How does the method, timing and severity of leaf removal affect Cabernet franc wine flavour?

Belinda Kemp, Jim Willwerth, Mary Jasinski, Stephanie Bilek, Judah Campbell, Tony Wang, Fei Wang, Steve Trussler, Margaret Thibodeau and Debbie Inglis.
Background to the study

- Industry-led, long term study over five years that includes leaf removal
- Pinot noir for sparkling & red table wine on the same vineyard & Cabernet franc.
- Title: Adaptation and Innovation: An integrative research program to improve grapevine health, wine quality, competitiveness and sustainability of the Canadian wine grape industry.

Funded by Natural Sciences and Engineering Research Council of Canada (NSERC) CRD grant and Ontario Grape & Wine Research Inc (OGWRI).
Aims and objectives

• To establish differences between mechanical and manual leaf removal after flowering.
• To investigate severity of leaf removal in the fruiting zone.
• To identify chemical and sensory differences between the resultant wines.
What is leaf removal and why do we do it?

- Improve air circulation
- Increase fungicide/insecticide spray penetration
- Expose the fruit to more sunlight
- Improve flavour compounds, colour, and bud fertility
- Reduce herbaceous or vegetative aromas in some cultivars

Striegler & Jones (2012)
Experimental design

(Diagram by Judah Campbell (2017)

- **Control**: 0% (NoLR)
  - 7 Days Post Bloom: 80% Manual (80%MA7PB)
    - 80% Mechanical (80%ME7PB)
  - 30 Days Post Bloom: 80% Manual (80%MA30PB)
    - 80% Mechanical (80%ME30PB)
  - At Bunch Closure: 33% Manual (33%BC)
    - 50% Manual (50%V)
    - 100% Manual (100%V)
- **Véraison**
Experimental design

• Niagara-on-the-Lake Vineyard, Four Mile Creek sub-appellation, Ontario.
• Vine spacing was 2.7m x 1.5m
• 25 vines per replicate per treatment
• 3 rows as replicates = 75 vines/treatment in a randomised block design
• A buffer zone of 5 vines before treatments began and grapes not picked from these vines
• Pendelbogen VSP system
• Soil type: Chinguacousy clay loam
Leaf removal machines

• **80%MEC7PB leaf removal:** a Gregoire DX30 was used each year.
  • This model uses suction to remove leaves from the fruiting zone.

• **80%MEC30PB leaf removal:** Collard P3000LZP Polyvalent was used each year.
  • This model uses pulsed air to blow the leaves from the fruiting zone.
### Treatment dates

<table>
<thead>
<tr>
<th>Stage</th>
<th>Treatment</th>
<th>Date executed 2016</th>
<th>Date executed 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 day PB</td>
<td>80% Leaf removal mechanical</td>
<td>28-Jun</td>
<td>04-Jul</td>
</tr>
<tr>
<td>7 day PB</td>
<td>80% Leaf removal manual</td>
<td>28-Jun</td>
<td>04-Jul</td>
</tr>
<tr>
<td>30 day PB</td>
<td>80% Leaf removal mechanical</td>
<td>26-Jul</td>
<td>28-Jul</td>
</tr>
<tr>
<td>30 day PB</td>
<td>80% Leaf removal manual</td>
<td>26-Jul</td>
<td>28-Jul</td>
</tr>
<tr>
<td>Bunch Closure</td>
<td>33% of entire Canopy</td>
<td>21-Jul</td>
<td>25-Jul</td>
</tr>
<tr>
<td>Véraison</td>
<td>50% Leaf removal</td>
<td>17-Aug</td>
<td>23-Aug</td>
</tr>
<tr>
<td>Véraison</td>
<td>100% Leaf removal</td>
<td>17-Aug</td>
<td>23-Aug</td>
</tr>
</tbody>
</table>

**Harvest dates:** Oct 18<sup>th</sup> 2016 / Nov 3<sup>rd</sup> 2017

*All treatments harvested on same day*
Photos of Cab Franc LR vines after treatment

NoLR  80%MEC7PB  80%MAN7PB  80%MEC30PB
80%MAN30PB  33%BC  50%V  100%V
a) 2016: 1666 GDD

b) 2017

Figure 1a & b. Weather graphs 2016 and 2017
Figure 2. A selection of 2016 point quadrat analyses (PQA) data

Meyers and Vanden Heuvel (2008)
Figure 3. A selection of 2017 point quadrat analyses (PQA) data

Meyers and Vanden Heuvel (2008)
## Harvest yield data

- **No disease in 2016 or 2017 in Cabernet franc grapes in any treatments.**
- **Shrivelling in 2017**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2016 Cluster weight (g)</th>
<th>2017 Cluster weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NoLR/C</td>
<td>125</td>
<td>124 ab</td>
</tr>
<tr>
<td>80%MEC7PB</td>
<td>128</td>
<td>137 bc</td>
</tr>
<tr>
<td>80%MAN7PB</td>
<td>117</td>
<td>141 c</td>
</tr>
<tr>
<td>80%MEC30PB</td>
<td>123</td>
<td>120 a</td>
</tr>
<tr>
<td>80%MAN30PB</td>
<td>139</td>
<td>137 bc</td>
</tr>
<tr>
<td>33%BC</td>
<td>126</td>
<td>129 abc</td>
</tr>
<tr>
<td>50%V</td>
<td>129</td>
<td>132 abc</td>
</tr>
<tr>
<td>100%V</td>
<td>120</td>
<td>120 a</td>
</tr>
<tr>
<td><strong>Pr &gt; F</strong></td>
<td>0.703</td>
<td>0.029</td>
</tr>
<tr>
<td><strong>Significant</strong></td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
### Harvest yield data (kgs/vine)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2016 Yield (kg)/vine</th>
<th>2017 Yield (kg)/vine</th>
</tr>
</thead>
<tbody>
<tr>
<td>NoLR/C</td>
<td>4.4 c</td>
<td>5.0 ab</td>
</tr>
<tr>
<td>80%MEC7PB</td>
<td>4.5 bc</td>
<td>5.5 bc</td>
</tr>
<tr>
<td>80%MAN7PB</td>
<td>4.7 bc</td>
<td>5.6 c</td>
</tr>
<tr>
<td>80%MEC30PB</td>
<td>5.2 ab</td>
<td>4.8 a</td>
</tr>
<tr>
<td>80%MAN30PM</td>
<td>4.9 abc</td>
<td>5.5 bc</td>
</tr>
<tr>
<td>33%BC</td>
<td>5.4</td>
<td>5.2 abc</td>
</tr>
<tr>
<td>50%V</td>
<td>4.9 abc</td>
<td>5.3 abc</td>
</tr>
<tr>
<td>100%V</td>
<td>4.3 c</td>
<td>4.8 a</td>
</tr>
</tbody>
</table>

Pr > F: 0.045 (2016), 0.029 (2017)

**Significant:** Yes (Pr > F < 0.05)

#### Yield (kg)/vine
- **2016 highest yield/vine** in 33%BC
- **2017 highest yield/vine** 80%MAN7PB
## Harvest yield data (cluster number/vine)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2016 CLUSTER#</th>
<th>2017 CLUSTER#</th>
</tr>
</thead>
<tbody>
<tr>
<td>NoLR/C</td>
<td>36 b</td>
<td>42 a</td>
</tr>
<tr>
<td>80%MEC7PB</td>
<td>37 b</td>
<td>52 bc</td>
</tr>
<tr>
<td>80%MAN7PB</td>
<td>41 ab</td>
<td>51 bc</td>
</tr>
<tr>
<td>80%MEC30PB</td>
<td>43 a</td>
<td>53 bc</td>
</tr>
<tr>
<td>80%MAN30PM</td>
<td>36 b</td>
<td>52 bc</td>
</tr>
<tr>
<td>33%BC</td>
<td>44 a</td>
<td>49 abc</td>
</tr>
<tr>
<td>50%V</td>
<td>39 ab</td>
<td>56 c</td>
</tr>
<tr>
<td>100%V</td>
<td>36 b</td>
<td>45 ab</td>
</tr>
<tr>
<td>Pr &gt; F</td>
<td>0.047</td>
<td>0.009</td>
</tr>
<tr>
<td>Significant</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

- **CLUSTER #**
  - Higher cluster # in 2016 = 33%BC & 80%MEC30PB
  - Treatment carry over effects in 2017
Grape soluble solids (°Brix) at harvest 2016 & 2017

Chemical analysis for 2016 Cabernet franc juice reported as mean ± standard deviation. Statistical analysis of data was determined by one-way ANOVA. Post hoc analysis was performed by Tukey’s HSD (p < 0.05).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2016 Soluble solids (°Brix)</th>
<th>2017 Soluble solids (°Brix)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOLR/control</td>
<td>23.6 ±0.2 a</td>
<td>24.5 ±0.2 ab</td>
</tr>
<tr>
<td>80%MA7PB</td>
<td>22.9 ±0.3 ab</td>
<td>22.8 ±0.3 c</td>
</tr>
<tr>
<td>80%ME7PB</td>
<td>22.8 ±0.7 ab</td>
<td>23.2 ±0.0 c</td>
</tr>
<tr>
<td>80%MA30PB</td>
<td>22.4 ±0.4 b</td>
<td>23.4 ±0.2c</td>
</tr>
<tr>
<td>80%ME30PB</td>
<td>22.8 ±0.1 ab</td>
<td>25.0 ±0.3a</td>
</tr>
<tr>
<td>33%BC</td>
<td>22.7 ±0.4 ab</td>
<td>23.6 ±0.2bc</td>
</tr>
<tr>
<td>50%V</td>
<td>23.4 ±0.5 ab</td>
<td>23.2 ±0.2c</td>
</tr>
<tr>
<td>100%V</td>
<td>22.8 ±0.3 ab</td>
<td>22.9 ±0.2c</td>
</tr>
</tbody>
</table>

Significance: p < 0.05, p < 0.001
Juice pH 2016 & 2017

Chemical analysis for 2016 Cabernet franc juice reported as mean ± standard deviation. Statistical analysis of data was determined by one-way ANOVA. For significant results post hoc analysis was performed by Tukey’s HSD (p < 0.05).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>pH 2016</th>
<th>pH 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOLR/control</td>
<td>3.41 ± 0.0 ab</td>
<td>3.52 ±0.0 ab</td>
</tr>
<tr>
<td>80%MA7PB</td>
<td>3.33 ± 0.0 bc</td>
<td>3.46 ±0.0b</td>
</tr>
<tr>
<td>80%ME7PB</td>
<td>3.31 ± 0.0 c</td>
<td>3.48 ±0.0b</td>
</tr>
<tr>
<td>80%MA30PB</td>
<td>3.34 ± 0.0 bc</td>
<td>3.46 ±0.0 b</td>
</tr>
<tr>
<td>80%ME30PB</td>
<td>3.45 ± 0.0 a</td>
<td>3.58 ±0.1a</td>
</tr>
<tr>
<td>33%BC</td>
<td>3.40 ± 0.1 ab</td>
<td>3.51 ±0.0ab</td>
</tr>
<tr>
<td>50%V</td>
<td>3.42 ± 0.1 ab</td>
<td>3.45 ±0.0 b</td>
</tr>
<tr>
<td>100%V</td>
<td>3.39 ± 0.0 abc</td>
<td>3.44 ±0.0 b</td>
</tr>
</tbody>
</table>

Significance

- p < 0.01

Titratable Acidity (TA (g/L)):
Statistically significant between years but not treatments

- 2016: TA (g/L) range: 4.5 - 5.3
- 2017: TA (g/L) range: 8.8 - 9.2
Cabernet franc juice parameters

2016: 
Not statistically significant

- TA (g/L) range: 4.5 - 5.3
- YAN (mg N/L): 99 - 129
- Malic acid (g/L): 0.9 - 1.7

2017: 
Not statistically significant

- Acetic acid (g/L) all <0.03
- TA (g/L) range: 8.8 - 9.2

2016: 
Statistically significant

- Acetic acid 0.2 \{100\%V\} - 0.10 (g/L) \{80\%ME30PB\}

2017: 
Statistically significant

- YAN (mg N/L): 100 \{100\%V\} - 145 \{80\%ME7PB\}
- Malic acid (g/L): 2.3 \{100\%V\} to 2.9 \{80\%MEC7PB\}
Winemaking 2016 & 2017

- Crushed & destemmed grapes by treatment
- 25 kg ferments
  - Inoculated with EC1118 yeast
- 7 day fermentations @ 28°C
  - 5 days on skins post fermentation
- NO MLF
- NO oak barrel aging
- No fining
- Filtered to 0.8mn
  - SO₂ (30 ppm)
  - & bottled with cork
- & bottled with cork
WINE chemical composition of wine 2017

**2016 TA (g/L)**
- 7.0 - 7.1
  - *Not Significant*

**2017 TA (g/L)**
- 5.5 - {80%MEC30PB} – 6.1 {NOLR/C}
  - *Significant*
Ethanol and residual sugar levels (RS (g/L) wines 2016 & 2017

2016: Alcohol (v/v%) 12.7 - 13 NS

2016: RS (g/L): 0 NS
### Malic acid levels (g/L) in 2016 & 2017 in wines

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2016 Malic acid (g/L)</th>
<th>2017 Malic acid (g/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NoLR</td>
<td>1.5</td>
<td>2.3 a</td>
</tr>
<tr>
<td>80%MAN7PB</td>
<td>1.3</td>
<td>2.1 abc</td>
</tr>
<tr>
<td>80%MEC7PB</td>
<td>1.6</td>
<td>2.2 abc</td>
</tr>
<tr>
<td>80%MAN30PB</td>
<td>1.5</td>
<td>2.1 abc</td>
</tr>
<tr>
<td>80%MEC30PB</td>
<td>1.5</td>
<td>2.0 bc</td>
</tr>
<tr>
<td>33%BC</td>
<td>1.6</td>
<td>2.3 a</td>
</tr>
<tr>
<td>50%V</td>
<td>1.5</td>
<td>2.3 a</td>
</tr>
<tr>
<td>100%V</td>
<td>1.5</td>
<td>1.9 c</td>
</tr>
<tr>
<td><strong>Significance</strong></td>
<td><strong>NS</strong></td>
<td><strong>Yes</strong></td>
</tr>
<tr>
<td><strong>Pr &gt; F</strong></td>
<td><strong>0.897</strong></td>
<td><strong>0.004</strong></td>
</tr>
</tbody>
</table>

Least amount of leaves removed in 2017 = higher malic acid.
Acetic acid levels (g/L) levels in wine 2016 & 2017

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2016 Acetic acid (g/L)</th>
<th>2017 Acetic acid (g/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NoLR</td>
<td>0.31 ab</td>
<td>0.49 ab</td>
</tr>
<tr>
<td>80%MAN7PB</td>
<td>0.30 ab</td>
<td>0.43 b</td>
</tr>
<tr>
<td>80%MEC7PB</td>
<td><strong>0.32 a</strong></td>
<td>0.44 b</td>
</tr>
<tr>
<td>80%MAN30PB</td>
<td>0.27 b</td>
<td>0.43 b</td>
</tr>
<tr>
<td>80%MEC30PB</td>
<td>0.27 b</td>
<td><strong>0.51 ab</strong></td>
</tr>
<tr>
<td>33%BC</td>
<td>0.29 ab</td>
<td><strong>0.56 a</strong></td>
</tr>
<tr>
<td>50%V</td>
<td>0.27 b</td>
<td>0.48 ab</td>
</tr>
<tr>
<td>100%V</td>
<td>0.27 b</td>
<td>0.48 ab</td>
</tr>
<tr>
<td>Significance</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Pr &gt; F</td>
<td>0.020</td>
<td>0.007</td>
</tr>
</tbody>
</table>
Colour of Cabernet franc red wines (2016) from different timings & severities of leaf removal in a Niagara-on-the-Lake vineyard, Ontario.
Total phenolics in wines in 2016

Lowest interior clusters

Total phenolics (A.U.)

- 80%MEC30PB
- 50%V
- 80%MAN7PB
- 100%V
- 80%MEC7PB
- 80%MAN30PB
- NoLR/C
- 33%BC

Different letters indicate significant differences.
Total tannin concentration wines 2016

Lowest interior clusters

(Campbell 2017)
Total tannin concentration in wines 2017

2017 WINE
Tannin concentration
(mg/L Epicatechin equivalents)
Total tannin concentration in 2016 wines
Early manual vs. Mechanical Methods

2016
- Statistically significant
- Highest wine tannin = 80%ME30PB
- Lowest wine tannin = 80%Man30PB

(Campbell 2017)

2017
- Not statistically significant
- Highest wine tannin = 80%ME30PB
• 2016 wines made in October 2016 carried out in Nov 2017.

• DA sensory panel training: 3 sessions/3 hours each = 9 hours

• Data from 12 Panelists used: 4 males, 8 females.

• Training with ref standards & scales

• Duplicate wines in 2 sessions

• Black glasses
Sensory analysis 2016 wines
Spider graph
Sensory analysis 2016 wines
Principal Components Analysis (PCA)

Biplot (axes F1 and F2: 58.13 %)

- Cooked/Canned Vegetal-Aroma
- Bitterness
- Green-Flavour
- Medicinal/Herbal
- Green Pepper-Aroma
- NoLR/C
- Berry-Aroma
- Astringency
- Cherry-Aroma
- Cherry-Flavour
- Prune-Aroma

80%ME30PB
80%MAN7PB

80%ME30PB
100%V
Sensory analysis 2016
Manual vs. Mechanical leaf removal
7 and 30 days PB

Cherry aroma = timing

All other descriptors = method i.e. manual or mechanical
Bitterness & astringency perception 2016

**Astringency** perceived to be highest in early LR manual wines

**Bitterness** perceived as being highest in 33%BC
2016 juice & wine chemical analyses
Agglomerative Hierarchal Clustering (AHC)

AHC is a classification method based on the dissimilarities between the wines.
Further analysis

• Phenolic analyses including tannin analysis of grape skins & seeds 2016 & 2017
• Methoxypyrazines levels in wines 2017 wines
• PQA data analysis
• Sensory analysis
• Free & total SO₂
• Total phenolics
• In-depth statistical analyses
Summary of results

- **Timing & severity:**
  - Vintage differences
  - Higher cluster exposure = lower kgs/vine
  - Higher phenolics in wine with early LR
  - 50%V similar to NoLR/Control
  - 33%BC similar to 100%V (chemical analysis)

- **Method:**
  - Low interior clusters so higher cluster exposure in early mechanical LR each year than early manual LR.
  - Higher pH in mechanical LR wines
  - **80%MEC30PB similar to 80%MAN7PB** (sensory & chemical analyses)
Acknowledgments

- **RESEARCHERS**: Jim Willwerth, Mary Jasinski, Stephanie Bilek, Judah Campbell, Tony Wang, Fei Wang, Steve Trussler, Margaret Thibodeau and Debbie Inglis.

- **Grape pickers & those that carried out leaf removal**: Margaret Hughes, Catherine Cahill, Tom Willwerth, Mark Willwerth, Andrea Barker, Andreanne Hebert-Hache, Cameron Hebert-Hache, Charles Bernard, Emma Rice, Toby Kemp, Veronika Kemp, Tony Wang.

- **Trius Winery for in-kind contributions**

- **Huebel Farms**: Matthias Oppenlander, Thomas Oppenlander, Aaron Oppenlander for in-kind contributions.

- **Malcolm Laurie** for his co-operation and enthusiasm.

**FUNDING**

- Ontario Grape & Wine Research Inc (OGWRI)
- Natural Sciences and Engineering Research Council (NSERC) CRD grant.


THATS ALL FOLKS!
Any questions?