Fertility Management

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13 Essential Nutrients

• Macronutrients:
  Nitrogen (N), Phosphorous (P), Potassium (K)

• Secondary Nutrients:
  Magnesium (Mg), Calcium (Ca), Sulfur (S)

• Micronutrients:
  Boron (B), Chlorine (Cl), Copper (Cu), Iron (Fe),
  Manganese (Mn), Molybdenum (Mo), Zinc (Zn)
Outline:

• General Concepts of Nutrient uptake
• Soil properties influencing uptake and availability
• Cover Crops and Mulches
• Impact of Production System
• Nitrogen
• Calcium
  – Function, Uptake and Managing Deficiency
• Boron
  – Function, Uptake and Managing Deficiency
• Tissue Sampling
• Nutrient Management Strategies
Nutrient Transport

- Nutrients must be dissolved (ion form) to be available for uptake

<table>
<thead>
<tr>
<th>Cations (+ charge)</th>
<th>Anions (- charge)</th>
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</thead>
<tbody>
<tr>
<td>Ammonium (NH$_4^+$)</td>
<td>Nitrate (NO$_3^-$)</td>
</tr>
<tr>
<td>Potassium (K$^+$)</td>
<td>Phosphate (H$_2$PO$_4^-$ and HPO$_4^{2-}$)</td>
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<tr>
<td>Calcium (Ca$^{2+}$)</td>
<td>Sulfate (SO$_4^{2-}$)</td>
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<tr>
<td>Magnesium (Mg$^{2+}$)</td>
<td>Borate (BO$_3^{-}$)</td>
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<tr>
<td>Manganese (Mn$^{2+}$)</td>
<td>Molybdate (MoO$_4^{2-}$)</td>
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<tr>
<td>Zinc (Zn$^+$)</td>
<td></td>
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<td>Iron (Fe$^{2+}$)</td>
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<tr>
<td>Copper (Cu$^+$)</td>
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Nutrient Uptake

• Roots have binding sites which selectively take up nutrients

• 3 main mechanisms:
  1) Interception - minor, only 1% of soil volume occupied by roots
  2) Mass Flow
  3) Diffusion
Nutrient Transport: Mass Flow

- Most important for N, Mg and Ca
- Ions are dissolved in solution and move with the mass flow of water
- Mass flow uptake is influenced by competition in the soil
Nutrient Transport: Diffusion

• Movement of ion from high to low concentration
• Most important for P and K (dependant on soil moisture, temperature, distance from root surface)
Soil: The Nutrient Bank

• Soil properties play an integral role in the availability of nutrients

• Soil factors affecting nutrient supply:
  – pH
  – Cation Exchange Capacity
  – Texture
  – Organic Matter
Soil pH

- Greatest nutrient availability with pH 5.5-6.5
Cation Exchange Capacity

• Calculated value that is an estimate of the soils ability to attract, retain, and exchange cation elements
• millequivalents per 100 grams of soil (meq/100g).
• Soils with high clay content (-ve charge) tend to have higher CEC
Soil Composition

• Texture
  – Ratio of Sand:Silt:Clay
  – High sand = low CEC
  – High clay= high CEC
  – Water holding capacity and movement

• Organic Matter:
  – Makes up 1-5% of soil
  – Influences nutrient availability in two ways:
    • Improves CEC
    • Decomposition of OM adds nutrients to soil
Floor Management

• Floor management practices directly impact tree/vine nutrient status and vigor
  – Mulch- increased nutrients
  – Cover Crop- time of competition and time of increased nutrient availability
  – Living mulch- competition for nutrients

• Mulch applications (especially legumes) increase nutrient content of tissue (N)
  – Increased insect and disease pressure

• Cover crop/living mulch
  – Can compete for nutrients and reduce vigor and nutrient uptake

• Can improve moisture management
  – Improved Ca management
IMPACT OF PRODUCTION SYSTEM
Low Vs. High Density Systems

• Tree density and size of tree at planting must be considered when developing nutrient management plan, especially Nitrogen

• High Density Systems
  – Plant highly feathered trees
  – Must be irrigated
  – Want to control vegetative growth in later years
NITROGEN
Role of Nitrogen in Plants

• Major component of the organic (carbon) compounds in the plant
  – Proteins, amino acids, DNA

• Essential component of the chlorophyll molecule
Nitrogen and Yield

• Adequate nitrogen at the appropriate time is essential for proper plant function which leads to high yield

• Increasing N does lead to higher dry matter however...

MORE GROWTH ≠ HIGH YIELD
or HEALTHY PLANTS!
Partitioning in the Plant

- High N application results in increased shoot growth and decreased root growth

Marschner, 1995, Fig. 8.16
High Density N Fertilization Years 1-3

• Highly feather trees require supplemental fertilizer (N) to support early growth
  – Nurseries should apply urea foliar spray before leaf drop to provide reserve in the trees
  – Spoon feed through the irrigation system 2 times/wk for 12 wks

• Forms of N readily available:
  – Calcium nitrate
  – Ammonium phosphate (?)
High Density N Fertilization Year 3 +

• Low fertilizer requirements required to keep trees ‘calm’
  – Minimal vegetative growth

• Consider soil fertility
  – 30-60 lb N/A
  – Can often be provided through mineralization

• Utilize soil and tissue analysis
CALCIUM:
Plant Function, Uptake and Deficiency
Calcium: Plant Function

- **Cell Wall Stabilization**
  - High content in middle lamella – cements cells together
  - Ca delays fruit softening by delaying degradation of cell wall polymers
  - Inhibits action of enzyme which causes tissue softening during ripening

Poovaiah et al (1988)
Calcium: Plant Function

- Cell Wall Stabilization Cont.
  - Ethylene and CO₂ production during storage (senescence)
  - May be a result of increased cell wall and membrane stability

Ethylene and CO₂ evolution on ‘Golden Delicious’ after 3 months storage

Calcium: Plant Function

• **Root and Shoot Growth**
  – Ca is essential for extension growth
  – As cell expands, Ca is released from cell wall and stimulates new cell wall construction
  – Loosened cell walls allow for expansion, then Ca is redeposit in the cell wall
Calcium: Plant Function

• **Directional Root Growth**
  - Ca accumulates at the bottom part of a root tip and causes differential growth which makes the root curve downward

• **Signal Molecule**
  - External stimuli that affect plant cells are transmitted across the cell membrane by ‘calcium waves’
Calcium: Supply

• Calcium is abundant in most temperate soils
  – +’ve charged ion which binds to soil particles so leaching is not a problem
  – Adding Ca to soil is not an effective method to deal with Ca deficiency
  – Uptake of Ca can only occur at the root tip where the root tissue is not yet fully developed
    • Active root growth is essential for Ca uptake
Calcium: Transport in Plants

- Calcium transport in plant is the main reason for deficiency
  - Root-shoot can take 3 days

- Calcium transport is restricted to xylem (water transport vessels)
  - Dependant on transpiration stream for movement
  - Accumulates in rapidly transpiring tissues
  - Fruit do not transpire as much but are growing rapidly

Kirby & Pilbeam (1894) Plant, Cell and Environ.
Calcium Deficiency

• Getting supply of Calcium to rapidly growing tissue is a challenge in many horticultural crops

• Poor correlation between tissue test and fruit or bud/flower content

• Fruit often has high demand but poor xylem development
Calcium Deficiency

• Bitter Pit/Cork Spot
  – Initial symptoms can begin 4-6 wks after petal fall when tissue have high respiration rates and ethylene production
  – Low levels of Ca alter membrane permeability and leads to cell injury

Photo: OMAFRA
Calcium Deficiency

- **Water Core** (aggravated by low Ca)
  - Pre-harvest disorder that results in water soaked flesh, not often visible on skin
  - Occurs in late harvest fruit exposed to low night temperatures
  - Result of accumulation of sorbitol-rich solution in the flesh
  - In moderate cases it can resolve in storage, but if severe, internal breakdown can occur
Managing Ca Deficiency:
Cultural Practices

• Maintain constant soil moisture
  – Excessive or deficient soil moisture causes drought stress and poor root growth
  – Fluctuations can result in bursts of vegetative growth alternating with water stress
  – Use of mulches can help reduce fluctuation
Managing Ca Deficiency: Cultural Practices

• **Maintain soil pH**
  
  – do not use fertilizers that reduce pH (Ammonium)
    
    • Low pH causes excessive Al and Mn availability and can restrict root growth and reduces availability of Ca

  – Avoid dolomitic lime unless Mg$^{2+}$ is needed
Managing Ca Deficiency:
Cultural Practices

• **Moderate Annual Crop Loads**
  – Avoid excessive dormant pruning
  – Proper thinning of flowers in spring

• **Avoid over fertilization**
  – Excess N, Mg$^{2+}$ or K$^+$ inhibit Ca$^{2+}$ uptake
  – Excess N causes too much vegetative growth
Managing Ca Deficiency:
Soil Amendments

• Gypsum (Calcium-Sulfate)
  – Relatively old practice
  – 2 Studies (MA and Nova Scotia) have shown that it can increase fruit Ca, but may be a response to effects on soil structure
Managing Ca Deficiency: Foliar Sprays

• Calcium Chloride sprays have been successful in controlling corking and bitter pit
  – Effective, low cost
  – Recommend 15-50 lbs/A per season in 6-8 cover sprays

• Many other products are available
  – Typically apply lower rates and are not as cost effective
  – Compare the cost per pound needed to achieve equivalent rate of lbs Ca/A
Managing Ca Deficiency: 
Foliar Sprays

• Some leaf injury can occur in wet, cool spring or hot, dry summer
  – If injury is noticed, reduce or skip a spray until after a rainfall

Ca burn on apples and leaves

Photos: BC Ministry of Ag and Lands
BORON:
Plant Function, Uptake and Deficiency
Boron: Plant Function

• Important role in cell wall synthesis and membrane stabilization

• Detoxifies phenolic substances that form in plant metabolism

• Essential for pollen tube elongation

Modified from Marshner, 1995, Fig.9.32)
Boron: Plant Uptake

• B is often deficient in Midwest fruit plantings

• Most B is found in organic matter
  – Soils low in OM tend to have more deficiency problems

• B becomes more available for uptake in acid conditions
  – Soils with pH > 7 more likely to be deficient
Boron Deficiency

• Symptoms occur in fruit and vegetative tissue

• Symptoms first visible in the spring
  – Failure of buds to break dormancy
  – Shoot die back
  – Blossom blasting (pear)
Managing Boron Deficiency

• Maintain high organic matter

• Maintain soil pH < 7

• Boron fertilizer application
  – No more than 5lbs/A
  – Minor deficiency – soil fertilizer (not useful if deficiency is due to high pH)
  – Severe deficiency can be corrected by foliar sprays
Boron Toxicity

• Occurs most often on acid soils – not often a problem in WI

• Symptoms- necrosis and chlorosis of lower leaf edges
Tissue Sampling

• Essential component of nutrient management plan
  – block should be sampled every 3 years

• Collect samples from different trees, but the same area on the tree

• Remove leaves from the middle section of new growth
Tissue Sampling

• Sampling dates: July 15-Aug 15

• ~ 60-70 leaves (10/sample)

• Include healthy comparison if you are testing for a deficiency
  – Remember to label samples!
  – Do not sample dead tissue
Long-Term Nutrient Management

• Soil nutrient levels do not change drastically from year to year
  – Monitoring levels can help track subtle changes over time and allow for intervention

• Manage your soils!
  – Maintain organic matter and pH levels

• Maintain constant water supply
Long-Term Nutrient Management

• Be aware of variables that can induce deficiency
  – Late harvest
  – Cold night temperatures late in season
  – Water status