Mineral Deficiencies, Toxicities, Diagnosis, and Corrections

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What is an essential nutrient?

• A component of plant structures, or involved in plant metabolism, whose absence results in:

  • Cell death
  • Severe abnormalities
  • An inability to complete its life cycle (successfully reproduce)
What are the essential nutrients?

• Macronutrients:
  • Primary
    • Nitrogen
    • Phosphorus
    • **Potassium**
  • Secondary
    • Calcium
    • Magnesium
    • Sulfur

• Micronutrients:
  • Iron
  • Manganese
  • **Boron**
  • Copper
  • **Zinc**
  • Molybdenum
  • Nickel

• Other:
  • Carbon
  • Hydrogen
  • Oxygen
Nutrient Mobility

- Soil mobile
  - Nitrogen (NO$_3^-$)
  - Sulfur
  - Boron
- Soil immobile
  - Phosphorus
  - Calcium
  - Magnesium
  - Potassium: mobility dependent on soil texture
  - Zinc
  - Manganese
  - Copper
  - Iron

- Plant mobile
  - Nitrogen
  - Phosphorus
  - Potassium
  - Magnesium
- Plant immobile
  - Boron: species dependent
  - Sulfur
  - Calcium
  - Zinc
  - Manganese
  - Copper
  - Iron
Nutrient Uptake in Plants

• Roots are taking up nutrients (generally) when leaves are on the trees
• Roots have a limited ability to take up nutrients in saturated conditions
• Roots can only take up nutrients from the soil solution
• Roots can only explore a tiny proportion of the soil surface area
Cation Exchange Capacity

- The Cation Exchange Capacity (CEC) is the soil’s ability to hold onto positively charged ions.
- Dependent on the amount and type of clay as well as organic matter.
- Inherent property of soils.
- The size of the CEC determines how many cations (nutrients) your soil can hold.
Cation Exchange Capacity

• NH$_4^+$
• K$^+$
• Mg$^{2+}$
• Ca$^{2+}$
• Na$^+$
• H$^+$
• Al$^{3+}$
• Other cations

• Anything positively charged can bind to the CEC
• Cations are not permanently bound to the CEC
• Soils with large CECs can hold more nutrients than soils with small CECs
Nutrient Availability in Soils - pH

- Nutrient availability is pH dependent
- The greatest availability of nutrients is between pH of 6 and 7.5

Figure 24.1 Effect of soil pH on relative availability of plant nutrients. A broad bar indicates high relative availability while a narrow bar indicates low availability.
Potassium

• Found in the soil in:
  • Soil minerals – mica, e.g.
  • Adsorbed to CEC
  • In the soil solution

• Taken up as K+

• Used by the plant in:
  • Involved in plant water status maintenance
  • Activates enzymes
Potassium

• Mobile in walnuts
• Pale older leaves
• Leaf edges fold up, curl in
• Leaf undersides develop grey cast
• Necrotic spotting on margins
• Leaf size, shoot growth reduced
• Nut size reduced
Potassium Fertilization

• 35-40 lbs K removed with 1 ton nuts
  • Only 12 lbs removed if hulls are returned to the field
• Fertilization only needed if deficiency symptoms present, or if growing in sandy or K fixing soils
• In sandy soils
  • Band, drill or fertigate 400 lbs/acre of K (for example, 900 lbs K$_2$SO$_4$)
Potassium Fixation: a special concern in Vermiculite rich soils

Slide credit: J. Caprile

Pettygrove et al, Better C
Potassium Fertilization

• 35-40 lbs K removed with 1 ton nuts
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• Fertilization only needed if deficiency symptoms present, or if growing in sandy or K fixing soils

• In sandy soils
  • Band, drill or fertigate 400 lbs/acre of K (for example, approx. 900 lbs K$_2$SO$_4$)

• In K fixing or clay soils
  • Band an initial application of 650 lbs K (for example, approx. 1500 lbs K$_2$SO$_4$)
  • Continue yearly maintenance applications of 200 lbs K/acre (approx. 400 lbs K$_2$SO$_4$ for example) until deficiency is remedied
Zinc

• Found in the soil:
  • Adsorbed and bound to other compounds (notably CaCO₃)
  • In the soil solution (in very low concentrations)

• Taken up as Zn²⁺

• Used by the plant in:
  • Enzyme catalyst for more than 300 enzymes
  • Involved in auxin biosynthesis
Zinc

- Immobile in walnuts
- Delayed opening of buds
- Small, chlorotic tufts of leaves, small nuts
- Interverinal chlorosis
- Wavy leaf margin
- Terminal dieback
- Increased oxidation in nuts

Photo: B. Beede
Zinc

Photo: B. Beede
Zinc Fertilization

• Soil applications
  • Trench 5-10 lbs ZnSO₄ per tree
  • Inject 5-20 gallons ZnSO₄ sulfate solution (1 lbs ZnSO₄ per gallon water) into the root zone
  • Broadcast 1-5 lbs zinc chelate pre-irrigation
  • Trench 10 lbs ZnSO₄ per tree and cover with 5 lbs sulfur in high pH soils

• Foliar applications
  • Mix 1-2 lbs of ZnSO₄ or zinc chelate in 100 gallons of water
  • Application rate should be 2-4 lbs Zn/acre
  • First application: just post bloom, when new growth is 6-10 inches long
  • Repeat a second or third time in 2-3 week intervals
Boron

• Found in the soil:
  • Adsorbed to clays, metal oxides, and organic matter
  • In the soil solution

• Taken up as $\text{B(OH}_3\text{)}$

• Used by the plant in:
  • Structural integrity of cell walls
  • Membrane function
  • pollination
Boron

- Weak growth
- Short internodes
- Misshapen leaves
- Terminal dieback
- Low yields

Photo: P. Brown
Boron Fertilization

• **Soil application**
  • **Broadcast** 50-75 lbs Borax per treated acre

• **Foliar application**
  • spray a mixture of 1 lbs Solubor per 100 gallons of water
  • Timing can be any time of the year, but best done during delayed dormancy or in the early growing season
    • Spraying during bloom can negatively affect pollen movement and flower health
Boron Toxicity

• Necrosis of the leaf tip and margins
• That appears in mid-late summer as levels accumulate in leaves
• Leaf curl and scorching of the entire canopy in severe cases
Boron Toxicity

• Switch to a low boron water source
• Leach from root zone
• Use tolerant rootstocks
  • Black most tolerant
  • English least tolerant
  • Paradox is in between
• Plant a tolerant crop
Chloride Toxicity

- Symptoms similar to boron toxicity
- Switch to higher quality water
- Leach (easily removed)
- Plant tolerant rootstocks
  - Black most tolerant
  - English least tolerant
  - Paradox in between
- Plant more tolerant crops
Soil Sampling

• Pre-planting soil sampling
  • Necessary for accurate picture of orchard
  • Samples should be to reasonable depth of rooting zone

• Routine soil sampling
  • Good for monitoring K, B, Na, Cl
Soil Sampling

• Sample 0-12 inches, discarding surface debris
• Pull samples from $\frac{1}{2}$ to $\frac{3}{4}$ of the wetted radius
Soil Sampling

- Sample 0-12 inches, discarding surface debris
- Pull samples from ½ to ¾ of the wetted radius
- Pull 8 to 12 subsamples for each sample
- Mix them WELL and send in one pound to a lab
Soil Sampling

• Don’t combine soil types
• Don’t combine irrigation blocks
• Don’t combine good and bad areas
Leaf Sampling

• Test yearly in July
• Useful for monitoring all nutrients
  • Exception: recent foliar micronutrient sprays
• Select terminal leaflet from 30-50 leaves on 20-30 trees
  • Don’t combine symptoms
  • Don’t combine soil types
  • Don’t combine irrigation blocks
  • Don’t combine varieties
# Leaf Sufficiency Values

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Deficient</th>
<th>Sufficient</th>
<th>Toxic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>&lt; 2.1%</td>
<td>2.2 – 3.2%</td>
<td>N/A</td>
</tr>
<tr>
<td>Potassium</td>
<td>&lt; 0.9%</td>
<td>&gt; 1.2%</td>
<td></td>
</tr>
<tr>
<td>Boron</td>
<td>&lt; 20 ppm</td>
<td>36 – 200 ppm</td>
<td>&gt; 300 ppm</td>
</tr>
<tr>
<td>Zinc</td>
<td>&lt; 18 ppm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium</td>
<td></td>
<td>&gt; 0.1%</td>
<td></td>
</tr>
<tr>
<td>Chloride</td>
<td></td>
<td>&gt; 0.3%</td>
<td></td>
</tr>
</tbody>
</table>
Questions?

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