis for profitable and environmentally responsible fertilizer application, but it can also be fun.

“I find great pleasure in going out on a good overcast day and sampling soil,” admitted Michael Larkin, a CCA with Crop Production Services in Madera, CA, during a talk this past November at the “Fresh Approaches to Fertilizing Techniques” conference in Visalia, CA. He discussed some strategies for getting a good soil sample during the conference, which was hosted by the California Department of Food and Agriculture Fertilizer Research and Education Program and the Western Plant Health Association.

According to Larkin, it isn’t simply a matter of hitting the field with hammer probe and Dutch auger in tow in search of soil. Ensuring you get a good soil sample demands asking several important questions prior to leaving the office.

First, you should consider why you are taking a sample in the first place. Knowing this and understanding how it will inform testing will lead to better success. Whether assessing soil quality concerns, plant nutrient supply, or predicting the probability of obtaining a desired response to fertilizers or amendments, the sampler must put into context the reasoning for testing.

Collecting soil samples is the first step and hence the foundation for all that follows: laboratory analyses, soil test interpretations, and nutrient management recommendations. “We don’t want to spend any more money than we need to, but we do want to make sure that we fulfill the crop need. And so it often provides a basis of recommendations that we make,” Larkin explained.

He also said it is important to remember that soil sampling is the largest source of error in the soil-testing process. Antonio Mallarino, CPSS and professor of soil fertility and nutrient management at Iowa State University, agrees that soil testing is not a perfect diagnostic tool. It is not free from error or uncertainty, but it is very useful for nutrient management, especially when the soil test method is properly calibrated by field research and research-based interpretations and recommendations are used.

“Soil test calibration based on local or regional field research is of paramount importance for most nutrients,” Mallarino says. “Any soil analysis will give a result, and a lab may be very good at testing and producing reliable results, but all of this is useless for most tests unless the method is properly calibrated.”

Properly used soil testing and research-based interpretations should result in nutrient application rates that are profitable and do not result in excesses that may impair water quality.
Tools and timing

Before sampling, soil sample bags should be obtained along with soil-sampling instructions, information on soil tests and recommendations, and nutrient management diagrams. These can be obtained from soil-sampling laboratories and county extension offices. The sampler will also need a soil sample auger and a clean plastic pail. Soil survey maps of fields and other technical resources can be obtained from the USDA's Natural Resources Conservation Service at www.nrcs.usda.gov/technical/maps.html. Electronic GIS-based survey maps for most regions of the United States can be found at http://soildatamart.nrcs.usda.gov/Default.aspx.

The best time to sample a field is either between harvest and fall fertilization or before spring fertilization. One should not sample shortly after a fertilizer or manure application or when the soil is excessively wet. Sampling at other times such as in winter or during the growing season is discouraged because result interpretations can be more complex and difficult. Fields should be sampled every two to four years for most crops or once in a crop rotation. The process is easier after you have obtained a comprehensive soil fertility map and record of each field.

Sample pattern and size

Each sample should represent a uniform soil area with similar past management. In general, each sample should represent 10 acres or less. With zone sampling, a field is subdivided into management zones based on soil characteristics, past and present management practices, and the goals desired, and samples are obtained for each zone. Grid sampling uses a systematic grid pattern to obtaining samples. Using a grid is best when little is known about the soils in the field or past management. It is also used with computer mapping of soil test results. No one grid size best fits all fields, but a suggested minimum size is one sample per 2.5 acres.

“Each [method] has advantages and disadvantages,” Larkin said. “I think we could argue all day long about what the best method is. I’ll argue that the more samples you can take, the more confident you can be in terms of the information you are providing. But certainly economics will play into how many samples you are able to pool from an individual field.”

After careful planning prior to sampling, the number of samples taken is the most important variable that will ensure reliability, according to Larkin.

“You need a sufficient number of cores to reduce the variability, but you also have to be efficient, and you have to be economic in terms of what you’re doing. And in most of the literature that you will look at, that number of about 12 to 15 [samples] has held through the years … once you get out to 8 or 9 cores, your variability or your standard deviation drops dramatically.”

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With the zone management system, soil survey maps can help in selection of each sampling area. Using the maps to delineate soils, slope phases, and erosion phases are useful because organic matter, nutrient levels, and soil pH can vary following the map’s units.

Avoiding errors

Visual observations are also important to distinguish areas with different soils and erosion. Avoid sampling odd or dissimilarly treated areas not representative of the management across the zone. Common examples of odd areas are old livestock lots, old fence lines, dead furrows, back furrows, fertilizer spills, and field depressions.

“Usually large within-field spatial variability of nutrient levels is the most common source of error and uncertainty in soil testing,” Mallarino says. Therefore, farmers or consultants should not “cut corners” in relation to the number of samples per field (following grid- or zone-sampling methods) or the number of cores for each composite soil sample. Soil testing is a site-specific diagnostic tool that adapts very well to new precision agricultural technologies. The use of soil testing integrated with tools such as GPS, remote sensing, yield monitors, and variable-rate application is key for improving the efficacy of nutrient management.

According to Mallarino, there is always bias in soil testing (different labs get slightly different results), although the NAPT program and other efforts have decreased this bias (see pages 9–14). Most states have soil test certification programs, so farmers may want to send samples to a certified laboratory.

“Soil test methods, interpretations, and recommendations vary across regions,” Mallarino says, “so farmers must be sure the lab they choose uses methods appropriate to their soils and research-based interpretations and recommendations appropriate for their soil and crops.”

The sampler needs to clarify what the testing lab wants or requires of the samples it will analyze. Knowing the lab’s analysis methodology will often dictate the depth of sampling, for instance, which may vary from lab to lab.

Sampling depth

“Sampling depth depends on purpose,” Larkin said. “There are two ways to sample. First in terms of uniform increments, or we can look at the soil profile and the physical characteristics of that soil profile and then manage according to that profile.”

Interpretation of P, K, and Zn soil test values and nutrient recommendations are based on soil samples collected from a 6-inch depth. The 6-inch depth should be used for all tillage systems and pastures. Samples to monitor surface pH should be collected from the top 2 to 3 inches in no-till systems where a shallower sample represents the soil depth that is affected by surface applications of nitrogen, manure, and limestone.

For ridge-tillage fields, samples should be taken from the ridge and in about equal amounts from the top and shoulders using a 6-inch depth. Collecting cores from the valleys will result in lower soil test values, which overestimate P and K fertilization needs.

After obtaining samples, check that each sample bag clearly identifies the field and sample area with a unique identifier or number. Samples should be sent to the test facility soon after they are taken. If stored, samples should be kept in a cool location out of intense heat. Laboratories will provide a sample information sheet to be filled out and submitted with the sample. For limestone recommendations, it is important to record sampling depth and incorporation depths. Recommendations vary for different crops, and yield information is needed for determining crop removal P and K rates. Sampling procedures for soil nitrate testing is a special case, and information on soil nitrate testing can be found with local extension publications and offices.

While Larkin acknowledged that cost is a concern when it comes to soil sampling, he also noted that there has been an uptick in sampling lately thanks to an increase in fertilizer prices.

“I’ll say that there’s been a lot more interest in soil sampling when the fertilizer prices trend upwards. So [in 2007 and 2008] when fertilizer prices were at an all-time record high, I think a lot of people were very interested in looking at their soil samples and making sure that they weren’t putting on more than what they absolutely needed.”

Mallarino agrees that the cost of soil sampling and testing relative to the crop prices and cost of fertilizers and other inputs has decreased significantly in recent years. Therefore, he recommends that farmers increase both the density and frequency of soil testing to improve nutrient management and the profitability of crop production.

It is also important to keep good records on sample locations and test results in order to evaluate the effectiveness of fertilizer programs and identify trend information over time. For example, identifying if soil test levels are above the optimum allows additions of P and K to be omitted for a period of time.

In short, the secret to getting a good soil sample is “a lot of hard work,” Larkin admitted.

—The University of Iowa Extension report Take a Good Soil Sample to Help Make Good Decisions contributed to this article. For more information, see www.extension.iastate.edu/Publications/PM287.pdf.
Your soil samples are precious things. When you ship them off to the lab, you expect accurate and precise results. However, human error, methodological variance, or a lack of laboratory certification programs can affect their precision and accuracy. Thankfully, there are ways of lessening this variability and ensuring quality, explained Dirk Holstege, director of the ANR Analytical Laboratory at the University of California–Davis, in a talk delivered at the “Fresh Approaches to Fertilizing Techniques” conference last November in Visalia, CA. And although quality is possible, it certainly isn’t easy.

“We’ve all been raised with Star Trek and CSI, where [you think] ‘oh, I’m going to analyze my sample on the mass spec and two minutes later, there’s a result,’” Holstege acknowledged. “That mass spec takes two hours to calibrate, and it takes another hour to get the results, and then it takes an hour of someone scratching their head to figure out what the results mean. So testing is complicated.”

The complications arise as soon as a lab is chosen. From the minute a sample arrives at a given lab, it will be tested in accordance with that lab’s protocol. And, even though Lab A might be performing the same test offered by Lab B, the results may vary significantly simply due to the way the sample is handled or the way the test is run.

“And to further complicate the situation, these methods can be performed differently by different labs,” Holstege explained.

While a variation from lab to lab may not be a surprise, the variance in quality of the testing may be. This may have to do with the fact that there is not a standard for regulation or certification for most labs.

“Agricultural labs are not regulated in the same way that a medical lab might be,” he continued. “There’s no agency that comes and audits how your soil test is being performed. The methods are not standard; they vary from lab to lab sometimes. There’s no testing that’s checked, and there are no certification programs for agricultural labs for soil and plant testing.”

Because of this, the client really needs to do some research before settling on a lab. To do so, Holstege stresses the importance of understanding “accuracy” versus “precision” (see Fig. 1, next page). Precision is the repeatability of a measurement—a grouping of results, which may or may not be “on target.” Accuracy is nearness to a target value for measurements, although this can still allow for a loose grouping of results around the target’s center. Bias is simply a propensity to be traditionally high or low; for example, the results of a given test are always about 2% higher than what you know to be truly on the mark.

What’s needed in quality testing, Holstege argued, is a combination of both accuracy and precision—and thus, replicable results along with results that are on target.

“To control that accuracy and precision, the labs have to do certain things. They have to use a standard method;
they have to verify that they’ve run the method correctly; and they have to get results that are comparable to other labs or to a known sample—they have to be able to run that known sample and get the same results.”

To ensure precision and accuracy, labs must implement quality control and assurance procedures. Quality control refers to a daily review of the quality of a lab’s processes. This is accomplished by running samples with known values, running duplicate samples, through instrument calibrations, etc. Quality assurance more broadly looks at the quality of the overall process, including efforts such as producing a quality assurance manual, ongoing training, equipment maintenance, and established procedures for when quality efforts fail. “Does the lab you are using have a quality control manual?” Holstege asked.

Additionally, while soil and plant laboratories are not certified, they can and should be actively participating in a proficiency program such as the Soil Science Society of America’s North American Proficiency Testing Program (see a list of participating NAPT labs on pages 11–14) to assess the quality of their results in comparison to other labs. In such a program, 10 labs might be sent the same sample and asked to run a given test. The goal is to return results that are shared by one or more labs. If six of the labs have results that are in a cluster while the others are scattered, this says something about the quality of the testing being done at those labs that aren’t part of the majority cluster.

“There’s no way that they can really know that they’re doing a good job unless they’re participating in a proficiency program and they’re getting comparable results to another lab,” Holstege explained.

Having answers to these types of questions when choosing a lab will lead to more accurate testing, better results, and ultimately better recommendations for your clients. Yet despite these cautions and suggestions to look for repetition and assurance, Holstege does not recommend using multiple labs. Instead, he suggests finding a lab that satisfies the criteria outlined here and sticking with it.

“You can’t go from one lab to the next and expect the same results; that’s the take-home message.” While you might conduct a bit of your own quality testing of a handful of labs by sending them each an identical sample, eventually you will want to settle on one in which you have confidence.

“The best thing is to pick one lab and stick with it. It may have a bias high or low. It will probably have pretty good precision, and they’ll be giving you the same number every time. If you’re jumping between labs, you’re going to see a lot of variation.

“You’re building a relationship with this lab, and you should understand the quality of the product that you’re going to get.”
The North American Proficiency Testing (NAPT) program, operated by the Soil Science Society of America, is the premier quality control program in North America for soil-, plant-, and water-testing laboratories. Labs participating in the program receive soil, plant, and water samples on a quarterly basis, which they analyze and then submit results back to NAPT for statistical comparison. NAPT looks at how close a lab’s results are to the median of all the labs (precision) and how similar the results are for a sample repeated throughout the year (accuracy). Labs use this information to correct any deficiencies in their analyses. The following labs participate in the program. For more information on the NATP program, see www.naptprogram.org.

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NAPT Program
North American Precision Testing Program
Newly certified

The following list includes newly certified individuals and those adding additional certifications since December and January.

Canada

Alberta
Bergstrom, Colin, St. Albert, AB (CCA-PP)
DeSmet, Belinda, Rycroft, AB (CCA-PP)
Gabert, R. Keith, Penhold, AB (CCA-PP)
Gamroth, Blake, Lethbridge, AB (CCA-PP)
Tolsma, Jason, Millet, AB (CCA-PP)

Manitoba
Cook, Jeffrey, Darlingford, MB (CCA-PP)
Eastley, Lisa, Hamiota, MB (CCA-PP)
Ives, Douglas, Ste Rose, MB (CCA-PP)
Manchur, James, Gilbert Plains, MB (CCA-PP)

Saskatchewan
Burnett, Wyatt, Swift Current, SK (CCA-PP)
Haus, Heather, Glenavon, SK (CCA-PP)
Mills, Jamieson, Moosomin, SK (CCA-PP)

United States

California
Cramer, Arnold, Durham, CA (CCA-CA)
Dhaliwal, Parm, Lodi, CA (CCA-CA)
Esmailian, Babgen, Glendale, CA (CCA-CA)
Fichtner, Scott, Clovis, CA (CCA-CA)
Ghilardi, Douglas, Lodi, CA (CCA-CA)
Healy, Kevin, Prunedale, CA (CCA-CA)
Johnson, Evan, Modesto, CA (CCA-CA)
Melgard, Paul, Turlock, CA (CCA-CA)
Mintz, Steven, Rio Oso, CA (CCA-CA)
Noah, Joel, Tracy, CA (CCA-CA)
Radtke, Roger, Dinuba, CA (CCA-CA)
Reineke, Brian, Foresthill, CA (CCA-CA)

Georgia
Brandenburg, Del, Cordele, GA (CCA-GA)

Illinois
Cannon, Joseph R., Camargo, IL (CCA-IL)
Perkins, Mark A., Havana, IL (CCA-IL)

Indiana
Banks, Brandon, Grandview, IN (CCA-IN)
Brunner, Philip, Indianapolis, IN (CCA-IN)
Fugate, Gilbert N., West Lafayette, IN (CCA-IN)
Fuhs, Brian, Ft. Branch, IN (CCA-IN)
Gumz, Mary, North Judson, IN (CCA-IN)
Morman, Steve R., Noblesville, IN (CCA-IN)
Weaver, Nicolas D., Haubstadt, IN (CCA-IN)

Louisiana
Gauthier, Stuart, Abbeville, LA (CCA-LA)
Scott, Lester, Minden, LA (CCA-LA)
Thompson, Menko, Pionere, LA (CCA-LA)

New York
Eckhardt, Matthew, Stephentown, NY (CCA-NR)

Pennsylvania
Miller, Joshua J., Stewartstown, PA (CCA-CB)

South Carolina
Heaton, W. Cory, Chester, SC (CCA-SC)
Perry, Philip R., Saluda, SC (CCA-SC)

Texas
Backus, Ron, Olton, TX (CCA-TX)
Iglesias, Jaime, El Paso, TX (CCA-TX)
Joy, Brandon, Plainview, TX (CCA-TX)
LeClair, Jeffrey, Cleburne, TX (CCA-TX)
LeGrande, George, Canyon, TX (CCA-TX)
Neeb, Andrew, Amarillo, TX (CCA-TX)
Peters, D. Alan, Seminole, TX (CCA-TX)
Schneider, Jacob, Lubbock, TX (CCA-TX)

X technology in the late 1930s to 1940s led to the development of new, more precise instruments like pH meters and glass electrodes, colorimeters, flame photometers, and procedures like the lime requirement buffer test.

Local county or company labs were common in the late 1930s through the 1960s, and many still exist today. Some were operated by extension offices, USDA-SCS (now NRCS), or by fertilizer dealers or other companies with farmer clients such as Campbell’s Soup. During the 1940s and 1950s, most land grant universities established a central or state soil-testing lab, and in the 1950s and 1960s, many state and regional co-ops and fertilizer marketing sales organizations established labs.

“Testing volume exceeded 200,000 samples per year by the 1960s in many states,” Mengel said. “Total testing in the U.S. peaked in the mid-1960s at about 3 million samples, but if you look at some of the more recent information on soil sampling, we’re back to that [level] now.

“Private testing companies really started coming into play in the 1960s and 1970s…. Today, many of these organizations play a really key role in a lot of states in providing testing services. And it’s not just for soils anymore—these people do environmental testing, feed sampling—a lot of those sorts of things.”

These days, large independent labs are becoming the dominant players in the soil-testing business as the number of state labs rapidly decreases, Mengel said. One of the downsides of this is that it has been accompanied by a decline in soil-testing research. In Mengel’s lab, the most recently developed procedure they use is the Mehlich-3 phosphorus extraction, which was published in the late 1970s.

“A lot of our procedures are getting some seniority. Many of them are plagued by issues of generation of hazardous waste. We need some more additional work going on.”
Meet the professional: Gary Wietgrefe

Over the course of his 30-year career, Gary Wietgrefe has worn many hats: salesman, author, inventor, researcher, teacher, ambassador, and CCA. However, throughout this career evolution, his role as an innovator has not waned. As a worldwide authority in millet and a leader within the CCA profession, Wietgrefe has capitalized on his diverse experiences to communicate agronomic issues with both the agricultural community and the broader public.

For the last 17 years, Wietgrefe has worked for Syngenta and its legacy companies, serving in a variety of roles. In his current position, he helps ensure safe and efficient seed handling through harvesting, transport, processing, and planting. During the late 1990s, Wietgrefe contributed to the creation of the TruBulk System, guidelines for bulk soybean seed handling that are now considered an industry standard for both soybeans and wheat.

International impact

Wietgrefe’s range of agricultural experiences largely contributes to his sense of innovation. After growing up on a farm in northern South Dakota, he joined the Air Force, spending three years overseas. However, living amongst artichoke fields and grape vines in Italy, and fields of row crops and vegetables in Japan, Wietgrefe still found plenty of opportunities to grow his agricultural experiences while abroad. After returning to the United States, he finished programs at South Dakota State University in both commercial economics and agricultural business. After graduation, he took a position with the South Dakota Department of Agriculture (SDDA). Along with the state’s international agriculture export specialist, Wietgrefe applied his own international experiences to help better serve producers. In 1981, he organized industry leaders for a USDA-sponsored international specialty products trade team, which traveled to the Netherlands, Germany, Italy, and Spain. Through his efforts, U.S. producers have seen markets expand widely for a variety of specialty products.

Although he has made many contributions to the soybean industry, Wietgrefe also has extensive knowledge and experience with millet, a crop he was introduced to through his work with the SDDA. His work on the crop began as a response to a series of calls from U.S. growers unable to sell their millet seed. It eventually developed into a trade mission that set record U.S. millet prices. Wietgrefe worked with a Canadian company to integrate U.S.-grown proso millet into European markets, and within four years, the U.S. had taken two-thirds of the market, with the crop’s quality receiving worldwide attention.

That experience taught Wietgrefe much about both the production and marketing of millet, leading him to compile his expertise in two books, one for buyers and one for farmers. The books have been used widely among growers and purchasers worldwide. In the mid-1990s, the books reached researchers from a Swiss organization working on the reintroduction of subsistence crops in Post-Soviet Mongolia. Wietgrefe became involved with the group’s agricultural development project, working with researchers and sending more information and different millet varieties for them to introduce in the region. In addition to furthering sustainability in the region, Wietgrefe’s contributions also helped the organization successfully complete and publish numerous research trials, adding to the then small body of literature on millet.

In 1997, Wietgrefe was chosen by Rotary International to travel to Turkey to share his expertise with the country’s agricultural community. In addition to conducting seminars for the Uluadag University Department of Field Crops and meeting with local farmers, Wietgrefe provided materials and support for millet and forage soybean research in Turkey. The research that followed spanned 10 years and resulted in numerous co-authored journal articles.

An active CCA

While traveling and contributing to international research, Wietgrefe was also taking on diverse roles within agriculture in the United States. He left the SDDA after four years, going on to hold a variety of positions, including establishing South Dakota’s largest grain terminal, representing 52 companies as a wholesale distributor of crop protection products, and opening a state certified seed conditioning facility for proso millet. In 1992, Wietgrefe saw potential in a new agricultural arena and took a position with Syngenta. “As I saw the GM technology come through, I decided to change careers and come into the seed business,” he says. In 1994, he helped establish the first environmental use permit for the first genetically altered Bt corn grown in South Dakota, including some of the first grown outside laboratories.

When the CCA program was developed in the mid-1990s, Wietgrefe jumped at the new professional opportunity. “I had been doing these types of [agronomic] activities,” he says, “but there was no organized structure where I could help deliver agronomic expertise or get training for it.” Since becoming certified, Wietgrefe has been active in the program’s development. As an ex-officio member of the South Dakota CCA board of directors, he has pushed for the continued evolution of the state’s program, leading efforts to better define its agronomic programs, exams, and objectives to reflect changes within
the discipline. “There are people who just attend meetings and people who do things,” he says. “I want to be a contributing member.”

Wietgrefe has also been an advocate for the value of CEUs, often earning double the required amount each two-year cycle. He says a big benefit of the CCA program is the expansion of training and course offerings, which help cover a number of agronomic topics that may not necessarily be offered by universities. “I recommend that, if they can, CCAs pick up at least half of their credits outside of the university system and certainly outside their own company.” For the last decade, Wietgrefe has organized and taught courses for CEU credit on many timely issues. He frequently does independent research, gaining knowledge and experience on topics that have yet to be widely published in journals. “It’s just a way of keeping up on different things that companies aren’t interested in doing yet.”

Beyond integrating his research into new courses and seminars, Wietgrefe is also constantly on the watch for information that may be valuable to CCAs and producers. Through Syngenta, he currently writes and distributes a newsletter on bulk seed handling equipment. “There is no other source in the industry to do it,” he says. He also regularly puts out news releases on research or updates he discovers that may be of interest to farmers or others with agronomic interests. “He can put complex agronomic issues and crop production fundamentals into simple terms that are easily understood by the media, grain merchandisers, and other non-farmer clients,” says Chip Flory, editor of Pro Farmer and director of the Midwest Crop Tour.

In the field

Each summer, farmers and non-farmers alike have a chance to learn from Wietgrefe while in the field. As a Midwest Crop Tour master scout, he has spent many summer days helping participants identify corn and soybean yield potential throughout the Corn Belt. For the non-producer audience, including people from the trading floors of Chicago and newswire reporters, Wietgrefe relates to their professions, providing easy-to-understand explanations to complex production factors. His international travels and research also help him connect with international clients on the tour. “Mr. Wietgrefe is not only an excellent agronomist, he’s an excellent and willing teacher who equally shares his insights with farming and non-farming Crop Tour participants,” Flory says.

For producers, Wietgrefe’s insights into crop production issues, including their impact on regional and national yield, are a critical asset to the annual event. Over the years, he has identified weed and insect infestation issues and predicted future trends, such as the expansion and establishment of western bean cutworms in the late 1990s. Many tour participants rely on his expertise and advice as they deal with current pest control issues and look to prevent problems in future crops. Flory believes Wietgrefe’s role in the Midwest Crop Tour is instrumental outreach. “His early warning of potential production problems to the hundreds of producers each year has undoubtedly helped Pro Farmer meet the goal of helping growers be prepared to manage regional and national production risks.”

More recently, Wietgrefe has brought the issue of volunteer GM crops to participants’ attention. In the past, many growers would ignore volunteer corn or soybeans, crops from the previous year that came back to grow uncontrolled in the following crop. While farmers thought these GM volunteers were guilty of nothing more than taking a small amount of water from neighboring plants, Wietgrefe saw a much larger issue. “I was always aware of looking for volunteers, trying to prevent rotations or lack of control that would create diseases down the road.” As an example, he describes how some cyst-resistant beans may volunteer in the same field during a corn cycle the following year, never allowing a break from that cyst rotation. Cysts, Phytophthora, and other root diseases can constantly develop during the following corn crop, impacting future crop protection. Wietgrefe explains that the cyst-resistant beans are an example of why herbicide trait resistance is an important consideration. “Even though it may not be a weed-related issue, those [volunteer] crops end up causing problems because of their carryover nature,” he says. “Infestation level does not decrease in the off year.” He advises producers to control all GM volunteers to prevent eventual resistance. “Pay strict attention to keeping them only for that protection year and keeping them controlled during the off year.”

For Wietgrefe, much of the concern around matters like volunteer GM crops centers on larger issues about proper technology integration. He recalls his time as a wholesaler when application rates for pesticides and herbicides increased without long-term productivity and efficiency following suit. For him, many of the advancements from new chemical technology were negated by consumer misuse. By working with farmers and non-producers in the agronomic industry, he is doing his part to help ensure that new tools are used properly for the advancement of agriculture. “Wietgrefe recognizes the building blocks of agronomic technology and is a strong advocate for professional crop advice,” Flory says.

Relaying his agricultural experience to others has been a constant in Wietgrefe’s diverse agricultural career, whether in South Dakota or Turkey, talking about millet or volunteer crops. “Although his continuous agricultural career was based in South Dakota,” Flory says, “Mr. Wietgrefe’s agronomic advice is far reaching.”
It’s a new concept, concedes Newell Kitchen, a soil scientist with the USDA-ARS Cropping Systems and Water Quality Research Unit in Columbia, MO, when he talks about a GPS-equipped, on-site soil-sampling system capable of producing immediate information about the soil nutrient levels in a given field. Instead of the laborious manual soil testing followed by the time-consuming process of submitting the sample to a lab and waiting for testing results, it is growing much more possible to collapse all of these activities into a single farm visit. The result is less time spent on sampling and more accurate application of inputs, meaning less money spent on unnecessary fertilizer applications and less runoff of unneeded ones.

“The greatest impediment to manual soil sampling followed by laboratory measurement for crop nutrient management is the time and expense associated with sampling, transportation, and analysis of the sample,” Kitchen said during a presentation last November at the Annual Meetings of the American Society of Agronomy (ASA), Crop Science Society of America (CSSA), and Soil Science Society of America (SSSA) in Pittsburgh, PA. “While improvements have been made relying on conventional soil-sampling methods, many farmers perceive a marginal value to this type of sampling and mapping. The conclusion of many has been that more efficient and less expensive tools and procedures are needed for managing within-field nutrient variability. From such has grown the development of on-the-go sensors.”

Kitchen, who is also ASA president-elect this year, argued that the current practice of manual soil sampling followed by laboratory testing procedures simply leaves too much to chance. Drawing a comparison to polling done to predict presidential election results, he illustrated the limitations.

“Let’s take a Gallup Poll, where they usually take 1,000 voters out of the U.S., and they survey those 1,000 and decide who is going to win the election based on those voters. Well that survey is 500 times more of the population than a farmer taking 10 soil sub-samples to represent the soil volume of a 40-acre field. 500 times more!”

If Gallup used the same sample size as a typical soil-sampling program, Kitchen said that’d be like surveying two likely voters and predicting who was going to win the election based on their responses.

“When we’re talking about how much soil we have out there, that helps to put into perspective what we’re trying to accomplish. And then we’re only talking about the top 6 to 8 inches of soil [in a sample] and...a 4-ft root zone, the Gallup Poll is 3,000 times more thorough!”

So, how can we get a better sample? The answer, Kitchen argued, relies on efficiency. And this is illustrated by the evolution of on-site sampling using soil sensors. In the early part of last century, there was the acknowledgement that it was important to sample the soil and to do so in certain zones, which led to more efficient use of fields—a realization that has
affected farming ever since. The next major jump forward came toward the end of last century with GPS, which now allowed for much more efficient and cost-effective grid sampling. But samples were still being taken out of the field and sent to the lab. The next logical step in efficiency has emerged, which allows for doing the sampling and testing via sensors on site.

The next logical step in efficiency has emerged, which allows for doing the sampling and testing via sensors on site.

Real-time sensors

Citing the work of Viacheslav Adamchuk, a professor and precision agriculture engineer in the Biological Systems Engineering Department at the University of Nebraska, Kitchen said that there are two sensor use approaches: real-time application and the map-based approach. With the map-based system, the sensor collects data out in the field, and a map is created of soil conditions in conjunction with a GPS. With the real-time application, the data is collected and applications of nutrients are made in real time with variable-rate application equipment. But, according to Kitchen, we are seeing more of an integration of these two approaches to arrive at a system in which GPS maps and real-time information are combined and applied to make decisions about nutrient needs in real time.

Sensors that collect real-time data on the variability of soil and other environmental attributes are in active development. Ideally, they collect data during other in-field operations such as planting, cultivation, pest control, or harvesting. Sensors for many soil attributes such as pH, organic matter, and nitrogen content are being developed. The on-the-go sensors can be classified as the following types: optical, electromagnetic, acoustic, mechanical, electrochemical, and pneumatic.

- Optical sensors use light reflectance to characterize soil. These sensors measure light reflectance in the near-infrared, mid-infrared, or polarized light reflectance.
- Electromagnetic sensors use electric circuits to measure the capability of soil particles to conduct electrical charge. The soil becomes part of the circuit and soil conditions affect the signal recorded by a data logger.
- Acoustic sensors measure the change in noise level due to interaction of a probe with soil particles, with the intent to measure soil texture.
- Mechanical sensors measure soil mechanical resistance. The sensors use a mechanism that penetrates or cuts through the soil and records the force measured with strain gauges or load cells.
- Electrochemical sensors are essential ion-selective electrodes found in the laboratory but moved to the field in on-the-go units. The electrodes determine the activity of specific ions, such as nitrate, potassium, or hydrogen in the case of pH measurement. These sensors could provide information about soil nutrient levels and pH.
- Pneumatic sensors could be used to measure soil air permeability on the go. The sensor would measure the pressure required to squeeze a given volume of air into the soil at a fixed depth.

Several of these types of sensors are commercially available.

Canopy reflectance in corn

In recent years, optical sensors that reflect light off of the crop canopy have been proposed and tested as a technology on which to base side-dress variable-rate N fertilization in corn, for example. A crucial element captured with this sensing strategy is that it accounts for differences within fields associated with soil and landscape factors.

Kitchen acknowledged that some may question whether these are truly “soil” sensors, but in essence, the plant itself is used as an indicator of soil fertility conditions.

In the January–February 2010 issue of Agronomy Journal, Kitchen serves as co-author on two different studies that seek to assess the utility of these sensors for on-the-go, variable-rate N fertilization in corn, which is found to increase profits and decrease N loss from fields.

Since more N fertilizer is applied to corn than any other crop, interest is high for exploring new technologies for improved corn N management. In recent years, light reflectance sensors have been proposed and tested as a technology on which to base side-dress variable-rate N applications in corn. A critical element captured with this sensing strategy is that it accounts for differences within fields associated with soil and landscape factors.

Kitchen and his colleagues used a crop canopy reflectance sensor from Holland Scientific to obtain measurements from the corn. 

Canopy reflectance sensing in Missouri. Photos courtesy of Dr. Newell Kitchen.
When foliar fertilization makes sense

Avoiding nutrient deficiency is key to good plant nutrition and optimum yields. However, it can occur for a variety of reasons during the growing season, and when it does, it is important to supply the crop with the nutrient it requires. In many cases, this will be done with a soil application, but Derrick Oosterhuis, a professor of cotton physiology at the University of Arkansas, says that sometimes a foliar application may be a better choice.

“One of the advantages of foliar fertilization is that you can react immediately,” Oosterhuis says. “You can put that fertilizer that’s required on, and you have a response literally within hours.”

Research by Dr. Oosterhuis and colleagues has shown that 30% of nitrogen that was foliar-applied to cotton was absorbed within one hour and translocated into the closest boll within 6 to 48 hours. If you put nitrogen on the soil, it’s going to take more time to get into the plant to the place where it needs to be used or it could be lost through runoff, leaching, or volatilization.

Oosterhuis says foliar fertilization can be a useful tool as part of a fertility program that consists of an initial soil test, an application at planting, sidedress applications later on, followed by tissue tests midseason onwards as the fruit develops, and finally foliar applications if necessary. In addition to allowing producers to quickly react to a nutrient deficiency, foliar fertilization can also allow them to add nutrients to a full-canopy crop; with aerial applications, producers don’t have to worry about damaging the crop.

Supplement to soil applications

Oosterhuis emphasizes that foliar fertilization should be seen as a supplement to traditional soil applications, not a replacement. Probably the most important use of foliar fertilization has been in the application of micronutrients where only small quantities are required. When larger amounts of nutrients such as nitrogen, phosphorus, or potassium are required by the crop, it can be difficult to supply adequate amounts with a foliar application without a large number of spraying operations or without causing phytotoxicity.

But sometimes conditions restrict root growth, Oosterhuis points out, which limits nutrient uptake through the roots. Foliar fertilization can be ideal under these conditions.

“There’s not a soil in the world that doesn’t have something restricting root growth to a certain extent,” Oosterhuis says, “whether it be wrong pH, low oxygen, poor drainage, insect damage, compaction, low soil temperatures, root pruning from cultivation, diseases—there’s always some item that does not create a perfect situation for roots. When some of these get out of hand, then it calls for a foliar application to prevent this restriction in nutrient uptake by whatever is harming the roots.”

Dr. Patrick Brown, a professor and director of international programs in the Department of Plant Sciences at the University of California–Davis, agrees. He talked about the use of foliar fertilizers in tree crops during the “Fresh Approaches to Fertilizing Techniques” conference hosted by the California Department of Food and Agriculture Fertilizer Research and Education Program and the Western Plant Health Association in Visalia, CA in November 2009.

“There are circumstances under very heavy cropping yields and high temperatures where the ability of the roots to deliver the potassium to the shoots is impaired, and no matter how much potassium you drop on that soil, you can still run into these circumstances. This occurs as a consequence
of competition between the shoot and the root. With the shoot drawing very heavily on the carbohydrate reserves, root growth doesn’t occur, and if root growth isn’t occurring, roots are not exploring new soil and new sources of potassium. So it’s a root growth limitation on uptake.”

In addition to situations where the crop’s demand for nutrients exceeds the supplying capacity of the roots, Brown said there may also be phenological reasons for applying foliar fertilizers that are associated with the time of year in which nutrient deficiencies occur. For example, tree crops require zinc early in spring for bud growth, but often the soils may be cold and transpiration limited, thereby limiting the mass flow of nutrients from the roots to the shoots. In these cases, Brown said, a foliar application may be the way to go.

“Zinc, boron, calcium, and copper are required in that critical stage of plant growth. It’s very difficult to predict that [deficiencies] are going to occur and so prophylactic foliar fertilization to eliminate the possibility of this occurring makes sense in many environments.”

Foliar fertilization may also make sense when elements are immobile in certain crops, according to Brown. For example, a targeted foliar application of boron in pistachio to an area of deficiency in the crop may make sense because boron is completely immobile in pistachio and so a soil application would be less effective.

“There’s very clearly a biological rationale for [foliar applications],” Brown said. “Justifying that it’s important is easy. Estimating its efficacy and how you’re going to go about doing it is a much more complex task.”

Complexities of leaf penetration

Part of the complexity is that a lot is still unknown about how foliar-applied nutrients penetrate the leaf.

“We know after more than 150 years of work remarkably little about how foliar fertilizers work. It’s complex because you have to think about all of the different aspects of application and all of the different aspects of penetration. And as it turns out, there is no universal mechanism between all species. And so when formulations are made to target a particular biology, a particular chemistry, by necessity they can’t solve the problem for all species.

“For those elements that penetrate easily, urea and boron, we’ve got a pretty good idea of how it works. For the other elements that have a charge on them, which includes every other element of interest, we know almost nothing about how this works.”

How much the stomatal pathway contributes to nutrient penetration through the leaves remains a big point of discussion among researchers, Brown said. He cited experiments showing that only 10% of the stomata actually move nutrients, even if the other 90% are open.

“This is a bit of a puzzle. The stomata movement is much less sensitive to the form of element. And what we sort of conclude from all of this is it’s so complicated that the best thing to do is spray and pray.”

When to spray

If you’re going to spray, it’s probably best not to do so during the lunch hour—at least not on a hot summer’s day, according to Oosterhuis.

“One of the biggest things I always tell people is the timing of your application is critical because we have a lot of data showing there’s a big diurnal effect.”

“One of the biggest things I always tell people is the timing of your application is critical because we have a lot of data showing there’s a big diurnal effect. When you put on a foliar fertilizer on a hot summer’s day, it really works best to either put it on early morning, late afternoon, or evening. If you put it on in the middle of the day, you lose a lot of it either through volatilization or just crystallization on the leaf and not going into the plant....

You need to be aware of if it’s a windy day or a very dry day or if there’s high humidity—because all of these things will affect the vapor pressure deficit and how quickly your material will disappear up into the atmosphere or run off the leaf or crystallize on the leaf.

“This is compounded by a dryland or water stress situation. If your plant is a little water stressed, then it’s definitely important to put it on early morning or late evening because it’s not going to go in very well in the middle of the day.... Under water stress conditions, the leaf cuticle of whatever crop you’re dealing with gets thicker by as much as a third, so you have a much longer path to traverse for the nutrient to get into the leaf, and furthermore, that extra cuticle, which is epicuticular wax, usually is more hydrophobic. Under water stress, not only do you get a thicker leaf cuticle, but the molecular composition changes to more long-chain waxes, and these are more hydrophobic. Water stress and time of day are really critical.”

Oosterhuis says the pH of the solution is also very important.

“When you mix up foliar fertilizers, you really need to make sure the pH is in an optimum range to get it into the leaf, and usually that’s between 4 and 6. Some of the foliar fertilizers—like potassium, for example—usually have very high pH’s of say 8 or even higher, and these don’t get in [the leaf] very easily. You really need to put a buffer in and bring the pH down to the 4 to 6 range.”

Flexibility for farmers

One of the benefits of foliar fertilization is that it can give farmers
Career preparation—
resumes and interviews

A
n informative video is available on the Career Center’s website to help you prepare for every part of the job search from exploring career options appropriate for your skills, values, and preferences to negotiating an offer. Resume and cover letter development as well as communication skills are also covered through this career development program presented at the 2009 Annual Meetings of the American Society of Agronomy (ASA), Crop Science Society of America (CSSA), and Soil Science Society of America (SSSA). To access the video, go to www.careerplacement.org/content/career.

Discover the value of mentoring

Do you want to invest in the future of the agricultural sciences and help cultivate the future leaders of our professions? If so, you should consider being a mentor for the ASA, CSSA, and SSSA Golden Opportunity Scholars Institute.

The program was developed to foster relationships between those working in ag careers and undergraduate students. Students go through an application process and, if selected as scholars, are matched with professionals who serve as mentors. Students benefit from the mentor’s expertise and experiences, and mentors benefit by knowing they are supporting the future of the profession. Whether it’s providing help with career goals, employment plans, or cultivating networks, mentors can play a big role in these one-to-one matchups.

As part of the program, mentors should plan to attend the 2010 ASA, CSSA, and SSSA Annual Meetings in Long Beach (www.acsmeetings.org) this fall to meet and start the mentoring relationship. The goal is to partic-
Science policy internship available

Are you looking for a hands-on learning experience in the science policy area? Do you want to help monitor and analyze agricultural, natural resources, and environmental legislation? If so, apply now for the ASA, CSSA, and SSSA science policy internship in Washington, DC. Eligible applicants will have completed at least the first semester of their sophomore year in agronomy, crop science, soil science, or a closely related discipline. The internship offers flexible start and end dates, lasting from 3 to 12 months, and carries a monthly stipend and living expenses.

For more information on the position, apply through the ASA, CSSA, or SSSA Awards Program at www.agronomy.org/awards, www.crops.org/awards, or www.soils.org/awards. For more information, contact Dr. Karl Glasener, director of science policy, at kglasener@sciencesocieties.org or 202-408-5382. Nominations must be initiated by April 14, 2010, and reference letters and final submissions are due April 21, 2010.

Foliar fertilization | FROM PAGE 21

some flexibility in their fertility program, according to Tom Fairweather, CCA and director of agronomy for Tessenderlo Kerley, Inc. When input prices are high, farmers may decide to scale back a little on nitrogen rates, knowing that they can always foliar feed later on if they detect any deficiency and get an immediate response. It can also be a good way to recover some nitrogen that was lost during a wet season.

“In 2008, we had a lot of rainfall, which leached a lot of nitrogen from the soil, and a lot of the corn was coming up short on nitrogen, and so additional foliar nitrogen went a long way in a lot of areas,” Fairweather says.

Farmers also see flexibility in being able to mix in nutrients with their foliar pesticide applications, Fairweather says. Fungi can survive in infested corn residue left on the soil surface, so as continuous corn and minimum- and no-till have become more widely used, more farmers have been applying foliar fungicides. And some are opting to add a little nitrogen in with the fungicide.

“It doesn’t take a whole lot of [nitrogen] to give it that booster shot,” Fairweather says. “On corn, with that rapid increase in growth, there’s a rapid increase in demand for nitrogen, so there’s some opportunities there to get a response…. On cotton, there’s been a lot of research showing that we get a pretty good response to application of potassium from first flower to about four weeks after first flower.

“There’s a lot more interest [in foliar fertilization] nowadays. As long as they can put it in with an herbicide or a fungicide spray, the growers usually go for it…. Our N-SURE product we found works well with Roundup. We can apply it with Roundup on Roundup-ready crops, and it works about as good as ammonium sulfate as a water treatment, so there’s an opportunity to get a little more nitrogen on in the slow-release form, which is a safe form of nitrogen—it doesn’t burn.”

Oosterhuis cautions that there could be some compatibility issues when mixing certain nutrients with pesticides that could alter the pH or interfere with their efficacy. Usually it’s OK to mix, but he advises producers to check with their adviser or extension agent first just to make sure. Some people like to mix nutrients too, but Oosterhuis doesn’t think this is usually warranted.

“A lot of fertilizer companies like to sell combinations, but I’m personally not convinced that all those nutrients are needed. So usually I recommend just putting on the one you need.”

Oosterhuis also recommends mixing in a spreader-sticker adjuvant with the foliar fertilizer to help keep it on the leaf so that it can be taken up before it dries, crystallizes, or runs off the leaf.
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Soil Science Step-by-Step Field Analysis
Sally Logsdon, Dave Clay, Demie Moore, Teferi Tsegaye, editors

Natural resource manager, agronomist, land use consultant, educator, environmental consultant…. The lines are blurred, the questions are complicated, and soil science is required knowledge. Soil Science: Step-by-Step Field Analysis provides the knowledge for conducting specific activities related to improved natural resource management. Readers will learn both new procedures and tips for improved performance in the field, with a focus on usefulness for real-life applications.

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- reducing sampling error for samples sent to a lab
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- site evaluation for specific end uses
- installing wells and piezometers, monitoring water table information
- surveying using simple or sophisticated equipment
- cleaning yield monitor data
- evaluation of overall soil quality
- identification of water repellency
- measuring soil density and water content, infiltration, temperature, and rainfall rate

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Safety Protocols for Soil Sampling

As we explore key safety issues, a set of recommended Safety Protocols (SP) is presented (Table 1). Some references on universal safety issues related to safe soil sampling are OSHA (1989), ASTM (1997), and “Drilling Safety Guide” (Diamond Core Drill Manufacturers Association, 2001).

Table 1. Recommended Safety Protocols. This list is not exhaustive.

| SP1 | An organization or work group should have a safety program. Safety should be the foundation of each work plan and activity. Our goal must be that each of us can return to our families at the end of each work day. |
| SP2 | Locate the presence of all utilities in the work area before digging. |
| SP3 | Know the address where you are working and make sure others know this address. |
| SP4 | Use the buddy system. |
| SP5 | Know the biological hazards in the work environment and make sure coworkers communicate about any known personal life-threatening allergies and where specialized first aid materials are located. |
| SP6 | Only enter confined spaces in compliance with industry-established procedures and with proper air-sampling, ventilation, engineering controls, and emergency retrieval systems in place. |
| SP7 | Plan for, have available, and use appropriate personal protective equipment. |

Safety Protocol 1
An organization or work group should have a safety program.
Safety should be the foundation of each work plan and activity. Our ultimate goal must be that each of us can return to our families at the end of each work day.

- At a minimum, workers should have the equivalent of Red Cross First Aid Training. Training is available for a minimum charge from the local chapter of the American Red Cross or from other private vendors.
- Each work place, vehicle, and personal equipment pack should be equipped with an appropriate first aid kit that contains the materials likely to be needed for first aid in that work environment.

Summary
Many people believe that soil sampling contains little risk, but this is not true. Soil sampling techniques available involve shovels, hand augers, backhoe pits, hydraulic direct push probes, and drill rigs that advance hollow stem augers. Some of the potential risks include sampling in areas containing buried utilities, pit cave-in, equipment failure, dehydration, muscle skeletal injury, and allergic reactions to plants and insect stings. The purpose of this section is to discuss the applicability of soil sampling methods and key safety issues associated with these methods. Each of these methods can have significant safety hazards, some of which can result in long-term injury or death. The safety protocols presented should be a starting point for project planning.

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**Safety Protocol 2**

Locate the presence of all utilities in the work area before digging.

- Call 811 or your local utility hotline to have publicly owned utilities located and marked.
- Contact private vendors and others, such as property owners, to locate probable locations of private utilities.
- After utilities are marked, walk the site and make sure that what is marked makes sense. Are there gas meters, water meters, or transformers that do not have utilities marked between them and a structure?

Utilities may be publicly owned, crossing right-of-ways on public or private property, or may be privately owned. Privately owned utilities may include water lines, natural or liquefied petroleum gas lines, sewer lines, etc. between the point of public ownership and the point of use such as between a water or gas meter and a structure.

As prescribed by federal law managed by the U.S. Department of Transportation, every state has some form of state-mandated program for the pre-location of buried utilities. Typically, there is a requirement for the operator of the excavating equipment (the company, agency, or homeowner) to contact the published 800 number and request that utilities be located. Usually there is a notification requirement of 48 to 72 hours before the scheduled work. There can be strict fines, as well as civil liability, for failure to comply. These fines are often levied if phone lines, gas lines, power lines, or other utilities are damaged and/or personal injury occurs. Compliance is important because right-of-ways for subsurface utilities can cross undeveloped tracts of land and may no longer be clearly marked. Examples of these are high-pressure natural gas lines, fiber optic lines, and water lines.

As of April 2007, the telephone number 811 can be dialed nationwide in the U.S. and the call will be forwarded to the local call center. Information is available on the Internet at [http://www.call811.com](http://www.call811.com), a webpage providing a consortium of utility industry stakeholders called Common Ground Alliance. This webpage has local contact numbers for each area of each state and additional information.

**Safety Protocol 3**

Know the address where you are working and make sure others know this address.

It is common for soil investigators to work in remote areas without access to 911 coverage, either from land telephone lines or cell phones with global positioning system (GPS) coverage. The daily work plan should list a street address, GPS coordinates outlining a proposed work area, or other means of identifying the work location. This work plan should be left with someone at home or work who will know how to find us if we do not return at the appointed time. It is also important to know the address of where we are working as a team in the event someone is injured on-site. Driving directions should be in the job file at the office and on-site.
Safety Protocol 4
Use the buddy system.

Ideally we should work in teams so that if someone is injured or is ill, help can be obtained. If the buddy system is not possible, it is imperative that someone knows where we are working and when they should expect us to return. Development of this discipline can be life saving.

Safety Protocol 5
Know the biological hazards in the work environment and make sure coworkers communicate about any known personal life-threatening allergies and where specialized first aid materials are located.

A key component of work site safety is protection from organisms that cause allergic or other severe reaction, including plants, bees, snakes, and ticks. All of these organisms can be present at the work site and the work force should take adequate precautions and be prepared to respond to the unexpected. Some individuals are highly allergic to bee venom and require immediate administration of antihistamine drugs to prevent fatal reaction. If you have these allergies, it is imperative that you communicate this to your team members and friends. Carry the prescription drugs for self administration and make sure family and co-workers know where they are and how to use them. It is important to know that bee venom contains complex organic acids; therefore, application of a baking soda paste or mild bleach solution is a very important first aid step and often stops a reaction. These first aid steps should always be used as our bodies may develop allergic responses of increasing magnitude over time in response to each subsequent event.

Poison ivy, poison oak, poison sumac, and other plants have oils to which many are allergic. (See http://www.poison-ivy.org for pictures of some of these plants and the allergic reactions.) If the work area includes exposure to these plants, use protective clothing to minimize exposure. Wash exposed skin with soap and water as soon as possible. Inhaled smoke from campfires or burning brush piles (or wild fires) that contain these plants may cause severe, even fatal, damage to lung tissue.

Safety Protocol 6
Only enter confined spaces in compliance with industry-established procedures and with proper air-sampling, ventilation, engineering controls, and emergency retrieval systems in place.

Sampling at some sites can present exposure to soil gas or chemical contamination. Workers should be familiar with confined spaces, their properties, and the dangers they can present. Confined spaces and regulations are well defined by the U.S. Occupational Safety and Health Administration (OSHA). Training materials are available at http://www.OSHA.gov and from many private vendors. One very common property of confined spaces is the potential for the absence of adequate levels of oxygen to sustain human life and/or the presence of organic or other chemicals that are acutely toxic. A good example is a well vault. When a low pressure weather system passes through an area, the earth “exhales.” A well containing hydrogen sulfide gas may “exhale” into the well vault, resulting in an at-
mosphere that may be immediately fatal if breathed. Well vault accidents are common in cold regions, where subterranean well houses are often used.

The atmosphere inside farm silos or manure pits can be anoxic. It is very common for three to five people to die in these accidents as family members and coworkers rush to assist someone they assume to have succumbed to heart failure.

Other examples of common confined spaces include a work trailer or lab where a volatile chemical is spilled, a septic tank, pump vault, sewer line, or storage tank.

Appropriate personal protective and air sampling equipment is imperative. This may include air-purifying respirators, chemical-resistant suits, or engineering controls such as a fan to move air away from a drill hole. While these techniques and equipment may be common to the environmental consulting community, the research community must be especially vigilant because of the typical inexperience of the student population and some technical staff.

Safety Protocol 7
Plan for, have available, and use appropriate personal protective equipment.

An important part of task planning is to verify that adequate personal protective equipment is in place. Selection of the personal protective equipment is based on the sampling equipment used, the terrain at the work site, weather, and other expected hazards. This may include adequate clothing for winter months, proper footwear, hard hats, eye and ear protection, communications equipment, and clothing that can be removed and disposed of if biological or chemical contamination is encountered. Soiled clothing can be a path for carrying contamination back to our homes and work places, impacting unsuspecting individuals.

Shovels and Hand Augers

Shovels and hand augers are the common tools of a scientist or soil evaluator who has limited capital resources or needs to access remote areas. These tools rely on the physical ability of the user to dig a hole. Holes are typically limited to a depth of about 4 feet, but hand augers may be extended to depths of 8 to 10 feet (~2.4–3 meters).

Use of a shovel or auger can cause acute damage to the user’s back or other muscles, especially if the operator is not used to using the equipment and/or is not in good physical condition. Care should be taken if the user has any history of disk damage or other back problems. In this case the user should consult a physician prior to engaging in digging work.

Stretching before and after use can be helpful. If sharp pain or other evidence of back problems occurs, the augering or shoveling should be stopped immediately and medical treatment should be sought.

Technique is important. The legs should be used to pull an auger from the ground. Only a limited amount of turning should be done with each lowering of the auger to limit the amount of friction that must be overcome to remove the bucket from the hole. Chronic health problems associated with personnel using augers (i.e., a soil mapper, environmental health officer, or consultant) include
damaged rotator cuff injuries, disk damage, and chronic tendonitis. Investing in mechanically powered equipment or adoption of policies requiring the client to pay for or provide use of a backhoe are important options for protecting the long-term well-being of the soil investigator.

Soil sampling using a shovel or auger is a physically demanding activity. Adequate hydration is important, especially in summer months. Care must be taken by the investigator and any team members present to avoid succumbing to heat stress or heat stroke, a life-threatening situation.

**Soil Pits**

Mechanical excavation of soil pits is an extremely effective technique to overcome the concerns listed above and to increase productivity, but soil pits do involve their own safety issues:

- Potential to encounter buried utilities or structures
- Danger of collapse and potential burial of an investigator in a pit
- Danger to someone standing too close to the backhoe
- Danger to the backhoe operator
- Danger when operating on steep slopes, slippery slopes, or in the woods

**Collapse**

OSHA and related state agencies regulate the construction industry and limit the depth of excavations that can be entered depending on several conditions. Generally, an excavation that is not shored and is not sloped cannot be entered if the trench or pit is more than 4 feet deep (~1.2 meters). This depth can be shallower in fill material, wet soils, or sandy and stony soils. Pit collapse is especially of concern because it is common for a soil investigator to bend over in the pit and sample the lower parts of the pit. If the soil caves in, a ton or more of soil may bury a person, resulting in asphyxiation. Pits should be sloped back or shored appropriately (per OSHA 29 CFR 1926; OSHA, 1989). If at all possible, pits should not be deeper than 4 feet (~1.2 meters).

**Inadvertent Burial**

A soil consultant was buried alive and died in a pit in Virginia. The consultant was describing a pit on a lot adjacent to one that a backhoe operator was tasked to close pits on. The backhoe operator apparently was not aware that the pits were present on two separate lots and pushed the pit full of soil, with the consultant at the bottom. A safety
flag or other system of communication should be used. If a machine arrives or starts working on or near the site that he or she is investigating, the soil investigator should immediately get out of a pit and make contact with the operator. Backhoe operators should be trained never to close a pit without checking to make sure there is no one in it.

**Safe Observation of Backhoe Operations**

No one should stand within the reach of the swing of the backhoe boom when the boom is fully extended. This is typically an arc that has a radius of 12 to 20 feet (~3.6–6 meters), depending on the machine. It is common for a bystander to be lulled into complacency by an experienced operator running a piece of machinery. However, backhoe booms, which move much faster than the reaction time of a bystander, have the potential for a deadly amount of momentum.

If a backhoe is moving through an area with standing or fallen trees, or is pushing over trees, observers should stay at a substantial distance because a tall tree can knock down another tree, potentially injuring someone 50 feet (~15 meters) or more from the machine. Observers are best to be well upslope or across the slope from a moving or operating machine. If a machine moving down or across a slope overturns, it may strike an observer standing 15 or 20 feet (~4.5–6 meters) downhill of the machine.

Hard hats should be worn by all observers and equipment operators. Seat belts should be worn by equipment operators to ensure that they remain within the roll-over protection system of their machine in the event of an upset. Nothing should be pitched into the cab of a running backhoe. In one documented incident, someone threw a piece of pipe into a running backhoe. The pipe landed on a control lever and the resulting movement of the machine fatally injured the operator.

**Hydraulic Push Probes**

Hydraulic push probes have been common soil sampling tools for more than 50 years. Modern designs (Fig. 1) now include units that advance the sampling tube with hydraulic percussive force. These tools have
become mainstays of both the scientific and environmental sampling communities, especially in soils that are not excessively stony. Typically the sample tube is called a split spoon (Fig. 2).

Push probes typically load the steel push rods with tremendous force. Care must be taken to use protective shields and to maintain a safe operating distance. Hard hats, safety glasses, steel-toed boots, and ear protection should be worn when percussive units are used.

A concern often overlooked with units powered by hydraulic oil is the potential for rupture of a hydraulic hose or fitting. Safety glasses should always be worn when operating this equipment for this reason. Exposure of body parts to a pressurized oil, air, or water stream can result in severe injury or death.

**Hollow Stem Auger Units (Drill Rig)**

These units tend to be powered by either direct drive or hydraulic drive (Fig. 3) and have the capability of delivering both high levels of rotational force and vertical force. They should only be operated by trained staff. Hard hats, eye protection, ear protection, and steel-toed boots are required for safe operation. This safety equipment is also required for any observers, such as soil scientists, geologists, or property owners.

The units typically are operated by advancing a hollow stem auger (a pipe with auger flights wrapped around it) into the soil. A center stem is retracted, a sampling device (usually a split spoon) is attached to the end of the stem and the stem is then driven with a drop hammer. The drop hammer may either be attached to a rope wrapped around a spinning cathe-
Drill rigs pose danger from many sources. These dangers include, but are not limited to, frayed cables, cathead ropes, hydraulics, rig upset, and objects falling from the mast. As the hollow stem augers often weigh 100 to 150 pounds, augers should be lifted with winch cables when loading and unloading the auger string to and from the hole. When they must be manually handled, two people should handle them to minimize the risk of back injury. As with use of hand augers, many back injuries can be prevented with good physical conditioning programs and stretching programs. Loose clothing or unrestrained hair, which has the potential for getting caught in the rotating auger and to draw the person into the equipment, must be avoided. Gloves should always be worn to protect the hands from cuts and abrasions from sharp metal and frayed cable.

Summary

Sampling of soil and sediments is accomplished by a variety of methods. Each of these methods poses safety hazards that must be mitigated by good management and worker practice.

Obviously, as the level of mechanization increases, the potential for more catastrophic injury occurs. Safe work practice starts with safety education and awareness. Commitment by management and workers to safe work practices results in higher productivity and long-term worker ability both on and off of the job.

References


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March–April 2010
Self-Study Quiz
Safety protocols for soil sampling
(no. SS 04015)

1. What is the minimum safety training that workers on a soil-
sampling team should have?
   - a. the equivalent of Red Cross First Aid Training.
   - b. the equivalent of CPR training.
   - c. Biological Hazard Mitigation training from OSHA.
   - d. the equivalent of EMT training.

2. The second step for safe soil sampling requires locating the
   presence of all utilities in the work area. This should include
   - a. dialing 911 to identify where utilities may be buried.
   - b. using GPS software to generate a map of the buried utilities.
   - c. calling 811 or your local utility, private vendors, and prop-
     erty owners.
   - d. consulting a current edition of the Utility Locator Hand-
     book.

3. Which of the following is NOT recommended in this article as
   being a necessary component of the daily work plan?
   - a. The work plan should include the location of off-site emer-
     gency equipment.
   - b. The work plan should include driving directions to the site.
   - c. The work plan should be left with someone off site who will
     know how to find the team if it doesn’t return.
   - d. The work plan should be a means of identifying the work
     location such as GPS coordinates or a street address.

4. In addition to knowing the biological hazards in the work
   environment, it’s important to make sure coworkers communi-
   cate about any known personal life-threatening allergies and
   - a. where specialized first aid materials are located.
   - b. where each worker’s medical team can be located.
   - c. how to treat bee stings with butter or ice.
   - d. how to avoid poison plants by burning the plants.

5. One should only enter confined spaces with proper air-
sampling, ventilation, engineering controls, and emergency
   retrieval systems in place. Examples include
   - a. lanterns that flicker when oxygen is low.
   - b. air-purifying respirators and chemical-resistant suits.
   - c. small testing meters to determine when nitrogen levels are
     too high.
   - d. heart and pulse monitors.

6. An excavation that is not shored and is not sloped cannot be
   entered if the trench or pit is more than
   - a. 6 ft deep.
   - b. 4 ft deep.
   - c. 3 ft deep in clay soil.
   - d. 5 ft deep in wet soil and gravel.

7. Which of the following were given as examples of personal
   protective equipment that may be used?
   - a. eye and ear protection.
   - b. communications equipment.
   - c. chemical suits and safety glasses.
   - d. hard hats.

8. Holes created with a shovel or hand auger are typically lim-
   ited to a depth of
   - a. 2–3 ft, but shovels may be extended to a depth of 12 ft.
   - b. about 4 ft, but hand augers may be extended to depths of
     8–10 ft.
   - c. about 6 ft, but hand augers may be extend to a depth of
     15 ft.
   - d. about 8 ft, but shovels may be extended to a depth of 10 ft.

9. Safety issues associated with soil pits include
   - a. poorly trained backhoe operators.
   - b. potential pit collapse and burial of an investigator.
   - c. inhalation of fuel fumes.
   - d. dipper disengagement on the backhoe due to compacted
     soil.

10. Commitment by management and workers to safe work prac-
    tices results in higher
    - a. productivity and long-term worker ability.
    - b. costs but better effectiveness.
    - c. rates of lost time due to minor accidents.
    - d. costs and lower effectiveness.

   Quiz continues
   next page
11. Which is true of the sampling device used with a hollow stem auger?
   - a. It is usually a split spoon attached to the end of the center stem, which is then driven with a drop hammer.
   - b. It is usually a grab sampler attached to the end of split stem, which is then driven with a drop hammer.
   - c. It is usually a center spoon attached to the boom, which is then driven with a drop hammer.
   - d. It is usually a split spoon attached to the end of a drill rig, which is then driven with a hydraulic hammer.

12. Since the hollow stem augers often weigh 100 to 150 lb, they should be
   - a. lifted with a chain hoist from the rig to the hole.
   - b. lifted with winch cables when loading and unloading the auger string to and from the hole.
   - c. “walked” into position over the hole.
   - d. raised and lowered hydraulically.

13. Hollow stem augers tend to be powered by either direct or hydraulic drive and have the capability of delivering both
   - a. high and low levels of rotational force.
   - b. high levels of forward motion and rotational force.
   - c. high levels of rotational force and vertical force.
   - d. low levels of rotational force and vertical force.

14. No one should stand within the reach of the swing of the backhoe boom when the boom is fully extended. This is typically an arc that has a
   - a. diameter of 8–12 ft.
   - b. radius of 10–20 ft.
   - c. radius of 12–20 ft.
   - d. radius of 5–9 ft.

15. Each method for sampling soil and sediments poses safety hazards that must be mitigated by
   - a. good management and worker practice.
   - b. regulations and certification.
   - c. work rules and steep fines if they are ignored.
   - d. large work teams.
To collect representative soil samples the sampler should:

- consider the variability of the parameter being measured
- use a sampling protocol that considers how the fertilizer was applied
- composite at least 15 to 30 individual cores from each sampling area into a single sample
- develop sampling protocols that consider prior management (such as feedlots and old boundaries)

Why Keep Records?

The beginning point for soil fertilizer management is to obtain a reasonably accurate measure of the soil nutrient concentrations. This can only be obtained when a representative soil sample is obtained. If the soil sample is not representative, the fertilizer recommendation and the long-term assessment of the fertility program may lead to faulty conclusions. Consider this example. Decreases in the soil test value over a period of time indicate that a crop is removing more phosphorus than the amount being added. Under these conditions the producer might decide to increase the fertilizer application. But, if the nutrient concentrations have large temporal fluctuation (10, 20, 5, 30, and 12 in Years 1, 2, 3, and 4), it is hard to derive meaningful information from the sequence of numbers—the producer can’t make a sound decision. Large temporal fluctuation can result from not collecting representative soil samples.

Collecting Representative Soil Samples

There are many different approaches to collecting representative soil samples. Soil samples can be collected from whole fields using random sampling or portions of fields using precision farming techniques (Fig. 1). In random sampling, a single composite sample is obtained by combining between 15 and 30 individual samples from a given area. It is important to point out that combining 15 to 30 individual cores from an area represents the minimum number of samples that should be combined. More is better.

Summary

Soil samples have been used to assess the health of soil, develop fertilizer recommendations, track the fate of contaminants, and determine the effectiveness of an agricultural system. To meet these goals, unbiased representative soil samples must be collected. Our discussion includes the importance of record keeping, how to collect representative soil samples in fields with complex histories, and what the laboratory values represent.

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Each individual sample is collected with a soil sampling probe that can be obtained from a number of different vendors. Most soil sampling probes consist of a stainless-steel tube, a handle, and tips that are designed for specific soil conditions. To collect a sample, the probe is pushed straight down into the soil to the desired depth. The probe is pulled out of the soil, and soil contained in the probe is placed in a bucket for mixing. Once the samples are mixed, a subsample is removed and placed in a sampling bag. Sampling bags can usually be obtained from the soil testing laboratory where the samples will be analyzed.

In grid sampling, cores are collected from specified locations on a grid within a field. A common grid sampling approach is to collect samples from a staggered unaligned design. The distance between the sampling points depends on the desired accuracy and the variability at the site. Representative samples should be collected at each grid point.

In management zone sampling, yield maps, remote sensing, apparent electrical conductivity data, soil survey maps, or topographic maps can be used to define zones (Chang et al., 2004). Prior to subdividing a field into management zones, a manager needs to ask the question, is the value of the spatial information worth the cost of collecting the data? The purpose of the management zone approach is to identify areas where the soil characteristics within a zone are similar. One of the most widely available data layers is soil survey information. Soil surveys were developed by the USDA-NRCS to provide soil and climatic information to land managers (Chang et al., 2002). When using soil survey information it is important to consider that soil information is available at several different scales. Published surveys, available from NRCS county offices, typically are Order 2 (Mount, 1999). Research suggests that in many situations Order 2 surveys do not provide the detail necessary for precision farming (Chang et al., 2004). Order 2 soil surveys can be improved by using yield monitor data, topography maps, or apparent electrical conductivity information to better identify boundary lines (Mount, 1999).

In grid cell sampling, a field is split into separate areas that can have a range of sizes. For example a 1/4 section (160 acres)–size field can be split into 4 cells that are 40 acres each or 16 cells that are 10 acres each. In grid cell sampling, a single composite sample consisting of between 15 and 30

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**Fig. 1. Relative shapes of different soil sample approaches.**

A. Location of grid point in a staggered unaligned system

B. Location of individual cores that will be combined to produce a single composite sample

C. Relative location of three management zones

D. Location of grid cells in a production field
randomly collected individual cores is obtained from each cell (Buchholz, 1993). It is important to point out that in highly variable situations, the number of samples should be increased.

To reduce soil sampling error, sampling protocols should account for prior management. Feedlots located within a sampling zone can influence phosphorus concentrations. Rotational sequences may impact organic matter content, and old fertilizer bands impact nutrient concentrations between crop rows. In the past, many fields contained small homesteads where animals were confined. The remnants from these enclosures can still impact soil properties (Fig. 2). Soil sampling strategies that do not account for prior management can contain substantial errors.

A recent study conducted in South Dakota showed that not accounting for prior use (an old homestead in this case) can increase soil test phosphorus values (Table 1).

In this study, soil test phosphorus values were lower in whole field composite samples when individual samples from the old homestead were excluded from the composite sample. Findings from this research showed that events that occurred 50 years ago still impact soil test values (Fig. 2) and that it is imperative to sample areas impacted by historical management separately from the rest of the field. Many of the small farms that dotted the countryside a hundred years ago had enclosures where horses, cows, and hogs were kept. Aerial photographs stored by USDA Farm Services Agronomy offices can provide clues to past management.

Soil test values can also be influenced by the approach used to apply the fertilizer. If the N and P fertilizer was banded into the soil, collecting representative soil samples can be very difficult. The impact of the fertilizer band on soil test values may impact soil test values for some time.

### Table 1. Soil test P concentrations in whole field and whole fields without homesteads.

<table>
<thead>
<tr>
<th>Field number</th>
<th>Field average</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>With homestead</td>
<td>Without homestead</td>
<td></td>
</tr>
<tr>
<td></td>
<td>μg P/g soil (or ppm)</td>
<td></td>
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</tr>
<tr>
<td>1</td>
<td>23.5</td>
<td>16.9</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>31.9</td>
<td>16.2</td>
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<tr>
<td>3</td>
<td>21.1</td>
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<td>4</td>
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<td>10.1</td>
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<td>40.2</td>
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<tr>
<td>12</td>
<td>16.5</td>
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</table>

Fig. 2. Location of old homestead and current soil test results.
Clay et al. (1997) showed that one year after anhydrous ammonia was injected into a field, the inorganic N distribution looked like a Christmas tree, with the highest concentrations located directly below the band (Fig. 3). This variation tends to decrease with time and tillage.

Sampling areas where fertilizers have been band applied requires extra care because oversampling bands can result in overestimating the amount of nutrient contained in the soil, while undersampling the band results in underestimating the amount of nutrients contained in the soil. Clay et al. (1997) recommended that a good way to sample nitrogen-banded fields is to sample the zone halfway between the crop row and the fertilizer band (if located in the center of the rows). Blackmer et al. (1991) recommended that a set of eight cores that have relative assigned values relative to the crop rows should be collected. The first sample is collected in the crop row. After moving to another random location, the next sample is collected one-eighth the distance between the row and next row. This process is repeated until eight cores are collected, combined, and mixed. Kitchen et al. (1990) suggested that in phosphorus-banded cropped fields with a 30-inch row spacing, one sample out of twenty should be collected from the band. For a row spacing of 21 inches, 14 samples from outside the band should be collected for every sample collected within the band.

As reported by Clay et al. (2002), our recommendations for collecting representative soil samples are to:

1. Utilize a sampling strategy that considers how the fertilizer was applied and the type of tillage system that is used. A single one-size-fits-all sampling protocol will not minimize bias.
2. Keep fertilizer records as to how much, when, and how fertilizer was applied. Oversampling bands can result in recommendations that underestimate the fertilizer recommendations.
3. Sample areas where animals were confined separately from the rest of the field. Evidence of old homesteads can be seed in old aerial photographs collected by USDA-NRCS. Many of these old aerial photographs are available in county NRCS offices.
4. In fields where N and P fertilizer were broadcast applied, a good strategy is to randomly collect between 15 and 30 individual cores from each sampling zone.
5. In reduced tillage cropped fields with a row spacing of 30 inches, collect only one core from old residual bands for every 20 cores outside the band. For a row spacing of 21 inches, 14 samples from outside the band should be collected for every sample collected from the band. If phosphorus was band applied 2 inches below and to the side of the seed, the band sample can be obtained by collecting one sample from each side of the seed. If nitrogen was band applied...
halfway between the two crop rows, the remaining samples should be collected halfway between the center of the crop row and the crop row.

6. If nitrogen and phosphorus bands are unknown, then collecting representative samples may be difficult. If residual bands are present and their locations are unknown, we recommend that the Blackmer et al. (1991) procedure be followed (Fig. 4).

7. Fertilizer recommendations are improved by increasing the number of samples contained within a composite sample. More is better. Composite samples consisting of only five or six cores can be misleading.

**What the Soil Laboratory Numbers Represent**

When making recommendations based on the soil test results, it is important to know what the soil test value represents. If a representative sample is collected, the soil test value represents the field average (Fig. 5).

The average value is the sum of all the individual values divided by the number of samples, whereas the median value is the point where 50% of the soil test results are above and below. Many soil nutrients have skewed distributions. Care must be used when using average values of skewed distributions for making fertilizer recommendations. For example, when fertilizing to the field average, areas with a nutrient concentration less than the average may be underfertilized, whereas areas with nutrient concentrations greater than the average may be overfertilized. Because the average value is often greater than the median, fertilizing to the average value can result in between 50 and 70% of the field being underfertilized.

To minimize the size of the areas that are over- and underfertilized, fields can be split into subfields, ranging in size from 10 to 20 acres, or management zones (Chang et al., 2002).

**Summary of Strategies to Improve Recommendations**

1. Keep accurate records.
2. Obtain old aerial images from USDA-NRCS or the USDA Farm Service Agency (FSA). Archived aerial images that were collected between 1955 and the present can be obtained at [http://www.fsa.usda.gov/FSA/apfoapp?area=apfohome&subject=landing&topic=landing](http://www.fsa.usda.gov/FSA/apfoapp?area=apfohome&subject=landing&topic=landing) (site URL verified 27 Feb. 2008).
3. Collect representative soil samples.
4. The fertilizer recommendation should consider changes in the soil nutrient concentration over time, yields, and the cost of the fertilizer. In other words, when developing your recommendation, compare soil test values collected in different years. If the soil test value is decreasing with time, then it is likely that plant nutrient uptake exceeds the amount of nutrient returned to the soil.
Acknowledgments

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References


Additional photo credit: Soil Sampling photo courtesy of USDA-NRCS.
March–April 2010
Self-Study Quiz
Reducing soil sampling errors
(no. SS 04016)

1. Collecting a representative soil sample requires several basic steps, one of which is to
   - a. composite at least 15 to 30 individual cores from each sampling area into a single sample.
   - b. composite at least five or six individual cores from each sampling area into a single sample.
   - c. composite no more than 10 individual cores into a single sample.
   - d. select a single representative sample and use it.

2. In grid sampling, cores are collected from specified locations on a grid within a field. A common grid sampling approach is to collect samples from
   - a. a preset grid that is geometric in nature.
   - b. a staggered unaligned design.
   - c. specific cells that cover a large area.
   - d. a uniform grid that covers several acres.

3. What is the disadvantage of using management zone sampling?
   - a. It isn’t very accurate.
   - b. It is very time consuming.
   - c. The cost may be higher than the advantage.
   - d. Management zone information is usually outdated.

4. To improve fertilizer recommendations when fertilizer banding has been practiced, but the pattern is unknown, you should
   - a. increase overall fertilizer applications the following year to mitigate “the band effect.”
   - b. increase the number of samples contained within a composite sample.
   - c. increase the number of composite samples containing three to four cores each.
   - d. wait a couple years to begin your sampling program, as the difference generally diminishes over time.

5. Soil test values can be influenced by past events. Findings from this research showed soil test values were impacted by events that occurred
   - a. 50 years ago.
   - b. 5 years ago.
   - c. 80 years ago.
   - d. more than 150 years ago.

6. Soil sampling strategies that do not account for prior management can contain substantial errors. Which of the following is NOT an example of the potential errors mentioned in this article?
   - a. Oversampling areas where fertilizers have been band applied can result in overestimating nutrients.
   - b. Undersampling areas where fertilizers have been band applied can result in underestimating nutrients.
   - c. Sampling areas where conventional tillage was used can result in higher organic matter levels.
   - d. Sampling areas where feedlots were located can influence phosphorus concentrations.

7. In the past, many fields contained small homesteads where animals were confined, which can affect current soil test values. How does this article recommend that you determine whether or not a small homestead existed on your sampling site?
   - a. Go to your county USDA-ARS office and look at the old aerial photographs of your site.
   - b. Talk to neighbors.
   - c. Unusually low phosphorus levels are a good indicator that a homestead existed on the site.
   - d. Peruse old deeds and bills of sale.
8. Fertilizing to the average soil test value as opposed to the median can result in
   a. most of the field being overfertilized, contributing to fertilizer runoff.
   b. the field being underfertilized by 10–20%.
   c. between 50 and 70% of the field being underfertilized.
   d. higher yields but more money spent on fertilizer.

9. If nitrogen was band applied halfway between the two crop rows in reduced tillage cropped fields with a row spacing of 21 inches, then
   a. samples should be taken in the center of the rows.
   b. samples should be collected halfway between the center of the crop row and the crop row.
   c. samples should be taken nearest to the plant base.
   d. 2 to 4 inches from the plant base.

10. If the soil test value is decreasing with time, then it is likely that
   a. plant nutrient uptake exceeds the amount of nutrient returned to the soil.
   b. plant nutrient uptake is less than the amount of nutrient returned to the soil.
   c. the amount of nutrient returned to the soil exceeds plant nutrient uptake.
   d. there is little relationship between plant nutrient uptake and the amount of nutrient returned to the soil.

SELF-STUDY QUIZ REGISTRATION FORM

Name: ___________________________________________________________
Address: _______________________________________________________
City: ___________________________________________________________
State/province: ____________________ Zip: ________________
CCA certification no.: ____________________

$20 check payable to the American Society of Agronomy enclosed.
Please charge my credit card (see below)
Credit card no.: ____________________
Name on card: ____________________
Type of card: ☐ Mastercard ☐ Visa ☐ Discover ☐ Am. Express
Expiration date: ____________________

Signature as it appears on the Code of Ethics: _______________________

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

This quiz issued March 2010 expires March 2013

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: _______________________________________________________

North Dakota, Wisconsin CCAs recognized

Top CCAs were honored in North Dakota and Wisconsin during the North Dakota 7th Annual CCA Meeting on January 19 in Fargo and the Wisconsin Crop Management Conference on January 12 in Madison, respectively.

At the North Dakota meeting, the 2009 North Dakota CCA of the Year Award was presented to Larry Lunder from Alliance Ag Coop, Bismarck, ND. Recipients of this highly prestigious award are nominated by either the North Dakota CCA board or a peer. Lunder graduated from North Dakota State University with a B.S. degree in crop and weed science. He became a CCA in 1997 and presently has around 150 customers and consults for approximately 100,000 acres.

Also recognized at the meeting were outgoing CCA board members Paul Thompson, USDA-NRCS, and Sherry Koch, Monsanto, both having served six years on the board. Thompson served as chair of the exam and continuing education committee and Koch served as chair of the finance committee.

During the meeting, North Dakota CCA board chair Matt Olson from Centrol Ag Consulting, gave the 2009 committee reports and a brief outlook on 2010. Board member Ted Alme reviewed his new excel CEU application form for meetings, which could result in faster turn around time and cost savings. Greg Krieger, president of the North Dakota Grape Growers Association, gave a presentation on grape production in North Dakota, which included sampling some wine from the state.

If you have questions about the North Dakota CCA program, call 701-277-3027 or visit www.ndag.org/ndcca.

At the Wisconsin meeting, Don Schmidt from Ag Ventures LLC in Coleman, WI was recognized as the 2009 Wisconsin CCA of the Year. Schmidt does a large percentage of the comprehensive nutrient management plans for Ag Ventures. He consults for more than 30,000 acres of nutrient management plans and promotes pest management plans to his customers as well. As an agronomist for more than 30 years, Schmidt has worked with various types of clients, including large expansive dairies, mid- to small-size dairy operations, cash grain, and hobby farmers. He participates in local and state meetings and organizations that promote nutrient management and environmentally sound farming practices.

Also, at the meeting, it was announced that the Wisconsin CCA program is providing University of Wisconsin system students from River Falls, Stevens Point, Platteville, and Madison the opportunity to apply for scholarship funding that partially offsets Wisconsin and international CCA testing fees. If approved by the Wisconsin CCA board, the students will be required to submit $50 with the registration form, and the remaining $200 fee will be paid by the Wisconsin CCA board.

For more information, call 866-359-9161.
Handheld GPS unit for field data collection

A new handheld unit from Trimble, the Juno ST handheld, is described as “a productive yet affordable, non-rugged GPS receiver for field data collection and mobile GIS.” The company says it is a compact, lightweight, fully integrated field computer, providing 2- to 5-m (6.6 to 16.4 ft) GPS positioning in real time or after post-processing.

Trimble says the product has been designed to maximize yield of positions in hostile environments, such as under forest canopy and up against buildings. For the user needing 2- to 5-m accuracy in the field, the integrated WAAS receiver provides for real-time corrections. Or the user can collect data in the field and post-process it back in the office to ensure positions are defined to the required accuracy level and to control the overall quality and consistency of data.

Trimble says the unit is fully compatible with its entire range of mapping and GIS software. The handheld runs on Windows Mobile version 5.0 software and provides integrated Bluetooth and wireless LAN technology options for connecting to the internet and corporate networks to access data and maps and to send and receive email and instant messages.

For more information, see www.trimble.com/junost.shtml.

Hay moisture tester

Baling hay at the proper moisture level is critical to ensure optimal storage life and quality of the forage. John Deere Merchandise says its new Windrow Hay Moisture Tester makes it easier and faster for producers to determine moisture level of windrowed hay in the field prior to baling.

According to Phil Lauer, product manager for the company, the portable, handheld tester allows hay producers to check hay moisture levels quickly at several places in the field to determine if it’s time to bale. “Without testing the moisture level of the hay in the field, producers have to guess when the hay is ready to bale,” Lauer says. “The Windrow Hay Moisture Tester takes the guesswork out of this forage management decision.”

The tester measures hay from 13 to 70% moisture content within ±2 to 4% accuracy. Producers simply add loose hay to a 5-gal bucket (not included), insert the handheld tester, and press a button. The moisture level of the hay sample is then digitally displayed within 30 to 60 seconds.

“The Moisture Tester is ideal for large and small hay growers and is a small investment to ensure that their hay crop is baled at the right moisture level for their needs,” Lauer says. “The simple operation, portability, and fast results of the in-field tester saves them the time, expense, and inconvenience of transporting a baler to the field before the hay is dry enough or baling hay that is too dry.”

The Windrow Hay Moisture Tester is available from local John Deere dealers. For more information, see JohnDeere.com.

Soil sensors

Veris Technologies has introduced two new soil sensors, the pH Detector and the Quad EC1000, which are described as “small yet powerful tools designed for use with ATVs.” The pH Detector is said to rapidly and accurately map pH variability and can be used to affordably map pH on a small grid or to measure pH at several locations within management zones.

The pH probe is inserted in the soil with an easy-push mechanism, and in about 10 seconds, a geo-referenced pH measurement is recorded on the Veris DataLogger. The cost for each sample is pennies, thanks to a durable metalloid pH sensor.

The Quad EC1000 is a soil electrical conductivity (EC) mapping system. It features four tine-mounted disks—two for injecting electrical current and two for measuring the voltage drop in the top 12 inches of soil. This new system is ideal for developing sampling zones and variable-rate seed population prescriptions.

The company claims that both systems are easy to use, easy to ship, and feature many of the same components found on its other on-the-go EC and pH mapping equipment.

For more information, see www.veristech.com.
Open Up a World of Possibilities

As a CCA, CPAg, CPSS, or CPSC, your certification shows the world that you have the experience, education, expertise, and ethics that make you a trusted partner for farmers and other clients. You take your responsibility to maintain your technical expertise and education seriously—so you should seriously consider membership in the American Society of Agronomy and Soil Science Society of America this year. The benefits are many:

**Education**—Earn necessary CEUs through Society branch and Annual Meetings.

**Research**—Access the latest research, including quick-read summaries through our research highlights and abstract searches.

**Networking**—Talk with experts and share knowledge through access to our Member Directory, Discussion Boards, and Divisions of Interest.

**Advocacy**—Support efforts to secure necessary funding and Congressional support on the issues that effect you and your customers.

Membership in ASA and SSSA opens up a world of possibilities, enhancing your certification status. For more information, please visit [www.agronomy.org/membership](http://www.agronomy.org/membership) or [www.soils.org/membership](http://www.soils.org/membership).
Stevens Hydra Probe Soil Sensor
turn your data into growth

All in one multi-parameter soil sensor

The Stevens Hydra Probe soil sensor is the most robust and unique soil sensor available. Users can select up to 22 parameters, including:
- Soil Moisture
- Soil Temperature
- Soil Electrical Conductivity
- Real and Imaginary Dielectric Permittivity
- and many more!

Features of the Stevens Hydra Probe

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

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

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

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

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

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