IPNI
Plant Nutrition **TODAY**
Better Crops, Better Environment...through Science

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Winter 2012, No. 1

SAMPLING SOILS WITH A HISTORY OF FERTILIZER BANDS

Soil sampling done properly often forms the basis for successful crop nutrition. But what's proper when your soil has had a history of fertilizer applied in bands? Will soil samples still mean anything?

Many nutrients are indeed rather immobile in the soil. Thus you can expect that a sample taken from a band location will differ sharply from one taken only a few inches away. You can also expect variations in soil concentrations of these nutrients in patterns matching the band spacing at which they were applied. Nevertheless, there are guidelines for effectively sampling soils with a history of band application. The guidelines differ depending on whether the band locations are known or not.

If the band locations are known, and the band itself is narrow—as occurs in a V-trench associated with single or double coulters as openers—a ratio of 1:20 in-band cores to between-band cores should be used for bands spaced 30 inches apart. If the banded zone is wider, as in strip tillage, or if the band spacing is different, the ratio should be the ratio of the band width to between-band width. In a recently published Illinois study—involving a strip-till corn-soybean rotation with P applied in strips 6 inches deep in the fall—a 1:3 ratio of in-row to between-row samples seemed adequate to estimate soil fertility.

If the band locations are unknown, a paired sampling approach can be effective: one sample consisting of cores taken at random, and the second consisting of cores each taken at a distance of half the band spacing from each of the first cores, perpendicular to the direction of the bands. Since the greatest deviation from the 'true' soil test level occurs when the band location is over-sampled, the sample with the lower soil test level is most likely to be representative. This approach was validated in a 1990 paper published in Soil Science Society of America Journal.

Nutrients differ in mobility. Bands of K may not remain as concentrated in soils over time as bands of P. There are at least three reasons for this. First, crops like corn and soybean take up much more K than P during the season. Secondly, a greater proportion of the K taken up is returned to the soil in crop residues because much of the P taken up ends up in the grain. Third, K moves more in soils than does P, causing bands of K to become more diffuse over time relative to P. So, greater uptake and recycling combined with greater mobility limits the longevity of concentrated bands of K. Micronutrients differ in mobility as well. Boron is usually much more mobile than zinc.

Band application offers many benefits, particularly for P. Bands located close to the seedlings supply P at a critical time of need for cereals like corn, wheat and other small grains. For soils with high P fixation capacity, or with soil test P lower than critical levels, band placement provides higher P use efficiency, since a given amount of applied P produces a larger yield response when banded compared to broadcast. Band placement reduces accumulation of high P levels at the soil surface (stratification) in no-till and conservation-till systems, particularly those using tillage implements that maximize crop residue cover and minimize vertical soil mixing. If the field has tendency to discharge surface runoff water, placing P below the soil surface also helps reduce the risk of P losses that potentially harm water quality.

Soil sampling strategies can effectively deal with a history of bands applied to the soil. While some extra effort may be required, you shouldn't need to fear losing the ability to track your soil's fertility depending on the choice you have made for the "right place" for nutrient application in your cropping system.

– TWB –

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Abbreviations: P = phosphorus; K = potassium.

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PLANTS TAKE UP MORE ELEMENTS THAN THEY NEED FOR GROWTH, SOME ARE BENEFICIAL TO LIVESTOCK AND HUMANS

Plant roots play an important role in absorbing water and nutrients needed for plant growth. In order for water and soluble ions to enter roots they must first come in contact with the root surface. Contact is achieved by **direct contact** as roots grow into the soil, **mass flow** of ions in soil water as transpiration of moisture out of the leaves pulls a minute stream of water from the soil, and **diffusion** within the water from locations of higher nutrient ion concentration like soil humus and mineral particles to areas of lower concentration near the roots.

Once in contact with roots, the ions can passively move into a free space between cells of the root epidermis and cortex cells. This movement is done through diffusion and surface electrostatic ion exchange. The cell surfaces of the epidermis and cortex are largely negative in charge and effectively exchange positively charges ions (cations), such as potassium (K^+), calcium (Ca^{+2}) and magnesium (Mg^{+2}). In order to maintain ion charge stability, roots will release hydrogen (H^+) ions off the cell surfaces into solution while adsorbing the cations noted above. The ions move towards the center of the roots passively until they come to a selective layer called the endodermis.

Movement past the impermeable endodermis layer requires that energy from metabolism be used to selectively move the ions across the membrane through tiny pores. Energy is needed because the osmotic concentration within plant cells is greater than soil solution. Cells outside the endodermis, such as root hairs can also actively absorb nutrient ions into themselves and pass the ions from cell to cell where the cell membranes contact each other. Movement is towards the endodermis and then towards the root and stem conductive organs called xylem that act as tiny pipes moving water and nutrient ions up from roots towards leaves.

Plants absorb many different ions needed for their growth, specifically all 14 essential mineral elements. These include the ionic forms of nitrogen (NH_4^+, and NO_3^-), phosphorus ($H_2PO_4^-$ and HPO_4^{-2}), K^+, sulfur (SO_4^{-2}), Ca^{+2}, Mg^{+2}, boron ($H_2BO_3^-$), chloride (Cl^-), copper Cu^{+2}), iron (Fe^{+3}), manganese (Mn^{+2}), molybdenum (MoO_4^{-2}), nickel (Ni^{+2}), and zinc (Zn^{+2}). Additionally there are other elements not required for plant growth that are absorbed by plant roots and end up in plant tissues.

Some of these non-plant required nutrients that are taken up by plants are needed for animal and human nutrition. Examples are sodium, cobalt, chromium, iodine, selenium, and vanadium. In some soils their natural availability in soil solution may be so low that supplements containing them are beneficial. For example, iodine is added in low concentrations to table salt. In some other situations a naturally occurring higher level of an animal-required element may have adverse effects on certain livestock species. For example, a level of selenium beneficial for cattle fed hay from a higher selenium-containing soil can have detrimental effects on horses.

There are other elements that are naturally occurring in soils that are absorbed by plant roots and are not needed for animal or human growth. Most are low in concentration and are not a concern, but some elements can occur in high enough concentrations in cultivated soils, naturally or as a result of human pollution, that there can be concerns about animal and human consumption of plant materials grown on these soils. The four main elements known to be a concern are the heavy metals lead, cadmium and mercury, and the non-metal arsenic.

In most instances crop plants take up elements in high enough levels that plant growth does well, and animals and humans consuming harvested crops do well nutritionally.

– TLJ –

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WHAT HAPPENS TO FERTILIZER IN SOIL?

A lot of careful consideration goes into selecting which fertilizer should be added to a crop. After all the decisions have been made, little thought is then given to what actually happens next. A brief review of some important fertilizer reactions can help you get the most benefit from these valuable resources.

There are five major processes that happen to applied fertilizer.

- It is taken up by the crop
- It reacts with soil minerals and organic matter to become part of the soil reserve
- It can leach from the root zone with water
- It can be lost to the atmosphere as a gas
- It can move from the field through soil erosion and water runoff

Nitrogen fertilizer can be subject to all five of these processes and may be the most difficult to manage of all nutrients. Nitrogen fertilizer is most commonly added in the form of nitrate, ammonium or urea. Their behavior is quite different and they need to be managed with their specific properties in mind.

Nitrate (NO_3^-): Nitrate is very soluble in soil and moves freely with water in the soil. Excessive rainfall or irrigation can easily move nitrate below the root zone. In wet soils, bacteria may convert nitrate to nitrous oxide (N_2O), causing a loss of a valuable resource and the production of a greenhouse gas. Nitrate can also be converted to inert N_2 gas.

Ammonium (NH_4^+): As a positively charged cation, ammonium is largely held on soil cation exchange sites. In warm aerated soils, ammonium is converted to nitrate within a few days or weeks. In flooded soils, ammonium can persist for long periods of time. When left on the soil surface, ammonium is in equilibrium with ammonia gas and can be lost to the atmosphere.

Urea ($CO(NH_2)_2$): As an uncharged molecule, urea moves freely with water in the soil. In warm soils, urea is decomposed to ammonium within a week or two by an enzyme (urease) that is present in almost all soils and plants. When urea is left on the soil surface, a portion of the ammonium will be lost as ammonia gas. If urea is placed beneath the soil surface or washed into the soil by rainfall, ammonia losses are very low.

All added N fertilizer is accessed by soil microorganisms before the plant roots have a chance for uptake. Since there are between 100 million and 1 billion bacteria in a single teaspoon of soil, their numbers in an entire acre are almost unimaginable. When conditions are optimal (warm temperature and adequate carbon), microorganisms will immobilize some of the added N in their cells and it will become part of soil organic mater.

Phosphate fertilizer quickly reacts in soil to form many new compounds and remains very close to where it is applied. The most common phosphate fertilizers are diammonium phosphate (DAP; 46% P_2O_5, pH 7.5 to 8) and monoammonium phosphate (MAP; 48 to 61% P_2O_5, pH 4 to 4.5).

Phosphate fertilizers are initially soluble in water and thus readily used by plants, but they quickly react with clays and other elements in the soil to become less soluble. These newly formed compounds will slowly dissolve and release soluble P over many months or years. These chemical reactions can be influenced by modifying the fertilizer properties or by minimizing fertilizer contact with soil with banded fertilizer application.

Phosphorus movement in agricultural soils is quite limited, with diffusion occurring in the range of a few millimeters to less than an inch. In very sandy soils or where application rates greatly exceed agronomic needs, P movement through the soil can be greater.

Since P fertilizer is tightly bound to soil particles, erosion from the field in runoff water can be a pathway of loss. Conservation practices should be implemented to minimize erosion losses. Added phosphate fertilizer is incorporated into microbial biomass and soil organic matter, but in smaller amounts than N.

Potassium fertilizer is most commonly added as potassium chloride. However, all forms of K fertilizer contain the identical chemical form (K^+). Other K-containing fertilizers may contain nitrate, sulfate, thiosulfate, or phosphate, but the behavior of the K will be the same.

Potassium is simpler to manage than N or P since it is not involved in biological transformations. Most K fertilizers dissolve quickly in the soil and the K will either immediately displace another cation on the clay surface or move with water until it displaces another cation.

To get the most value from fertilizers, it is important to know what happens after they are added to the soil. Many people have little appreciation for the complex task of delivering the right nutrition to growing plants. Integrating knowledge of soil chemistry, soil microbiology and soil physics will go a long way in helping improve fertilizer management.

– RLM –

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Abbreviations: N = nitrogen; P = phosphorus; K = potassium.

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GOING FOR HIGH YIELDS

High yields are always exciting. Many farmers observe 300 plus bu/A in parts of their fields and 100 plus bu/A of soybean. But they aren't everywhere. Should they be? Is it realistic to expect farm average yields will eventually be that high or higher?

A tool that can help you get an idea of potential yield is Hybrid Maize. It's a user-friendly crop model available from the University of Nebraska (http://hybridmaize.unl.edu). The model outputs potential yields that are based on management and weather inputs. The goal in the field is to achieve 85% of those potentials. Hybrid Maize can help you answer if 300 and 100 bu are really realistic goals for corn and soybean yields on your fields. To run it under your conditions, you'll need daily weather data from nearby stations, although it does come with some limited weather datasets. You might also want to consider purchasing your own weather station.

Farmers going for high yields usually dedicate some part of their farm to discovery. On-farm trials are part of the high-yield culture. Hybrid and variety comparisons are the norm, but there is another type of experiment you can conduct. Try establishing field-length strips that compare two management practices: your current approach and a "high yield" approach. Keep the strips in the same place over time and monitor the progress each season for each crop. Try different things on the high-yield strips, such as changes in plant population, fertility, planting date, and hybrid or variety selection; but be sure to keep the second set of strips as your current practices. You need both to determine if your attempts at a high-yield system do, in fact, create real improvements in yield in any given year. A couple of publications to get you started on field research are:

http://www.agry.purdue.edu/ext/corn/news/timeless/onfarmresearch.pdf.

http://nanc.ipni.net/articles/NANC0034-EN.

Going for high yields takes dedication to gleaning all the information your farms and fields generate. Good record keeping and computer file management are essential. Being able to pull up yield maps from each field and look at how they have changed over time can help identify areas in the field that are consistently higher or lower yielding—leading to specialized management for those areas.

Don't just pour it on. High yields don't necessarily take more nutrients. When it comes to N, more isn't always better. Many have found that the higher-yielding parts of the field require less N than the lower-yielding ones. Soil testing is still the best tool for assessing soil fertility. Grain samples can help you get a handle on nutrient removal and what it takes to keep up.

Going for high yields is a process of discovery. Trying new things, comparing new approaches to current ones, keeping track of what happened, and using available models and tools can help you get an idea of what is realistic and how best to get there.

–TSM –

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Abbreviation: N = nitrogen.

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THE RIGHT WAY TO GROW RICE…4R NUTRIENT STEWARDSHIP

Rice is life … for about three billion people in the world today. And, with the world's population growing every day, improved fertilizer management is now more critical than ever in order to achieve the necessary increases in rice yield and quality. 4R Nutrient Stewardship can help growers apply the right fertilizer source, at the right rate, at the right time, and in the right place needed to meet their rice production goals. The practices resulting from a *combination* of these factors are site-specific, of course, but the scientific principles are universal.

Choosing the right fertilizer source for any crop requires an understanding of soil and environmental conditions. In rice, this means recognizing how plant nutrients behave under flooded, anaerobic conditions. For example, elemental S must be oxidized into the sulfate form to become plant available; this reaction can't happen in a flooded field. So, S requirements in rice are best met using a sulfate fertilizer source like ammonium sulfate.

Nutrient requirements for rice, particularly N, are dependent on variety or hybrid. Yield potential, growth duration, susceptibility to lodging, whether the rice is first crop or ratoon; all of these things affect the nutrient requirement. Now some of this nutrient requirement for rice will be provided by the soil; the rest must be added using fertilizer. In the US and other developed rice-producing nations, soil testing is the predominate method used for determining soil nutrient supply and fertilizer application rates. However, throughout much of Asia, where 90% of the world's rice is produced, soil testing is not available. For these regions, there are science-based, decision support tools like Nutrient Manager™ or the Nutrient Expert™ software that are available to help growers choose the right fertilizer rate for their fields.

The right timing choice for rice depends on production system, but whether the rice is water-seeded, drill-seeded, or transplanted, early season N is critical for tiller development. However, applying too much N early is not advised because of the risk of losing the flood and much, if not all, of the early-applied N. So to address this, most rice production systems around the world recommend splitting the N into multiple applications during the growing season. On coarse-textured, low CEC soils, splitting K between pre-flood and panicle initiation has also proven beneficial; however, P and other nutrients are not typically utilized more efficiently when applied in multiple doses.

In many situations, the right place for immobile nutrients like P is banded near the plant to increase uptake efficiency. This practice is especially effective in soils with low pH where much of the applied P gets tied up by iron or aluminum. In rice however, banding is not as much of an issue because once the field is flooded, the soil pH moves toward neutral, which increases the availability of soil P. It is important to remember, however, that even though no P deficiencies may have been observed in a rice crop, once the field is drained, pH will return to near its original level and P deficiencies can appear in subsequent crops.

4R Nutrient Stewardship provides the framework needed to increase productivity and profitability of rice production in both the highly intensive agricultural systems of the developed world and the smallholder systems in developing nations. It is this increase in productivity aligning with the environmental and social goals of sustainable agricultural systems that will be critical to help feed the growing population and ultimately provide global food security.

To learn more about how the 4Rs can be applied to rice production, visit the IPNI website www.ipni.net in early 2013 to view the video "The Right Way to Grow Rice…4R Nutrient Stewardship." If you want to simply know more about 4R Nutrient Stewardship, check out the currently available DVD "The Right Way to Grow…4R Nutrient Stewardship".

– SBP –

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Abbreviations: N = nitrogen; P = phosphorus; K = potassium; S = sulfur; CEC = cation exchange capacity.

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WATER QUALITY STAKEHOLDERS – ARE YOU AT THE RIGHT TABLE?

Among the many causes of water quality impairment in the U.S. summarized by the EPA, nutrients rank third on the national 303(d) impaired waters list (http://iaspub.epa.gov/waters10/attains_nation_cy.control?p_report_type=T). All forms of P account for roughly 60% of the nutrient impairments, N (all forms) 37%, and general "eutrophication" the remainder. Agriculture is listed as the top source of water quality impairment in assessed rivers and streams; third in assessed lakes, reservoirs, and ponds; and seventh in assessed bays and estuaries (http://www.epa.gov/waters/ir/index.html).

Applied nutrients, especially mobile forms in soil like nitrate that may not have been taken up during crop harvest, may be subject to some movement and potential loss. Losses may occur via erosion, leaching, drainage, and runoff; particularly when crops are not actively growing in fields and rainfall is abundant. The magnitude and timing of some of these unintended nutrient losses should draw attention to more skilled cropping system management; especially better conservation and nutrient management practice choices and effective implementation.

Some water quality challenges have continued to persist like the internationally recognized annual hypoxic zone (*bottom waters with <2 mg/L dissolved oxygen*) in the Gulf of Mexico, with its associated N and P loads delivered via the Mississippi River. In spite of documented trends for higher crop yields and greater crop harvest nutrient removal, the annual nitrate-N loads from the Mississippi River Basin to the Gulf of Mexico have not changed appreciably since 1980. The annual total P loads have increased more than 10%, and orthophosphate P (soluble) loads have increased more than 5% since the early 1980s. In contrast, total N loads have declined by more than 20% over the last 30 years. Soluble nutrient losses to surface and groundwater resources are also attracting more public interest and scrutiny outside the Mississippi River Basin, especially in more populated watersheds around the country.

Practical, science-based nutrient management and farming expertise are essential at local, state and national levels. There is a growing need for agriculture to clearly discuss the challenges and options available to improve crop nutrient recovery and to reduce losses from fields. Such agricultural "stakeholder" involvement is key to ensuring that agricultural interests and sound science are in front of policymakers, regulators and government officials who are responsible for ensuring that water quality meets designated use requirements.

For sure, our urban neighbors, municipal wastewater treatment managers, city and county officials, environmental advocates, conservation groups, and others are getting involved, expressing concerns, and calling for water quality protection and restorative actions. Most of us within the farm community proudly view ourselves as responsible stewards of our nation's land resources. Seldom do we hesitate to join friends, family and others in conversations about the weather, or last year's production problems. Yet, when we sit down at our family tables to partake of the abundant, nutritious and affordable food produced through our labors … should we also be thinking about taking a place at the local, state and national water quality policy tables to help chart our collective water quality future?

– CSS –

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Abbreviations: N = nitrogen; P = phosphorus.

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GRAIN SORGHUM FERTILIZATION

The Great Plains produces the majority of grain sorghum in the U.S., with most production concentrated in two states. Kansas is generally the number one state for production followed by Texas. In 2011 Kansas produced 51% of U.S. grain sorghum, and Kansas and Texas together produced 78%. Most is used in feed, but some goes to ethanol and some to gluten free food products.

Grain sorghum is considered an exceptionally efficient crop. With a large fibrous root system, it is fit for production across a wide range of environments. Most in the Great Plains is grown under dryland conditions. It is often considered a rather low input crop when it comes to fertilizer, especially compared to corn. Therefore, and all too often, lesser attention is given grain sorghum nutrition. The fact remains though that it is a major crop in the Great Plains, and a brief review of a few fertility principles is in order.

Although estimates vary from source to source, and the real numbers may vary considerably depending on conditions, sorghum (grain only) removes about 66 lb N, 37 lb P_2O_5, and 27 lb K_2O per 100 bushels (5,600 lb) produced (http://nugis.ipni.net).

Nitrogen is the nutrient that most frequently limits sorghum production. Recommendations for N fertilizer will vary based on factors such as yield potential, soil texture and cropping sequence. The published recommendation equation from the KSU soil testing laboratory is based on yield goal (bu/A) multiplied by 1.6, with other sources of N and adjustments subtracted from the product of that multiplication (http://www.agronomy.ksu.edu/soiltesting). Grain sorghum begins a period of rapid growth, biomass accumulation and nutrient uptake at the five-leaf stage, approximately 3 weeks after emergence. Between this stage and booting about 70% of N will be taken up. Nitrogen fertilizer timing should account for this rapid growth period.

While grain sorghum P fertilization should be based on soil test rest results, work from north central Kansas has shown that a combination of N and P in a starter can have a marked effect on both yield and hastening maturity, even at relatively high soil test levels (Gordon and Whitney, 2002, *In* Better Crops No. 3).

As with P, a soil test is the best guide for K fertilization. The likelihood of response to K fertilizer is greatest in the eastern reaches of the region, where sandy soils and low soil K levels are more common.

Grain sorghum may also be responsive to some micronutrients. Work in Kansas has shown that in 19 of 23 study sites grain sorghum was responsive to Cl^- fertilizer (Mengel et al., 2009, *In* Better Crops No. 4). Soil critical levels for Cl^- have been well established over the past 20 years. Zinc and iron may also need to be addressed, particularly in high pH, calcareous conditions in the west.

– WMS –

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Abbreviations: N = nitrogen; P = phosphorus; K = potassium; Cl^- = chloride.