UNIVERSITY OF GEORGIA
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ZINC (Zn) – TREE ESSENTIAL ELEMENT

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Zinc (Zn) is a hard, brittle, bluish-silver metal resistant to corrosion. Zinc can exist in ten isotopes, five stable, and the rest all short-lived. It was known in the 1200s in India, and later identified and named from German for "tin." It is used for galvanizing steel, and in batteries, coins, castings, paints, sunscreen, photocopiers, and cathode ray tubes.

In Trees

Zinc is a required metal in trees. Zinc is a divalent (+2) metal cation, but unlike most other metals, does not undergo valence changes (i.e. no oxidation / reduction cycles). There are many zinc using or zinc activated enzymes in trees. Zinc functions to activate proteins, sometimes as an active site, and sometime as a structural or conformational component. Many times zinc is seen cross-linking sulfur in proteins.

Zinc performs two dominant roles in trees:1) Part of several enzymes constituents; and, 2) Activator / modifier of several enzymes.

For example, zinc is required in trees for the proper transcription of DNA and gene expression. It is a key component in photosynthetic enzymes. Zinc is required for growth regulator (auxin) synthesis and for combining amino acids into proteins. Under anaerobic conditions, zinc helps detoxify alcohol accumulation. Deficiency symptoms can quickly occur physiologically downstream from any of these points.

In Soils

In soil, zinc at low to neutral pH is found in the form Zn2+, and at high pH is found in the form of ZnOH+. At pH 8.2 to 10.0, zinc is poorly available or unavailable to trees. High pH (>8.2) tends to generate insoluble zinc (ZnCO3) and produce zinc deficiencies in trees. Figure 1. Figure 2.

Element Availability Problems

Zinc is cited as being intermediate in mobility within a tree, but deficiency symptoms can occur in both new tissues and in all tissues equally. Figure 3. Zinc deficiency in trees is first seen as leaves darkening and taking on a blue-green color which fades into a general yellowing. Leaves become stunted with a mottled appearance between the veins. Leaves eventually become distorted and die. Tree shoots become distorted, stunted with internodes not expanding, and die. Roots tend to exude gums and resins, and stop growth. Zinc deficiency is common in highly weathered and calcium rich soils with pH

>8.2 where zinc becomes insoluble. In organic soils, or soils with a large amount of composted organic matter, zinc tends to become bound up and unavailable. Figure 4

As zinc becomes more deficient, more phosphorus is taken up by trees. Zinc competes with nickel for transport and activation sites generating zinc deficiencies when nickel concentrations are too great. High concentrations of zinc suppresses potassium, calcium, and magnesium. Figure 5. Under anaerobic conditions, or through enrichment, cobalt minimizes problems of high zinc concentrations.

Zinc is easily added to enrich tree sites with many effective and low cost products. Traditionally, zinc nitrate ($Zn(NO3)2$) as a 1% foliar application has been used to small trees and shrubs. In some cases and under some conditions, this foliar spray can cause leaf damage. Using ZnSO4 as a 0.18% solution with hydrated lime has been cited as preventing zinc damage to leaves as a foliar spray. Zinc has not been found to be effective as a trunk injection or implant. Mycorrhizae in trees tend to mitigate and protect trees from zinc toxicity impacts.

Assessment

Zinc shares deficiency symptoms with many other essential elements in trees. Proper identification of the cause for deficiency symptoms must, at the least, involve both tissue analysis for deficiencies and soil testing for general elemental levels.

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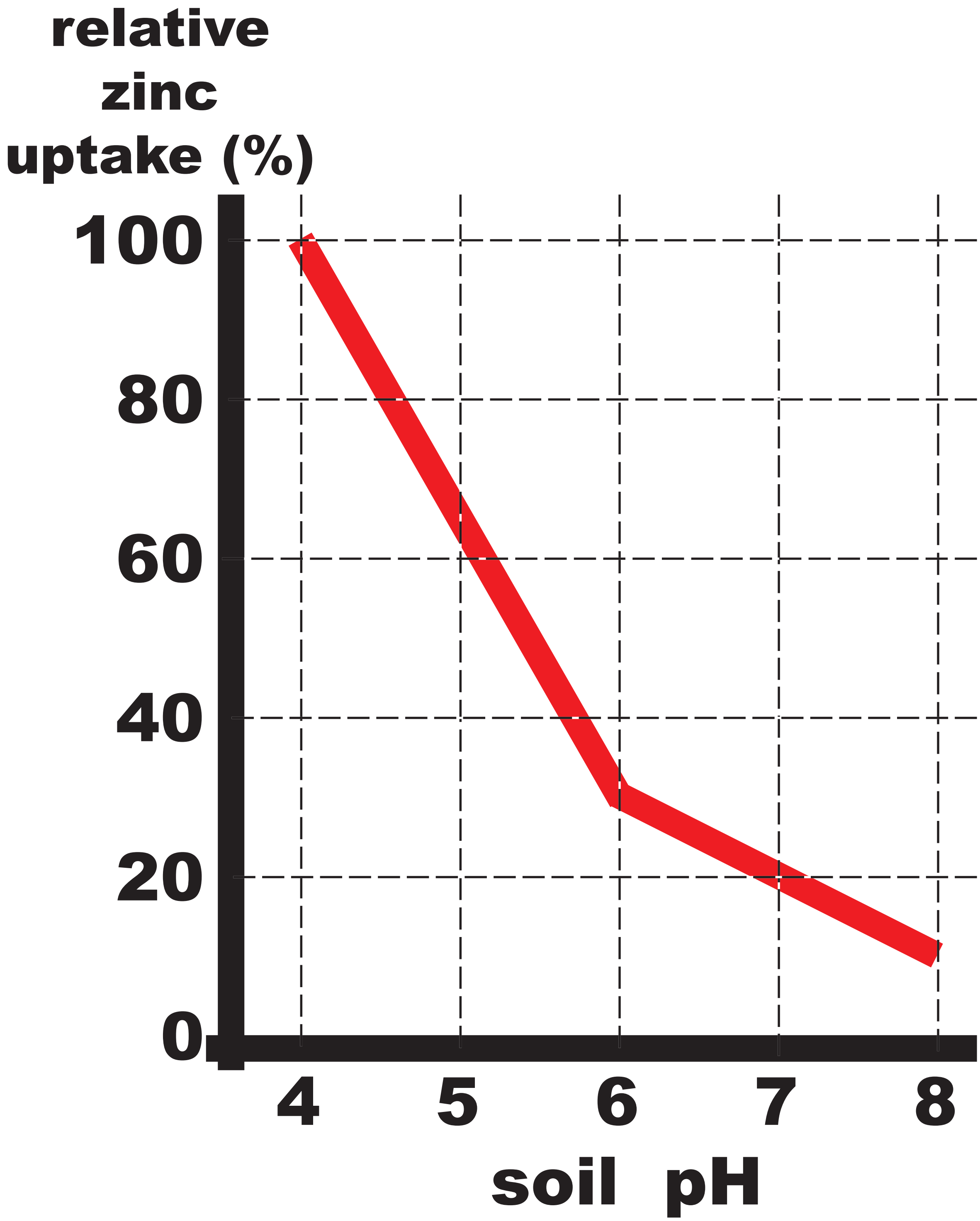

Figure 1: Estimated impact of soil pH on relative zinc (Zn) uptake in percent.

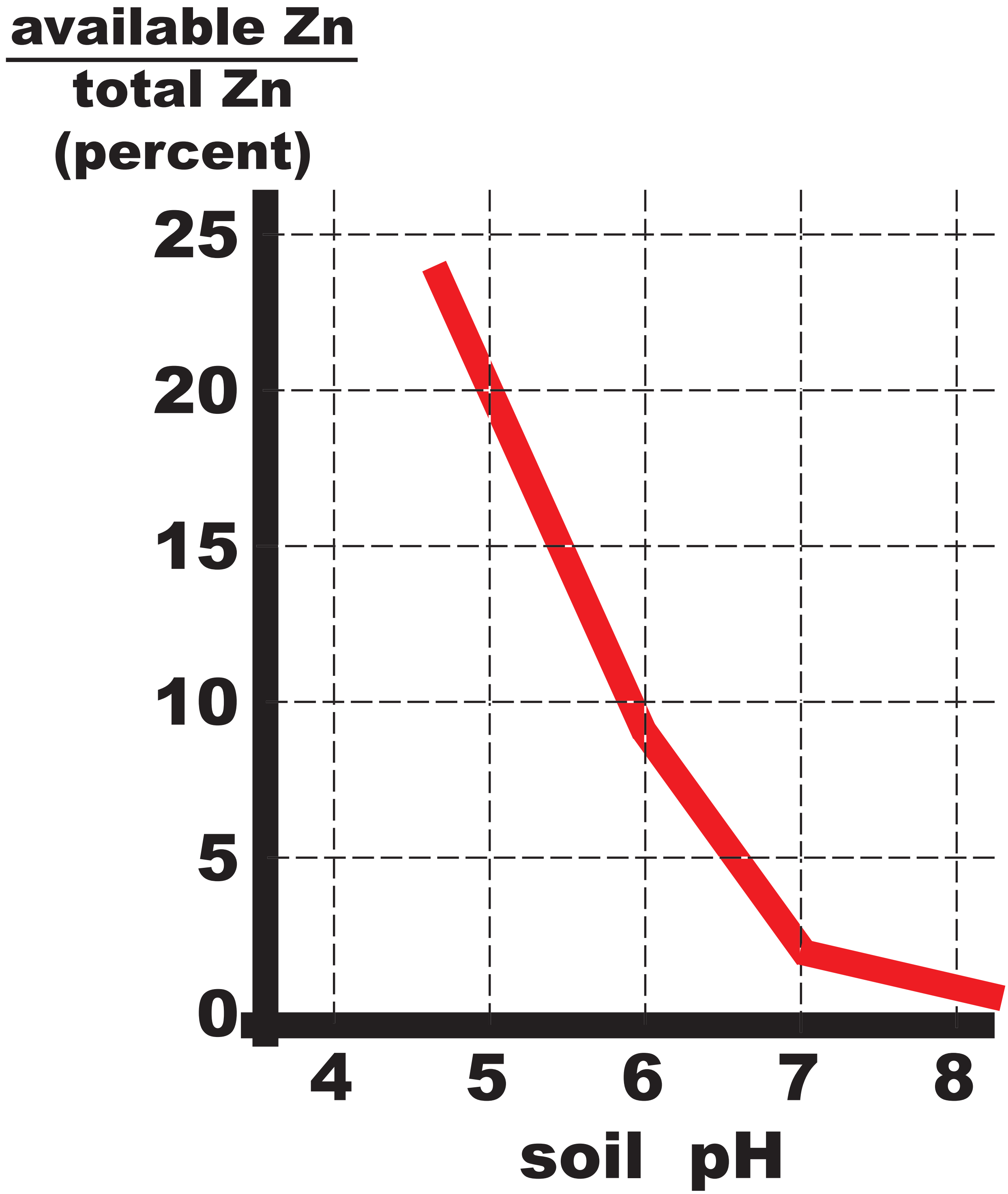

Figure 2: Estimated soil pH impact on tree available zinc (Zn) as a percent of total soil zinc (Zn) concentration.

symptom tissue location & age	element mobility inside tree	causal elemental deficiency
new tissues	immobile	Zn -- also B, Ca, Co, Cu, Fe, Mn, Ni, S
all tissues equally	mobile	Zn -- also Cl, Cu, K, Ni, N, P, Si
intermediate	mobile / immobile	Zn -- also Mn, Mo, S

Figure 3: Symptom location of zinc deficiency in a tree. Zinc is considered an intermediate among elements for mobility within a tree (immobile rank 8th).

tree part	primary symptom	element deficiency responsible
roots	stunted / damaged	Zn -- also B, Cl, Cu, Mn, N, Ni, P, K, S, Si
	gum exuded (exanthema)	Zn -- also Cu
shoots	stunted / damaged / killed	Zn -- also B, Ca, Cl, Cu, Fe, Mn, Mo, N, Ni, P, K, S
	gum exuded (exanthema)	Zn -- also Cu
young leaf	wilting	Zn -- also B, Cl, Cu, K, Mo
leaves	color -- blue-green / dark	Zn -- also Cl, K, P
	color -- dark viens	Zn -- also Cu, Mn, P
	color -- general chlorosis	Zn -- also B, Cl, Cu, Fe, K, Mg, Mo, Mn, Ni, S
	intervienal chlorosis / death	Zn -- also Fe, Mg, Mo, Mn, Ni, S
	stunted / distorted blades	Zn -- also B, Cl, Cu, K, Mg, Mn, Mo, N, N
whole tree	growth regulator disruption / dysfunction	Zn -- also Co

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

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Zn

element symbol

ZINC

element number	30
element family type	METALS
normal form of pure element at biological temperatures	SOLID METAL
average rounded atomic weight	65
number of native isotopes	4
concentration group	DEKA-ELEMENT
element concentration in tree (ppm)	38
element proportion in tree (carbon & oxygen levels = 450,000)	85
element concentration rank in tree (carbon & oxygen rank = 1)	13
relative tree concentration (compared to element in Earth's crust)	>
different chemical oxidation states	1
most stable chemical oxidation state	2
oxidation states within a biologic compound	+2
oxidation states as a biologic active center	+2
total oxidation state range in biologics	1

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) **Cd*, Hg***

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

solubility of element's compounds --

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

Zn++ 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 -
Mo O	N_a -	N_n -	Ni -	P -	S -	Si O	Zn X	

Figure 5: Chemical summary sheet for zinc.