PLANT NUTRITION TODAY
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PHOSPHORUS AND SOIL HEALTH

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Soil health has elicited interest from many. The idea of looking at the soil as a living system with physical, chemical, and biological aspects of its functioning engages imaginations of crop producers and consumers alike. Policymakers and extension educators have particularly linked onto soil health as a key attribute in reduction strategies for phosphorus (P) loss. Are their expectations warranted?

The importance of maintaining good physical structure in soil is well known. Producers and soil experts have long appreciated the importance of a soil's capacities to let rainwater enter the profile, to retain that water in a tension range available to plants, and to remain in aggregate forms resistant to erosion. While these properties are not new, they are still important to managing P loss—and good crop yields. Major practices influencing the physical attributes of the soil include returning adequate amounts of crop residue to the soil, managing tillage to conserve soil organic matter, and avoiding compaction by staying off the land when it is too wet.

The chemical aspect of soil health has also been valued for a long time. Producers sample soils to test for the availability of a wide array of chemical constituents of the soil. A healthy soil needs levels of nutrients that support the full potential of plant growth, since plants are the primary producers of the organic materials that feed the biology of the soil. Soil bacteria, fungi, protozoa, nematodes, arthropods, and earthworms all feed on material derived from plants.

> *"It can't be assumed that more nutrient cycling, on its own, means less nutrient loss."*

The biological aspect is likely the "newest" area of soil health. Tests that measure how rapidly a soil emits carbon dioxide give an indication of how much activity the available organic materials in a soil can support. Such tests, however, need to be interpreted with care. Owing to the very biodegradability being measured by the test, such materials do not last long in the soil, and the test would be expected to give very different results depending on the composition of crop residues and the weather conditions encountered since the last additions of fresh organic matter.

NRCS-USDA photo

In biological nutrient cycling, one organism dies, and another feeds on its contents. A fungus secretes enzymes that break down old plant tissue, bacteria

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> “Soil conservation should be practiced with care. It can’t be used as an excuse to leave P fertilizer or manure on the surface of the soil.”

in turn digest the fungus, and higher organisms feed on them both, in turn excreting unneeded nutrients. Each time, carbon dioxide is released, total organic matter declines, and the amounts of each nutrient in the mineral form increase. Membranes and cell walls of microbial organisms are disrupted, and the contents of the cells—including the soluble phosphate stored in the vacuole—are often released into the soil. Each time a nutrient cycles, it goes through release as well as re-absorption. Some of it is prone to loss before another organism can take it up. It can’t be assumed that more nutrient cycling, on its own, means less nutrient loss. Synchrony of release with re-absorption is likely the most important attribute for minimizing nutrient loss.

Soil health is a concept worthy of attention. The practices it encourages—cover crops, conservation tillage, crop rotation, and more—go a long way towards preventing soil degradation. These practices are essential to averting the worst cases of P loss. Some of the latest loading reduction targets, however—particularly those aimed at reducing losses of dissolved phosphate—may not be met through soil health alone, and definitely require attention to nutrient application placement and timing as well.

Many studies, dating back decades, document that in conservation tillage systems—as the top inch or two of soil enriches in soil organic matter, biological activity and nutrients—concentrations and often loads of dissolved P in runoff increase. Soil conservation should be practiced with care. It can’t be used as an excuse to leave P fertilizer or manure on the surface of the soil. The optimum combination of tillage and fertilizer placement practices is likely to be specific to soil and landscape, and in many areas, requires continuing research.

Tom Bruulsema/IPNI photo

Strip-till implement for placement of granular fertilizers 4 to 6 inches below the soil surface, with minimal disturbance of crop residue.

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PLANT NUTRITION TODAY

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NITROGEN FERTILIZER MANAGEMENT: PRECISION TO DECISION

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Production agriculture is firmly entrenched in a digital revolution. Critical information that can help guide on-farm decisions is more easily accessible, more rapidly available, and more inexpensive than ever before. The downside of all this information is that advisors and growers are becoming inundated with data to the point that it sometimes inhibits the decision-making process rather than enhancing it. Kansas State University ag economist, Terry Griffin, likes to say "data are useless." This statement often draws immediate argument from those providing the data, but is clarified when explained that data—in and of themselves—actually do have little value until they are analyzed and applied in an intelligent manner to improve some practice.

One of the sessions at InfoAg 2016 addressed how an already sound, science-based nitrogen (N) fertilizer management strategy can be enhanced by incorporating precision ag technologies. The session consisted of a three-part case study of a Virginia farm that tracked the N fertilizer decision making process from the scientific principles that underlie 4R Nutrient Stewardship, through the analytical processes and data management at the farm advisory level, to the on-farm decisions, evaluation, and adaptive management strategies employed by the grower.

The first point made was that the basic questions regarding N fertilizer management have been the same for centuries: *What source do I apply? what rate do I apply? What time in the growing season do I apply it?* and *What placement method do I use?* What has changed is our understanding that these questions must be answered simultaneously as source, rate, time, and place are not independent of one another. This fact results in a complex, site-specific recommendation; however, the framework of 4R Nutrient Stewardship allows us to make N fertilizer decisions that adhere to the science-based fundamentals that drive sound agronomic practices while incorporating all the technology and data-driven solutions that producers have access to.

> *"What has changed is our understanding that our questions about right **Source, Rate, Time** and **Place** must be answered simultaneously as their relationships are not independent of one another."*

Jim Wallace, owner and chief consultant for Agritek, then discussed how they use multiple layers of on-farm soil and crop data to develop management zones for variable-rate seeding and N fertilizer applications. The grower was already changing N rates based on soil type, but grid sampling and multiple years of yield data identified variation within the soil

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“ Precision agriculture and 4R Nutrient Stewardship are critical components for meeting sustainability goals and management objectives on the farm. However, technology and data are not silver bullets. ”

zones that were able to be delineated. The more intensive data analyses also led to plant population changes within zones that affected yield potentials and subsequently N fertilizer recommendations. The result was a corn yield increase of nearly 30% over the two previous corn crops and even though N fertilizer rates increased, the yield boost was great enough to result in a higher N use efficiency.

Virginia farmer, Paul Davis, then completed the session by discussing how a combination of university research and technology have enhanced his operation. In cooperation with researchers from Virginia Tech, Paul has conducted on farm trials to determine the biomass production and N uptake of various cover crops, which led to his incorporation of a vetch cover in front of his corn crop that he estimates saves him 70 to 80 lb N/A (78 to 90 kg/ha) in a good year. He has also made changes in his N timing and placement strategy based on university research and moved to a more intensive starter and in-season approach. He adopted the GreenSeeker™ technology in 2007, again based on research conducted on his farm, and has seen his N use efficiency increase by approximately 7%. Paul finished his presentation by saying how the precision services provided by Agritek combined with scientific research helped him make better on-farm decision that resulted in higher profitability. The higher income allowed him to purchase the equipment needed to be even more precise in his seeding, fertilization, and irrigation management.

Precision agriculture and 4R Nutrient Stewardship are critical components for meeting sustainability goals and management objectives on the farm. However, technology and data are not silver bullets. Unless precision agriculture is practiced within the context of a science-based decision framework like 4R Nutrient Stewardship, it can create more confusion and frustration than solutions. Likewise, the complexity of the holistic approach to nutrient management in the 4Rs is greatly simplified and enhanced by incorporating the tools, technologies, information management, and documentation strategies of precision agriculture.

The higher income generated from using precision agriculture guidance allows farmers to purchase the equipment needed to be even more precise in their seeding, fertilization, and irrigation management.

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DOES FERTILIZER NITROGEN HELP OR HARM SOIL BIOLOGY?

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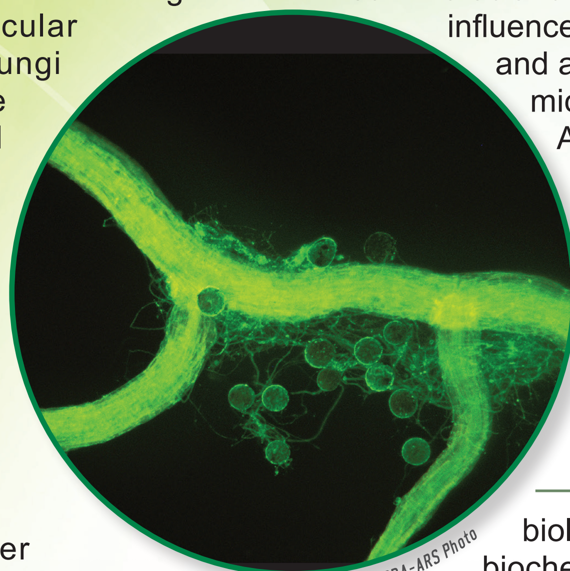
Many farmers and their advisers have learned that reduced tillage (including no-till) and continuous soil vegetative cover favor the presence and activity of beneficial fungi termed arbuscular mycorrhizal fungi (AMF). These fungi are well recognized for their symbioses with the roots of corn, wheat, soybean, and many other major crops—including cover crops—and their ability to enhance root acquisition and uptake of phosphorus, water, and micronutrients.



S. Wright/USDA-ARS Photo

Glomalin, the substance coating this microscopic fungus growing on a corn root, can keep carbon in the soil from decomposing for up to 100 years.

In addition, AMF contribute a substance called "glomalin" in the crop rooting zone that favors the development of stable soil aggregates; enhancing the development and maintenance of soil porosity, soil structure, water infiltration, and resistance to erosion. Recent science has shown that AMF obtain a sizeable amount of nitrogen (N) from decomposing organic matter; and they also obtain inorganic N in direct competition with plant roots. Changes in tillage practices, crop systems and rotations, the addition and removal of soil carbon (i.e., soil organic matter), and the addition of manures, crop residues, and fertilizer can affect the total soil microbial biomass and also influence the distribution and activity of different microbes in addition to AMF.

Soil chemical and physical properties affect soil biology, microbiology, biochemistry, and ecology ...and vice versa. With the emergence and sophistication of tools like DNA extraction, fatty acid markers, specific enzymatic analyses, other advanced methods, and computing and analytical tools we are learning much more about the diversity and function of different groups of soil microbes.

Adding N, irrespective of source, affects N availability in soil-crop systems and often shifts the population of microorganisms. Where the N source has a net soil acidifying effect, the fungal population tends to thrive more so than the population of bacteria. Nitrogen and other essential nutrients affect the ability of plants

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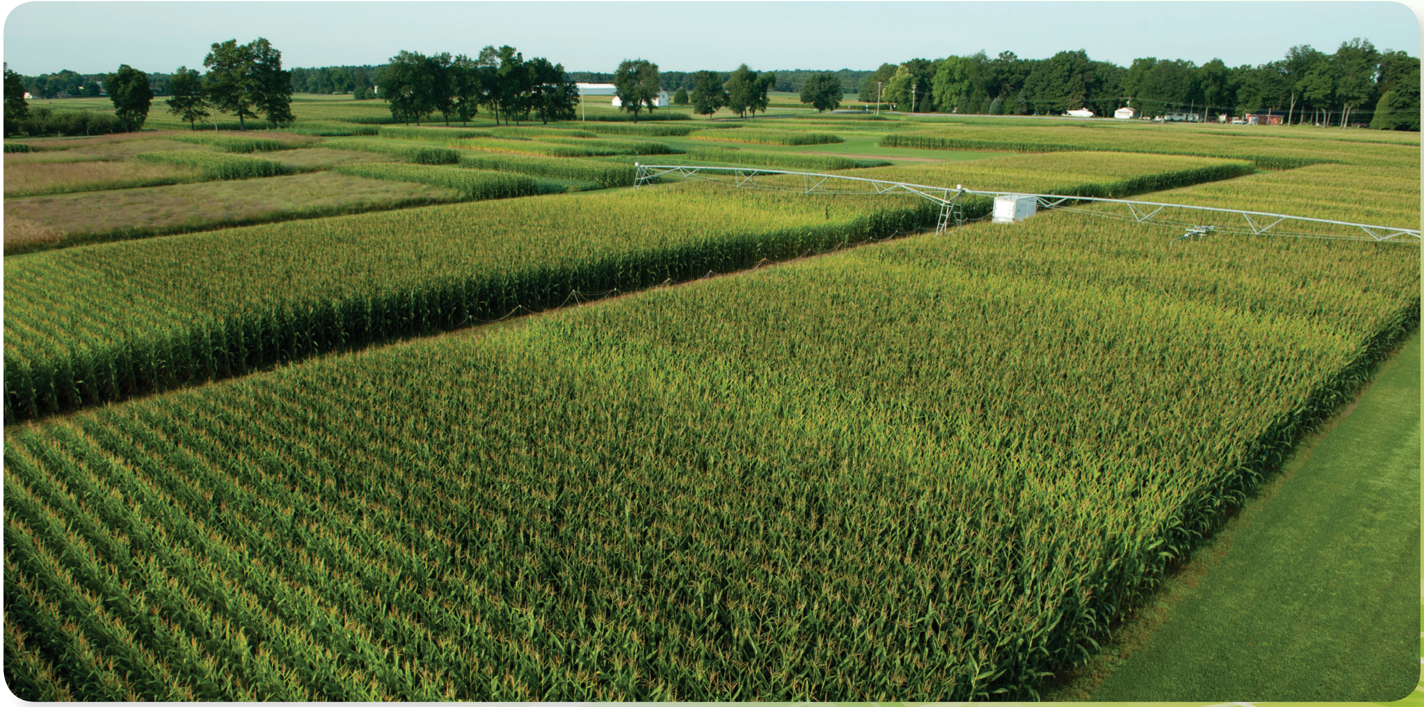
“Long-term studies from around the world have shown that balanced fertilization to meet crop nutritional needs and soil fertility optimization usually increases soil microbial biomass N and C ...”

to capture carbon dioxide, and return carbon (C) to the soil in residues, roots, and root exudates. Long-term studies from around the world have shown that balanced fertilization to meet crop nutritional needs and soil fertility optimization usually increases soil microbial biomass N and C; as well as soluble N and C, and total soil N and C. Increases in soil N availability as affected by N fertilization at Long-Term Ecological Research sites in Minnesota and Michigan were not found to have any consistent effects on the richness or the diversity of soil bacterial communities. Other long-term work in Nebraska showed that agronomic rates of N had only minimal effects on AMF diversity and colonization of corn roots, but the frequency of different AMF types did vary with the N rate applied.

As the management and protection of soil physical properties improves, and as we enhance the chemical and soil fertility properties for increased crop production and resiliency, we should strive to better understand those management impacts on soil biology and microbiology. There is so much more to learn, especially about the effects of crop and soil management on the important soil functional attributes noted above, and many more processes whose understanding remains in an infant state. For now, we can say that appropriate agronomic N management can lead to increased and replenished soil organic matter levels, sustained beneficial root relationships with AMF, higher yielding and better quality crops, and the potential for sustainable soil health.



K. Stepnitz/Michigan St. Univ. Photo

Aerial view of the KBS LTER Resource Gradient Experiment examining crop response to different levels of nitrogen fertilizer and water; stripes in the field demonstrate effects of different fertilizer rates.

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PLANT NUTRITION TODAY

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FERTILIZING FOR DUAL-PURPOSE WHEAT

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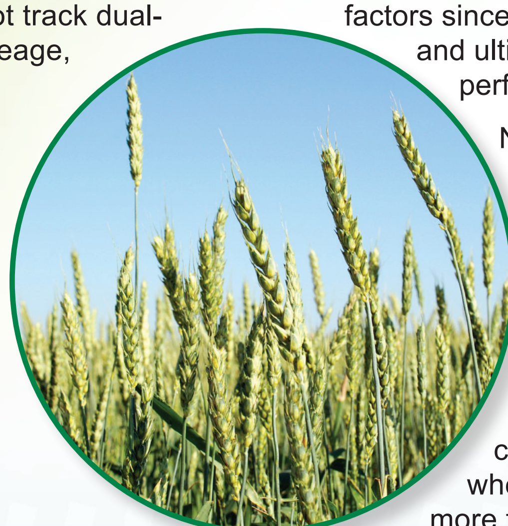
Producing winter wheat for both grazing and grain—or dual purposes—is common in the southern Great Plains, with acreage tending to decline moving northward. The dual-purpose system works well in states such as Texas and Oklahoma because temperatures favor wheat growth well into the winter months, there is relatively little snow and ice cover, and most producers have experience with livestock.

The USDA does not track dual-purpose wheat acreage, but a paper by Taylor et al. (2010) summarized some estimates along with citations. Estimates for dual-purpose wheat in the paper included two-thirds of Oklahoma wheat acres, and more than half of the wheat planted in Texas, Oklahoma, and New Mexico combined. If we assume that 50% of wheat in these three states and further assume that 20% in Kansas is grazed, and use the average of USDA wheat acres planted in the three most recent years (2013, 2014, and 2015), then the estimated area of dual-purpose wheat in these four states comes out to almost 8 million acres. This is clearly an important system in the southern Plains, as it is in other parts of the world such as Argentina, Uruguay, Australia, and Morocco.



Dual-purpose wheat is generally planted about a month earlier than for grain only production, and is seeded at about 1.5 to 2 times the density. Grazing is typically initiated about 45 to 60 days after planting, and is usually terminated by first hollow stem growth stage.

Most dual-purpose wheat is grazed by stocker cattle, or young animals that are usually bought in the fall and sold at the end of the grazing period. Thus optimizing animal gain is of upmost concern, which means that both forage quantity and quality are important factors since they affect animal, and ultimately whole system performance.

Nitrogen (N) is commonly, but not always, the most limiting nutrient in the dual-purpose system. It affects biomass production and forage quality, especially protein content. Dual-purpose wheat generally requires more fertilizer N than grain only production because of N removal (and rearrangement) by grazing. The N fertilizer adjustment is often made on the basis of desired stocker gain per acre. For example, the recommendation from Oklahoma State University soil testing lab calls for 30 lb additional N for each 100 lb stocker gain desired, while Kansas State University calls for an additional 40 lb N for each 100 lb gain. The word *additional* is important here because the recommended N per unit stocker gain is *added* to the N recommended for the system's grain yield target. Split N applications are well suited for the dual-purpose system since

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> "Among the components of a successful dual-purpose system is an effective fertility program that accounts for optimizing both animal performance and grain yield."

adjustments can be made for forage removal and environmental conditions.

All too often wheat used for grazing in the southern Plains does not receive sufficient phosphorus (P). Remember that P plays many important roles such as enhancing rooting and tillering, and perhaps most importantly sufficient P helps to get the most out of applied N fertilizer. For example, in a Texas study the addition of 40 lb P_2O_5/A to 160 lb N/A increased forage yield by 68% over the N only treatment. Soil testing is a useful tool in determining the need for P input.

The potential benefit of other nutrients such as sulfur (S) should not be overlooked. For example, in one Kansas study where 100 lb N/A was applied the addition 7.5 lb S increased forage crude protein by 4.6% (Feekes 3-5) when averaged over four site years and two S sources.

Producing winter wheat for grazing and grain requires considerable skill and balancing of many moving parts. Among the components of a successful dual-purpose system is an effective fertility program that accounts for optimizing both animal performance and grain yield.

Note: 1 lb = 0.454 kg; 1 A = 0.404 ha.

M. Stewart/IPNI Photo

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1. Taylor, K.W., F.M. Epplin, B.W. Brorsen, B.G. Fieser, and G.W. Horn. 2010. J. Ag. Appl. Econ. 42:87-103.

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PLANT NUTRITION TODAY

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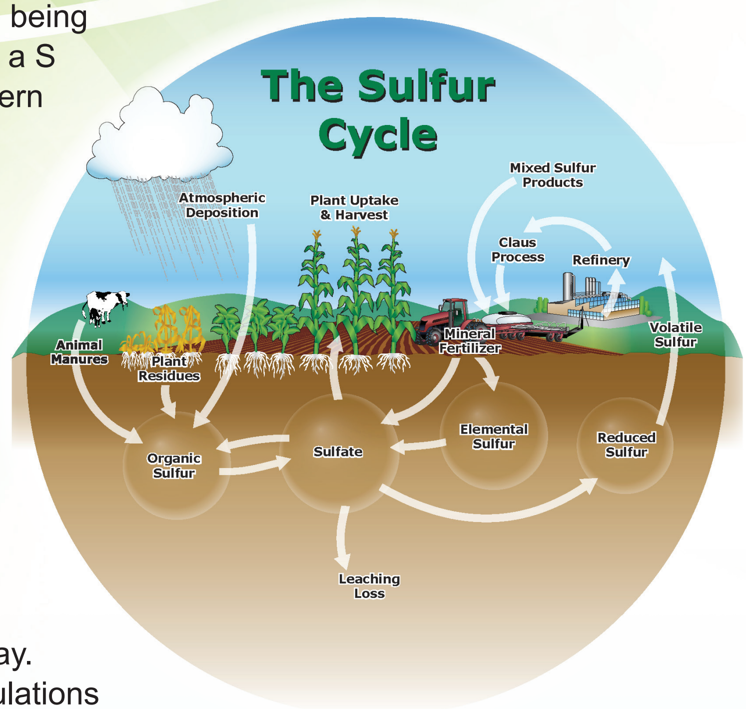
WHY ALL THE FUSS ABOUT SULFUR FERTILIZERS?

A few decades ago there was very little mention of adding sulfur (S) as a fertilizer. In the late 1970s, I can remember my soil fertility professor at the University of Alberta being credited with documenting a S deficient field soil in Southern Alberta—an area where S deficiencies were not thought to be possible. It wasn't that crops back then didn't need or use S, but just that most soils supplied adequate amounts to meet crop demand.

Reasons for this include:

- Most early phosphorus (P) fertilizers contained more S than they do today. For example, early formulations of mono-ammonium phosphate (MAP) fertilizer (11-48-0) contained as much as 2.4% S and today's 11-52-0 product can contain as little as 0.75% S.
- More S demanding crops are grown more now than ever before. The most common example for western Canada is canola. Canola acres are now only second to spring wheat in the region and canola absorbs about twice as much S compared to wheat under similar growing conditions.
- Overall crop yield potentials have increased due to higher yielding varieties, which means greater uptake of sulfate from soil and increased removal in the harvested portions of crops.



- The air emissions of S have been reduced. Earlier emissions from coal-thermal electric generation facilities, diesel engine exhausts from transport trucks and freight trains, gas and oil refining plants, and other industrial manufacturing plants contained higher levels of sulfur dioxide (SO_2). Many fields near industrialized areas previously received deposition of

> "Emissions of SO_2 have been reduced with stricter environmental standards."

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> "Canola absorbs about twice as much S as wheat under similar growing conditions."

oxidized forms of S, usually in rain containing these S compounds, and was commonly called acid rain. This meant there were often adequate or even excess amounts of S for crop growth. The acid rain adversely decreased soil and especially water pH to the extent of disrupting ecosystem health. The SO_2 reductions are achieved by removing the majority of SO_2 out of industrial emissions, a process called "scrubbing" out the SO_2, and also fuels for diesel engines are now required to meet low-S content standards.

Because of less additions of S along with P fertilizers, greater removals of S from fields due to higher S-removing crops, higher yielding crops, and less SO_2 emissions into the air, there is a greater need to apply S-containing fertilizers to agricultural fields to meet crop S needs.

G. Sulewski/IPNI

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PLANT NUTRITION TODAY
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WHAT DID FERTILIZER DO FOR US TODAY?

13 OCTOBER 2016 GLOBAL FERTILIZER DAY GROW. FOOD. LIFE.

TODAY is **Global Fertilizer Day.** One day set aside to acknowledge fertilizer's every day contributions.

Fertilizer is a primary source of plant nutrition. As a result, fertilizer's role in sustaining crop production is essential to providing our daily nutritional needs. Our farmers' ability to feed 7.5 billion people each day is impressive, but in some areas of the world this doesn't actually happen. Where ever soil fertility is lacking, farmers confront a failure to provide an abundant and nutritious food supply. Responsible use of fertilizer accomplishes this feat in an environmentally sound and economically viable manner.

The International Plant Nutrition Institute (IPNI) is dedicated to the responsible management of plant nutrients from all sources. There is not nearly enough manure or on-farm resources to meet the global nutrient demand. Therefore, our scientists are involved in solution-driven research aimed at advancing the science of fertilizer use. The evidence of progress, like the following examples, is gathering with each day.

TODAY a resource-poor family growing coffee on the mountain slopes of northern Peru continued to build the fertility of their fields and harvested another good crop. This took them and their neighbors another step closer towards secure incomes, a stronger community, and better prospects for the next generation through plans for enhanced schools.

TODAY soybean farmers in Kenya and Uganda gained training in fertilization using the principles of 4R (right source, right rate, right time, and right place) nutrient stewardship. This training provides field-tested solutions to close yield gaps and establish these farmers as a reliable supplier of this important source of dietary protein in their communities.

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> “Where ever soil fertility is lacking, farmers confront a failure to provide an abundant and nutritious food supply.”

TODAY banana farmers in Guangxi, China were able to reduce their total nitrogen loss towards emission to the air or leaching to groundwater, by adopting properly timed applications of controlled-release urea. These new nitrogen fertilizers better match the nutrient demands of bananas, giving farmers simpler, more efficient solutions.

TODAY a farmer in the Midwest U.S. is practicing 4R Nutrient Stewardship as he manages his method of phosphorus application to reduce losses from runoff. Keeping phosphorus in the field where it can be used by growing crops minimizes any potential damage to surface water.

no-tillfarmer.com

TODAY an oil palm plantation in Indonesia is developing practical fertilization techniques needed to support the efforts of its many smallholder planters. This avoids unsustainable area expansion into the surrounding natural forest. Smallholders can be confident that these new fertilization practices are designed to produce more palm oil per tree from their existing lands.

TODAY when you go to the market or grocery store … remember fertilizer provides the nutrients that sustains life and those who produce it.

Learn more about Global Fertilizer Day
http://fertilizerday.com

13 OCTOBER 2016
GLOBAL FERTILIZER DAY
GROW. FOOD. LIFE.

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PLANT NUTRITION TODAY
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ALL PLANT NUTRIENTS INTERACT

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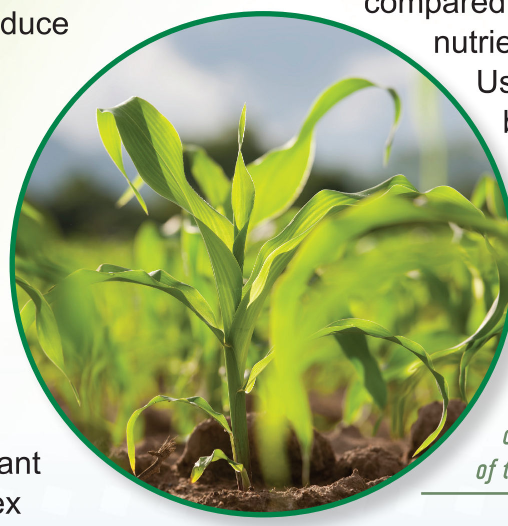
At the core of most successful crop production is allowing plants to reach their full photosynthetic potential. This simple objective is complicated by hundreds of factors, some controllable and others subject to the whims of nature.

Providing adequate nutrition is one of the controllable factors that should not be allowed to stunt plant growth and reduce the quantity and quality of harvest. Preseason nutrient planning most often focusses on alleviating each nutrient deficiency, one at a time. However, we are increasingly aware that every plant nutrient has complex interactions with other plant nutrients and they work together to boost overall plant health. These interactions are termed synergistic (acting positively together) and antagonistic (in opposition).



Nutrient interactions occur when one nutrient influences the uptake and utilization of another nutrient. Interactions are observed to occur in the soil, at the surface of the root, or within the plant. Other nutrient interactions influence crop health in less obvious ways, such as improving resistance to drought stress or susceptibility to insect damage.

Here are a few examples of nutrient interaction that illustrate the importance of this principle:

- Positive interactions between nitrogen (N) and phosphorus (P) frequently lead to higher crop yields and increased P uptake, compared to when either nutrient is used alone. Using ammonium-based fertilizer together with fertilizer P often leads to even greater P uptake and yields.

Interactions are observed to occur in the soil, at the surface of the root, or within the plant.

- High application rates of potassium (K) or ammonium-based fertilizer for cool-season grasses reduces the uptake of magnesium (Mg), sometimes resulting in Mg-deficiency disorders in grazing animals. High rates of K fertilization may also limit uptake of calcium (Ca) and other cations as they compete for plant uptake.
- The proper ratio of N and sulfur (S) in plant proteins falls within a fairly narrow range. Applications of S

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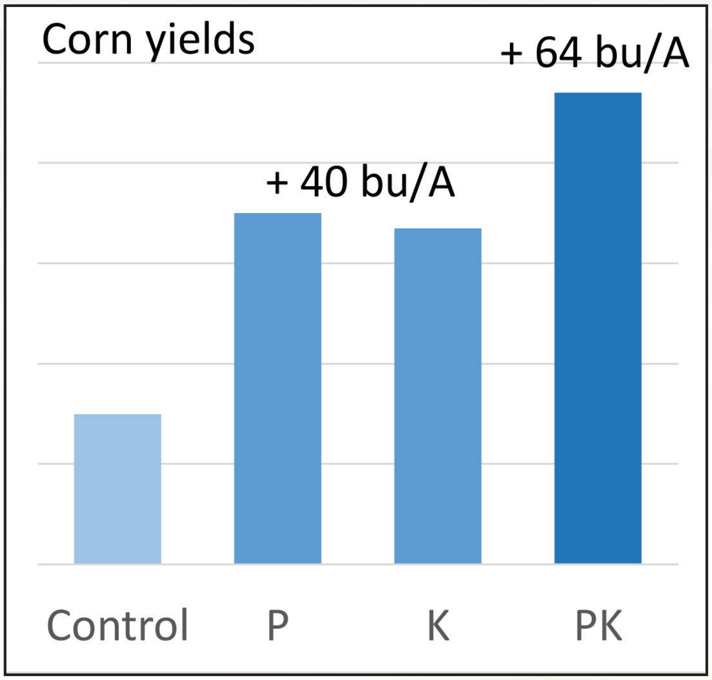
“Every plant nutrient has complex interactions with other plant nutrients and they work together to boost overall plant health.”

or N fertilizer alone may skew this ratio and cause a reduction in growth, yield, and harvest quality.

- Due to their chemical similarities, adding P fertilizer can release sulfate and molybdate from the surface of soil minerals, increasing their availability for plant uptake.
- The interaction between P and zinc (Zn) has been often reported, but their relationship is frequently confusing. Excessive P concentrations may result in reduced Zn uptake and yield by some plants, but this is not a universal response as it depends on the crop and growing conditions.
- Molybdenum (Mo) application to many legumes usually does not directly improve plant growth, but may enhance N fixation and plant stand longevity.

Soybeans showing molybdenum (Mo) deficiency in the foreground, compared to plants that received Mo in the background.

- Interactions between Ca and P are sometimes confusing. Both Ca and P synergistically support each other during uptake and translocation, but they can chemically precipitate to form relatively insoluble compounds in the soil.



In one typical experiment, applying P and K fertilizer together resulted in a yield-boosting interaction that resulted in more harvested corn grain than when either nutrient was applied alone.

Plants require all 14 essential mineral nutrients for normal growth, but they must be in the proper balance. Nutrients interact in synergistic and in antagonistic ways in complicated physiological and chemical reactions. These interactions can vary depending on soil properties and the specific crop. Regular analysis of soil and plant tissue is important to confirm that no individual nutrient is severely out of balance and possibly disrupting the contribution of other nutrients. Clearly, these complex nutrient interactions deserve additional examination as we push towards higher and sustainable yields.

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