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# IRON (Fe) – TREE ESSENTIAL ELEMENT

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Iron (Fe) is a shiny, silver-white, easily corroded metal. Iron can exist as eight isotopes, four stable, one long-lived (~1.5 million years), and three short-lived. Iron was known to early people and its name is from Anglo-Saxon. It is the most common metal in our culture. It is never found in its pure form. Iron is used in steel making. It is one of the few elements which is magnetic.

## In Trees

Iron is a universal component of plant life. Trees use iron in a myriad of tasks. Iron is stored in trees as ferritin, an iron complex protein. Iron is used in a tree in heme and iron-sulfur proteins which utilize the reversible energy states of iron. The heme groups play an important part in attracting damaging oxygen radicals, especially in photorespiration and when the tree is under anaerobic conditions. The iron-sulfur proteins are used throughout the tree in electron transport chains. Deficiency symptoms can quickly occur physiologically downstream from any iron using point.

Iron performs two dominant roles in trees: 1) Structural and active parts of enzymes and metabolites like heme pigments, ferredoxin and iron-sulfur proteins; and, 2) As an activator / modifier of enzymes through out the tree.

For example of iron use in trees, iron-sulfur and iron-copper combinations are responsible for almost all electron conserving processes in a tree including ATP production. The photosynthetic system is filled with iron containing electron transport materials like cytochromes and ferredoxin. Iron is also critical to nitrogen and sulfur metabolism processes. Chlorophyll production and maintenance requires iron, and both processes are sensitive to deficiency. Iron also is used with copper in the final respiration step in trees reducing oxygen to water.

## In Soil

Iron is found in two ionic forms in soil, ferrous ($Fe^{++}$) and ferric ($Fe^{+++}$). Iron in aerobic soil exists either as insoluble oxides or in the ferric form ($Fe^{+++}$) bound within organic compounds. In the tree, iron is taken up by membrane carriers in the ferrous form which is then processed using cell energy into the ferric form. Tree roots exude protons and organic acids which lowers rhizosphere pH and increases iron solubility while facilitating binding of iron into organic structures. This process also occurs with phosphates. At soil pH 7.3 to 10.0, iron is poorly available or unavailable to trees.

## Element Availability Problems

Iron deficiency is similar to manganese deficiency. The deficiency symptoms are concentrated in young tissues because iron, once placed, is immobile. Figure 1. In young leaves yellowing occurs between vascular bundles (veins). Eventually the entire leaf yellows and begins to prematurely senescence. Soil with high pH (more basic), high calcium concentrations, and / or high calcium carbonate concentrations (lime) accelerate iron immobilization within leaves and associated tissue yellowing and bleaching. Figure 2. High manganese, copper, and zinc concentrations, especially under acid conditions, can also lead to iron deficiencies. Figure 3.

Soil compaction, over watering / flooding (anaerobic conditions), and high pH lead to iron deficiency. Iron is minimally soluble in a soil between a pH of 7.0 and 9.0. Above pH 6, insoluble iron-phosphate complexes are generated also minimizing phosphorus availability. Iron concentrations are very low on calcareous soils especially around pH 8.0. Iron toxicity can occur when too much iron is added to an acid soil. Figure 4. The tree roots will appear brown and dead, and leaves will darken and die without abscission. Fertilization with iron should be in the form of an organic compound or as iron phosphate.

Assessment

Iron shares toxic and deficiency symptoms with many other essential elements. 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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| symptom tissue location | element mobility | element deficiency |
|---|---|---|
| new tissues | immobile | Fe -- also B, Ca, Co, Cu, Mn, Ni, S, Zn |

Figure 1: Iron is considered the most immobile element (immobile rank #1) with deficiency symptoms developing first in new tissues.

| tree part | primary symptom | element deficiency |
|---|---|---|
| shoots | stunted / damaged / killed | |
| | | Fe -- also B, Ca, Cl, Cu, Mn, Mo, N, Ni, P, K, S, Zn |
| leaves | bleaching white | |
| | | Fe |
| | general chlorosis | |
| | | Fe -- also B, Cl, Cu, K, Mg, Mo, Mn, Ni, S, Zn |
| | intervienal chlorosis / death | |
| | | Fe -- also Mg, Mo, Mn, Ni, S, Zn |

Figure 2: When deficient, iron has been cited as generating these tree symptoms.

**Fe**

element symbol

# IRON

| | |
|---|---|
| element number | **26** |
| element family type | **METALS** |
| normal form of pure element at biological temperatures | **SOILD METAL** |
| average rounded atomic weight | **56** |
| number of native isotopes | **3** |
| concentration group | **DEKA-ELEMENT** |
| element concentration in tree (ppm) | **75** |
| element proportion in tree (carbon & oxygen levels = 450,000) | **170** |
| element concentration rank in tree (carbon & oxygen rank = 1) | **11** |
| relative tree concentration (compared to element in Earth's crust) | **>** |
| different chemical oxidation states | **2** |
| most stable chemical oxidation state | **3** |
| oxidation states within a biologic compound | **+2/-3** |
| oxidation states as a biologic active center | **+1/-2** |
| total oxidation state range in biologics | **4** |

among tree essential elements --

| | |
|---|---|
| relative atomic radius | **MEDIUM** |
| relative ionic radius | **MEDIUM** |
| relative first ionization energy | **MEDIUM** |
| relative atomic density | **HIGH** |

other element family members (*toxic) **Ru, Os***

most commonly available tree form (form in bold dominant) $Fe^{+2}$, **$Fe^{+3}$**

solubility of element's compounds --

| | | |
|---|---|---|
| **Fe++** | **insoluble** | **= $O^{--}$, $S^{--}$, $OH^{-}$** |
| **Fe++** | **soluble** | **= $NO_3^{-}$, $SO_4^{--}$, $C_2H_3O_2^{-}$, $CO3^{--}$ (slightly)** |
| **Fe+++** | **insoluble** | **= $O^{--}$, $S^{--}$, $OH^{-}$, $CO_3^{--}$, $C_2H_3O_2^{-}$** |
| **Fe+++** | **soluble** | **= $NO_3^{-}$, $SO_4^{--}$** |

## Coder Element Interaction Matrix for Trees (CEIMT)

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

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

Figure 3: Chemical summary sheet for iron.

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| tree part | primary symptom | element toxicity |
|---|---|---|
| roots | root browning / death | Fe -- also Mn, Ni |
| leaves | darkened yellow-brown | Fe -- also Mg |
| | brown lesions | Fe -- also Mn |

Figure 4: When toxic, iron has been cited as generating these tree symptoms.