Do Online Training Courses Change Behavior?
California Grape Growers, Continuing Education & Powdery Mildew Management

Olena Sambucci
Travis J. Lybbert
PUR Workshop
University of California, Davis
June 7, 2016
Motivation

DPR License Renewal
Continuing Ed. (CE) Requirement

20–40 CE credits every two years

CE Course

Currently, over 300 courses available

Change in Behavior?
Western Farm Services Course on Managing Powdery Mildew (PM)

• Online CE Course
  – Over 1800 participants completed the course 2004-2011

• Areas of emphasis:
  – Prevention of PM outbreaks using the Powdery Mildew Index (UC IPM)
    • Timing of applications
    • Choice of product

  – Resistance Management
    • Choice of product
    • Dosage
Questions

• Does the course make a difference?
  – Do people learn online in a way that makes a difference?

• Does the course achieve specific objectives?
  – Changes in observed PM management
  – Net impact on the environment
Powdery Mildew

• Fungal disease, damages many plants
• In grapes, $189 mln to control in 2011
• 74% of grape pesticides, 17% of total pesticides in CA (by weight)
• Entire growing season (March-October)
• Specific fungicides, sprays every 1–3 weeks
Powdery Mildew Index (PMI)

- Available to growers in CA starting in 1996
- Promoted by UC IPM
- Public and private weather stations
- Weather subscription services
## Powdery Mildew Index (PMI)

<table>
<thead>
<tr>
<th>PMI Index</th>
<th>Disease Pressure</th>
<th>Pathogen Reproduction</th>
<th>Bio and SARs</th>
<th>Sulfur</th>
<th>Sterol Inhibitors</th>
<th>Strobilurins</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–30</td>
<td>Low</td>
<td>present</td>
<td>7–14</td>
<td>14–21</td>
<td>21 or label</td>
<td>21 or label</td>
</tr>
<tr>
<td>30–60</td>
<td>Intermediate</td>
<td>every 15 days</td>
<td>7</td>
<td>10–17</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>60 and above</td>
<td>High</td>
<td>every 5 days</td>
<td>n/a</td>
<td>7</td>
<td>10–14</td>
<td>14</td>
</tr>
</tbody>
</table>

Interval between sprays (days)
DPR Licenses and Permits

• Persons who apply or sell pesticides (QAL, QAC)

• Persons who advise on agricultural pesticide applications (PCA)

• Minimum continuing education (CE) hours to renew (2 years)
  – 20 hours for private applicators
  – 40 hours for pest control advisors

• Online or in-person CE courses approved by DPR
Online Course on PM Management
Data Sources

Agricultural Commissioner’s Office for each county in CA:
Operator Identification Numbers (OINs) for the course-takers (permit numbers)
Records of course completion from Western Farm Services

PUR Database: Daily plot-level pesticide applications since 1990
Data Sources

Course Takers: 1996–2012

<table>
<thead>
<tr>
<th>Region</th>
<th>N</th>
<th>Plots</th>
<th>Sprays</th>
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<tbody>
<tr>
<td>NC</td>
<td>31</td>
<td>168</td>
<td>62,065</td>
</tr>
<tr>
<td>CC</td>
<td>62</td>
<td>797</td>
<td>207,110</td>
</tr>
<tr>
<td>NCV</td>
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<td>634</td>
<td>141,765</td>
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<tr>
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PUR Database: Daily plot-level pesticide applications since 1990
## Data Sources

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### PUR Database: Daily plot-level pesticide applications since 1990

California Department of Pesticide Regulation

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**Map of California showing regions: North Coast, Central Coast, Southern Central Valley, Northern Central Valley, Other.**

**Graph showing GT Powdery Mildew Model with risk levels for different dates.**
Data Sources

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PUR Database: Daily plot-level pesticide applications since 1990

Pesticide Use Risk Evaluation Indicator (PURE)
Potential Effects of the Course

• Use of the PMI
  – Timing of applications
  – Choice of product given observed disease pressure

• Resistance Management
  – Alternate categories of fungicides
  – Full label rate dose

• Impact on the Environment
  – Change in annual PURE values
Each section is approximately 1 square mile or 640 acres.
## Available Control Plots

<table>
<thead>
<tr>
<th>Region</th>
<th>Permits</th>
<th>Total</th>
<th>Wine</th>
<th>Non-Wine</th>
<th>Total Sprays</th>
<th>PM</th>
<th>Non-PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>NC</td>
<td>2,052</td>
<td>5,939</td>
<td>5,937</td>
<td>12</td>
<td>412,849</td>
<td>72.3</td>
<td>27.7</td>
</tr>
<tr>
<td>CC</td>
<td>807</td>
<td>3,022</td>
<td>2,961</td>
<td>324</td>
<td>304,346</td>
<td>64.9</td>
<td>35.1</td>
</tr>
<tr>
<td>NCV</td>
<td>928</td>
<td>3,494</td>
<td>2,742</td>
<td>1,811</td>
<td>328,845</td>
<td>62.7</td>
<td>37.3</td>
</tr>
<tr>
<td>SCV</td>
<td>5,314</td>
<td>16,906</td>
<td>3,314</td>
<td>14,131</td>
<td>1,573,939</td>
<td>61.4</td>
<td>38.6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>9,110</strong></td>
<td><strong>29,370</strong></td>
<td></td>
<td></td>
<td><strong>2,620,942</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Results

1. **Use of the PMI**
   a. Timing of sprays
   b. Choice of product
   c. Application dosage
   d. Changes in annual costs per acre

2. **Resistance management**
   a. Timing of sprays
   b. Number of chemical categories
   c. Dosage

3. **Impact on the environment**
   a. Changes in annual values for each environmental dimension: 
      *air, surface water, groundwater, soil, bees*
Use of the PMI: Timing of Sprays

\[ S_{ijdt} = \lambda_i + \delta_j + \beta_1 PMI_{ijtd-7} + \beta_2 (PMI_{ijtd-7})^2 + \beta_3 (PMI_{ijtd-7})^3 + \phi X_{ijdt} + \gamma N_{it} + \epsilon_{ijdt} \]
Use of the PMI

Choice of Chemical: Sulfur

\[ S_{ijdt} = \lambda_t + \delta_j + \beta_1 PMI_{ijtd-7} + \beta_2 PMI_{ijtd-7}^2 + \beta_3 PMI_{ijtd-7}^3 + \phi X_{ijdt} + \gamma N_{it} + \varepsilon_{ijdt} \]
Use of the PMI
Choice of Chemical: Synthetics
Use of the PMI
Choice of Chemical: Contact
Use of the PMI
Dose Percentile: Sulfur
Use of the PMI

Dose Percentile: Synthetic
Use of the PMI

Dose Percentile: Contact

North Coast

Central Coast

Northern Central Valley

Southern Central Valley

Dose Percentile (contact)

PMI Value

Dose Percentile (contact)

PMI Value

Dose Percentile (contact)

PMI Value

Dose Percentile (contact)

PMI Value

nontaker

taker
### Changes in Annual Applications and Pounds per Acre

<table>
<thead>
<tr>
<th>Sterol Inhibitors</th>
<th>NC</th>
<th>CC</th>
<th>NCV</th>
<th>SCV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lbs/acre</td>
<td>N app</td>
<td>Lbs/acre</td>
<td>N app</td>
<td>Lbs/acre</td>
</tr>
<tr>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>0.05</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Strobilurins</th>
<th>NC</th>
<th>CC</th>
<th>NCV</th>
<th>SCV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lbs/acre</td>
<td>N app</td>
<td>Lbs/acre</td>
<td>N app</td>
<td>Lbs/acre</td>
</tr>
<tr>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>0.22</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sulfur</th>
<th>NC</th>
<th>CC</th>
<th>NCV</th>
<th>SCV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lbs/acre</td>
<td>N app</td>
<td>Lbs/acre</td>
<td>N app</td>
<td>Lbs/acre</td>
</tr>
<tr>
<td>–15.83</td>
<td>–1.47</td>
<td>10.17</td>
<td>1.61</td>
<td>10.17</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Contact</th>
<th>NC</th>
<th>CC</th>
<th>NCV</th>
<th>SCV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lbs/acre</td>
<td>N app</td>
<td>Lbs/acre</td>
<td>N app</td>
<td>Lbs/acre</td>
</tr>
<tr>
<td>n/a</td>
<td>n/a</td>
<td>4.57</td>
<td>n/a</td>
<td>4.57</td>
</tr>
</tbody>
</table>

(3) \[ S_{ijt} = \lambda_t + \delta_j + \beta_1^{post} Z_{it} + \phi X_{jt} + \gamma N_{it} + \varepsilon_{ijt} \]
## Changes in Annual Costs Per Acre

<table>
<thead>
<tr>
<th></th>
<th>NC</th>
<th>CC</th>
<th>NCV</th>
<th>SCV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2011 $/acre</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sterol Inhibitors</td>
<td>n/a</td>
<td>n/a</td>
<td>1.30</td>
<td>–1.82</td>
</tr>
<tr>
<td>Strobilurins</td>
<td>n/a</td>
<td>n/a</td>
<td>34.20</td>
<td>7.40</td>
</tr>
<tr>
<td>Sulfur</td>
<td>–28.13</td>
<td>23.51</td>
<td>20.43</td>
<td>5.27</td>
</tr>
<tr>
<td>Contact</td>
<td>n/a</td>
<td>24.68</td>
<td>29.10</td>
<td>n/a</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>–28.13</td>
<td>48.18</td>
<td>85.03</td>
<td>14.49</td>
</tr>
</tbody>
</table>
Resistance Management

• Rotation of fungicides with different modes of action
• Avoid multiple applications of “at risk” groups
• Full label dosage rate
• Decrease intervals during periods of high disease pressure
• Number of chemical categories applied annually; chemical dosage rates
## Resistance Management

<table>
<thead>
<tr>
<th>Region</th>
<th>N all chemical categories</th>
<th>N categories with high resistance potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Coast</td>
<td>0.19 (0.29)</td>
<td>0.08 (0.54)</td>
</tr>
<tr>
<td>Central Coast</td>
<td>0.40 (0.00)</td>
<td>0.24 (0.00)</td>
</tr>
<tr>
<td>Northern Central Valley</td>
<td>0.48 (0.00)</td>
<td>0.46 (0.00)</td>
</tr>
<tr>
<td>Southern Central Valley</td>
<td>−0.05 (0.27)</td>
<td>−0.06 (0.11)</td>
</tr>
</tbody>
</table>

\[(3) \quad S_{ijt} = \lambda_t + \delta_j + \beta_i^{post} Z_{it} + \phi X_{jt} + \gamma N_{it} + \varepsilon_{ijt} \]
Environmental Impact: Pesticide Use Risk Scores

- Per acre values for each pesticide application listed in PUR data

- Pesticide toxicity and local environmental conditions (topography, proximity to water sources, etc.), plus significant weather around the time of application

- Aggregated to annual plot-level scores for five environmental dimensions: surface water, ground water, soil, air, bees.

Data: PURE

- **Soil**: Box plots show the distribution of Annual PURE Scores Per Acre for non-PM and PM conditions.
- **Air**: Similar box plots for Annual PURE Scores Per Acre across non-PM and PM conditions.
- **Surface Water**: Box plots indicating the spread of Annual PURE Scores Per Acre.
- **Groundwater**: Additional box plots for Annual PURE Scores Per Acre.
- **Bee**: Box plots for Annual PURE Scores Per Acre.
- **Integrated**: Box plots illustrating the integrated data for Annual PURE Scores Per Acre.
## Impact on the Environmental Risk Scores

<table>
<thead>
<tr>
<th>Region</th>
<th>Surface Water</th>
<th>Groundwater</th>
<th>Soil</th>
<th>Air</th>
<th>Bees</th>
<th>Integrated</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Coast</td>
<td>–0.49 (0.61)</td>
<td>–0.09 (0.97)</td>
<td>10.74 (0.00)</td>
<td>–1.16 (0.53)</td>
<td>0.07 (0.81)</td>
<td>9.00 (0.01)</td>
</tr>
<tr>
<td>Central Coast</td>
<td>0.70 (0.13)</td>
<td>–0.92 (0.23)</td>
<td>6.11 (0.00)</td>
<td>2.54 (0.04)</td>
<td>0.99 (0.01)</td>
<td>6.23 (0.00)</td>
</tr>
<tr>
<td>Northern Central Valley</td>
<td>0.69 (0.04)</td>
<td>1.88 (0.01)</td>
<td>4.94 (0.00)</td>
<td>3.12 (0.00)</td>
<td>–0.60 (0.04)</td>
<td>4.88 (0.00)</td>
</tr>
<tr>
<td>Southern Central Valley</td>
<td>0.11 (0.68)</td>
<td>1.51 (0.00)</td>
<td>2.47 (0.00)</td>
<td>–1.44 (0.02)</td>
<td>0.29 (0.22)</td>
<td>2.11 (0.01)</td>
</tr>
</tbody>
</table>

\[
(4) \quad \text{PURE}_{ijt}^k = \lambda_i + \delta_j + \beta_{i}^{\text{post}} Z_{it} + \gamma N_{it} + \theta_j + \varepsilon_{ijt}
\]
Impact on the Environmental Risk Scores

- Surface Water
- Groundwater
- Soil

Air
Bee
Integrated

Years Before/After Online Course
Robustness Checks

• Course-takers only
• Alternative specifications of the propensity score
• Repeat vs. one-time course takers
• Early group vs. late group of course takers
Conclusion

• Observable changes to PM management after the completion of the course

• In all regions except NC, increase in annual number of sprays and lbs per acre
  – Not necessarily consistent with intended use of the PMI

• In all regions except NC, increase in costs per acre
  – Demonstrates perceived private benefit to the growers

• Impact on the environment largely negative

• Specific course objectives may require more flexible design
  – PM management programs are region-specific