Copper Management Demands Attention

By Richard J. Hull

Of the six metallic micronutrient elements, copper (Cu) is one of the least abundant in plant tissues. Only molybdenum and nickel are required in lesser amounts.

The sufficiency range for Cu in turfgrasses reported by Jones (1980) is five to 20 parts per million (ppm) of leaf tissue dry weight. This compares with 35 to 100 ppm for iron (Fe) and 20 to 55 ppm for zinc (Zn). A summary of Cu concentrations reported in turfgrasses is presented in Table 1. While values differ among the three laboratories, probably due to different analytical methods used, it appears that field-grown turfgrasses contain about 20 to 30 ppm Cu.

It's probably evident by now that many trace elements perform similar functions in plants. While I shall try not to repeat what we have already considered, it is useful to recognize the similarity in biological functions exhibited by these nutrients. Understanding functional similarities can help the turf manager judge the value of applying these nutrients as part of a turf management program. We shall consider this further before closing our discussion of Cu use by turfgrasses but first let's see exactly how Cu is obtained by and used in turfgrasses.

Copper in soils

Most soils contain little Cu, with values from over 1,000 sites in the United States ranging from one to 191 ppm (Kubota, 1983). Soils considered high in Cu have about 50 ppm, with most soil being substantially less than that.

Soil Cu exists in two oxidation-reduction forms: oxidized cupric (Cu^{2+}) and reduced cuprous (Cu^{+}).

The reduced Cu^{+} form exists mainly in soils that are constantly waterlogged where, being highly unstable, it generally forms inorganic or organic compounds that are insoluble. Cuprous is the stable form of Cu in most Cu-minerals. But when they are weathered and solubilized, the Cu^{+} is rapidly oxidized to Cu^{2+} and can even react with itself to produce Cu^{2+} and elemental Cu^{0} (Clarkson & Hanson, 1980).

TABLE 1

Copper content in leaf tissues of several turfgrasses

Turfgrass	Copper content*		
	Waddington & Zimmerman (1972)	Butler & Hodges (1967)	Turner (1980)
		ppm	
Annual bluegrass	26	-	-
Kentucky bluegrass	25	30	7.3
Colonial bentgrass	31	19	-
Creeping bentgrass	35	-	-
Tall fescue	23	34	
Creeping red fescue	25	20	8.4
Perennial ryegrass	24	38	8.0
Bermudagrass	-	43	-
Zoysiagrass	-	18	

* As reported in Turner & Hummel (1992)

The oxidized Cu^{2+} form is more abundant, but it's a strong oxidizing agent and readily reacts to form mineral complexes and metallo-organic groups. Being a divalent cation, Cu^{2+} also binds strongly to mineral (clay) and organic cation exchange sites. The consequence of Cu^{2+}s reactive nature is that its concentration in soil water is rarely more than 1 or 2 ppm.

In neutral or alkaline soils, Cu^{2+} forms weakly soluble salts with carbonate ($CuCO_3$) or hydroxide [$Cu(OH)_2$] resulting in even less of the soluble ionic form being available for plant uptake. Consequently, Cu deficiency is most likely to be observed in high pH soils, similar to the situation with iron (Fe^{3+}) in well-limed soils (Hull, 1999).

Copper uptake

The absorption of Cu by plant roots is not well understood. Because Cu^{2+} is present in the soil solution at concentrations of 1 to 2 ppm and within the cytoplasm of root cells at even lower concentrations, uptake should be passive, moving down a concentration gradient. The cytoplasm of root cells also is electrically negative compared to the soil solution, making additional energy available to transport Cu^{2+} into root cells from a positively charged soil environment to the negatively charged cell cytoplasm.

All that is required for Cu^{2+} uptake is the presence of membrane channels through which cations can pass. There is ample evidence that such cation transport channels exist in root epidermal and cortical cells (Marschner, 1995). Most of the data that I've seen for Cu uptake by grass roots shows a linear relationship between Cu^{2+} concentration in the soil solution and Cu accumulation in roots. This is consistent with the passive influx theory outlined above.

Research, comparing the efficiency of Cu uptake by several cultivars of wheat and other annual grasses, shows dramatic differences among cultivars (Marschner, 1995). Some cultivars grow poorly and produce no grain at low Cu levels while others produce normal yields at the same Cu concentrations. This indicates Cu absorption is under genetic control and could cast doubt on the passive uptake theory. However, more recent molecular studies have shown Cu-efficient cultivars to have the genes for the enzymes that synthesize the phytosiderophore mugineic acid that enables most grasses to capture and absorb Fe^{3+} from iron-poor soils (Hull, 1999).

Although this organic chelating agent does not bind Cu^{2+} as readily as it does Fe^{3+}, it does react with Cu sufficiently to increase its solubility and enhance its uptake by roots. It appears that Cu^{2+} uptake by turfgrass roots might occur through passive transport along an electrochemical gradient between soil solution and root cells, as well as by chelate capture from the soil and transport across cell membranes.

It has also been demonstrated that nutrient uptake by several plants is enhanced dramatically when the plant roots have a mycorrhizal association with specific soil fungi (Marschner, 1995). This symbiotic relationship between root and fungus has been shown to increase markedly a plant's ability to recover phosphorus (P) from low fertility soils. Among the micronutrients, Zn and Cu have proven to be more available to plants when roots are mycorrhizal. This beneficial association appears to work best when plants are growing in low fertility soils.

High soil fertility, especially high P, inhibits mycorrhizal associations, resulting in little if any benefit to plants. It is, therefore, questionable if mycorrhizae can be helpful in making poorly available nutrients like Cu more available to turfgrasses. Since turf is normally grown at fairly high fertility levels, it would likely be difficult to maintain healthy mycorrhizae that could make Cu or other nutrients more available.

If turf is growing on a soil of alkaline pH and high cation exchange capacity due to the presence of clay or organic matter, the soil's capacity to immobilize Cu^{2+} would be great, making little available to plant roots and causing a Cu deficiency. Adding Cu fertilizer to such a soil would do little good because most would be quickly bound into the soil matrix and largely unavailable for root absorption. Similar availability problems have been observed for manganese (Mn), Fe and Zn. While grasses are less prone to soil fixation problems than are most broad-leaved plants, maintaining adequate micronutrient supply to turfgrasses still can be difficult on nutrient-binding soils.

Under these conditions, Cu is often more effectively applied as a foliar spray several times during the growing season. Any soluble Cu source can be used, but chelated forms applied with a surfactant are normally most effective. Water is the medium by which Cu^{2+} penetrates the leaf surface, so applications made late in the day, when free water will persist for several hours, are more effective. Because Cu is not readily translocated from grass leaves to other plant organs, applications should be repeated every six weeks.

Most foliar applied Cu will be lost in clippings, so this should not be viewed as a long-lasting solution to a soil unavailability problem.

Copper sources, management

The most common Cu source applied to turf is copper sulfate that contains 25 percent Cu and is highly water soluble. This salt readily dissolves to release Cu^{2+} ion, the most plant-available form of Cu. Copper sulfate is most effective when applied to acid or neutral soils ,but in alkaline soils the Cu^{2+} rapidly precipitates to an unavailable form. Organic soils and those having a high clay content also strongly bind Cu^{2+}, making it less available to grass roots. If these soil conditions are prevalent in your area, you are at risk of experiencing a Cu deficiency and applying copper sulfate may provide only temporary or no relief.

Even sand-based greens may be deficient in Cu and other micronutrients if none were supplied during construction and topdressings were lacking in these elements. Copper is not normally mobile in soil, but in sandy acid soils with low cation exchange capacity, Cu can be lost by leaching. This can occur on greens, especially new greens, where subtle turf problems may be noted that can be difficult to explain.

In a Rutgers University study, take-all patch disease of creeping bentgrass was found to be reduced substantially by monthly applications of Mn and Cu (Hill et al., 1999). The requirement of Cu and Mn for lignin biosynthesis and the resulting increase in disease resistance was the explanation offered for their results.

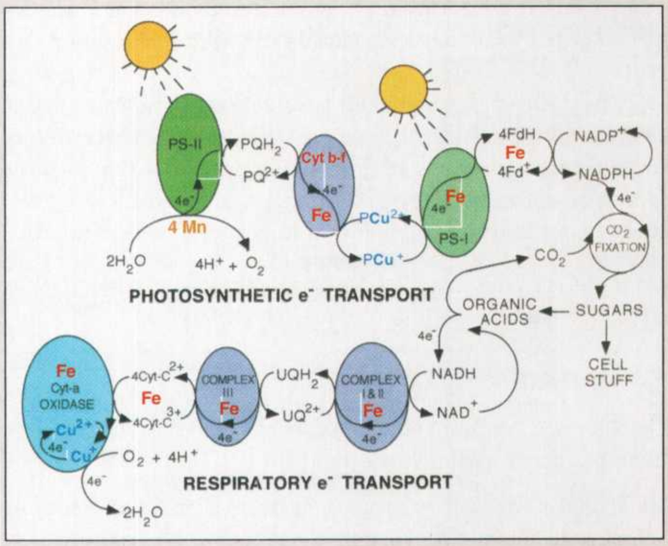
Applications of copper sulfate will correct any Cu deficiency, and its addition might well become part of a turf fertility program. As with Zn and Mn, Cu tissue levels should be monitored every three or four years to insure turf is receiving sufficient Cu and to check on possible toxicity levels. Leaf analysis is not a good indicator of plant Cu toxicity because transport from roots is limited. Cores should be taken and roots removed for Cu analysis. Root samples can be collected during hollow core aeration.

If roots are found to contain much above 25 ppm Cu, stop adding that element and look for other sources that could contribute to high Cu levels. Waste water and sludge-based topdressings are likely sources of excess Cu.

Chelated Cu sources are more expensive than copper sulfate, but their Cu is less likely to be immobilized in soils prone to metal fixation. These materials contain about 13 percent Cu but because little of the Cu is released as Cu^{2+}, it's not fixed and rendered unavailable to plants. The chelate remains soluble and can be drawn toward plant root surfaces, where increased acidity will promote somewhat more Cu^{2+} release and absorption into roots.

Chelated Cu can also be applied as a foliar fertilizer where it may be absorbed by

COPPER AND THE PHOTOSYNTHETIC EFFECT



The functions of copper (Cu) in photosynthetic and respiratory electron transport.

leaves and effectively meet turf needs. While one might question the efficiency of foliar feeding as a general practice for turf fertilization, there is no question about its effectiveness as a means of supplying micronutrients, especially metallic ions and chelated forms.

Copper deficiency is not likely to be a problem for turf managers unless metal immobilizing soils are involved. However, fine turf maintenance is an intensive demanding operation where success depends on covering all the bases. Micronutrient sufficiency is one of those bases that the turf manager might well want to touch.

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