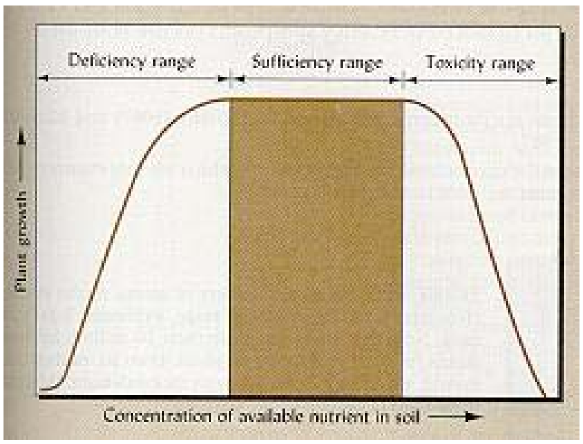
Micronutrients

Co, Cu, Fe, Mn, Ni, Zn (cations)
B, Cl, Mo (anions)

These are referred to as micronutrients because their concentration in plants is about 1 / 10 or less than concentration of macronutrients.

Deficiency and Toxicity

Deficiency, *sufficiency* and *toxicity* ranges



Causes of deficiencies

High yields remove substantial amounts
High analysis fertilizers contain few micronutrient impurities
Better understanding of plant nutrition and improved methods of plant and soil analysis

Causes of toxicities

Sufficiency range is narrow
Wet (reducing) conditions and low pH may increase Fe and Mn to toxic concentrations
Incidental applications, like Cu and Zn in sludge or B and Mo in irrigation water

Roles in Plant Nutrition

Various functions in enzyme systems. Note that since micronutrients are immobile in plant, deficiency symptoms appear on younger tissue.

Iron deficiency in peach.

Manganese toxicity in cotton.

Sources of Micronutrients

Inorganic sources

Include the structure of primary and secondary minerals and surface adsorbed or bound ions.

Organic combinations

Generally less important but chelates aid availability

Soil Conditions Associated with Micronutrient Deficiencies

Acid sandy soils	Low levels present
Organic soils	Levels may be low
High pH	Cations less soluble
Intensively farmed	Depleted

Availability of Cations

pH

$Fe^{3+} + OH^{-}$ <=> $FeOH^{2+}$
$FeOH^{2+} + OH^{-}$ <=> $Fe(OH)_2^{+}$
$Fe(OH)_2^{+} + OH^{-}$ <=> $Fe(OH)_3$ precipitate

Overliming may induce deficiencies.

Redox conditions (aeration)

Reduced forms are more soluble Fe^{2+} > Fe^{3+} and Mn^{2+}> Mn^{4+}. Toxicity is possible if pH is sufficiently low. Conversely, under well aerated (oxidizing) and high pH conditions, metal deficiencies are possible.

Anions

Cl^{-} is present in soils in relatively large amounts. It is deposited from the atmosphere and applied in KCl fertilizer.

B deficiency is common. Its availability greatest at low pH but readily leached from acid, sandy soil.

H_3BO_3 <=> $H^{+} + H_2BO_3^{-}$

It is bound to mineral and organic colloids and its availability lowest pH 7 to 9.

Mo shows increasing availability increases with pH.

H_2MoO_4 W $H^{+} + HMoO_4^{-}$
$HMoO_4^{-}$ W $H^{+} + MoO_4^{2-}$

MoO_4^{2-} is the dominant form at pH > 6. Liming increases its availability.

Chelates

Organometallic complexes with 2 or more sites capable of bonding to metal.

These include natural products released by plants or components of soil humus. There are also synthetic chelate amendments. Chelates may increase the solubility and availability of micronutrients by increasing the solution (in chelated form) concentration, for example

$Fe(OH)_3 + EDTA^{4-}$ W$FeEDTA^{-} + 3OH^{-}$

Effectiveness of added metal chelate depends on its relative stability constant - the greater the tendency for formation of the chelated form the greater the solubility of the chelated metal. Problems may arise when a metal chelate is added to soil if the stability constant for added micronutrient is lower than the stability constant for another metal in soil. In this case, the added micronutrient tends to be replaced. For example, the stability constant for FeEDTA is greater than that for ZnEDTA so that

$ZnEDTA^{2-} + Fe^{3+}$ W $FeEDTA^{-} + Zn^{2+}$

Also, a chelated micronutrient added to the soil may also be displaced by a metal with a *lower* stability constant if the concentration of the second metal, like Ca^{2+} is large.

Despite these limitations, chelates are used with Cu, Mn, Zn and Fe. Often the problem with replacement is offset by slow replacement kinetics. Also, the chelate may be applied as a foliar spray or banded. Chelates are expensive but used.

Micronutrient Management

A few points

Important to maintain balance among micro-nutrients

Slightly acid pH 6 to 7 is generally optimal

Moisture and aeration affects availability of Fe and Mn

Banded application to soil more efficient than broadcast

Foliar sprays avoid fixation problem

Incorporation into fritted glass provides low concentration of micronutrients as glass weathers