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Editor's note: This is the second article in a five-part series from the International Plant Nutrition Institute titled "Know Your Fertilizer Rights," sponsored by The Fertilizer Institute and the Canadian Fertilizer Institute. The series is based on fertilizer best management practices structured around the "4R" nutrient stewardship concept. For more information, visit www.ipni.net.

The four fertilizer rights: Selecting the right source

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The Four Fertilizer Rights (4R) concept was developed to connect the ideas of selecting the right source, right rate, right time, and right place for nutrient stewardship. The first article in this series (see March–April 2009 *Crops & Soils*, page 13) discussed the use of these "rights" for getting the best value from applied fertilizers, as defined by different stakeholders. This current article highlights the importance of selecting the right source of fertilizer for achieving your individual goals that will meet specific economic, environmental, and social objectives. Although the focus is on selecting the right source, none of these decisions can be made without consideration of the other "rights" to achieve the best results.

The idea of selecting the most appropriate nutrient source seems simple in concept, but many factors need to be considered when making this choice. Plant nutrition requirements, soil conditions, fertilizer delivery issues, environmental risks, product price, and economic constraints are all important considerations when selecting the most appropriate fertilizer source. Some decisions may be based on the availability of various materials within reasonable distance. The accessibility of fertilizer application equipment may also narrow the options. It is tempting to rely on tradition and experience when making these decisions, but a thoughtful review of these factors helps farmers gain the maximum benefit from these valuable resources and the significant economic investment they represent.

Selecting the right fertilizer source begins with determining which nutrients are actually required for optimal plant growth. This decision should be made with the help of diagnostic tests such as soil analysis and tissue testing. These tests need to be made in advance of the fertilizer application decisions. If this information is not available, nutrient applications can be made based on nutrient removal rates in the harvested crops or personal experience such as knowledge of past cropping and fertilizer practices on a given field. However, guessing the appropriate nutrient requirement can lead to numerous problems associated with under- or over-fertilization or can lead to overlooking specific nutrients until shortages become severe. Commit to getting the necessary diagnostic information for each field before fertilizer decisions need to be made.

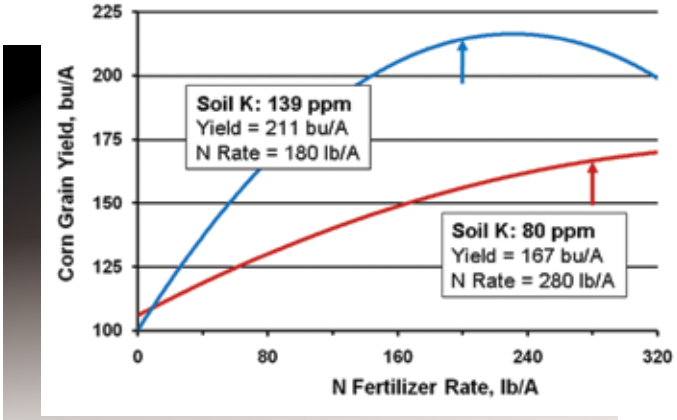
It is common to focus on a single nutrient that is in short supply to the exclusion of the other nutrients. For example, a lack of adequate nitrogen (N) is easy to detect by observing stunted growth and chlorotic leaves. However, the maximum value from applied N will not be obtained if secondary deficiencies of nutrients such as phosphorus (P) or potassium (K) are not also corrected (Fig. 1). Although we often focus on individual nutrients, they must function together to support healthy plant growth.

Forms of fertilizer

Selecting the right source of fertilizer frequently begins with choosing the form of nutrients to apply.

Fluid fertilizers. Due to their versatility for mixing many nutrients into a homogenous material that can be applied uniformly in the field, fluid fertilizers are popular. For example, fluids are effective and give placement flexibility when applied as starter fertilizers or dribbled as a topdress application, and they also perform well when applied with irrigation water. They are easy to handle and are excellent carriers for a variety of micronutrients, herbicides, and pesticides.

Fertilizer suspensions. Suspension-type fertilizers are also appropriate in some situations for the same reasons as clear fluid fertilizers. They can be made from less soluble materials, and higher nutrient concentrations can be achieved than



▶ **Fig. 1. High yields of corn are obtained with less N when other nutrients, such as K, are present in adequate concentrations (Ohio). Balanced nutrition is key to improving yields and minimizing N fertilizer loss.** *SOURCE: Murrell and Munson. 1999. Better Crops 83(3):28–31.*

with clear fluids. Larger quantities of micronutrients can be incorporated into suspensions as well as powdered herbicides and insecticides that are not suitable for clear fertilizers.

Compound fertilizers. In many circumstances, compound fertilizers, containing various ratios of N-P-K and other nutrients, are a good choice. Compound fertilizers may be easier to transport and apply than individual nutrients. They are convenient for a basal application of several nutrients, followed later in the growing season with additional N or whatever nutrient is needed. Compound fertilizers are useful for obtaining a uniform application of nutrients since all of the nutrients are contained in each pellet and they are not susceptible to particle segregation, which occurs with some blends made from individual fertilizer materials. Unique chemistry can be incorporated into individual complex granules, such as addition of small amounts of elemental sulfur (S) to enhance nutrient availability by promoting acidification surrounding the particle. The nutrient composition of compound fertilizers should be selected to match the needs of the individual fields.

Bulk blends. Two or more granular fertilizers can be mixed together to make bulk blends to meet the specific needs of a customer. Each field can receive the specific amount of each nutrient recommended. Bulk blends are popular since they can be made from lower-cost components with relatively inexpensive equipment. The blended materials must have chemical and physical properties that are compatible. One potential problem that can occur with bulk blends is separation of the mix during transportation and handling. Fertilizer blending specialists are aware of this concern and match uniform particle sizes of different nutrients as much as possible.

The salt index. If the fertilizer will be placed in close proximity to the seed, the "salt index" is also a factor to consider. The salt index is an indication of the osmotic contribution that the fertilizer will make when dissolved in the soil solution. It does not predict the actual damage to a seedling but allows comparisons to be made among fertilizer sources. Fertilizers with a higher nutrient content often have a lower salt index per unit nutrient since a smaller amount of actual material is added to the soil. Fluid fertilizers may have a lower salt index than granular fertilizers since they are more uniformly distributed over a greater soil volume.

Selecting the right source of fertilizer requires understanding the soil, climate, crop growing conditions, and the farmer's goals in order to make the best decisions. An overview of the properties of a few example fertilizer materials will illustrate some of the considerations to make when selecting the right source.

Soil application

Nitrogen

There are many excellent fertilizer sources of N. Selection of specific fertilizer sources is made with a view to factors such as price, available application equipment, and the nutritional needs of the crop. Because of potential impacts on water and air quality, which can vary greatly with N source, weather, soil, and cropping system, increasing emphasis needs to be given to potential losses when using this valuable nutrient.

Anhydrous ammonia. Widely used for direct application, anhydrous ammonia contains the highest N content of all fertilizer sources, but many safety features must be considered when transporting and applying anhydrous ammonia, and strict safety procedures must be followed during handling. Soil moisture content should not be too dry or too wet when anhydrous ammonia is applied in order to avoid volatile losses due to poor sealing. It is the product of choice for fall application for corn in the Midwestern U.S. Addition of a nitrification inhibitor may be beneficial where the potential for loss through leaching or denitrification is elevated (e.g., in sandy or poorly drained soils receiving substantial rainfall). Anhydrous ammonia can also be added through irrigation water but may be susceptible to ammonia volatilization loss when using this technique.

Urea. A relatively high nutrient concentration and lower production costs make urea the most common N fertilizer used worldwide. Urea normally hydrolyzes to ammonium within a few days when the urease enzyme is present. Urease is abundant in most soils, plants, and residues. If urea is left on the soil surface without incorporation by tillage or downward movement with water, it may be susceptible to considerable volatile ammonia loss. Once urea moves beneath the soil surface, the loss of ammonia is mostly eliminated. Chemical additives have been used to temporarily inhibit the urease enzyme and reduce ammonia loss from surface-applied urea. The use of additives should be considered when urea cannot be incorporated, especially when soil pH is high, or when plentiful crop residues remain on the surface. Nitrification inhibitors can also be used with urea where the potential for nitrate leaching or denitrification is elevated. Solutions of urea are effective for foliar application since damage to plant tissue is less than with many other N sources.

Nitrogen solutions. Solutions containing a mixture of approximately half of the N from urea and half from ammonium nitrate are widely used. The behavior of this liquid, urea ammonium nitrate (UAN), as a N fertilizer is similar to each of the individual components. UAN is desirable because of its ease in handling, complete solubility, and mixing compatibility with many other fluid fertilizers and chemicals. Nitrogen solutions are particularly well suited for sidedress, fertigation, and weed and feed applications.

Controlled-release fertilizers. In some production systems, use of controlled-release fertilizers (CRFs) can provide significant benefits in yield, labor savings, environmental impacts, and management flexibility when the particular fertilizer material is properly matched with crop demand and growing conditions. The mechanism for controlling the release of nutrients varies considerably for different ▶

products. Many controlled-release products have a polymer shell surrounding the soluble fertilizer (most often urea). The coating will respond to moisture and elevated temperature to gradually allow the nutrient to diffuse through the polymer shell over a length of time. The recommended timing of application is provided with the product label. The release of N from other CRF materials is controlled by biological activity or by slowly dissolving in water.

A number of other N-containing fertilizers can also be excellent choices, depending on the crop need and other factors. These sources might include materials such as ammonium sulfate, ammonium thiosulfate, and numerous nitrate-based materials. Each can be the right source under various conditions.

Organic sources of N. For many cropping conditions, organic sources of N can be beneficial. When animal manures are used as a N source, it is important to know the nutrient content of the material, expected volatile loss of ammonia (depending on application timing and placement), and nutrient release rate. Manures having a high ratio of ammonium to carbon release N relatively quickly. When manure contains more organic N or bedding material, it will release N more slowly. These slower N-releasing manures generally provide more second-year N availability, which should be considered when using them. Some cover crops (especially legumes) and crop residues are also potential N sources that can provide a valuable source of plant nutrients.

Phosphorus

Plant-available P concentrations in soil are generally quite low due to the high reactivity of P with various mineral components. The soil chemistry involving P fertilizers is complex and involves both rapid surface adsorption reactions and extended solid-phase transformations. In most soils, selection of a particular P fertilizer does not greatly affect the short or long-term plant availability.

The most commonly used dry P fertilizers are monoammonium phosphate (MAP) and diammonium phosphate (DAP). While MAP and DAP are N sources, their primary value is as a P source. Ammonium polyphosphate (APP) is the most commonly used liquid source of P.

A major difference between MAP and DAP is the pH directly surrounding the granule following dissolution. A saturated solution of MAP has a pH of <4 while DAP has a pH of 8. Therefore, a band application of DAP in high-pH soils can result in the release of ammonia, which may harm germinating seeds. The potential for ammonia loss from surface application of DAP is greater than for MAP, especially on alkaline soils. There is no significant agronomic difference in the P fertilizer value of these materials.

Liquid APP. Approximately half of the P in liquid APP is orthophosphate, and the remaining half is made up of polyphosphate compounds. The polyphosphate molecules rapidly convert to orthophosphate and become available for plant uptake. This slight delay in P availability occurring during polyphosphate hydrolysis has no detrimental effect on plant growth. In some soil conditions when P is added in a granular form, its initial plant availability may be limited by slow water movement into the granule, resulting in decreased plant availability compared with liquid P fertilizers. However, for most practical purposes, differences in P availability between liquid and dry sources are not significant.

Animal manures. Animal manures can be an excellent source of P for plants. When manure is used primarily as a N source, the amount of P applied is often 3 to 5 times more than many plants require, which can result in excessive P accumulation following multi-year applications. An alternative is to apply manure to provide adequate P and then supplement that with additional N fertilizer to meet crop requirements. Management of animal manure should include a plan to avoid surface runoff of nutrients. In many manures and composts, >75% of the total P is present in the orthophosphate form, which will behave similarly to fertilizer P. The fraction of organically bound P requires microbial degradation before it is available for plant uptake, much of it occurring within a year.

Potassium

There are many excellent fertilizer sources of K. Since the behavior of K from these materials is identical in the soil, a major consideration is the accompanying anion that is present in the fertilizer material.

Potassium chloride. Because it is often the least expensive and the most abundant K mineral in commercial deposits, potassium chloride is the most widely used source of K. Potassium sulfate is also an excellent nutrient source where S is also desirable or where chloride application should be minimized. It is less soluble than potassium chloride and not used widely for making fluid fertilizers. The use of potassium-magnesium sulfate provides a valuable soluble source of three essential plant nutrients. Other sources of K, such as potassium thiosulfate and potassium nitrate, are used effectively in more specialized conditions. Potassium present in plant residues, manure, and compost remains soluble and readily available for plant uptake, similar to K fertilizer.

Fertigation

Application of nutrients with irrigation water is commonly done to save labor, increase the flexibility of timing nutrient application, and improve nutrient efficiency. Fertilizer sources intended for fertigation are prepared so that precipitation and clogging of the irrigation system are avoided. There are many excellent fertilizers that are compatible with any type of irrigation system. Particular attention needs to be given when adding P-containing fertilizers to any irrigation water that contains abundant calcium or magnesium in order to avoid plugging. Remember that nutrient distribution through fertigation is no better than the uniformity of the water delivery system.

Foliar application

For some crops, foliar nutrition may be the most economical and reliable method for providing certain nutrients, especially micronutrients. There can be large differences in the effectiveness of various fertilizer sources in actually penetrating into leaves and providing the desired nutritional benefit. In specialized cropping conditions, foliar nutrition may be useful in supplementing soil nutrient supplies during critical growth stages as part of an overall nutrition plan, but this practice is not beneficial for most agronomic crops. Local recommendations should be followed for selecting the most effective foliar nutrient source on specialty crops.

Many factors are involved in combining the 4R concept of selecting the right source–rate–time–place combination to meet the specific economic, environmental, and social goals. There is clearly no one "perfect" source of nutrients for all situations. As technology and economic conditions change, a periodic re-evaluation is required for getting the most value from plant nutrients. This article, which discusses the most common plant nutrient and fertilizer sources, points to the need for continued conversations between the Certified Crop Adviser and his/her clients when evaluating plant nutrition and potential fertilizer sources. ■

May–June 2009 Self-Study Quiz

The four fertilizer rights: Selecting the right source (no. SS 03900)

This quiz is worth 1 CEU in Nutrient Management. A score of 70% or higher will earn CEU credit. The International CCA program has approved self-study CEUs for 20 of the 40 CEUs required in the two-year cycle. An electronic version of this test is also available at www.certifiedcropadviser.org. Click on "Self-Study Quizzes to Earn CEUs."

DIRECTIONS

1. After carefully reading the article, answer each question by clearly marking an "X" in the box next to the best answer.
2. Complete the self-study quiz registration form and evaluation form on the back of this page.
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1. Selecting the right source of fertilizer should be based on

- ❑ a. economic considerations.
- ❑ b. individual goals with multiple objectives.
- ❑ c. availability of application equipment.
- ❑ d. potential for the greatest yield.

2. Soil analysis and tissue testing are important when selecting the right nutrient source by

- ❑ a. suggesting specific forms of fertilizer that should be used.
- ❑ b. guiding selection of the most affordable nutrients.
- ❑ c. helping to choose between dry and fluid nutrient sources.
- ❑ d. identifying the specific nutrients that may be limiting crop growth.

3. The source of fertilizer nutrients that are used

- ❑ a. never makes a difference to the farmer.
- ❑ b. is determined by price.
- ❑ c. requires integration of many factors.
- ❑ d. has a minimal environmental impact.

4. Compound fertilizers can be useful for

- ❑ a. targeting specific nutrient needs in the field.
- ❑ b. stopping nitrogen leaching losses
- ❑ c. providing a simultaneous application of several nutrients.
- ❑ d. minimizing off-field nutrient losses.

5. The potential for soluble fertilizers to damage young seedlings is estimated by

- ❑ a. pressure bomb.
- ❑ b. salt index.
- ❑ c. the ratio of carbon to nitrogen.
- ❑ d. soil biological activity.

6. Urea continues to gain popularity as a nitrogen fertilizer because

- ❑ a. the white granules reflect solar radiation.
- ❑ b. it is readily identified in a bulk blend with other nutrients.
- ❑ c. it can be quickly converted to a volatile form for plant uptake.
- ❑ d. it is the highest nitrogen-containing solid fertilizer commonly available.

Quiz continues next page

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7. Controlled-release fertilizers

- ❑ a. are too costly for agronomic crops.
- ❑ b. always result in greater yield and quality.
- ❑ c. provide an additional option for nutrient management.
- ❑ d. allow nutrients to be applied at any time of the year.

8. An important difference between monoammonium phosphate (MAP) and diammonium phosphate (DAP) is

- ❑ a. DAP provides phosphorus in a more plant-available form.
- ❑ b. the nitrogen in DAP will be used more readily by the plant.
- ❑ c. the soil pH around a MAP granule will be lower.
- ❑ d. only MAP will convert to polyphosphate.

9. Most potassium fertilizer sources

- ❑ a. contain potassium in different chemical forms.
- ❑ b. differ primarily in the accompanying anions.
- ❑ c. should be selected based only on price.
- ❑ d. are more effective than manure as a potassium nutrient source.

10. A good use for a urease inhibitor would be when

- ❑ a. anhydrous ammonia is used.
- ❑ b. urea is incorporated into the soil.
- ❑ c. urea is broadcast on the soil surface.
- ❑ d. UAN is applied with center-pivot irrigation water.

SELF-STUDY QUIZ REGISTRATION FORM

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

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SELF-STUDY QUIZ EVALUATION FORM

Rating Scale: 1 = Poor 5 = Excellent

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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: _____