Effects of Preharvest Factors on Fruit Development and Quality

Jinhe Bai & Anne Plotto

U.S. Horticultural Research Laboratory, Fort Pierce, FL

Indian River Citrus School, Handling and Processing
Preharvest Effects on Fruit Quality

- Effect of Genetic Material
- Effect of Cultivar and Maturity
- Effect of Rootstock
- Effect of Nutrient Deficiency
Effect of Genetic Material

‘FALLGLO’


Released in 1987

‘US EARLY PRIDE’

Irradiation induced mutation of Fallglo with very low seed count
Effect of Genetics on Fruit Size

Fruit Weight

- Fallglo
- US Early Pride

Harvest date:
- 2 Oct
- 14 Oct
- 29 Oct
- 13 Nov
- 25 Nov

McCollum, Hearn, Ritenour, FSHS Proceedings 2010
Effect of Genetics on Maturity

SSC (Brix)/TA

McCollum, Hearn, Ritenour, FSHS Proceedings 2010
Effect of Genetics on Storage

Harvest October 21
SSC (Brix)/TA

McCollum, Hearn, Ritenour, FSHS Proceedings 2010
Effect of Genetics on Volatiles

2014-2015 evaluation of USDA Sweet-orange-like hybrids

Jinhe Bai & Ed Stover

(m): mandarin (C. reticulata); (o): sweet orange (C. × sinensis); (tlo): tangelo [mandarin - grapefruit (C. × paradisi) hybrid].

Sweet orange and grapefruit are also hybrids as follows: sweet orange (mandarin - pummelo hybrid) and grapefruit [pummelo (C. maxima) -sweet orange hybrid]

Pedigree of ‘Ambersweet’ and the hybrids (boxed) used in this research (Pink font color indicates varieties/lines for the flavor profile evaluation).
Sweet Oranges:
- Blue: Hamlin
- Red: Midsweet
- Black: FF-1-74-52

Volatile profile comparison:
- FF-1-74-52 is similar to sweet oranges
Volatile profile comparison:
FF-1-74-52 has more peaks (quality) and abundant concentration (quantity)

Mandarin:
- Blue: Dancy
- Peak#: 30

Black:
- FF-1-74-52
- Peak #: 67
2. Common in sweet oranges, mandarins, and all hybrids (frequency more than 50% in all lines)

<table>
<thead>
<tr>
<th></th>
<th>FF-1-30-52</th>
<th>FF-1-75-55</th>
<th>FF-1-76-51</th>
<th>FF-1-74-52</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dancy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FF-1-30-52</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FF-1-75-55</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FF-1-76-51</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FF-1-74-52</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treca</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ridge</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pineapple</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carny</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parson</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midsweet</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hamlin</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. Common (>50%) in sweet oranges but lack (<25%) in some or all mandarin/hybrids

<table>
<thead>
<tr>
<th></th>
<th>3A</th>
<th>3B</th>
<th>3C</th>
<th>3D</th>
</tr>
</thead>
<tbody>
<tr>
<td>FF-1-30-52</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FF-1-75-55</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FF-1-76-51</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FF-1-74-52</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treca</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ridge</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pineapple</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carny</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parson</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midsweet</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hamlin</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. Detected (>25%) in FF-1-74-52 and some sweet oranges but absent in mandarin and other hybrids

4A In at least one sweet orange (>25%)

<table>
<thead>
<tr>
<th></th>
<th>4A</th>
<th>4B</th>
<th>4C</th>
<th>4D</th>
</tr>
</thead>
<tbody>
<tr>
<td>FF-1-30-52</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FF-1-75-55</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FF-1-76-51</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FF-1-74-52</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treca</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ridge</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pineapple</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carny</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parson</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midsweet</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hamlin</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4B Rare (<25%) in sweet oranges

5. Detected only in some sweet oranges

6. Rare (less than 25%) in sweet oranges and FF-1-74-53 but in some mandarin and/or other hybrids

7. Low (<50%) in any class.
<table>
<thead>
<tr>
<th>Compound</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>d-limonene</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>β-myrcene</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>α-terpinolene</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>E-2-heptenal</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>ethanol</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>92</td>
</tr>
<tr>
<td>acetaldehyde</td>
<td>100</td>
<td>100</td>
<td>92</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>85</td>
<td>85</td>
</tr>
<tr>
<td>α-phellandrene</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>77</td>
</tr>
<tr>
<td>γ-terpinene</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>77</td>
</tr>
<tr>
<td>α-pinene</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>90</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>o/p/m-cymene</td>
<td>100</td>
<td>92</td>
<td>85</td>
<td>100</td>
<td>90</td>
<td>80</td>
<td>85</td>
<td>100</td>
<td>100</td>
<td>92</td>
</tr>
<tr>
<td>α-terpinene</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>92</td>
</tr>
<tr>
<td>p-mentha-1(7),8-diene</td>
<td>100</td>
<td>100</td>
<td>92</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>92</td>
<td>54</td>
</tr>
</tbody>
</table>

1. Common in sweet oranges, mandarins, and all hybrids (frequency more than 50% in all lines)
### 3. Common (> 50%) in sweet oranges but lack (<25%) in some or all mandarin/hybrids

<table>
<thead>
<tr>
<th></th>
<th>3A 1/4</th>
<th>3B 2/4</th>
<th>3C 3/4</th>
<th>3D 4/4</th>
</tr>
</thead>
<tbody>
<tr>
<td>β-phellandrene</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>linalool</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>terpinen-4-ol</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>valencene</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>ethyl butanoate</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>hexanal</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Ethyl hexanoate</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>E-2-hexenal</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Ethyl octanoate</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>RI1120</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>α-panasinene</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>γ/δ-selinene</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>E-caryophyllene</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Alloaromadendrene</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>selina-3,7(11)-diene</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>4,11-selinadiene</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>nootkatene</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>β-elemene</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>β-selinene</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>intermedeol</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>aromandendrene</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>nootkate</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>selin-11-en-4-alpha-ol</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>α-gurjunene</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>
4. Detected (> 25%) in FF-1-74-52 and some sweet oranges but absent in mandarin and other hybrids

<table>
<thead>
<tr>
<th></th>
<th>4A In at least one sweet orange (&gt; 25%)</th>
<th>4B Rare (&lt; 25%) in sweet oranges</th>
</tr>
</thead>
<tbody>
<tr>
<td>aromadendrene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d-germacrene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cadina-1(10)-6,8-triene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E-eudesma-6,11-diene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>β-selene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>carvyl acetate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>perilla aldehyde</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d-carvone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E-2-pentenal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-carene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>vanillin</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Detected (> 25%) in FF-1-74-52 and some sweet oranges but absent in mandarin and other hybrids.
Volatile analysis of FF-1-74-52 classifies it as a sweet orange.

Volatile analysis of FF-1-74-52 classifies it as a sweet orange.

Volatile analysis of other hybrids were too different from sweet orange, and closer to mandarin profile.

Effect of Fruit Maturity on Acids

Jinhe Bai

Valencia oranges harvested from February to May

TA and Citric acid

<table>
<thead>
<tr>
<th>Month</th>
<th>TA</th>
<th>Citric acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>February</td>
<td>1.1</td>
<td>1.0</td>
</tr>
<tr>
<td>March</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>April</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>May</td>
<td>0.6</td>
<td>0.6</td>
</tr>
</tbody>
</table>
Effect of Fruit Maturity on Sugars

Jinhe Bai

Valencia oranges harvested from February to May

**Total sugars**

February  
March  
April  
May

- **SSC**
- Sucrose
- Glucose
- Fructose
Effect of Fruit Maturity on Limonoids

Jinhe Bai

Valencia oranges harvested from February to May

Limonoids

February March April May

Limonin Nomilin
Effect of Fruit Maturity on Volatiles

Jinhe Bai

Valencia oranges harvested from February to May

- **Sweet**
  - Ethyl esters (fruity); sesquiterpenes

- **Sour, bitter**
  - Non-ethyl/non-methyl esters

- **Proper SSC/TA ratio**
  - Monoterpenes and straight-chain aldehydes

Harvest time
Effect of Cultivar and Maturity

<table>
<thead>
<tr>
<th></th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>July</th>
<th>Aug</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fallglo</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sunburst</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dancy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Murcott</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Honeybell</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Florida Dept. of Citrus
www.floridajuice.com
Objectives

• To determine harvest maturity of commercial and new tangerine cultivars
• Sensory evaluation and instrumental analysis
Sensory evaluation

- 10 panelists
- Training for eight 1-1½ hour sessions
- Ballot development
- Reference standards
Fruit samples

• Two locations
  – Lake Alfred (UF) and Leesburg (ARS)

• Harvest every 2 to 3 weeks:
  – 2010-2011: Dec 8, Jan 3, Jan 20, Feb 2, Mar 9
  – 2011-2012: Dec 12, Jan 9, Jan 30, Feb 20, Mar 5
USDA 5-51-2

- Hybrid (Clementine x Orlando) x Seedling
- Mid-season sweet orange
- High quality juice
- Difficult to peel
- Less susceptible to HLB?
USDA 5-51-2

2010-2011

High peel oil
Dry and bland at 2nd harvest (freezes)

Brix TA*10 S.S./T.A.
Sugar Belle® ‘LB8-9’
(U.S. Patent PP21,356)

• A mandarin hybrid released by UF IFAS citrus breeding program
• Similar to Minneola tangelo, but earlier maturity, greater disease resistance, and superior flavor
• Few to no seeds
Sugar Belle® ‘LB8-9’

2010-2011 – “High acid” year

- Dec. 8: too sour, underripe
- Jan. 3: just right flavor, while still sour
- Jan. 20: overripe – slimy texture

Sugar Belle® ‘LB8-9’

Dec. 8, Jan. 3, Jan. 20

Brix, TA, Brix/TA
Sugar Belle® ‘LB8-9’

2011-2012 – “Low acid” year

- Dec. 12: very sour, lemony
- Jan. 10: overripe

Graphs and data showing:
- Tangerine
- Sourness
- Fruity-non-citrus
- Floral
- Sweetness
- Bitterness
- Juiciness
- Ripeness
- Pumpkin

Bar chart showing:
- SSC
- TA*10
- SSC/TA
UF-411 (8-9 x Murcott)

- Large fruit, easy-to-peel, excellent flavor
- Maturity Jan. through March
- In the process of being released
UF-411 (8-9 x Murcott)

2010-2011 – “High acid” year

- Dec, Jan: too sour but interesting flavor
- End Jan and Feb: very sweet and sour, mix of orange and tangerine flavor

Dec. 8
Jan. 3
Jan. 20
Feb. 2

Dec. 8 Jan. 3 Jan. 20 Feb. 2

Brix TA*10 Brix/TA
UF-411 (8-9 x Murcott)

2011-2012 – “Low acid” year

- Season characterized by low acid fruit
- Fruit maturity early January
- End Feb., March already overripe

![Graph showing taste profiles over time]
Conclusion Maturity Study

• Significant year effect: cold spring and late bloom in 2011 resulting in sour fruit; early season and low acid fruit in 2012.

• Determined harvest windows for Sugar Belle™, UF 411, LS Murcott, and other UF and USDA hybrids.

• Volatile data were analyzed to correlate with sensory data.
Rootstock Effect
Effect of Rootstock on Fruit Quality

McCollum, Bowman & Castle
FSHS Proceedings 2002

- ‘Marsh’ Grapefruit
- Field Trial Martin County
- Harvest Dec. 12, 2001

### SSC (°Brix)

<table>
<thead>
<tr>
<th></th>
<th>Sour Orange</th>
<th>Carrizo</th>
<th>Smooth Flat Seville</th>
<th>Swingle</th>
<th>US 812</th>
<th>Cleopatra</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variety</td>
<td>a</td>
<td>b</td>
<td>c</td>
<td>b</td>
<td>bc</td>
<td>bc</td>
</tr>
</tbody>
</table>

### TA

<table>
<thead>
<tr>
<th></th>
<th>Sour Orange</th>
<th>Carrizo</th>
<th>Smooth Flat Seville</th>
<th>Swingle</th>
<th>US 812</th>
<th>Cleopatra</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variety</td>
<td>a</td>
<td>c</td>
<td>b</td>
<td>ab</td>
<td>ab</td>
<td>ab</td>
</tr>
</tbody>
</table>
Effect of Rootstock on Fruit Quality

McCollum, Bowman & Castle
FSHS Proceedings 2002

- ‘Marsh’ Grapefruit
- Field Trial Martin County
- Harvest Dec. 12, 2001
Effect of Rootstock on Fruit Quality

- Rootstock effect significant for all quality attributes
- Sour orange & Swingle largest fruit
- SO and SW highest for sheepnose

McCollum and Bowman, ASHS 2015

‘Ray Ruby’ Grapefruit
Effect of maturity and water deficit

Pantin, Fanciullino, Massonet et al., 2013
Frontiers in Plant Science
Effect of Nutrient Deficiency on Quality of Citrus Fruit


http://www.crec.ifas.ufl.edu/extension/greening/ndccg.shtml
**Sympton description**
Cracking of the fruit.

**Made worst by**

**Important for**
Leaves are properly formed and remain throughout cycle. Overall tree growth is more vigorous. Yield often increases. Fruit-size more regular and uniform. Better quality fruit. Better skins - less 'Albedo Breakdown' (creasing).

**Cause description**
Calcium deficiency
**Sympton description**
Phosphorus deficiency leads to **fruits** with coarse and thick peel.

**Made worst by**

**Important for**
Vegetative growth increased. Leaves are much greener. **Fruit** set is increased. Yield boosted, **fruit quality enhanced (sugar/acid improved)**. Particularly important in young trees with poorly developed root systems.

**Cause description**
Phosphorus deficiency on orange (right)

---

**P – Phosphorus MW 31**

![Healthy vs P deficit]

- Coarse, hollow core and thick rinds
**Symptom description**
With potassium deficiency leaf margins of the older leaves turn pale yellow or sometimes bronze. With ongoing deficiency chlorosis spreads over the whole leaves.

**Made worst by**

**Important for**
Larger leaf area maintaining through season. Shoot growth more vigorous. Fruit load increase/benefit to yield. Fruit are larger with better color, skin texture and flavoring (more acidity). Level of vitamin C increases.

**Cause description**
Potassium deficiency

**K – Potassium MW 39**

reduced fruit size with very thin peels of smooth texture; easy to course plugging; creasing rind disorders; splitting at the styler or blossom-end
Sympton description
Boron deficiency causes the death of the terminal growing point. The tree loses its apical dominance and sends out multiple shoots.

Made worst by

Important for
More uniform and vigorous vegetative growth. Leaves are properly formed and premature drop is avoided. Fruit set and development is improved. Fruit quality (juice/sugar levels) enhanced. Fruit/rind ratio improved. Yield increased.

Cause description
Boron deficiency on shoots

Necrotic-corky areas on the fruit surface
Sympton description
Copper deficient plants show **dark green and enlarged leaves**. Stems are more slender than normal and appear flat and angular. Limbs die back and gumming may occur under new bark or on fruits. Symptoms are more prominent in young citrus.

**Made worst by**

**Important for**
Young trees come into production more rapidly. Vegetative growth is more even. Large foliage area (leaf number) maintained. **Fruit mature better (flavor and juice levels enhanced)**. Premature fruit drop prevented. Fruit skin-quality is much improved.

**Cause description**
Copper deficiency on citrus Symptoms of copper deficiency are rarely seen where copper based fungicides are applied.

---

Cu – Copper MW 63.5

Fruit splitting, gumming
Symptom description
The older leaves are pale green to yellow and abscise. The life of a leaf can be shortened from 1-3 years to 6 months. The leaf veins have a clear color tending to white.

Made worst by
Low or high pH soils. Sandy or light soils (leaching.) Low organic matter. Drought conditions. High rainfall (leaching) or heavy irrigation. Addition or high levels of non-decomposed organic matter/manure (eg straw). Fast growing crops.

Important for
Foliage lusher and greener. Shoot growth vigour increased. Fruit set/crop load increased. Yield is increased. Juice quantity and quality improved (acidity and soluble solids increased).

Cause description
Nitrogen deficiency Sulfur deficiency causes similar symptoms, but it begins at the younger leaves and the veins are usually green.
Thank you!
Questions?