Table 15. Forms, deficiencies, and sources of micronutrients: guidelines for turf managers.

Nutrient	Deficiency Occurrence	Deficiency Symptoms	Fertilizer Sources
Iron (Fe)	Occurs with soil pH >7.0; excessive Ca, Zn, Mn, P, Cu, and bicarbonate (HCO_3) levels in irrigation water; and poor rooting, poor soil drainage, and cold soils. At low soil pH, P can combine with Fe to form insoluble (unavailable) iron phosphate, while at high pH, excessive P uptake by plants may inactivate absorbed Fe. For each increase in pH, there is a 100-fold decrease in soluble Fe^{+2}. Heavy metals and/or bicarbonates from effluent water or sewage sludge as soil amendments may compete with Fe for plant uptake. Deficiency symptoms are most severe during warm days/cool nights, when root growth is insufficient to support shoot growth.	Chlorosis resembling N deficiency, except that chlorosis is interveinal and first occurs in the youngest leaves, since Fe is immobile within the plant. Older leaves are affected later. N deficiency causes the entire leaf, including veins, to yellow simultaneously. Leaves deficient in Fe finally turn white. Fe chlorosis tends to be in randomly scattered spots, creating a mottled appearance, and looks more severe when turf is mowed closely; N deficiency develops uniformly over a large area and appears unaffected by mowing.	Ferrous sulfate (19%-21% Fe and 19% S); usually foliarly applied; limited acidifying effect. Ferrous ammonium sulfate (5% Fe, 16% S, and 7% N); usually foliarly applied; also provides some N; moderate acidifying effect. Chelated iron (6%-7% Fe); longer greening effect than the other Fe sources; limited acidifying effect.
Manganese (Mn)	Occurs in peat and muck soils (insoluble complexes are formed); alkaline soils high in Ca (for each increase in pH, there is a 100-fold decrease in soluble Mn^{+2}); also occurs with low temperatures; poor drainage. Excessive Fe, Cu, Zn, K, and Na levels can reduce Mn adsorption. A Fe to Mn ratio in leaf tissue should be at least 2:1. Adjusting soil pH to less than 7.0 usually reduces Mn deficiencies.	Interveinal yellowing (yellowing between veins) in youngest leaves; veins remain dark green to olive green color, since Mn is an immobile element within the plant; small, distinct necrotic leaf spots develop on leaves; leaf tips may turn grey to white, droop, and wither. On closely mowed turf, mottled or blotchy appearance develops; little or no response to N occurs.	Manganese sulfate (26%-28% Mn).
Zinc (Zn)	Alkaline soils decrease solubility and availability; excessive soil levels of Cu^{+2}, Fe^{+2}, and Mn^{+2}; high soil moisture, nitrogen, and phosphate levels. Lower light intensities reduce root uptake.	Mottled, chlorotic leaves, rolled and thin leaf blades; stunted growth; dark, desiccated-looking leaves (starting with the youngest ones); leaves finally turn white.	Zinc sulfate (35% Zn); zinc chelate (9%-14% Zn); zinc oxide (78% Zn).
Copper (Cu)	Deficiency is common in peats, mucks, and highly organic soils because Cu binds tightly with these. Excessive levels of Fe, N, P, and Zn and high soil pH encourage deficiency. Toxic levels can result from excessive applications of sewage sludge, use of poultry manures, copper sulfate, and copper-containing pesticides such as Bordeau mixture. Liming to pH 7.0 is the simplest means of overcoming Cu phytotoxicity.	Yellowing and chlorosis of leaf margins; leaf tips initially turn bluish, wither and droop, eventually turn yellow and die; youngest leaves become light green and necrotic; plant dwarfing with inward rolling of leaves, which turn a blue-green color; symptoms progress from the leaf tips to the base of the plant. Toxicity symptoms reflecting excessive levels include reduced shoot vigor, poorly developed and discolored root systems, and leaf chlorosis resembling iron deficiency.	Copper sulfate (13%-53% Cu); copper oxide (40% Cu); copper chelates (9%-13% Cu).
Boron (B)	Organic matter is the principal source of B; availability increases with decreasing soil pH; deficiencies are most common in high pH, leached, or very dry soils; Ca decreases translocation of B in plants.	Immobile within the plant; thickening, curling, and chlorotic leaves develop on dwarf (rosette) plants; chlorotic streaks develop in the interveinal areas; symptoms first appear in meristematic tissues.	Borax (11% B); fertilizer borate (sodium tetraborate -- 14%-21% B).
Molybdenum (Mo)	Availability increases with increasing soil pH; deficiencies are most common in acid sands or highly weathered soils; excessive Cu, Fe, Mn or sulfate may reduce plants' utilization of Mo.	Resembles mild N deficiency with pale yellow-green, stunted plants; mottled yellowing of interveinal areas then appears in older leaves.	Ammonium molybdate (54% Mo) liquid; sodium molybdate (40% Mo); molybdenum trioxide (66%).
Chlorine (Cl)	Less available in alkaline soils, or soils high in NO_3^- and SO_4^{-2}; very mobile in acid to neutral soils. Excessive levels reduce the amount of water available to plants, causing premature leaf yellowing; leaf tip and margin burning; and leaf bronzing and abscission.	Chlorosis of younger leaves and wilting of plants.	Ammonium chloride (66% Cl); calcium chloride (65% Cl); magnesium chloride (74% Cl); potassium chloride (47% Cl); sodium chloride (60% Cl). Most often applied in large quantities, along with the potassium source in fertilizers.