Copper

ESSENTIAL ELEMENTS

THE FERTILIZER INSTITUTE

Copper (Cu) is one of eight essential plant micronutrients. When Cu is deficient, common crop responses to its application include reduced disease, increased crop growth and improved quality. Commonly applied Cu sources include fertilizer, animal manures, biosolids, and pesticides.

Copper in Plants

Copper has an essential function in human health and for plant growth. Its essential status for plant nutrition was not recognized until 1931. Normal Cu concentrations in plants range from 5 to 20 ppm. Plant roots absorb the divalent form (Cu^{2+}; cupric) and can readily reduce it to the monovalent form (Cu^{+}; cuprous). The ease of converting Cu back and forth between the cupric and cuprous forms gives Cu unique functions in the plant. Copper plays roles in photosynthesis and respiration, including the final transfer of electrons to oxygen. Copper helps form lignin in cell walls, which provide support to hold plants upright. It is particularly important to the formation of viable pollen, seed set and stress resistance.

Copper in Soils

Total Cu in soils commonly ranges between 1 to 40 ppm, but the Cu concentration dissolved in the soil solution is much lower. The availability of Cu in soils for plant uptake is affected by the following characteristics:

- **Organic matter.** Copper is more tightly bound to organic matter than any other micronutrient. Plant Cu deficiencies often occur in crops growing on peats, mucks, and soils with more than 8 percent organic matter. Critical concentrations of soil test Cu (DTPA-extractable Cu) are much higher in these soils than in mineral soils.
- **Texture.** Plants growing in sandy-textured soils are more likely to be deficient than those growing in loams and clays. Clay-textured soils generally hold more Cu in exchangeable form, available to crops. Other soil components, such as oxides and carbonates, can further reduce Cu availability.
- **Soil pH.** Copper solubility decreases as pH increases to 7 and above. Higher pH increases the strength by which Cu is held by soil clays and organic matter, thus making it less available to crops.
- **Nutrient balance.** High concentrations of zinc (Zn), phosphorus (P), aluminum (Al), and iron (Fe) in soils can depress Cu absorption by roots and aggravate Cu deficiency. Risks of Cu deficiency also increase with higher rates of nitrogen (N) application.

Fertilizing Soils with Copper

Source: When additional Cu is required, the most common fertilizer source is copper sulfate, although many other excellent materials are available **(Table 1)**. Additional sources of Cu include livestock and poultry manures, and municipal wastes or biosolids. Some animal manures contain elevated concentrations of Cu due to its addition to animal feed, or its use in foot baths to prevent foot rot.

Table 1. Common Cu Sources[1,9.]

Source	Formula	Cu, %
Copper Sulfate	$CuSO_4\ 5H_2O$	25
Copper Chelate EDTA	Na_2Cu EDTA	13
Copper Sulfate monohydrate	$CuSO_4\ H_2O$	35
Copper Acetate	$Cu(CH_3COO)_2\ H_2O$	32
Copper Ammonium Phosphate	$CuNH_4PO_4\ H_2O$	32
Cupric Oxide	CuO	75
Cuprous Oxide	Cu_2O	89
Animal Manures[2]	-	0.002 - 0.07
Biosolids[3]	-	<0.43; mean 0.074

Rate: Where crop deficiencies have been identified, the right rate depends on the specific Cu source. Copper fertilizers vary in their Cu content and solubility in soil. For example, rates of 3 to 14 lb/A of Cu as copper sulfate or around 0.5 lb/A of Cu as chelate are used for soil application, with lower rates for foliar application.

Time: Since Cu is tightly retained in soil, the timing of soil applications is flexible, and Cu availability can be improved for several years following a single application. Foliar applications are usually limited to emergency situations where the deficiency is identified after planting, or as part of a maintenance foliar fertilization program.

Place: Effectiveness of Cu delivery is increased by thoroughly mixing fertilizers into the root zone or by band application near the seed row. The risk of root injury increases when a high rate of Cu is band applied near the seed.

Copper Deficiency Symptoms

Copper deficiency symptoms vary with the crop. Mild or moderate deficiency may reduce yield or plant growth without clear signs. Copper does not move in the plant, so symptoms appear first in younger growth.

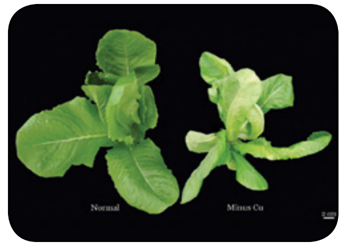
This information was originally developed by the International Plant Nutrition Institute.

IPNI2010PPI05-2460

Healthy to severely Cu deficient wheat heads, showing signs of melanosis.

IPNI2010PPI06-1766

"Pig-tailing" of wheat leaves is a common copper deficiency symptom.



D. PITCHAY

Copper deficiency in lettuce compared with normal growth (left).

IPNI2010PPI05-2302

Copper deficiency in citrus.

In corn and small grains, young leaves become yellow and stunted; early symptoms may be confused with those of frost or drought. In advanced stages, leaves may brown at the margins similar to potassium (K) deficiency symptoms. In small grains, ergot infection, stem melanosis, take-all root rot, and Fusarium head blight can increase when Cu is deficient. Browning of the head and bending of the stem at maturity are common signs of Cu deficiency in wheat and barley. The heads are often empty and contain shriveled grain.

In many vegetable crops, leaves may look wilted, turn a bluishgreenish cast before turning yellow and curling, and flower production fails.

Copper Toxicity Symptoms

Copper toxicities can occur after repeated applications of manures, biosolids or pesticides that are high in Cu. Symptoms of toxicity include reduced shoot vigor, poorly developed root systems, discolored roots, and leaf chlorosis (yellowing). They can be confused with symptoms of Fe deficiency. Crop species differ markedly in tolerance; for example, bean tolerates Cu toxicity much better than corn does. Regulatory limits exist in some states to control the application of Cu-rich manures to land.

Crop Response to Copper

Crop species and cultivars vary considerably in their sensitivity to Cu deficiency and in their response to Cu application (**Table 2**). Sensitivity to Cu toxicity does not necessarily follow the reverse order. A set of 115 field trials on spring wheat in the Prairie Provinces of Canada found an 87 percent frequency of grain yield response to applied Cu where the DTPA-extractable Cu in the soil was less than 0.4 ppm5. Grain yield response to added Cu at these concentrations averaged 47 percent, and at soil test levels between 0.4 and 0.8 ppm, the yield boost averaged 10 percent. While the soil test was effective at identifying deficiencies, the frequency of profitable response to applied Cu ranged from 19 to 77 percent (depending on wheat price and required rate of return) for soils testing below 0.4 ppm, and was very rare at higher Cu concentrations.

In North Dakota, a concentration below 0.4 ppm of the DTPA extractable Cu correctly identified four of ten sites where Cu application reduced Fusarium head blight in spring wheat.6 Reducing this disease may have great economic value in some years. The soil test did not correlate well to predicting yield increases to added Cu. In Australia, critical DTPA-extractable Cu concentration is around 0.12 ppm, but this test has moderate to poor reliability. When tissue concentrations of Cu in the youngest expanded leaf blade in wheat

Table 2. Crop sensitivity to Cu deficiency.[1,4.]

Medium Response	Medium Response	Least Response
Alfalfa	Apples	Asparagus
Beet, Table	Barley	Bean
Canary Seed	Beet, Sugar	Canola
Carrot	Blueberry	Grass (forage)
Citrus	Broccoli	Grape
Flax	Cabbage	Lupine
Lettuce	Cauliflower	Pea
Oat	Celery	Peppermint
Onion	Clover	Pine
Rice	Corn	Potato
Spinach	Cucumber	Rapeseed
Sudan Grass	Parsnip	Rye
Wheat	Pineapple	Soybean
	Radish	Spearmint
	Sorghum	Turfgrass
	Strawberry	
	Timothy Grass	
	Tomato	
	Turnip	

References

1. Havlin, J. et al. 2014. Soil Fertility and Fertilizers, 8th edition.
2. Xiong, X. et al. 2010. Resources, Conservation and Recycling 54:985-990.
3. Lu, Q., et al. 2012. Applied and Environmental Soil Science article ID 201462.
4. Marschner, R. 1995. Mineral Nutrition of Higher Plants, 2nd edition.
5. Karamanos, R. et al. 2003. Can. J. Soil Sci. 83:213-221.
6. Franzen, D.W. et al. 2008. Agron. J. 100:371-375.
7. Brennan, R., et al. 1986 Aust. J. Exp. Agric. 37:115-124.
8. Norton, R. http://anz.ipni.net/article/ANZ-3214. Accessed Apr. 2015.
9. Martens, D.C. and D.T. Westerman. 1991. In, Mortvedt et al., eds.,