SL411

The Four Rs of Fertilizer Management[1]

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Fertilizers or nutrients are required in most crop production systems in Florida. While all soils in Florida can supply nutrients for crop production, nutrients may not be always available in adequate amounts for economical crop production. Supplying needed nutrients for crop production involves attention to four major fertilization factors (the 4Rs): *right rate*, *right source*, *right placement*, and *right timing*. Attention to these factors will provide adequate nutrition for crop production while minimizing the risk of loss of nutrients to the environment. The 4Rs (terminology promoted by the International Plant Nutrition Institute [2014]) are important components of nutrient best management practices, and university Extension specialists have been promoting these components of nutrient management for many decades. In this publication each factor is described, as well as how the information can be provided from a soil test report to help farmers make efficient use of their investment in fertilizer for crop production and for environmental protection. These factors are often interrelated; for example, placement and timing of fertilizer may need to be addressed together, such as the right placement of bands of fertilizer for side-dressing during the appropriate stage (i.e., right timing) of crop growth during the growing season. While not a formal part of the 4Rs, the importance of irrigation to overall nutrient management is stressed in this publication.

Right source

Selecting the *right source* of fertilizer or the right material to deliver the nutrients is important. The right source can be related to the following questions:

- What source of nutrient(s) would be the least expensive per unit of delivered nutrient?
- Should an organic source (compost or manure) of nutrient be considered?
- When is a controlled-release fertilizer the right source?
- What sources can simultaneously deliver more than one needed nutrient?
- When should a liquid form be used instead of a dry form?
- When should the salt index of the fertilizer be considered in selecting the right source?

The right source often involves the ease of application of a nutrient and cost per unit of nutrient. In addition, efficiency of nutrient use may be considered. For example, a controlled-release nitrogen source may be preferred to deliver small amounts of nutrients throughout the growing season, instead of larger amounts of nitrogen delivered in a few side-dressings from a soluble source.

The right source may be manure, if the farmer would like to take advantage of the organic matter supplied along with the plant nutrients. The organic matter may increase the water-holding capacity and nutrient supply of the soil.

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Right rate

Crops require a certain amount of plant nutrients for production of profitable crops. Part of this nutrient quantity can be supplied from the soil, and the remainder must come from fertilizer, either synthetic sources or organic forms (such as livestock wastes composts) or green manure crops. The first key to practicing the *right rate* concept is soil testing (see Hochmuth et al. 2014). Before the crop is planted and any fertilizer has been applied, soil testing can help determine the portion of the crop nutrient requirement that is already available from the soil. Using a strong research information base, the recommendation for the right rate of fertilizer can be made from the soil test result.

The *right rate* refers to the amount of fertilizer needed for the crop production season and is based on extensive research over locations, crops, varieties, and years. The right rate also refers to the amount of fertilizer applied at one time in the growing season. For example, the farmer needs to know, depending on the cropping system used, the right rate of fertilizer to apply in the following scenarios:

- In the preplant application, while the mulched bed is made for plasticulture vegetables
- As a starter fertilizer for direct-seeded crops like potato, corn, or cotton
- As the amount to inject (fertigation) into the drip irrigation system at any one time
- In a single side-dressing during the growing season for an unmulched crop
- In a single fertigation through the center-pivot irrigation system

Sometimes the right rate to apply at any one time is related to the nutrient involved. For example, in plasticulture vegetables, all of the phosphorus may be applied to the soil while the bed is made. Likewise, a portion of the nitrogen and potassium may be applied while the bed is being made and the remainder applied through the drip irrigation system.

Right timing

The *right timing* of nutrients takes into consideration the growth pattern of the crop and, therefore, natural changes in nutrient demand during the season. Crop development begins slowing from seed germination or transplanting, then increases through fruiting, and finally slows down at maturation. This pattern for crop development is referred to as *sigmoidal* growth (Figure 1). Anticipating changes in growth and nutrient demand is important so that fertilizer application can be timed to meet the needs of growth. A good example of timing of nitrogen and potassium fertilization to meet changes in crop development can be seen for drip-irrigated tomato (Figure 2).

The right timing is often interrelated with the right rate and right placement. For example, as the drip-irrigated tomato crop develops, the rate changes with time so that smaller rates are applied later in the growing season. Greater rates of nutrients are applied at or just before the time when the vegetative growth rate is maximal and fruits are being developed.

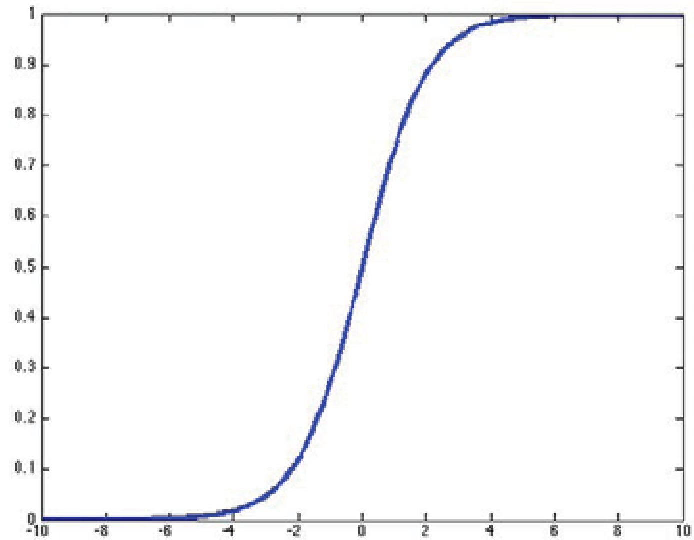

Figure 1. A sigmoidal function—for example, slow crop growth at first, then a zone of rapid increase, followed by attenuation of growth.

Period in the season	Amounts of N and K (K_2O)
Preplant	0 to 70 lb per acre
Weeks 1–2	1.5 lb/acre/day
Weeks 3–4	2.0 lb/acre/day
Weeks 5–11	2.5 lb/acre/day
Week 12	2.0 lb/acre/day
Week 13	1.5 lb/acre/day

Figure 2. Recommendations for injecting N and K_2O for mulched, drip-irrigated tomatoes in Florida.

Rainfall is difficult to predict; however, when possible, fertilizer application should be timed to minimize the chance of leaching of nutrients due to heavy rainfall.

Right placement

For maximum nutrient efficiency, nutrients need to be placed where the plant will have the best access to the nutrients. For most crops, the *right placement* is in the root zone or just ahead of the advancing root system. Most nutrient uptake occurs through the root system, so placing the nutrients in the root zone maximizes the likelihood of absorption by the plant.

Banding and broadcasting are two general approaches to nutrient placement. *Banding* is the placement of fertilizer in concentrated streams or bands in the soil, typically near the developing plant. *Broadcasting* is the spreading of fertilizer uniformly over the surface of the soil. Whether to use banding or broadcasting often depends on the type of crop and the development or spread of the root system. Broadcasting is usually most effective either later in the season when roots of a row-crop have explored the space between the rows, or for forage crops that cover the entire soil surface. Fertigation of nitrogen through a center-pivot irrigation system for corn may be a type of fertilizer broadcasting system.

Placement and timing interact because as the crop develops, the root system expands. Placement of fertilizer ahead of the advancing root system for unmulched crops, like potato or cotton, avoids damage to the root system by the fertilizer application equipment. Another example of this interaction would be for fertigation with a pivot irrigation system. The first side-dressings of nitrogen early in the growth cycle for corn may be applied by knifing liquid fertilizer to the side of the row, followed later in the season with applications through the irrigation system. These combinations of timing and placement maximize the likelihood of nitrogen uptake by the plant related to the expansion of the root system.

The tillage system may affect the placement of nutrients. For example, incorporating a nutrient may not be possible in certain minimum tillage systems. In no-till corn production, early nitrogen and phosphorus applications can be made by banding near the seeds with the planter, with later applications of nitrogen by the center-pivot irrigation system.

The right placement is also related to the nutrient in question. For example, phosphorus can become fixed in unavailable forms when it is mixed in with some soils. The main reason P is banded is that it is immobile in the soils and therefore has to be placed nearer to the roots (or the roots have to grow towards the P granule). In sandy loams, P applied to the surface will get adsorbed and can accumulate over time. Accumulations also occur in soils applied with P sourced from organic or manure related amendments. In these situations, banding of the fertilizer reduces, at least temporarily, the mixing of the fertilizer with the soil and increases the chance that phosphorus will remain in a soluble form for root uptake. For example, banding starter-phosphorus may be preferable to broadcasting.

The right placement may also relate to the form of the nutrient source, such as urea nitrogen. Nitrogen from urea may be subject to loss by volatilization when the urea is left on the surface of soil with a high pH. Incorporating the urea or applying a small amount of irrigation to move the urea into the soil helps reduce volatilization losses.

In certain situations and for certain nutrients, foliar applications of fertilizer may be preferred. For example, micronutrients may be more efficiently applied to the foliage for iron or manganese when the soil pH is high.

Integrated approach

All nutrient management practices are the result of many years of research and field experience at the commercial farm level (Table 1), and these practices are subject to refinement as farmers gain experience and as new research is completed. Optimal nutrient management rarely relies on a single practice, but rather a combination of practices. Selecting the best combination is the goal of all nutrient

Table 1. Examples of scientific principles behind nutrient management and the associated practices.

	Right Source	Right Rate	Right Placement	Right Timing
Scientific principles	Which nutrients are needed; based on soil testing; potential for nutrient loss	Crops vary in nutrient needs; Crop Nutrient Requirement; prevent excessive amounts	Mobility of nutrients; rooting patterns; bedding of crops; mulching; volatilization	Dynamics of crop growth and nutrient demand; risk of nutrient loss
Application of knowledge	Soil-supplied nutrients; crop residue; fertilizers; manures; blends; single-nutrient source; soluble; CRFs	Costs; nutrient use efficiency; likelihood of nutrient loss; variable-rate application	Band; broadcast; foliar; fertigation; production system, (e.g., no-till); surface vs. buried	Preplant; at planting; first flower; first fruit; logistics of field timing and equipment; mineralization of manure

management that addresses profitable crop production while protecting the environment from nutrient loss.

Importance of irrigation management

In the sandy soils of Florida, there is a fifth R: *right irrigation practices*. Mobile nutrients such as nitrogen and potassium can be leached with the water moving through the soil in the root zone. Excessive irrigation, or irrigation when the soil water-holding capacity is full, will cause nutrients to be leached below the root zone. Farmers should track soil moisture, because coupling knowledge about soil moisture status with crop water requirements is the best way to maximize water-use efficiency and minimize nutrient leaching. UF/IFAS Extension recommends applying 30 lb/acre N after a leaching rainfall of 3 inches in four days or 4 inches in seven days.

In areas where fertigation is possible, the optimal rate, timing, and placement of nutrients can be collectively achieved, especially for N and K. When using fertigation, efficiency in application of fertilizer and irrigation water can be significantly increased, and environmental losses from the production systems can be minimized.

Summary

The concept of the 4Rs is important for maximizing fertilizer-use efficiency, promoting profitable crop production, and protecting the environment from pollution due to losses of nutrients from agricultural land. Selecting the right fertilizer rate, right fertilizer source, right fertilizer placement, and right fertilizer timing are important aspects of best management practices. Farmers should consider all the options for each "right" component and select the best combinations for maximizing crop profitability and minimizing negative environmental impacts.

Growers and crop educators and advisors should constantly measure fertilizer use efficiency associated with the 4Rs and make adjustments to improve efficiency. An example of how to measure nutrient use efficiency by crops is presented by Prasad and Hochmuth (2014). The 4Rs is a nutrient management program promoted by the International Plant Nutrition Institute (http://www.ipni.net/4R). We need to develop sets of 4R practices for the growers in Florida based on factors such as location, soils, crops produced, water management system, nutrient sources, and agronomic/horticultural management options. In the long run, real-time weather data can be dynamically linked to these 4R sets to guide real-time modifications of the practices during a growing season.

Other publications in this series on soil testing

Hochmuth, G., R. Mylavarapu, and E. Hanlon. 2014. *Soil Testing for Plant-Available Nutrients—What Is It and Why Do We Use It?* Gainesville: University of Florida Institute of Food and Agricultural Sciences. http://edis.ifas.ufl.edu/ss621.

Hochmuth, G., R. Mylavarapu, and E. Hanlon. 2014. *Developing a Soil Test Extractant: The Correlation and Calibration Processes*. Gainesville: University of Florida Institute of Food and Agricultural Sciences. http://edis.ifas.ufl.edu/ss622.

Hochmuth, G., R. Mylavarapu, and E. Hanlon. 2014. *Fertilizer Recommendation Philosophies*. Gainesville: University of Florida Institute of Food and Agricultural Sciences. http://edis.ifas.ufl.edu/ss623.

References

International Plant Nutrition Institute. 2014. http://www.ipni.net/4R.

Prasad, R., and G. Hochmuth. 2014. *How to Calculate a Partial Nitrogen Mass Budget for Potato*. Gainesville: University of Florida Institute of Food and Agricultural Sciences. http://edis.ifas.ufl.edu/ss614.