Intensive Orchard Systems for High Quality, High Efficiency Sweet Cherry Production

Gregory Lang
Michigan State University
Worldwide sweet cherry production (and fruit size) has increased dramatically over the past two decades.

Production remains profitable due to high quality, increasing labor efficiencies, and strong demand by consumers.
Hybrid Rootstocks (Gisela): Dwarf Trees, High Yields, and Precocious Cropping

**Hedelfingen NC-140**
Michigan spring 2000 (3rd Year)

**Do small trees yield small fruit size?**

Blossom Clusters / cm^2*
Sweet Cherry Formation of Fruit and Leaf Canopy “Units”

Year 1 - New shoot growth with single leaves

Year 2 – Basal non-spur fruiting sites, with formation of future spurs

Year 3 – Fruiting spurs + basal fruiting sites + new shoot leaves

Ayala and Lang, 2004
Dynamics of Fruit-to-Leaf Area Balance

Year 3:
Fruit populations: 1 spur (e.g., 75 total), 1 non-spur (e.g., 10 total)
Leaf populations: 2 spur (e.g., 120 total), 1 shoot (e.g., 10 x 2X)
Leaf-to-Fruit Ratio: 140 leaves / 85 fruit = 1.65

Year 4:
Fruit populations: 2 spur (e.g., 150 total), 1 non-spur (e.g., 10)
Leaf populations: 3 spur (e.g., 180 total), 1 shoot (e.g., 10 x 2X)
Leaf-to-Fruit Ratio: 1.25 (from Year 3 to Year 4, a 25% decrease)
Crop-to-Leaf Area Balance on Dwarfing Rootstocks

Rainier / Gisela 7 - Bud Thinning, Yield, Fruit Quality

**Marketable Yield**

- **<25 mm (Processing)**
  - Control: 8.7
  - 3 buds/spur: 6.5
  - 2 buds/spur: 3.2
  - 1 bud/spur: 2.2

- **>25 mm (Export)**
  - Control: 7.6
  - 3 buds/spur: 10.9
  - 2 buds/spur: 12.0
  - 1 bud/spur: 10.9

- **Total Yield**
  - Control: 16.1 mt/ha
  - 3 buds/spur: 17.4 mt/ha
  - 2 buds/spur: 15.2 mt/ha
  - 1 bud/spur: 13.1 mt/ha

*Lang and Whiting, 1999*
The genetic potential for large fruit exists in many varieties, even on dwarf trees (Gisela 5) grown in sandy soil, if the physiology is optimized through management.
Crop Load Effects on Dwarfing Rootstocks

Growth responses, single leaf, and whole canopy photosynthetic response to crop load manipulation on Gisela 5.

Target treatments

Control: 84 fruit/m² LA

Thinned: 20 fruit/m² LA

No Crop
Results:

Increasing crop loads affected: fruit yield, fruit size, fruit sugar, fruit firmness, tree growth.

However, differences in daily photosynthesis were not detected.

Crop load affected how the tree used carbon, not how it gained carbon.

Crop Load (Fruit Number per Leaf Area, m²)

- Soluble Solids (%)
  - $y = 26.76 - 0.08x + 0.0002x^2$, $r^2 = 0.84$

- Fruit Weight (g)
  - $y = 9.96 - 0.02x$, $r^2 = 0.88$

**Conclusion**

Canopy leaf area becomes limiting at ≤200 cm²/fruit (3-4 shoot leaves/fruit or 7-8 spur leaves/fruit)

*Whiting and Lang, 2004, JASHS 129:407-415*
Growth Sensitivity of ‘Bing’ Sweet Cherry on Gisela 5 Rootstock to Increasing Crop Load

Trunk expansion >

fruit soluble solids (Stage III) >

fruit growth (Stg. III) >

Leaf area/spur* >

shoot elongation >

fruit growth (Stg. I and II) >

Leaf area/shoot

*early competition for reserves
### Managing the Sugar Supply to Fruit

<table>
<thead>
<tr>
<th>Year</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaf population</td>
<td>Fruiting spurs</td>
<td>Non-fruiting spurs</td>
<td>Current season shoot</td>
</tr>
</tbody>
</table>

![Diagram showing the movement of carbon dioxide (13CO₂) through the plant's growth cycle from 2001 to 2003.](image)

*Ayala and Lang, 2004*
Marlene Ayala

$^{13}\text{CO}_2$ Research
Fruiting Spur Leaves are the Major C Source for Fruit; New Shoot Leaves Also Are Critical, Especially in Mid-Stage III

Carbon Sources and Proportional Distribution to Fruit

- Fruiting spur leaves: 55%
- Non-fruited spur leaves: 29%
- Shoot leaves: 16%

Fruit: 25% final size
Shoot: 16 leaves

Beginning of Stage III (44 days after full bloom)

Ayala and Lang, 2004
Growth Sensitivity of ‘Bing’ Sweet Cherry on Gisela 5 Rootstock to Increasing Crop Load

Trunk expansion >

fruit soluble solids (Stage III) > New shoot leaves needed

fruit growth (Stg. III) > New shoot leaves needed

Leaf area/spur* > Late season C & N storage

shoot elongation >

fruit growth (Stg. I and II) >

Leaf area/shoot

*competition for reserves

Crop Load Effects on $^{13}$C Movement to Fruit

Balanced crop loads improve uniformity of quality fruit
Anticipation of the future unbalanced cropping sites can help in *pre-emptive* management to better balance leaf-to-fruit ratios and improve performance.

A dormant heading cut to remove: 15 to 30% of last year’s shoot can reduce 25 to 40% of the future crop density.
This heading cut promotes new shoot leaf populations and non-spur fruit populations, while reducing future spur fruit populations.
Basic Growth & Fruiting Units

This heading cut promotes new shoot leaf populations and non-spur fruit populations, while reducing future spur fruit populations.
Basic Growth & Fruiting Units

Year 3:
Fruit populations: 1 spur (e.g., 40 total), 2 non-spur (e.g., 20 total)
Leaf populations: 3 spur (e.g., 135 total), 2 shoot (e.g., 20 x 2X)
Leaf-to-Fruit Ratio: 2.90

This heading cut promotes new shoot leaf populations and non-spur fruit populations, while reducing future spur fruit populations.
VCHERRY – Leaf and Fruit Population Changes in Response to Pruning and Training Systems

Model tree growth and cropping to quantify the dynamics of leaf and fruit number, and how the LA:F ratio changes with tree training and pruning

Total Leaf Area = 0.75 m²
VCHERRY – Leaf and Fruit Population Changes in Response to Pruning and Training Systems

Model tree growth and cropping to quantify the dynamics of leaf and fruit number, and how the LA:F ratio changes with tree training and pruning

Total Leaf Area = 3.5 m²
Model tree growth and cropping to quantify the dynamics of leaf and fruit number, and how the LA:F ratio changes with tree training and pruning.

- Total Leaf Area = 9.4 m²
- LA:F = 223 cm²
Strategies to Optimize Precision Cropping: The Highly-Structured Tree

De-construct the tree canopy into a simple fruiting unit to manage leaf-to-fruit ratios, then repeat many times

Lang, 2000
Double-Canopy Fruiting Wall
UFO Fruiting Units and Yield

Tree Spacing: 1.5 m x 2.5 m 2,666 trees/ha

Fruiting unit (upright shoot) spacing: 20 cm

<table>
<thead>
<tr>
<th>Fruiting Units (shoots/ha)</th>
<th>Target Yield (ton/ha)</th>
<th>Fruit Size (g/fruit)</th>
<th>Crop Load (fruit/upright)</th>
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<tbody>
<tr>
<td>18,662</td>
<td>20.0</td>
<td>10.0</td>
<td>107</td>
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<tr>
<td>18,662</td>
<td>17.5</td>
<td>11.0</td>
<td>85</td>
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<tr>
<td>18,662</td>
<td>15.0</td>
<td>12.0</td>
<td>67</td>
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</table>
NC140 Sweet Cherry Canopy Systems Trial

KGB

TSA

SSA

UFO

Kym Green Bush
Tall Spindle Axe
Super Slender Axe
Upright Fruiting Offshoots

Rootstock Vigor:
Gisela 3 – very dwarfing
Gisela 5 – dwarfing
Gisela 6 - vigorous

Spacing: 1.5 x 3.5 m
(SSA) 0.75 x 3.5 m
NC140 Sweet Cherry Canopy Architecture Trial Sites (13 Planted in 2010)

**Cultivar: Skeena**
- Summerland, British Columbia
- Kentville, Nova Scotia

**Cultivar: Regina**
- Geneva, New York
- Hudson Valley, New York

**Cultivar: Benton**
- Clarksville, Michigan
- (Walnut Grove, California)

**Other Collaborative Trials**
- Italy, Turkey, Chile, New Zealand
System x Rootstock Effect on Tree Vigor (TCSA), Fall 2012

Root Competition
KGB Fundamental Fruiting Unit
SSA Fundamental Fruiting Unit
UFO Fundamental Fruiting Unit
Basic Tenets:
1) minimize permanent wood
2) maximize fruiting units
3) fill vegetative space and begin significant fruiting within 3 years
4) reach full production within 5 years
5) maintain high production indefinitely via renewal of fruiting units
Lillrose and Lang, 2011 (preliminary data, not analyzed for publication)
Estimated Canopy Volume, Fall Year 3

Generally, trees on Gi6 had filled or over-filled their allotted space; trees on Gi3 had under-filled their space except for SSA.

**3-Dimensional Canopies**
- **KGB revised spacing**: 1.75 x 4.0 m (1777/ha)
- **TSA revised spacing**: 1.5 x 3.5 m (1904/ha)
- **SSA revised spacing**: 0.75 x 2.75 m (4848/ha)
- **UFO revised spacing**: 1.5 x 2.5 m (2666/ha)

**2-Dimensional Canopies**
2012 Spring Frost-induced Canker Spur Death
Thus, canker-killed spurs reduced yield potential for 2013 and 2014 by at least 5 to 8 t/ha.
### 2013 (Year 4) Yields*, Michigan

<table>
<thead>
<tr>
<th>Proposed modified orchard spacing (m)</th>
<th>KGB</th>
<th>TSA</th>
<th>SSA</th>
<th>UFO</th>
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<tbody>
<tr>
<td>Trees/ha</td>
<td>1777</td>
<td>1904</td>
<td>4848</td>
<td>2666</td>
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<tr>
<td>Rootstock</td>
<td></td>
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</tr>
<tr>
<td>Gi3</td>
<td>1.3</td>
<td>7.1</td>
<td>9.2</td>
<td>3.7</td>
</tr>
<tr>
<td>Gi5</td>
<td>0.6</td>
<td>2.2</td>
<td>-</td>
<td>0.9</td>
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<tr>
<td>Gi6</td>
<td>0.1</td>
<td>1.4</td>
<td>3.4</td>
<td>1.1</td>
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*Yield potential reduced by 5 to 8 t/ha due to 2012 spur death
## 2014 (Year 5) Yields*, Michigan

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<th>Proposed modified orchard spacing (m)</th>
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<th>TSA</th>
<th>SSA</th>
<th>UFO</th>
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<tbody>
<tr>
<td>1.75 x 4.0</td>
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<td>0.75 x 2.75</td>
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<td>Rootstock</td>
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<td>Gi5 4.1</td>
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*Yield potential reduced by 5 to 8 t/ha due to 2012 spur death

Preliminary data, not for (Greg Lang, Michigan State University)
<table>
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<tr>
<th>Year 2</th>
<th>SSA/Gi3  &gt; SSA/Gi6  &gt; UFO/Gi3  &gt; TSA/Gi3  &gt; TSA/Gi5 = UFO/Gi5</th>
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<tr>
<td>Year 3</td>
<td>SSA/Gi3  &gt; SSA/Gi6  &gt; TSA/Gi3  &gt; UFO/Gi3  &gt; TSA/Gi5 = UFO/Gi5</td>
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<td>Year 4</td>
<td>SSA/Gi3  &gt; TSA/Gi3  &gt; UFO/Gi3  &gt; SSA/Gi6  &gt; TSA/Gi5</td>
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<td>Year 5</td>
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*SSA/Gi3 and SSA/Gi6 declined 32% and 45% from Year 4 to Year 5*
<table>
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<th>Year</th>
<th>SSA/Gi3</th>
<th>SSA/Gi6</th>
<th>UFO/Gi3</th>
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<td>Year 5</td>
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<td>UFO/Gi3*</td>
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<tr>
<td></td>
<td>KGB/Gi3</td>
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</table>

*UFO/Gi3 and UFO/Gi5 increased 2X to 10X from Year 4 to Year 5*
<table>
<thead>
<tr>
<th>Year</th>
<th>SSA/Gi3 &gt; SSA/Gi6 &gt; UFO/Gi3</th>
<th>&gt; TSA/Gi3 &gt; TSA/Gi5 = UFO/Gi5</th>
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<td>SSA/Gi3 &gt; TSA/Gi3 &gt; UFO/Gi3</td>
<td>&gt; SSA/Gi6 &gt; TSA/Gi5</td>
</tr>
<tr>
<td>Year 4</td>
<td>UFO/Gi5 &gt; TSA/Gi3* = TSA/Gi5*</td>
<td>&gt; UFO/Gi3 &gt; SSA/Gi3 = KGB/Gi3</td>
</tr>
</tbody>
</table>

*TSA/Gi3 and TSA/Gi5 increased 28% to ~4X from Year 4 to Year 5*
Dormant Pruning Time per Plot 2013

- **UFO**
  - Gi.3: 67 hr/ha
  - Gi.5: 53 hr/ha
  - Gi.6: 82 hr/ha

- **KGB**
  - Gi.3: 195 hr/ha

- **TSA**
  - Gi.3: 82 hr/ha

- **SSA**
  - Gi.3: 67 hr/ha
  - Gi.6: 195 hr/ha
Mechanized Summer Pruning for Light
Total Pruning Times 2014 (per tree and per ha)

- **KGB**: 280 hr/ha
- **TSA**: 221 hr/ha
- **SSA**: 379 hr/ha
- **UFO**: 260 hr/ha

*hand-pruned**

**hedged**
The *Orchard Establishment Phase* of the trial is complete, the *Mature Production Phase* has begun.

SSA is most precocious, but has high labor needs for pruning, and productivity may be declining.

TSA and UFO have had a good balance of precocity, productivity, and labor efficiencies.

KGB is least precocious, with modest productivity thus far, and is less amenable to summer hedging.
V-UFO Fruiting Units and Yield

Tree Spacing: 2.0 m x 4.0 m  1,250 trees/ha

Fruiting unit (upright shoot) spacing: 10 cm (alternating)

<table>
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<tr>
<th>Fruiting Units (per ha)</th>
<th>Target Yield (ton / ha)</th>
<th>Fruit Size (g/fruit)</th>
<th>Crop Load (fruit/upright)</th>
</tr>
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<tbody>
<tr>
<td>25,000</td>
<td>40.0</td>
<td>12.0</td>
<td>133</td>
</tr>
</tbody>
</table>

133 fruits / 3.2 (~2.75) m
= 48 fruit per m leaf area
(angled upright shoot)