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Copper 4R management—Deficiency or toxicity?

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Copper nutrition is critical to the success of a crop, but the complex relationships of copper to soil properties that impact availability need to be understood when making 4R decisions about copper application.

The micronutrient copper, while an elemental mineral needed by plants in small amounts, is essential for healthy growth and development. The challenge with many micronutrients that are heavy metals is that there is a fine balance between deficiency and toxicity. Using 4R Nutrient Stewardship principles for copper applications or soil management for copper supply that consider the right nutrient source at the right rate, right time, and in the right place will help avoid toxicity or deficiency.

Copper in Plants and Soil

Copper is taken up by the roots. Within the plant, it can be converted from cupric (Cu^{+2}) to cuprous (Cu^{+}) to support photosynthesis, respiration, lignin formation, viable pollen production, seed set, and plant stress resistance. Copper is immobile in plants, and copper concentration increases in the roots and new growth on shoots when the amount of soluble copper in the soil increases (Alva et al., 2000). At very high available copper soil concentrations, root growth decreases.

For copper, like other micronutrients, there is a narrow range in the soil between deficiency to and toxicity. However, the concentration of plant-available copper in the soil is highly dependent on soil pH, soil organic matter, and soil texture. Copper has

limited mobility in the soil, leading to accumulation of the total copper concentration. However, total copper concentration in the soil is not well related to the crop response. Soil copper concentration can be measured as water soluble; exchangeable; organically bound; associated with carbonates and hydrous oxides of iron, manganese, and aluminum; residual; and total (Alva et al., 2000). The water-soluble and exchangeable fractions are the two that are available for crop uptake and will influence a deficient or toxic response from a plant.



Copper deficiency in wheat.

Copper as copper sulfate (CuSO_4) was added to Florida soils with soil organic matter ranging from 0.4 to 1.7% and pH ranging from 5.7 to 8.2. After 47 days, the soils were analyzed for exchangeable, sorbed, organically bound, precipitated, and total copper concentrations (Whalen et al., 2000).

Exchangeable or readily soluble copper in the soils increased with increasing copper application rate (up to 400 ppm) in the soils with lower pH levels (Whalen et al., 2000). In the higher-pH soil (8.2), readily soluble copper decreased as application rate increased. However, across all three soils, readily soluble copper was the smallest fraction of the total copper in the soil (Whalen et al., 2000). The proportion of copper that was organically bound to the soils and not available for plant uptake decreased with increasing copper application rates for all three soils. Finally, the copper that precipitated to form hydroxide, carbonate, or phosphate forms of copper in the soils, also not available to plants, increased in all three soils as copper application rates increased (Whalen et al., 2000). The soils tested had a wide range of pH values, and this allowed the project to show that readily soluble copper was the only fraction influenced by soil pH with decreases in

availability when soil pH increased to 8.2 (Whalen et al., 2000). Soil pH is a common soil analysis, and it needs to be considered when managing for copper nutrition.

Sequential extraction of copper from soils has also been used to better understand the fate of applied copper from CuSO_4 . In this method, copper is extracted from the soil with eight different solutions that represent different levels of availability to plants and locations of copper in the soil matrix. The initial extractions measure the fractions that are highly available to plants, followed by those that may become available to plants, and finally the fractions of copper that will likely never be available to plants. In three soils that were incubated for 29 days after application of 38 lb/ac of copper from CuSO_4 , less than 2% of the total copper measured was in an available form (Miller et al., 1987). After CuSO_4 application, most of the copper in these soils was unavailable to plants and associated with other minerals or organic matter (Miller et al., 1987). These results further support that when a copper deficiency is observed or predicted, it is important to know soil pH, organic matter, and mineral makeup to determine whether the deficiency is related to applied copper being made unavailable or the rate of copper to be applied.

In some cases, the accumulation of copper in the soil is from continuous use of another copper-based product, pesticide, or animal manure or other organic source that was not applied as a fertilizer over many years. Accumulation of copper in the soil is not necessarily an indication of plant toxicity issues. For example, over a 20-year period of annual application, the amount of copper applied totaled 370 lb/ac. The plant-available copper in the soil did increase, as was reported in other studies, but the largest increase was in the fraction of copper that was not plant available (Payne et al., 1988). Understanding how a mineral like copper behaves in the soil is a key part of implementing a 4R nutrient management strategy for meeting crops needs.

Sources of Copper

There are multiple sources of copper fertilizer with varying copper content and availability after application. The interactions of copper in the soil discussed above present challenges for copper application. While copper sulfate (CuSO_4) is the most commonly used source of copper fertilizer, there are also chelated or complexed forms of copper available. In one study, multiple sources of copper were compared across four locations where symptoms of copper deficiency in wheat were observed. Copper was applied at rates up to 5.0 lb/ac to test the response of wheat and soybeans (Barnes & Cox, 1973). Wheat and soybean yield increased with copper application regardless of the source of copper applied (Barnes & Cox, 1973).

Rate of Copper Application

Copper availability to crops from the soil is strongly influenced by soil pH, soil organic matter, and mineral content; knowing these factors before determining a rate of application is important. Wheat yield in Mid-Atlantic soils of the United States had a larger response to copper application than did soybeans, but both wheat and soybean yield response was optimized at 2.5 lb/ac of copper (Barnes & Cox, 1973). The influence of soil conditions on copper availability to plants is evident when you contrast these results with the results of Payne et al. (1988) where annual copper applications averaged 14.7 lb/ac with an accumulated application of 370 lb/ac and no difference in corn grain or silage yields. Careful consideration of local conditions, soil-testing methods, and crop response when determining application rates of copper is key to making good recommendations.

Timing and Placement of Copper Application

Copper is not highly mobile in soil, and multiple studies have demonstrated that, even at high application rates, copper is stored in the soil in unavailable forms that will not

be available to plants. Available copper concentration was measured at the depth of 9.8 to 13.8 inches after cumulative application of 370 lb/ac of copper and was not significantly different than the available copper in the top 0 to 7.9 inches, demonstrating a lack of leaching of copper through soil (Payne et al., 1988). The low mobility of copper in the soil also impacts decisions on how to apply copper fertilizers. With little vertical movement of copper in the soil, surface application can result in accumulation in the top inches of the soil. Mixing copper applications in the soil should be considered when deficiency symptoms have been observed. Additionally, in-season or foliar application of copper can be effective to correct observed crop deficiencies.

Conclusions

Copper nutrition is critical to the success of a crop, but the complex relationships of copper to soil properties that impact availability need to be understood when making 4R decisions about copper application. Soil pH and organic matter content have a strong impact on the availability of copper to plants and are easily measured on a standard soil test.



This article is part of a series from The Fertilizer Institute highlighting some of the latest 4R research.



RIGHT SOURCE

Matches fertilizer type to crop needs.



RIGHT RATE

Matches amount of fertilizer to crop needs.



RIGHT TIME

Makes nutrients available when crops need them.



RIGHT PLACE

Keeps nutrients where crops can use them.

References

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