Mechanized Harvesting for Fresh Market Blueberry

Lisa DeVetter, Fumiomi Takeda, Wei Yang, Scott Korthuis, Brian Foote, and Changying (Charlie) Li

[Logo images for University of Georgia, Oregon State University, USDA, OXBO, and Washington State University]
Harvesting Fresh Market Blueberries is Increasingly Challenging

- Over 70% of fresh-market blueberries are harvested by hand.
- Industry is constrained by high labor costs, low worker availability, and competition from other operations.
- Mechanization is one solution to the labor challenge.
- Current commercial technologies for machine harvest of fresh-market blueberries are not efficient and fruit quality is jeopardized.
Challenges with Machine Harvesting Blueberries for Fresh Markets

The fruit is soft and delicate!

- One-cell-layer epidermis
- One-cell-layer hypodermis
- Non-pigmented fleshy, thin-walled parenchyma cells

Non-pigmented fleshy, thin-walled parenchyma cells
Bruised Fruit have Reduced Fruit Quality and a Shorter Shelf Life

- Dropped and machine-harvested fruit will become **bruised**, reducing quality and **post harvest life**.
- Bruised area is usually **wedge-shaped** and **dark** from the **impact** that caused the bruise.
Response to Industry Problem – USDA SCRI Funded Project

- USDA SCRI project led by Dr. Charlie Li, “Scale Neutral Harvest Aid System and Sensor Technologies to Improve Harvest Efficiency and Handling of Fresh Market Highbush Blueberries”
- USDA NIFA 2014-51181-22383
Principal Investigators

C. Li (PD)     H. Scherm      J. Chen       F. Takeda       D. Zilberman
UGA         UGA          UGA           USDA-ARS      UC-Berkeley
B. Cline     E. Stafne
NCSU        MS State

R. Beaudry     A. Freivalds   W. Yang     S. Sargent     J. Williamson   L. DeVetter   K. Gallardo
MSU         PSU          OSU         UF            UF               WSU         WSU

Collaborators: Jim Olmstead, Driscoll’s (formerly UF); Renee Holland, UGA; Maggie Schaber, NCSU; Scott Korthuis and Brian Foote, Oxbo
Berry Impact Recording Device (BIRD)

- Wireless data-logging sensor
- Weighs 6.9 g and 21 mm in diameter
- Travels with fruit through harvesting, transportation, and packing lines
- Determines major points of impact through an internal accelerometer and microprocessor
Determining Points of Impact using BIRD: Harvesting

- Detached & falling
- Catch plate
- Conveyor belt
- Lug/flat filling

Time (s)
Impact (g)
0 0.7 2.2 4 6 6.9 7.3
0 100 200 300 400 500

Phase 1
Phase 2
Phase 3
Phase 4
Jiang et al. (2016) showed bruised and healthy tissues emit different spectra using nondestructive near-infrared (NIR) hyperspectral imaging technology.
Harvester Phase 1: Harvest-Assist System with Pneumatic Hand-Held Shakers (2015-2016)

Semi-Mechanical Blueberry Harvesting System

Soft-Catch Surface

<table>
<thead>
<tr>
<th>Harvest Method</th>
<th>Percentage of berries with $\geq 19%$ damage$^2$</th>
<th>Average bruise Area (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand harvest</td>
<td>9.2 $a$</td>
<td>8 $a$</td>
</tr>
<tr>
<td>Harvest-aid shaker</td>
<td>15.6 $a$</td>
<td>10 $a$</td>
</tr>
<tr>
<td>OTR Littau harvester</td>
<td>65.5 $b$</td>
<td>37 $b$</td>
</tr>
<tr>
<td>$P$-value</td>
<td>$&lt;0.0001$</td>
<td>$&lt;0.0001$</td>
</tr>
</tbody>
</table>

$^2$Percentages analyzed on transformed data; raw averages presented. Mean separation using DIFF option in SAS Proc Mixed.
Harvester Phase 2: Harvest-Aid System with Pneumatic Hand-Held Shakers in Oxbo 7420 (2017)
Harvester Phase 2: Harvest-Aid System with Pneumatic Hand-Held Shakers in Oxbo 7420 (2017)

New prototype tested in ‘Elliott’ and ‘Aurora’ in 2017
Harvester Phase 3: New Prototype with Orbirotor® Heads

<table>
<thead>
<tr>
<th>Treatment</th>
<th>24 hours after harvest</th>
<th>2 weeks after harvest</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bruise rating&lt;sup&gt;2&lt;/sup&gt;</td>
<td>&lt; 10% bruise</td>
</tr>
<tr>
<td>Elliott</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plastic surface</td>
<td>36 c&lt;sup&gt;y&lt;/sup&gt; 17 b 24 c</td>
<td></td>
</tr>
<tr>
<td>Black neoprene</td>
<td>29 b 17 b 42 b</td>
<td></td>
</tr>
<tr>
<td>Hand (control)</td>
<td>18 a 42 a 67 a</td>
<td></td>
</tr>
<tr>
<td>P-value</td>
<td>&lt;0.0001 0.0172 0.0034</td>
<td></td>
</tr>
<tr>
<td>Aurora</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plastic surface</td>
<td>16 b 42 b 69 b</td>
<td></td>
</tr>
<tr>
<td>Black neoprene</td>
<td>11 a 69 a 81 ab</td>
<td></td>
</tr>
<tr>
<td>Hand (control)</td>
<td>10 a 74 a 89 a</td>
<td></td>
</tr>
<tr>
<td>P-value</td>
<td>0.0002 0.0283 0.0425</td>
<td></td>
</tr>
</tbody>
</table>

<sup>2</sup>Ratings were on a 0 to 100 scale with 0 indicating no bruising and 100 indicating the entire cut surface was bruised.

<sup>y</sup>Twenty-five berries per one of four replicates were evaluated at each sampling time; Means with the same letter within a column are not different due to treatment at α = 0.05.

<sup>x</sup>NS denotes not statistically significant.
USDA SCRI Project Funding has Ended

▪ Duration of USDA SCRI: 9/2014 to 8/2018
▪ Few funds for work in Washington State
▪ Promising results – Washington Blueberry Commission provided funding in 2018 to keep the momentum going and fund new trials
Objectives of 2018 Research

1. Develop harvest **technologies** and **practices** that allow for machine harvest of fresh market blueberry with **high fruit quality** → *Phase 4 of Harvester Research*

2. Characterize changes in **firmness** during berry development

3. Evaluate **packing lines** for practices that could decrease fruit quality

4. **Extend** project information
Objective 1 – Harvest Technologies and Practices

**Prosser**
- Compared *machine* (*plastic* or *neoprene* surface) to *hand harvest* in a *third-pick ‘Draper’* field using an Oxbo 7040
- Feedback – improve selectivity and pack out

**Lynden**
- Compared *machine* to *hand harvest* in *first- and second-pick ‘Draper’* and *first-pick ‘Liberty’* using Oxbo 8040
- Experimented with different *head* and *ground speeds* to improve *selectivity*
Oxbo 8040 – Tested in Lynden
Oxbo 8040 – Tested in Lynden
Improving Machine Harvest Efficiency and Fruit Quality for Fresh Market Blueberry

- Harvest selectivity – in field and pack out
- Firmness using a FirmTech II (Bioworks, FirmTech II, Bioworks, Wamego, KS)
- Incidence of bruising
- Assessed firmness and bruising 1, 7, 14, 21, and 28 days after harvest
### Results – Third-Pick ‘Draper’ in Prosser

*Harvested July 19, 2018*

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Pack out (%)</th>
<th>Firmness (g/mm)</th>
<th>48 hours</th>
<th>7 days</th>
<th>21 days</th>
<th>28 days</th>
<th>Bruising</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic</td>
<td>66</td>
<td>145.9 b&lt;sup&gt;y&lt;/sup&gt;</td>
<td>159.2 a</td>
<td>130.4</td>
<td>124.0</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Neoprene</td>
<td>72</td>
<td>149.3 b&lt;sup&gt;b&lt;/sup&gt;</td>
<td>147.5 b</td>
<td>122.0</td>
<td>123.9</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Hand</td>
<td>-z</td>
<td>160.1 a&lt;sup&gt;a&lt;/sup&gt;</td>
<td>143.5 b</td>
<td>123.3</td>
<td>123.4</td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>

*Data not available or pending (bruise data are pending).*

Means with the same letter within a column are not different due to treatment at $\alpha = 0.05$.

<sup>y</sup>Data not available or pending (bruise data are pending).

<sup>a</sup>Means with the same letter within a column are not different due to treatment at $\alpha = 0.05$. 

*P*-value  

- 0.0175  

<0.001  

NS  

NS  

-
# Results – First-Pick ‘Draper’ in Lynden

*Harvested July 24, 2018*

<table>
<thead>
<tr>
<th>Treatment (head speed; ground speed)</th>
<th>Pack out (%)</th>
<th>Firmness (g/mm)</th>
<th>1 day</th>
<th>7 days</th>
<th>14 days</th>
<th>21 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trt. 1 (315 rpm; 0.3 mph)</td>
<td>92</td>
<td></td>
<td>156.2 b&lt;sup&gt;y&lt;/sup&gt;</td>
<td>154.7 b</td>
<td>148.5 b</td>
<td>133.8</td>
</tr>
<tr>
<td>Trt. 2 (600 rpm; 0.5 mph)</td>
<td>92</td>
<td></td>
<td>157.7 b</td>
<td>157.8 b</td>
<td>152.1 b</td>
<td>128.7</td>
</tr>
<tr>
<td>Trt. 3 (550 rpm; 0.4 mph)</td>
<td>93</td>
<td></td>
<td>153.2 b</td>
<td>142.9 c</td>
<td>150.9 b</td>
<td>129.8</td>
</tr>
<tr>
<td>Hand</td>
<td>-</td>
<td></td>
<td>179.7 a</td>
<td>180.8 a</td>
<td>166.6 a</td>
<td>136.2</td>
</tr>
<tr>
<td><em>P</em>-value</td>
<td>-</td>
<td></td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>0.004</td>
<td>NS</td>
</tr>
</tbody>
</table>

<sup>2</sup>Data not available or pending (*bruise data are pending*).

<sup>y</sup>Means with the same letter within a column are not different due to treatment at α = 0.05.
# Results – First-Pick ‘Liberty’ in Lynden

*Harvested Aug. 9, 2018*

<table>
<thead>
<tr>
<th>Treatment (head speed; ground speed; head gap)</th>
<th>Pack out (%)</th>
<th>Firmness (g/mm)</th>
<th>1 day</th>
<th>7 days</th>
<th>14 days</th>
<th>21 days</th>
<th>28 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trt. 1 (320 rpm; 0.32 mph; 3 inch)</td>
<td>74</td>
<td></td>
<td>122.07 bc</td>
<td>110.50 b</td>
<td>99.06 bc</td>
<td>113.86 a</td>
<td>90.91 d</td>
</tr>
<tr>
<td>Trt. 2 (263 rpm; 0.5 mph; 2 inch)</td>
<td>75</td>
<td></td>
<td>126.91 b</td>
<td>109.94 b</td>
<td>97.10 bc</td>
<td>103.79 bc</td>
<td>106.28 b</td>
</tr>
<tr>
<td>Trt. 3 (400 rpm; 0.65 mph; 2 inch)</td>
<td>73</td>
<td></td>
<td>114.71 cd</td>
<td>107.74 b</td>
<td>94.08 c</td>
<td>103.60 bc</td>
<td>103.29 bc</td>
</tr>
<tr>
<td>Trt. 4 (470 rpm; 0.7 mph; 2 inch)</td>
<td>90</td>
<td></td>
<td>124.56 b</td>
<td>109.57 b</td>
<td>97.62 bc</td>
<td>97.56 c</td>
<td>96.97 cd</td>
</tr>
<tr>
<td>Trt. 5 (505 rpm; 1 mph; touching)</td>
<td>72</td>
<td></td>
<td>112.79 d</td>
<td>106.80 b</td>
<td>101.60 b</td>
<td>104.49 bc</td>
<td>95.56 d</td>
</tr>
<tr>
<td>Hand</td>
<td>-</td>
<td></td>
<td>148.46 a</td>
<td>148.86 a</td>
<td>129.33 a</td>
<td>106.70 ab</td>
<td>114.55 a</td>
</tr>
</tbody>
</table>

- **P-value**
  - <0.0001
  - <0.0001
  - <0.0001
  - 0.0052
  - <0.0001

> Data not available or pending (bruise data are pending).

Means with the same letter within a column are not different due to treatment at α = 0.05.
Objective 3 – Packing Line Assessments

- Assess **two packing lines in eastern Washington** and **two packing lines in western Washington** using the BIRD sensor
- **Shared results** with packing house manager
- Overall, **well designed packing lines**
How does **cooling** impact **fruit quality**?

Experiment done with hand-harvested ‘Liberty’ on Aug. 15, 2018

<table>
<thead>
<tr>
<th>Treatment</th>
<th>1 day</th>
<th>7 days</th>
<th>14 days</th>
<th>21 days</th>
<th>28 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>No pre-chill; ambient packing</td>
<td>99.6 b</td>
<td>94.9 c</td>
<td>105.6 b</td>
<td>94.9 b</td>
<td>98.3 b</td>
</tr>
<tr>
<td>Pre-chilled; ambient packing</td>
<td>110.5 a</td>
<td>107.7 b</td>
<td>111.4 ab</td>
<td>112.0 a</td>
<td>129.6 a</td>
</tr>
<tr>
<td>Pre-chilled; not packed</td>
<td>115.8 a</td>
<td>120.9 a</td>
<td>117.6 a</td>
<td>114.7 a</td>
<td>122.5 a</td>
</tr>
</tbody>
</table>

*P*-value

|       | <0.0001 | <0.0001 | 0.046   | <0.0001 | <0.0001 |

*Fruit was pre-chilled to 49 °F.*

*Means with the same letter within a column are not different due to treatment at α = 0.05; note **bruise data are pending**.*
Objective 4 – Outreach
Field Day in Prosser, WA
Next Steps…
Continued Research

Objectives:

1. Develop and test harvest technologies and practices that allow for the mechanical harvest of fresh market blueberry with high fruit quality and high harvest efficiency

2. Packing line assessments

3. Compare food safety risks associated with traditional and new harvesting technologies

4. Assess the microbial quality of fruits harvested by hand and the modified OTR harvester prototype

5. Extend project information
Long-Term Goal of Research

Support commercial development of effective, durable, and scale-neutral machine harvesting technologies that allow growers to economically harvest high-quality blueberries for fresh market.
Acknowledgements

Funding:
- USDA SCRI
- Washington Blueberry Commission

Industry Collaborators:
- Maberry Packing, LLC
- Munger Farms
- Olsen Brothers
- Oasis Farms
- Sakuma Brothers

Technical Support:
- Sean Watkinson, Huan Zhang, Nadia Bostan, Amit Bhasin, and Weixin Gan
Please Complete this Survey about Harvesting

Results will be kept Anonymous

Blueberry Mechanical Harvesting Survey, 2018-2019

Objective: To collect data for the USDA-funded project, Scale-neutral Harvest-aid System and Sensor Technologies to Improve Harvest Efficiency and Handling of Fresh-market Highbush Blueberries. Participation is voluntary and confidentiality among survey participants will be maintained.

Section 1. About Your Harvesting Methods

1. Please indicate the harvesting method(s) that you used over the past three harvest seasons (2016-2018) and the percent of your annual production harvested by each method. Your answer(s) should total to 100%. An example answer is provided.

<table>
<thead>
<tr>
<th>Harvest method</th>
<th>Fresh Pack Berries</th>
<th>Processed Berries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand</td>
<td>[Example 80%]</td>
<td></td>
</tr>
<tr>
<td>Mechanical</td>
<td>[Example 10%]</td>
<td>[Example 10%]</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. From 2016-2018 (past three harvest seasons), these were the top **THREE (3)** problems/challenges you encountered in growing highbush blueberry for fresh market:
Thank you!
Any Questions?

Lisa Wasko DeVetter, PhD
Assistant Professor of Small Fruit Horticulture
Washington State University NWREC
Email: lisa.devetter@wsu.edu
Website: https://smallfruits.wsu.edu/
Twitter: Lisa DeVetter @WSU_SmallFruits
Harvester Phase 1: Harvest-Assist System with Pneumatic Hand-Held Shakers (2015-2016)

- Campagnola “Alice” Shaker
- Electric powered
- Double movement rakes
- While rakes shift sideways, all the teeth move in rotatory, opposite motion
- ~60 sq. inch harvest area per unit
- Rakes carry 1,150 cycles per minute
- 11 interchangeable teeth
- Potential to integrate into catch frame with softer surfaces
Objective 2 – Characterize Changes in Firmness during Berry Development

- Collected four, 30-berry samples per field from **S3 (late green) → S7 (post harvest)** stages in western and eastern Washington
- Sampled ‘Duke’ and ‘Liberty’ in Prosser
- Measured **firmness** and will measure **soluble solids** and **acidity**
- Results pending, but will help develop **harvest indices**