Managing nutrition in high density apple and sweet cherry

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Nutrient management in apple and cherry

- compared with high density apple production little information is available for sweet cherry

- principles similar and can be applied to both
Nutrition and water management are linked

Water is

- a **solvent** for nutrients in the soil and plant
- a **transporting agent** for nutrients to the root and within the plant
- **irrigation management** is the key to nutrient placement and retention in root zone
Increasing density - more water and nutrient management options
Nutrient Availability

- Accessible to plant roots
- Timed to match demand
- Sufficient quantity
Root distribution under drip irrigation

Neilsen et al. 1997
Can. J. Plant Sci. 77
Nutrients can be targeted to where roots grow.
Nutrient solubility and mobility

- **Mobile nutrients** – N, B, Cl
  - remain dissolved in the soil solution
  - move by mass flow

- **Moderately mobile nutrients** – Ca, Mg, Na, K
  - remain dissolved in solution and are easily exchanged from soil particles
  - move by mass flow

- **Immobile nutrients** – K, P, Zn, Mn
  - fixed by soil
  - move by diffusion (occasionally mass flow)
Mobile nutrients – N, B
Mobile nutrients

- Nitrogen
  - very mobile
  - allows flexibility in application
  - but difficult to control
Control of soil N supply beneath drip emitter with fertigation

Neilsen et al. 1998
JASHS 123
N is stored in leaves.

Root-supplied

Summer

N is withdrawn from leaves and stored in roots and woody tissue.

Foliar sprays

Fall

Remobilised from storage within the tree.

Sources of N for growth in the spring

Root-supplied after bloom.

Timed to meet demand
## Contribution of stored N to vegetative growth

<table>
<thead>
<tr>
<th>Species</th>
<th>%</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walnut</td>
<td>88-92</td>
<td>Frak et al., 2002. Plant Phys. 130</td>
</tr>
<tr>
<td>Peach</td>
<td>38-46</td>
<td>Tagliavini et al., 1998 Tree Phys. 18</td>
</tr>
<tr>
<td>Sweet Cherry</td>
<td>12-27</td>
<td>Grassi et al., 2002 Plant, Cell, Env. 25</td>
</tr>
</tbody>
</table>
Leaf N moves into storage in the fall

As tree N status increases the amount of N moved into storage increases

Re-drawn from Cheng et al., 2002 J. Hort. Sci & Biotech 77
Fall applied foliar urea

- In trees with low leaf N, fall urea applications may increase N storage for growth next year.
- In high N trees foliar urea is not necessary.

Re-drawn from Cheng et al., 2002 J. Hort. Sci &Biotech 77
Contribution of winter storage N to tree performance in sweet cherry
Contribution of winter storage N to tree performance in sweet cherry

- Leaf stripping decreased fruit number & reduced yield
- Fruit development highly dependent on stored N
- Leaf stripping did not affect shoot leaf development (data not shown)
- Shoot growth more dependent on current season supply
Timing of N demand for growth in apple in relation to phenology

- Before full bloom leaf growth (spur leaves) supported by remobilized N
- Root uptake occurs mainly after bloom to support shoot and fruit growth
- N inflow into fruit occurs mainly after cell division

Guak et al. 2003, J. Exp. Bot 54
Neilsen et al., 2006 Acta Hort 721
Effect of timing of N applications on fruit for Gala/M.9 over 3 years

<table>
<thead>
<tr>
<th>N applications weeks after bloom</th>
<th>Significant (number of years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-4</td>
<td>1</td>
</tr>
<tr>
<td>4-8</td>
<td>1</td>
</tr>
<tr>
<td>8-12</td>
<td>1</td>
</tr>
</tbody>
</table>

### Response

- **Bloom**: 1
- **Yield**: 1
- **Size**: 1
- **SS**: 2
- **Malic acid**: 2
- **SS/Malic acid**: 2
- **Starch**: 3
- **% red**: Not significant
### Nitrogen amount - removal in fruit and senescent leaves of apple trees

<table>
<thead>
<tr>
<th>Variety</th>
<th>g/tree</th>
<th>kg/ha*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Golden Delicious/M.9 first year</td>
<td>2.7</td>
<td>8.9</td>
</tr>
<tr>
<td>Gala/M.9 third year</td>
<td>6.5</td>
<td>21.7</td>
</tr>
<tr>
<td>Elstar/M.9 fourth year</td>
<td>10.2</td>
<td>34.0</td>
</tr>
<tr>
<td>Gala/M.9 sixth year</td>
<td>12.3</td>
<td>41.0</td>
</tr>
</tbody>
</table>

• assumes a tree density of 3300 trees/ha (1336 trees/acre)

Neilsen et al. 2002
HortTechnology 12
Nitrogen requirements for sweet cherry

- most soils cannot supply sufficient N

- classic N deficiencies seen (pale, small leaves, leaf drop)

- recommend 2.2-3.4% leaf N

- ~50-130 kg N/ha recommended
  - high rate on sandy soil
  - low rates in soils with high organic matter

Hanson and Proebsting 1996 *in* ‘Cherries crop production and physiology’ (eds. Webster & Looney)
Lapins/Gisela.5 N treatments

Fertigation treatments
N (8 weeks post full bloom)
1. Low (42 ppm) ~63 kg/ha
2. Medium (84 ppm) ~126 kg/ha
3. High (168 ppm) ~ 254 kg/ha

Broadcast treatments
5. Broadcast N at bloom (75 kg ha-1, 2m strip)
6. Broadcast at bloom plus post- harvest fertigated N (med. rate, 4 weeks, August)
Leaf and fruit N - Lapins/Gisela 5

**Leaf**

- High N increased leaf and fruit N concentration

**Fruit**

- Large crop in 2004 reduced N concentration in fruit

Graphs showing:
- Leaf N (%): 2000-2005
- Fruit N (mg/100g FW): 2000-2005

Legend:
- Low N
- Medium N
- High N

Notations:
- *: significant difference
- **: highly significant difference
- ***: extremely high difference
- ****: extremely high difference
Tree growth - Lapins/Gisela 5

But high N decreased tree growth
Tree yield - Lapins/Gisela 5

- High N inputs do not necessarily lead to high yields.
- Fertigated N improved yield compared with broadcast N.
# Fruit size (g/fruit)

<table>
<thead>
<tr>
<th>N rate</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
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<td>UT</td>
<td>T</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>12.6</td>
<td>11.0</td>
<td>10.0</td>
<td>11.0</td>
<td>11.4</td>
<td>9.7</td>
</tr>
<tr>
<td>Medium</td>
<td>12.0</td>
<td>10.0</td>
<td>9.0</td>
<td>10.0</td>
<td>9.8</td>
<td>10.1</td>
</tr>
<tr>
<td>High</td>
<td>12.3</td>
<td>9.6</td>
<td>9.0</td>
<td>8.1</td>
<td>8.6</td>
<td>9.4</td>
</tr>
</tbody>
</table>

Low  ~ 63 kg/ha; Medium ~126 kg/ha; High ~ 254 kg/ha
Fruit quality

Nitrogen treatments had no effect on firmness or sweetness (data not shown).

But high N fruit was less acid.
Mobile nutrients – N, B

- Boron
  - very mobile
  - Narrow range between sufficiency and deficiency
Boron deficiency

Blossom blast

Surface cracking
Soil boron - effect of soil texture

30 cm beneath drip emitter
Soil solution boron

![Graph showing soil solution boron levels with key dates and values: 0.336 g Boron/tree/year.](image)
Leaf and fruit B concentration in response to application method

Neilsen et al. 2004
Can. J. Plant Sci. 84
Lapins/G.5 - B

- Deficiency level <20 ppm leaf B
- 2003 overall average = 28.7 ppm
  - drip treatment = 21.5 ppm
- 2004 overall average = 29 ppm
  - drip treatment = 22.1 ppm
Immobile nutrients

- Phosphorus and potassium
  - immobile

  - much less information available on internal cycling and uptake patterns than N

  - Spatially targeted applications required
Resorption of major nutrients from poplar leaves in Fall

Redrawn from Keskitalko et al., 2005 Plant Physiol. 139
Fertigated phosphorus in apple (drip irrigation)

Neilsen et al. 1999
HortTechnology 9
P fertigation trial - five apple cultivars tested

P fertigated at 20g/tree one week after full bloom

- Gala
- Cameo
- Fuji
- Silken
Phosphorus effects on fruit production - 5 apple cvs/M.9

- Phosphorus additions are effective when targeted to the roots through fertigation
### Phosphorus effects on fruit quality - 5 apple cvs/M.9

<table>
<thead>
<tr>
<th>Year</th>
<th>Statistically significant effect on quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>reduced incidence of water core, all cultivars</td>
</tr>
<tr>
<td>2003</td>
<td>reduced browning of cut surfaces, all cultivars</td>
</tr>
<tr>
<td>2004</td>
<td>increased soluble solids, all cultivars</td>
</tr>
</tbody>
</table>

Phosphorus increases the stability of cell walls.
Lapins/Gisela.5 P and K treatments

- Fertigated through micro-sprinkler with medium N rate

- Annual P (20g/tree, end April)

- Annual K (14-31g/tree, 4 weeks, June)
Leaf and fruit P - Lapins/Gisela 5

P fertigation did not affect growth or nutrient conc. (data not shown) leaves and fruit.

Irrigation effects inconclusive.

P fertigation using drip may be more useful than P fertigation with microsprinkler.
Potassium

- Management options
Soil solution K concentration in response to fertigation under drip

Neilsen et al. 2004 JASHS 80
Effect of fertigated K on leaf K concentration

Averaged for four apple cultivars (Gala, Fuji, Spartan, Fiesta)

Leaf K (% dw)

Year 1 Year 2 Year 3 Year 4 Year 5

0g K/tree/year
15g K/tree/year

Neilsen et al. 2004 JASHS 80
Leaf and fruit K - Lapins/Gisela 5

**K fertigation (microsprinkler) did not affect leaf or fruit K conc. (data not shown)**

- Leaf and fruit K are reduced under drip irrigation, likely due to soil K leaching
- Low crop in 2005, reduced overall demand for K
Nutrient management and soil quality
Consequences of fertigating with NH$_4^+$ based fertilizers

Soil chemical changes in 20 orchards (3-5 years old) receiving drip irrigation and fertigation

<table>
<thead>
<tr>
<th></th>
<th>pH</th>
<th>Ca</th>
<th>Mg</th>
<th>K</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alley</td>
<td>7.0</td>
<td>1235</td>
<td>144</td>
<td>211</td>
<td>0.97</td>
</tr>
<tr>
<td>Beneath emitters</td>
<td>6.2</td>
<td>911</td>
<td>114</td>
<td>88</td>
<td>0.19</td>
</tr>
<tr>
<td>Significance</td>
<td>***</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>****</td>
</tr>
</tbody>
</table>

*, **, ***, ****, significantly different at p<0.05, 0.01, 0.001, 0.0001
Effects of mulches and composts

Long –term compost/mulch trial at Summerland, B.C.
Long-term compost/mulch trial. Soil property changes over 7 years

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Total C (%)</th>
<th>Total N (%)</th>
<th>Extractable P (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check</td>
<td>1.0c</td>
<td>0.10bc</td>
<td>40b</td>
</tr>
<tr>
<td>Biosolids (GVRD)</td>
<td>1.9a</td>
<td>0.18a</td>
<td>205a</td>
</tr>
<tr>
<td>Paper Mulch</td>
<td>1.3bc</td>
<td>0.12b</td>
<td>26b</td>
</tr>
<tr>
<td>Black plastic</td>
<td>0.9c</td>
<td>0.09c</td>
<td>29b</td>
</tr>
</tbody>
</table>

Water and nutrient management are linked

- Retention of nutrients in the root zone for as long as possible will improve nutrient use efficiency
  - fertilizer applications are timed to meet tree demand
  - water applications are scheduled to meet evaporative demand
Loss of water and N beneath the root zone in response to irrigation scheduling

Water loss (L/tree)

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Scheduled to meet ET</td>
<td>646</td>
<td>168</td>
<td>1304</td>
<td>286</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unscheduled (fixed rate)</td>
<td>1304</td>
<td>286</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Neilsen et al. 2002 HortTechnology 12

- Water and N losses related during fertigation period
- Water losses high under unscheduled irrigation during periods of low ET
Seasonal water & N loss beneath the root zone in response to irrigation type

- N losses follow water drainage closely
- Losses under drip higher during periods of high ET (mid-summer)
- Water replacement rate too high for soil storage capacity

Graph showing:
- Water drainage (L/tree)
- Nitrogen loss (g/tree)

Legend:
- Drip
- Microsprinkler

Fertigation arrow indicating periods of high ET (mid-summer)
Timing of P leaching in response to irrigation system and compost

- P susceptible to leaching under compost
- Movement as Organic P?
- Over-application of water in micro-sprinkler plot, day 236, increased P losses.
Conclusions

Mobile nutrients

- Water management (scheduling, irrigation method) and timing of N application determines the retention of N in the root zone and availability.

- Aided by improved understanding of tree N cycling and time of root uptake

- Fertigation allows precise timing of N additions and is more effective than broadcast applications

- Very high N applications, may be detrimental to production

- B deficiency more prevalent in sandy soils and can be managed by fertigation –with care
Conclusions

**Less mobile nutrients**

- Fertigation may improve the mobility and effectiveness of P applications, but only with drip irrigation.
- Drip irrigation, may cause soil K leaching and reduce availability – K fertigation through drip can offset this.
- Fertigating K through microsprinkler does not improve K uptake.
- Size controlling rootstocks may take be more susceptible to K deficiency.
- P leaching may occur when organic amendments are used.
Financial support

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Thank you