UNIVERSITY OF GEORGIA
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MANGANESE (Mn) – TREE ESSENTIAL ELEMENT

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Manganese (Mn) is a hard, whitish-gray metal not found in its pure form in nature. It can exist as seven isotopes, one stable, five short-lived and one long-lived (~3.7 million years). It was discovered in 1774 and was named from the Latin word for "magnet." Manganese is similar to iron in it will rust. It is used in steel making, as a glass colorant, and in batteries.

In Trees

Manganese is taken up in a tree as the ion Mn++. Other manganese ions in a soil are converted to Mn++ for uptake. Figure 1. Manganese is a metal used in small amounts, but essential to a number of key processes in trees. Manganese performs three dominant roles in trees:

1) Parts of enzymes like the water splitting enzyme in light harvesting center two (LHCII);
2) Within the superoxide dismutase enzyme; and,
3) Activator / modifier of many enzymes including many in the citric acid cycle.

For example, manganese helps facilitate photosynthesis. Manganese serves as the center block upon which water is split at the start of photosynthesis (LHCII) and oxygen is given off. Manganese is also part of a scavenger enzyme which removes damaging oxygen radicals inside cells (antioxidant). Deficiency symptoms can quickly occur physiologically downstream from any these points.

Manganese stimulates and supports amino acid and lignin synthesis. Pest resistance in trees is facilitated by manganese through increasing lignification, generating more defensive compounds, and chemically inhibiting several fungal enzymes. In some uses in a tree, manganese and magnesium are interchangeable in limited amounts.

Manganese is an essential elements tied in many ways to oxygen management in a tree. Manganese is immobile to intermediately mobile in a tree, and any deficiency will tend to show on new tissues. Figure 2. Deficiency is usually seen on fully expanded new leaves, not on forming leaves.

In Soils

Manganese is commonly deficient in soil with a pH from 7.3 - 8.5, as well as soils with free calcium carbonate (CaCO3). Generally as pH increases, manganese availability declines sharply. At pH 7.3 to 10.0, manganese is poorly available or unavailable to trees. Organic soils and soils with high concentrations of composted organic matter tend to tie-up manganese. Figure 3.

Element Availability Problems

Manganese deficiency commonly generates uneven mottled yellowing and bleaching between leaf veins mimicking iron deficiency (iron deficiency presents more evenly through out tissues). Leaves and new shoots will show dead patches, marginal and tip bleaching, and discolored streaks. Leaf veins may become darker as blades become more yellow in color. Manganese may also present with stunted tissues. Figure 4.

In trees, manganese deficiency symptoms usually occur around the outside of middle crown areas while magnesium deficiency are usually seen at crown top in new tissues. The time between yellowing and bleaching of leaf tissues and death is usually short. Manganese deficiency is mistaken and misdiagnosed for magnesium, iron, or sulfur deficiencies.

Manganese toxicity occurs in anaerobic and acid soils (along with cobalt and nickel). Under these conditions of manganese toxicity, periderm lesions, leaf deformation and speckling can occur. Figure 5. More and more manganese is taken up as soil pH falls (becomes more acidic).

Figure 6 provides an essential element summary sheet for manganese. Manganese is needed in a tree around the 45ppm range. Added manganese is antagonistic to the availability of many other tree essential elements. Manganese availability does have a synergistic relationship with availability of the ammonium form of nitrogen

Assessment

Manganese shares both toxic and deficiency symptoms with many other essential elements in trees. Proper identification of the cause for toxicity or deficiency symptoms must, at the least, involve tissue analysis for deficiencies and soil testing for toxicities.

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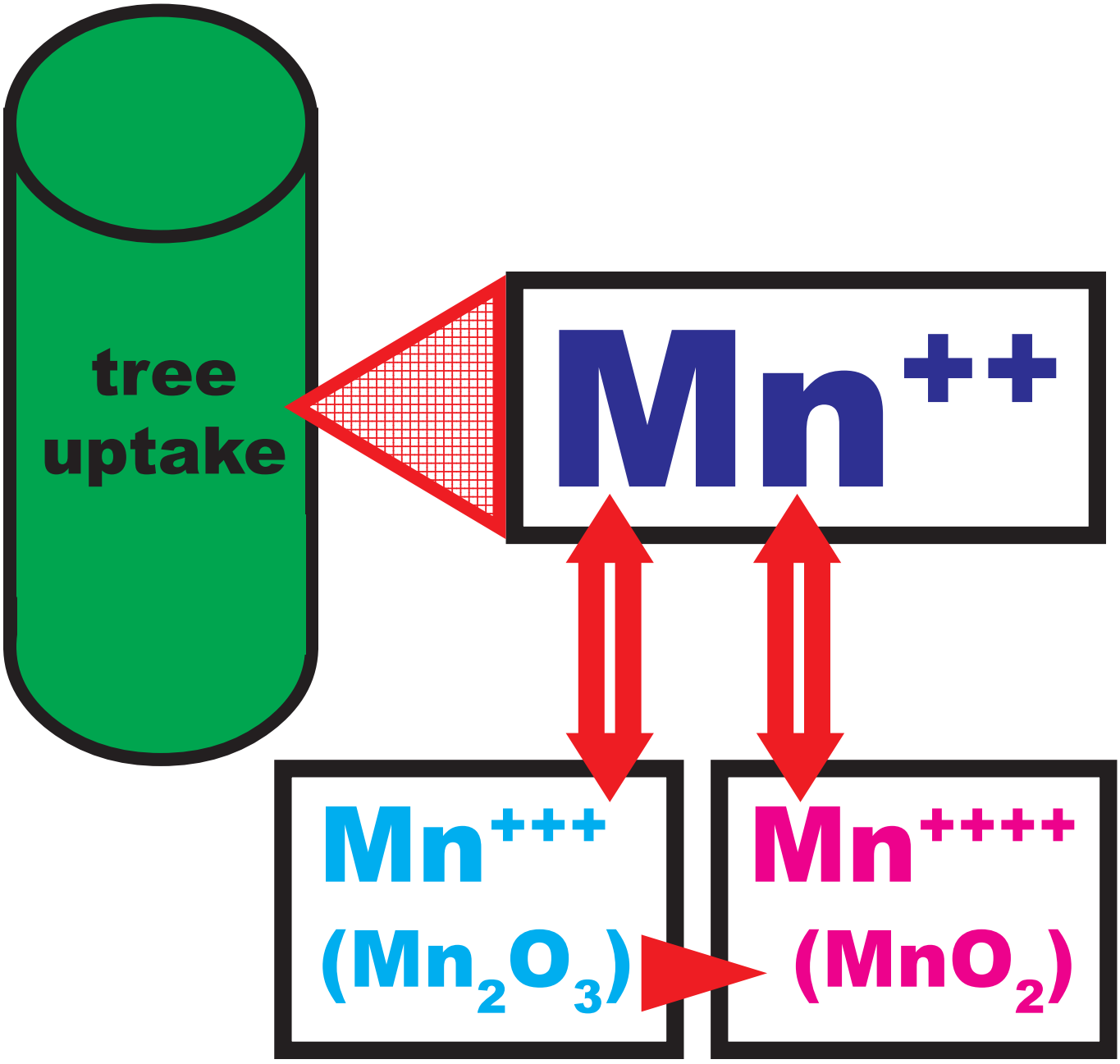

Figure 1: Conversions of manganese (Mn) in a healthy soil. Mn^{++} is the ion form in soil solution and on soil exchange sites available to trees.

symptom's tissue location	element mobility inside tree	element causing deficiency
new tissues	immobile	Mn – also B, Ca, Co, Cu, Fe, Ni, S, Zn
diffuse across tree	mobile / immobile	Mn – also Mo, S, Zn

Figure 2: Symptom location of manganese deficiency in a tree. Manganese is considered immobile to intermediate among elements for mobility within a tree. (immobile rank 7th).

Figure 3: Estimated relative availability of manganese (Mn) in soil associatd with soil pH level.

tree part	primary symptom	element deficiency responsible
roots	stunted / damaged	Mn -- also B, Cl, Cu, N, Ni, P, K, S, Si, Zn
	increase pest effectiveness	Mn -- also Ca, K, Mg, Si
shoots	stunted / damaged / killed	Mn -- also B, Ca, Cl, Cu, Fe, Mo, N, Ni, P, K, S, Zn
leaves	color -- dark viens	Mn -- also Cu, P, Zn
	color – general chlorosis	Mn -- also B, Cl, Cu, Fe, K, Mg, Mo, Ni, S, Zn
	intervienal chlorosis / death	Mn -- also Fe, Mg, Mo, Ni, S, Zn
	stunted / distorted blades	Mn -- also B, Cl, Cu, K, Mg, Mo, N, Ni, Zn
whole tree	increase pest effectiveness	Mn -- also B, Cl, K, Mg, Ni, Si

Figure 4: When deficient, manganese has been cited as generating these symptoms in trees.

tree part	primary symptom	element cauing toxicity
roots	root browning / death	Mn – also Fe, Ni
shoots	periderm lesions	Mn – also Ni
leaves	color -- chlorosis	Mn – also B, Ca, Cl, Co, Cu, Ni
	curling / cupping / distorted	Mn – also Cl, Mo, Ni
	marginal burn / scorch	Mn – also B, Cl,Ni
	brown lesions	Mn -- also Fe

Figure 5: When toxic, manganese has been cited as generating these symptoms in trees.

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Mn MANGANESE

element symbol

element number	**25**
element family type	**METALS**
normal form of pure element at biological temperatures	**SOLID METAL**
average rounded atomic weight	**55**
number of native isotopes	**1**
concentration group	**DEKA-ELEMENT**
element concentration in tree (ppm)	**45**
element proportion in tree (carbon & oxygen levels = 450,000)	**100**
element concentration rank in tree (carbon & oxygen rank = 1)	**12**
relative tree concentration (compared to element in Earth's crust)	**>**
different chemical oxidation states	**5**
most stable chemical oxidation state	**2**
oxidation states within a biologic compound	**+2/+7**
oxidation states as a biologic active center	**+1/-3**
total oxidation state range in biologics	**5**

among tree essential elements --

relative atomic radius	**LARGE**
relative ionic radius	**MEDIUM**
relative first ionization energy	**MEDIUM**
relative atomic density	**HIGH**

other element family members (*toxic) **Tc, Re**

most commonly available tree form (form in bold dominant) **Mn^{+2},** Mn^{+4}

solubility of element's compounds --

Mn++ insoluble = O^{--}, S^{--}, OH^{-}, $CO3^{--}$

Mn++ soluble = NO_3^{-}, SO_4^{--}, $C_2H_3O_2^{-}$

Coder Element Interaction Matrix for Trees (CEIMT)

(+ = positive or synergistic; - = negative or antagonistic)

B -	Ca -	Cl O	Co -	Cu +-	Fe -	K -	Mg -	Mn X
Mo -	N_a +	N_n -	Ni -	P +-	S O	Si -	Zn -	

Figure 6: Chemical summary sheet for manganese.