Retrofitting intelligent spray system on airblast sprayers for sustainable horticultural crop production

Heping Zhu, Ph.D.

Ag. Engineer/Lead Scientist
USDA-ARS, ATRU, Wooster, Ohio, USA
Adjunct Professor
FABE, The Ohio State University

For Mid-Atlantic Fruit and Vegetable Convention. February 2, 2022.
Foliar Spray Application – most common method of delivery in modern crop production
Pesticide Spray Application Is a Complicated Process. Quality of Applications Depends on:

- Delivery equipment and methods
- Physical properties of spray formulations
- Type and amount of chemicals
- Types of pests and diseases
- Diversity of crops and their growth habits
- Operator skills
- Uncontrollable weather conditions
- Extensive worker safety and environmental regulations
- Cost-benefits of spray applications
Current spray practices have very low efficiency and require a complicated calibration process to determine the amount of chemicals to be used.
Laser-guided intelligent sprayer technology

Advanced and affordable spray systems that employ intelligent technologies with coordinated strategies to minimize human involvement in pesticide spray applications
Use individual tree foliage volume to control spray outputs of each nozzle instead of traditional gallons per acre.

270° radial, 90-ft range

43,200 points/s

Convert point-to-point distances to surface structures

Each nozzle output is controlled by individual canopy foliage volume with 10Hz PWM valve:

\[
Q_i = \frac{E_{vol}}{t} = \frac{h \cdot W \cdot v \cdot t \cdot \rho \cdot \nabla}{t} = h \cdot W \cdot v \cdot \rho \cdot \nabla
\]
Universal control system as a retrofit on sprayers

Commercial intelligent spray controller

- Algorithms
- Laser sensor
- PWM flow control valve
- Air Filtration
- GPS

Existing sprayers

- Retrofit
- Flow controller
- Android Tablet Display
Spray trials in an apple orchard

Conventional mode (45 gpa)

Total spray volume used for the test row
Conventional application: 3.3 gallon
Automatic application: 2.1 gallon

36% reduction
Examples of Results

Canopy deposition

Canopy Deposition in spray direction

μL/cm²

Front: 2.076, 1.689, 1.341
Middle Front: 0.862, 0.718, 0.586
Center: 0.427
Middle Back: 0.159
Back: 0.252

Intelligent: Front, Middle Front, Center, Middle Back, Back
Conventional: Front, Middle Front, Center, Middle Back, Back

No significant difference
Ground Deposition Under Trees

Spray loss to the ground under the canopy

Intelligent: 0.273
Conventional: 0.463

41% reduction in off-target loss under trees
Airborne spray drift at different heights and different distances from the sprayed row

65.5% reduction in total spray drift loss
Average numbers of codling moths trapped in conventional constant-rate (Con) and intelligent variable-rate (Int) spray apple plots
Severity of diseases (%) of scab in apple trees, brown rot in peach fruits and phomopsis in blueberry plants treated with conventional constant-rate (Con) and intelligent variable-rate (Int) applications in 2019.

Non-pathogenic fungi to thrive and compete with pathogenic fungi.
Chemical reductions and cost savings with intelligent sprayers in an Ohio fruit farm

### Spray volume reduction (%)

<table>
<thead>
<tr>
<th>Year</th>
<th>Apple</th>
<th>Peach</th>
<th>Blueberry</th>
<th>Raspberry</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>64.8</td>
<td>23.7</td>
<td>44.4</td>
<td>49.4</td>
</tr>
<tr>
<td>2018</td>
<td>52.3</td>
<td>34.0</td>
<td>50.6</td>
<td>56.7</td>
</tr>
<tr>
<td>2019</td>
<td>32.1</td>
<td>32.0</td>
<td>55.7</td>
<td>55.3</td>
</tr>
</tbody>
</table>

### Cost savings ($/acre)

<table>
<thead>
<tr>
<th>Year</th>
<th>Apple</th>
<th>Peach</th>
<th>Blueberry</th>
<th>Raspberry</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>983</td>
<td>61</td>
<td>292</td>
<td>117</td>
</tr>
<tr>
<td>2018</td>
<td>755</td>
<td>220</td>
<td>289</td>
<td>81</td>
</tr>
<tr>
<td>2019</td>
<td>394</td>
<td>177</td>
<td>346</td>
<td>53</td>
</tr>
</tbody>
</table>
On-farm tests of the intelligent spray system in orchards, vineyards and nurseries in different states since 2013

Wooden’s Apple House in Tennessee
The Apple Barn in Tennessee
Bauman Orchards in Ohio
Moreland Fruit Farm in Ohio
Lynd Fruit Farm in Ohio
Blueberry Patch in Ohio
Klingshirn Winery in Ohio
Titan Peach Farm in South Carolina
5 R Enterprises (Pecan Farm) in Texas
Willoway Nurseries in Ohio
Herman Losely & Son Nurseries in Ohio
Klyn Nurseries in Ohio
Hans Nelson & Sons Nurseries in Oregon
J Frank Schmidt Nurseries in Oregon
Hale & Hines Nursery in Tennessee
Pleasant Cove Nurseries in Tennessee
Compared to conventional sprayers with comparable controls of insects and diseases, the intelligent sprayers:

1. increased spray deposition uniformity
2. minimized off-target losses (up to 87% reduction in airborne spray drift, up to 93% reduction in spray loss on the ground),
3. reduced pesticide use by up to 70%,
4. annual chemical savings by $50-$980 per acre.
Smart Guided Systems commercialized the intelligent spray control system (https://www.smartguided.com/)

Smart-Apply® Intelligent Spray Control System™

For the most accurate, updated, and comprehensive information on the Smart-Apply Intelligent Spray Control System™, visit SmartApply.com

John Deere sells the product through dealer network.
Retrofitting intelligent spray control system

- GPS for Speed & Coverage Maps
- LIDAR (Laser)
- Controllers for Spray Nozzles
- Nozzle Solenoids
- Algorithm’s for Calculating Spray Volume
- Air Filtration for LiDAR Lens
- Android Tablet Display
Retrofitting example
Attach a PWM solenoid valve to the nozzle body.
Retrofitting example
Spray settings on tablet

<table>
<thead>
<tr>
<th>LEFT NOZZLES</th>
<th>Number of nozzles: 9</th>
<th>Nozzles offset:</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO.</td>
<td>BOTTOM HEIGHT</td>
<td>TOP HEIGHT</td>
</tr>
<tr>
<td>1</td>
<td>18.0</td>
<td>28.0</td>
</tr>
<tr>
<td>2</td>
<td>28.0</td>
<td>35.0</td>
</tr>
<tr>
<td>3</td>
<td>35.0</td>
<td>41.0</td>
</tr>
<tr>
<td>4</td>
<td>41.0</td>
<td>49.0</td>
</tr>
<tr>
<td>5</td>
<td>49.0</td>
<td>57.0</td>
</tr>
<tr>
<td>6</td>
<td>57.0</td>
<td>65.0</td>
</tr>
<tr>
<td>7</td>
<td>65.0</td>
<td>74.0</td>
</tr>
<tr>
<td>8</td>
<td>74.0</td>
<td>81.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RIGHT NOZZLES</th>
<th>Number of nozzles: 9</th>
<th>Nozzles offset:</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO.</td>
<td>BOTTOM HEIGHT</td>
<td>TOP HEIGHT</td>
</tr>
<tr>
<td>1</td>
<td>18.0</td>
<td>28.0</td>
</tr>
<tr>
<td>2</td>
<td>28.0</td>
<td>35.0</td>
</tr>
<tr>
<td>3</td>
<td>35.0</td>
<td>41.0</td>
</tr>
<tr>
<td>4</td>
<td>41.0</td>
<td>49.0</td>
</tr>
<tr>
<td>5</td>
<td>49.0</td>
<td>57.0</td>
</tr>
<tr>
<td>6</td>
<td>57.0</td>
<td>65.0</td>
</tr>
<tr>
<td>7</td>
<td>65.0</td>
<td>74.0</td>
</tr>
<tr>
<td>8</td>
<td>74.0</td>
<td>81.0</td>
</tr>
</tbody>
</table>
Monitoring travel speed, spray volume applied, nozzle activations, and parameter settings through tablet screen.

Before spray operation:

During spray operation:

- Speed: 4.0 MPH
- Spray log - No application log: 11.15 GAL
- Torro 160 Left (inch): 200.0 Right (inch): 200.0 Vertical min (inch): 15.0 Rate (oz/ft3): 0.3 Sprayer status: Disconnected Laser: Disconnected Status: Disconnected

- Settings:
  - On Delay: 400 ms
  - Off Delay: 100 ms

- L6060 DUAL GEN Left (inch): 36.0 Right (inch): 27.0 Vertical min (inch): 36.0 Rate (oz/ft3): 0.2 Sprayer status: Connected Laser: Connected Status: Ok

- Settings:
  - On Delay: 500 ms
  - Off Delay: 300 ms

- Nozzles:
  - Nozzles Off
  - Nozzles On

- Spray:
  - Manual
  - Pulsing
Specialty crop growers have upgraded their standard sprayers with the commercial product for precision applications of pesticides and other foliar agents since 2019.

<table>
<thead>
<tr>
<th>Crops</th>
<th>Countries</th>
<th>Sprayers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple</td>
<td>USA</td>
<td>Rear’s Mfg</td>
</tr>
<tr>
<td>Citrus</td>
<td>Canada</td>
<td>Turbo Mist</td>
</tr>
<tr>
<td>Peach</td>
<td>Chile</td>
<td>FMW</td>
</tr>
<tr>
<td>Hazelnut</td>
<td>India</td>
<td>Nelson Hardie</td>
</tr>
<tr>
<td>Pecan</td>
<td>Switzerland</td>
<td>Hardi: ZENIT</td>
</tr>
<tr>
<td>Grape</td>
<td>Australia</td>
<td>TIFONE: Storm 2000</td>
</tr>
<tr>
<td>Blueberry</td>
<td>New Zealand</td>
<td></td>
</tr>
<tr>
<td>Raspberry</td>
<td>South Africa</td>
<td></td>
</tr>
<tr>
<td>Nursery</td>
<td>Mexico</td>
<td></td>
</tr>
</tbody>
</table>
Dr. Mark Gleason leads investigations of intelligent sprayers to apply pesticides in apple orchards for IPM programs.

Project's objectives are:

- Assess combining Intelligent Sprayer technology with warning systems for fire blight and summer diseases to achieve season-long pest and disease management of apples.
- Compare economic profitability and cost effectiveness of using the Intelligent Sprayer with disease-warning systems to current practices for control of apple diseases and arthropod pests.
- Share the projects' advances with apple growers in the eastern half of the U.S. through diverse outreach approaches and an IPM Information Portal.

https://www.smartapplespray.plantpath.iastate.edu/
Thank You!

Questions?

For additional information, please contact Dr. Heping Zhu at HEPING.ZHU@USDA.GOV.