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Selecting the Right Nutrient Rate: Basis for Managing Fertilization Programs

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Summary. Selecting the "right" nutrient rate for fertilization programs is one of the most important decisions growers face. On one hand, increasing fertilizer prices and environmental concerns have increased the awareness of accurately managing fertilization programs, thus reducing fertilizer amounts during cropping seasons. By contrast, many growers fear not obtaining the desired crop performance and economic returns, especially when fertilization is assumed as "inexpensive insurance" to improve yields, thus leading to overfertilization. The objective of this paper was to provide general principles for selecting and monitoring the right nutrient rate within the framework of the "4R" nutrient management concept (right rate, right source, right placement, and right timing) to protect environmental quality while maintaining productivity. Some methodologies to determine, apply, and adjust fertilization rates during the growing season were discussed, including in-season monitoring procedures, such as petiole sap testing, plant diagnostic analysis, leaf color evaluation, and plant growth index.

Nutrient rates: What is "right"?

Minimizing nutrient losses and increasing crop utilization is a desirable goal for the fertilizer industry, grower associations, and environmental groups throughout the world. One tool to achieve that goal is the use of fertilization best management practices that allow improving agricultural environmental and economic sustainability of crops (Roberts, 2007). The implementation of these best management practices is tightly linked to four aspects of nutrient management for crops, which are defined as the "4R" nutrient management concept: "right" rate, source, placement, and timing (Bruulsema et al., 2009; Roberts, 2007). Therefore, the objective of this paper was to provide general principles for selecting and monitoring the right nutrient rate within the framework of the "4R" of nutrient management concept to protect environmental quality while maintaining productivity (Bruulsema et al., 2009).

It is widely recognized that having a single nutrient rate recommendation for a given crop is unrealistic and unpractical because of the relative nature of this practice across different locations, soils, seasons, cultivars, fertilization practices, and production techniques. Instead, the appropriateness of a given nutrient rate, and therefore a fertilization program, depends on factors within the farm (e.g., irrigation and available equipment), as well as exogenous conditions (e.g., fertilizer prices and environmental regulations). The "right" nutrient rate needed during a cropping season is the summation of the crop requirement and the nutrient losses in the environment and the soil. The crop nutrient requirement is defined as the amount of a given nutrient needed to achieve the desired growth and development. This requirement will depend intrinsically on the crop type and its yield potential (Phillips et al., 2009), and it could be supplied from three main sources of nutrients: 1) atmospheric deposition and inputs, 2) the natural soil supply, and 3) the applied fertilizers. The former is important in the case of the essential elements carbon (C), hydrogen, and oxygen, which are in most cases under non-limiting conditions, and for sulfur (S), deposition is in the form of acid rain (Ceccotti et al., 1998). Nevertheless, it is widely understood that the soil supply and fertilizers comprise the bulk of the amounts needed to satisfy the crop nutrient requirement.

The key for designing an effective fertilization program is to accurately determine the amounts of fertilizer needed to supplement the soil nutrient supply potential. However, in some cases, the amount of fertilizer applied could be higher than needed by the crop to replenish a share of the natural soil nutrient pool (Phillips et al., 2009). Obviously, the nature of a given soil will have a profound influence on the amounts of nutrient available for plant absorption. Soils with considerable organic matter content and cation exchange capacity will tend to be richer, acting as nutrient reservoirs, than highly weathered and degraded soils.

On the other hand, the determination of the "right" nutrient rate will depend heavily on the correct assessment of the possible nutrient losses. These losses refer to reduced nutrient availability because of biological and mineral immobilization, volatilization, leaching, and runoff. Biological and mineral immobilization occurs when soil microbes, including bacteria, use C atoms as an energy source or as a building block for their structures. A typical example of this process is nitrogen (N) fixation by microbes in the presence of a high C to N ratio (Bengtsson et al., 2002), whereas mineral immobilization takes place when nutrients become unavailable because of strong adsorption to the cation exchange capacity complex such as potassium (K) ions in expandable clay fields, or by forming insoluble compounds, such as phosphorus (P) combining with aluminum forming relatively insoluble aluminum phosphates. Volatilization of ammonia (NH_3) and nitrous oxide (N_2O) are two cases of N losses in soils because of microbial activity (Reddy et al., 1979; Snyder et al., 2007). Atmospheric concentrations of N_2O have risen steadily during the last century, and the proportion of cropland N_2O emissions directly induced by fertilizer is estimated at about 23% worldwide (Snyder et al., 2007). Nutrient leaching and runoff are two physically driven processes that could cause severe nutrient depletion in agricultural regions. Hong et al. (2007) indicated that application of N fertilizer has increased dramatically in recent decades, and it is projected to continue because of the pressure to produce more food in less land. The environmental

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