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

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PLANT NUTRITION STEWARDSHIP: SCIENCE AND ETHICS

Stewardship involves both science and ethics. A recent Bouyoucos Conference sponsored a small group of scientists and philosophers to meet in Nebraska to discuss the topic "Soil Stewardship in an Era of Climate Change." They focused their discussion on three areas: ethics, sustainability, and communication. The goal was to integrate these areas to come up with practical advice for applying science to soils.

Scientists are often uncomfortable talking about ethics. Ethics depend more directly on beliefs and values than on the observable facts, testable hypotheses, and logical conclusions that form the mainstay of science. Nevertheless, this group agreed that the choice for science as a career is often ethically motivated, and that ethics play a role in both the conduct and application of science.

An ethic is a belief about the value something holds and proper conduct towards it. Ethical arguments are normative—dealing with what ought to be—but include rational and logical premises as well. Facts and causal relationships do not determine what ought to be, but we need to know them in order to specify ethical behavior, guidelines, and goals.

Sustainability is an example of an ethical goal. It can be motivated by concern for future generations, or by beliefs about the value of the natural environment. Soil faces sustainability challenges, including erosion and other forms of degradation, not just from existing practices but also from future changes in climate.

The four "rights" of plant nutrition stewardship also have an ethical component. There is a moral value judgment when choosing the right nutrient source, metering out the right rate at the right time and in the right place. The value judgment is based on how this combination of actions meets sustainability goals. These goals are determined, not by science, but by scientifically informed people who apply their beliefs and values when choosing targets for outcomes. For example, in a setting where a pre-plant application of nitrogen optimizes yield but results in excess groundwater nitrate, a stewardship approach would seek a management strategy (perhaps split-application, perhaps a controlled-release source, perhaps a technology yet to be developed) that both optimizes yield and limits nitrate loss to groundwater. If these benefits are understood and shared by the stakeholders, support for changes in technology should be easier to obtain.

Setting sustainability goals involves science communication. Many scientists feel their work is not adequately understood or appreciated, and is not appropriately used in development of policy, regulation and practical recommendations. Science can help define the right management to achieve particular sustainability goals, but scientists must recognize the ethics, beliefs, and values of their audience to meaningfully engage public dialogue on such goals. Cal DeWitt, Professor, University of Wisconsin, described the situation in this way: "Plant and soil scientists, agronomists and agricultural extension agents—together with farmers, gardeners, and every person on earth—are in a continual, sustained, and interactive relationship with plants and soils." Science not only pulls out the facts and describes cause and effect, but also builds appreciation for the complexity and beauty of ecosystems, both natural and managed.

Can we improve our sustainability ethic? Codes of ethics for professional crop advisers, agronomists, and soil scientists often emphasize ethical behavior in terms of the interest of the client. But they also include the interest of the public, which extends to sustainability and therefore, sustainability ethics. Can we more clearly define a professional ethic for the conservation, renewal and improvement of the resources involved in plant nutrition, including soil, water, air, nutrient supplies, and plant genetics?

– TWB –

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Abbreviations: N = nitrogen.

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HIGHER EFFICIENCY FERTILIZERS, HOW THEY WORK AND COULD YOU REDUCE FERTILIZER RATES IF AN INCREASED EFFICIENCY FERTILIZER IS USED?

There is much discussion about increasing the efficiency of fertilizers. It is useful to understand what is meant by efficiency. The main meaning is that fertilizer use by the target crop is improved and results in improved crop yields and/or quality of the harvested portion of the crop. Another important meaning is that lower amounts of nutrients are lost from the plant-soil system. Loss means that nutrients from applied fertilizers are released into water, air, or soil out of reach by crop plants. Nutrients stored in crop residue and soil within rooting depth of crop plants is not considered lost but is largely available for future crop use. Of the three primary fertilizer nutrients, N is most subject to potential losses. Phosphorus losses are comparatively lower than N losses, but are still of concern environmentally. Potassium losses are minimal and tend to be of little concern environmentally.

Increased efficiency fertilizers are formulated in three main ways. The first is to apply a physical coating with controlled release properties so the nutrients are released over time based on temperature and soil moisture content. The second way is to supply nutrients in a less soluble form that needs to be converted chemically or biologically over to a more soluble and available form. This is not a controlled release, but is more accurately called a delayed release. The third way is to add an inhibitor product that blocks or at least delays the action of biochemical or biological processes that transform a fertilizer product into a form more susceptible to losses. Whether the fertilizers are controlled release, delayed release, or treated with an inhibitor, the nutrients are less soluble and available initially compared to regular soluble fertilizers. Hopefully, the nutrients become available in time and quantity to satisfy crop needs while decreasing potential losses before crop use.

Nitrogen can be lost from a field through ammonia (NH_3) volatilization, leaching of nitrate (NO_3^-) into groundwater, and gaseous emissions of nitrous oxide (N_2O) and di-nitrogen (N_2). Ammonia is a gaseous form of N that can float into and mix with the air, then be carried downwind. It can originate from crop residues relatively high in protein as they begin to decompose on the soil surface, or hydrolysis of urea (splitting of the urea molecule into CO_2 and NH_3), contained in urea fertilizer or livestock manures, that are applied to field surfaces. The hydrolysis of urea is facilitated by the action of the urease enzyme present in soils, and crop vegetation and residues. This loss process is delayed and reduced by treating urea-containing fertilizers (e.g. 46-0-0) with a **urease inhibitor.** Leaching of N occurs when NO_3^- ions dissolved in water move downward and out of the rooting zone of crops in the soil, with the saturated flow of water. Both N_2O and/or N_2 gases are emitted from soils when oxidized N in the form of nitrite (NO_2^-) or NO_3^- are converted over to the N_2O or N_2 gases by soil bacteria experiencing low oxygen conditions due to wet soil conditions. Nitrous oxide is one of the atmospheric gases considered contributing to greenhouse gas warming of the earth. While N_2 is not a greenhouse gas, losses of N in this form still represent less efficient use of applied N fertilizer. Urea or other ammonium (NH_4^+) producing N fertilizers can be treated with **nitrification inhibitors** that keep the N in the ammonium form and prevent the stepwise conversion by certain soil bacteria from NH_4^+ to NO_2^- and finally to NO_3^-.

Rates of nutrients applied using increased efficiency fertilizer products should normally not be reduced unless there are actual reduced losses of nutrients to the surrounding environment. For example, an increased efficiency P fertilizer may help increase the uptake of this year's applied P into crop plants. However, if there are no significant changes in overall P losses from the crop-soil system, long-term P fertilizer rates should be maintained close to harvested crop P removal rates. If losses by NH_4^+ volatilization, leaching, or gaseous N_2O and N_2 emissions are actually reduced, the rate of N applied can probably be reduced proportionally.

– TLJ –

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

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TISSUE TESTING CAN SAVE YOUR CROP

The use of tissue testing and plant analysis dates back to the nineteenth century. Since that time, considerable research has been devoted to refining this tool for assisting farmers to efficiently manage crops. The relationship between nutrient concentrations in plant tissue and the ultimate yield or quality is fundamental for using this information. The general relationship between plant yield and tissue nutrient concentrations is shown in Figure 1.

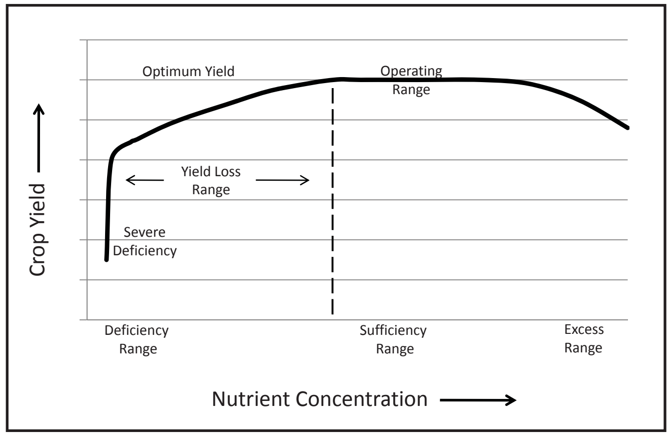

Figure 1.

Plant analysis is commonly used for many valuable purposes. Some of the uses of plant analysis include:

- Predicting potential deficiencies in current or future crops;
- Diagnosing nutrient deficiency, toxicity, or imbalances;
- Predicting the need for various essential nutrients at critical growth stages;
- Validating the effectiveness of the current fertility program;
- Assessing nutrient concentrations in tissue to create nutrient budgets and quantify nutrient removals;
- Determining the value of plant material as an animal feed.

Monitor Nutrient Uptake. Avoiding nutrient deficiencies is the best way to maintain yield and quality. A periodic check of plant nutrient concentrations during the growing season can be a helpful way to avoid deficiencies and imbalances before they occur.

Diagnose Deficiency. Since all fields vary in soil properties across the landscape, it is natural that plant growth will also vary across the field. It is likely that there will be differences in soil texture and clay content, soil rooting depth, drainage, organic matter content, etc. in the field. Since all of these factors can influence nutrient availability for crops, it is expected that the nutrient supply will not be uniform in the field. When deficiencies first become visible, it is advisable to take plant tissue samples from both the problem areas and from areas of the field that appear normal. The practice of sampling tissue from both deficient and healthy plants makes it easier to diagnose the nature of the problem.

Plan Nutrient Programs. Regular tissue testing is useful as a guide for future nutrient management decisions. For example, if magnesium concentrations are low in the plant tissue, management decisions can be made to correct this situation in the future. It may include addition of soil amendments, fertilizers, foliar nutrition, or possibly switching to an alternate crop.

When beginning a tissue testing program, be certain to consult with a specialist to get the samples taken at the appropriate stage of growth, at the correct position on the plant, and properly handled for delivery to the analytical lab. If the samples are not taken correctly, it will not be possible to interpret the laboratory results or know how to perform corrective action. Building a history of plant nutrient concentrations over years can also be valuable for spotting emerging problems before they cause yield or quality to decline.

– RLM –

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CONSIDERATIONS FOR MAINTENANCE APPLICATIONS OF PHOSPHORUS AND POTASSIUM

Maintenance applications are a commonly used strategy. The goal of a maintenance application is to keep soil test levels from decreasing appreciably. In order to calculate maintenance rates the total amount of P and K removed since the last application or fertility evaluation is needed. For a list of removal rates of various crops, visit this site: http://www.ipni.net/northcentral/nutrientremoval.

Maintenance applications are used when target soil test levels have been reached or they are used when a field has no recent soil test information. In the latter case, they are used to keep a field in a holding pattern until proper fertility assessments can be made. Because they are such an important part of nutrient management, knowing what they can and cannot do is helpful for making informed decisions. The following are some considerations for maintenance applications of P and K

- **Look backward to improve accuracy.** Often, maintenance applications are made according to the yield expected by succeeding crops – looking forward. The problem with this is that future yields are unknown. If yields come in below expectations, you'll have applied too much. If they come in higher, you'll have applied too little. To improve accuracy, look back at the yields of crops grown since the last applications of P and K. These yields are known. Adding up past crop removals and applying those amounts is the best way to keep from over- or under-applying.
- **Determine your target soil test levels.** Since maintenance applications are meant to keep soil test levels about the same, make sure you have recent soil tests to assess where you are. Low testing areas will be kept low and higher testing areas will be kept high. Do you want to draw down levels? If so, apply less than removal. If you want to build them up, apply more.
- **Know your profit risks.** Maintenance applications may or may not be the most profitable ones in the short term. If soil test levels are higher, there is only a small probability of crop response to nutrient applications. At these levels, there will be little chance of short-term revenue gains. However, at lower soil test levels, there are very high chances of very profitable yield gains with maintenance applications. In fact, at very low soil test levels, profitable fertilizer rates exceed maintenance rates and under-applications can leave substantial profits unrealized.
- **Know your risks of managing soil test variability.** Maintenance applications made at higher soil test levels that are intended to try and catch any lingering responses possible from lower testing areas that may have been missed in an overall fertility assessment of a given area.

Keeping these aspects of maintenance applications in mind can help farmers and advisers make improved decisions about rate selections this fall.

– TSM –

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Abbreviations: P = phosphorus; K = potassium.

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THE ROLE OF SPATIAL VARIABILITY IN NUTRIENT MANAGEMENT

A thorough understanding of spatial variability in agricultural fields can influence many aspects of nutrient management. Whether it is what nutrient source to apply, what rate to use, when to make the fertilizer application, or what placement method to employ, understanding spatial variability can help growers, advisers, industry, and policymakers contribute to more efficient and effective fertilizer management.

Understanding spatial variability can help guide technology development. Yield monitors, mapping software, and variable-rate fertilizer applicators were all developed based on the knowledge that not all areas of a field possess the same yield potential and often don't have the same nutrient requirement. Precision agriculture technology currently provides growers and advisers the tools needed to identify, diagnose, and treat spatial variability in fields. However, continued investigation into the effects of variability on fertilizer management will improve our understanding of the situation and will lead to refined approaches and the development of new technologies needed to meet the challenges.

By applying fertilizer only where it is needed in the field, productivity and profitability can be improved. Most standard nutrient recommendation strategies involve determining an average fertilizer need for the field and a single rate is applied to the entire field. Using this strategy, some areas of the field receive more than the optimum amount of fertilizer while other areas may not be receiving enough. Applying fertilizer in this manner results in lower productivity and profitability due to missing out on additional yield in the parts of the field that are under-fertilized and further reduced profitability where fertilizer is over-applied. Understanding how fertilizer requirement varies spatially in a field will allow the grower to use variable-rate application technology to redistribute fertilizer accordingly throughout the field.

Considering spatial variability when making fertilizer management decisions can also improve environmental quality and cropping system sustainability. Using spatial information to better match crop requirement with nutrient supply will result in less fertilizer remaining in the field with the potential to negatively impact the environment through various loss mechanisms. Understanding the sources and influence of spatial variables such as soil type, water and nutrient holding capacity, slope, topsoil thickness, etc., can aid growers and advisers in selecting appropriate BMPs for each field that will support the long-term health of the cropping system.

Understanding spatial variability is critical when following 4R Nutrient Stewardship. 4R nutrient stewardship is selecting the "right" fertilizer source and applying it at the right rate, at the right time in the growing season, and in the right place. What is "right", however, depends on many site-specific factors, including the degree of spatial variability a particular grower might be dealing with. Failing to consider spatial variability when making nutrient management decisions can result in what appears to be the "right" choice for the field being quite "wrong" in many areas of that field.

Following 4R nutrient stewardship at the appropriate spatial scale can lead to improved fertilizer efficiency and effectiveness, increased productivity and profitability, and lower risk of environmental impacts due to misapplication of fertilizer.

– SBP –

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Abbreviation: BMPs = best management practices.

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NUMERIC NUTRIENT CRITERIA FOR WATER QUALITY— ARE YOU AWARE OF RECENT EPA ACTIVITIES?

States and tribal agencies have had the responsibility in the USA to establish nutrient criteria for water quality protection, based on the Clean Water Act. According to the U.S. Environmental Protection Agency (EPA), over 10,000 nutrient and nutrient-related water quality impairments have been listed among 49 states. Some states and tribes have made progress in moving from “narrative” nutrient criteria to “numeric” criteria for the protection of surface water resources, while others have faced more challenges. Learn more at this website: **http://www.epa.gov/waterscience/criteria/nutrient/strategy/status.html**. Because of well-recognized regional water quality issues such as the Chesapeake Bay and the northern Gulf of Mexico, and prominent coastal issues as in Florida and California, there are increasing pressures to advance establishment of numeric criteria for surface waters. Numeric nutrient criteria may be used to establish standards, which enable determination of Total Maximum Daily Loads (TMDLs).

The EPA has initiated the formation of an ad hoc technical committee to advise the Ecological Processes and Effects Committee (EPEC) of its Science Advisory Board (SAB). Website: **http://yosemite.epa.gov/sab/sabpeople.nsf/WebCommitteesSubcommittees/Ecological%20Processes%20and%20Effects%20Committee** This new ad hoc nutrient criteria committee is being asked “To augment the expertise of the EPEC”... “with specialized knowledge in the use of empirically-derived stressor-response relationships as the basis for developing nutrient assessment endpoints and criteria for the protection of aquatic life”. A “short-list” of 27 nominees for the nutrient criteria committee has been formed, listed at this site: **http://yosemite.epa.gov/sab/sabproduct.nsf/02ad90b136fc21ef85256eba00436459/5972e2a88464d45e85257591006649d0!OpenDocument&TableRow=2.1#2**

In the absence of state and tribal numeric water quality nutrient criteria, the EPA has advocated since 2001 ecoregional criteria for N and P. Website: **http://www.epa.gov/waterscience/criteria/nutrient/ecoregions/.** The criteria are largely based on a simple statistical approach using overlapping data from monitored vs. selected “reference” waters. This newly-formed EPA science committee may establish new numeric nutrient (e.g. N and P) criteria for lakes, reservoirs, rivers, streams, and wetlands in fourteen ecoregions, based on the risk of biological impacts of nutrients. If states and tribes have not established numeric criteria, or have not sufficiently addressed development of numeric criteria, EPA’s ecoregional nutrient criteria may be imposed.

In addition to these actions, the EPA will soon release a report of its Integrated Nitrogen Committee, which will be calling for more control of the human-induced releases of reactive N (basically, all N forms other than atmospheric N_2, which makes up 78% of the air we breathe) into the environment. Taken collectively, these water quality actions by EPA underscore the need for intensified efforts by farmers, as well as the urban public (homeowners, turf managers, etc.) to embrace and to implement fertilizer best management practices (BMPs) based on the 4R Nutrient Stewardship encouraged by the fertilizer industry. If you are not familiar with the BMPs that support the 4R principles (right source, right rate, at the right time and right place), talk with your Certified Crop Adviser, ag consultant, Extension educator, or fertilizer industry representative to learn more. Expanded implementation of 4R Nutrient Stewardship to protect water quality, while enhancing crop production and efficient nutrient recovery, may help prevent the risk of undesirable regulatory actions.

– CSS –

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Abbreviations: N = nitrogen; P = phosphorus; BMPs = best management practices.

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FERTILIZER AND FOOD PRODUCTION

The world demand for food will increase sharply over the coming years as population is expected to increase by almost 40% from the current 6.7 to an expected 9.2 billion by 2050. Aside from the increased population projections, another factor impacting food concerns is consumer affluence, where a shift toward more meat consumption is seen in countries where diets have traditionally been more grain based. For example, since 1995 meat consumption in the developing world has increased by 16% and in China it has increased by almost 40%. This increasing demand for meat protein means greater demand for feed grains.

Food production will clearly need to increase to meet the demands of a larger and more affluent population. One report (The Millennium Project, State of the Future, 2008) indicated that food production will have to increase by 50% by 2013 and double in 30 years to help solve the food issue. Increased food production will require intensified production since the amount of available arable land is finite. Genetics and biotechnology will help intensify production, as will fertilizer and other inputs.

A fundamental question that the fertilizer industry has sought to address for some time now is "how much of crop production is attributable to fertilizer input?" An *Agronomy Journal* paper addressing this question was published by Stewart et al. (2005). Several long-term studies in the USA, England, and the tropics, along with the results from an agricultural chemical use study and nutrient budget information, were evaluated. A total of 362 seasons of crop production were included in the long-term study evaluations. Crops utilized in these studies included corn, wheat, soybean, rice, and cowpea. The average percentage of yield attributable to fertilizer generally ranged from about 40 to 60% in the USA and England and tended to be much higher in the tropics. The paper concluded that the commonly cited generalization that at least 30 to 50% of crop yield is attributable to commercial fertilizer nutrient inputs is a reasonable, if not conservative estimate.

Intensification of production and increasing yield on limited arable land is clearly important in securing an adequate food supply, and the importance of the role of fertilizer in this is undeniable. However, another important aspect of fertilizer and its role in food production involves crop quality and human health. There are many affects of nutrient input on crop quality, and among the more interesting is the impact fertilizer inputs can have on human heath affecting compounds. IPNI has published several papers and supported studies in this area over the past few years. One of the most noteworthy studies was one involving cantaloupe in the Rio Grande Valley of Texas. This study showed that foliar K applications during cantaloupe fruit development and maturation improves fruit marketable quality by increasing firmness and sugar content, and fruit human health quality by increasing ascorbic acid, beta-carotene, and K levels (Lester et al., 2007, *Better Crops*).

Meeting the world's escalating food needs cannot be achieved without fertilizer input. Sans fertilizer, the world would produce only about half as much staple foods and more forested lands would have to be put into production (Roberts, 2009, *Better Crops*). Inorganic commercial fertilizer plays a critical role in the world's food security and is important from both the yield and food quality perspectives.

Intensification of production will be increasingly essential to the challenge of meeting future food demands. However, this intensification must be done so as to minimize environmental impact. That's why the concepts of Ecological Intensification (EI) and the Four Rights (4R) Nutrient Stewardship framework (right fertilizer source-rate-time-place) are so timely. For more information on these concepts, visit the IPNI website at **>www.ipni.net<**.

–WMS–

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Abbreviation: K = potassium.