Alternatives for Managing Replant Pests and Problematic Weeds
Acknowledgements:

- Almond Board of California
- California DPR
- TriCal, Inc.
- KARE and CSUF Staff
- Wonderful Orchards
<table>
<thead>
<tr>
<th>Ground carbon source</th>
<th>Estimated $ / ton</th>
<th>Rate Tons / trt. ac.</th>
<th>Estimated material $ / ac for &quot;50% strips&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mustard seed meal</td>
<td>$1,700</td>
<td>3</td>
<td>$2,550</td>
</tr>
<tr>
<td>Rice bran</td>
<td>$283</td>
<td>9</td>
<td>$1,274</td>
</tr>
<tr>
<td>Almond hull</td>
<td>$192</td>
<td>9</td>
<td>$864</td>
</tr>
<tr>
<td>Tomato pomace</td>
<td>$185</td>
<td>9</td>
<td>$833</td>
</tr>
<tr>
<td>Grape pomace</td>
<td>$155</td>
<td>9</td>
<td>$698</td>
</tr>
<tr>
<td>Pistachio hull</td>
<td>$150</td>
<td>9</td>
<td>$675</td>
</tr>
<tr>
<td>Olive pomace</td>
<td>$115</td>
<td>9</td>
<td>$518</td>
</tr>
<tr>
<td>Almond hull/shell, &quot;pollinator&quot;</td>
<td>$104</td>
<td>9</td>
<td>$468</td>
</tr>
<tr>
<td>Almond shell</td>
<td>$80</td>
<td>9</td>
<td>$360</td>
</tr>
</tbody>
</table>
## Perspectives on nutrients in alternative substrates

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Total C (%)</th>
<th>C:N ratio</th>
<th>N (%)</th>
<th>P (%)</th>
<th>K (%)</th>
<th>N.F. Carb (%</th>
<th>Starch (%)</th>
<th>A.D. Lignin (%)</th>
<th>pH</th>
<th>N in 9 (or 65) tons (lb)</th>
<th>P in 9 (or 65) tons (lb)</th>
<th>K in 9 (or 65) tons (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mustard meal</td>
<td>45</td>
<td>7</td>
<td>6.1</td>
<td>0.81</td>
<td>0.8</td>
<td>22</td>
<td>2.9</td>
<td>1.4</td>
<td>5.1</td>
<td>1091</td>
<td>146</td>
<td>151</td>
</tr>
<tr>
<td>Rice bran</td>
<td>45</td>
<td>19</td>
<td>2.4</td>
<td>1.77</td>
<td>1.4</td>
<td>32</td>
<td>15.3</td>
<td>3.0</td>
<td>6.2</td>
<td>427</td>
<td>318</td>
<td>246</td>
</tr>
<tr>
<td>Tomato pomace</td>
<td>46</td>
<td>19</td>
<td>2.5</td>
<td>0.31</td>
<td>1.0</td>
<td>10</td>
<td>6.4</td>
<td>16.7</td>
<td>5.0</td>
<td>445</td>
<td>55</td>
<td>180</td>
</tr>
<tr>
<td>Grape pomace</td>
<td>45</td>
<td>24</td>
<td>1.9</td>
<td>0.23</td>
<td>1.5</td>
<td>35</td>
<td>0.44</td>
<td>12.4</td>
<td>4.1</td>
<td>340</td>
<td>41</td>
<td>270</td>
</tr>
<tr>
<td>Pistachio hull</td>
<td>50</td>
<td>28</td>
<td>1.8</td>
<td>0.08</td>
<td>1.1</td>
<td>17</td>
<td>0.94</td>
<td>20.6</td>
<td>5.3</td>
<td>324</td>
<td>14</td>
<td>198</td>
</tr>
<tr>
<td>Olive pomace</td>
<td>50</td>
<td>26</td>
<td>1.9</td>
<td>0.21</td>
<td>1.7</td>
<td>9</td>
<td>0.1</td>
<td>21.0</td>
<td>4.7</td>
<td>344</td>
<td>38</td>
<td>306</td>
</tr>
<tr>
<td>Almond hull and shell</td>
<td>41</td>
<td>60</td>
<td>0.9</td>
<td>0.10</td>
<td>2.1</td>
<td>43</td>
<td>0.4</td>
<td>6.7</td>
<td>4.8</td>
<td>156</td>
<td>19</td>
<td>372</td>
</tr>
<tr>
<td>Almond hull only</td>
<td>40</td>
<td>59</td>
<td>0.7</td>
<td>0.09</td>
<td>2.1</td>
<td>52</td>
<td>&lt;0.01</td>
<td>4.1</td>
<td>4.9</td>
<td>122</td>
<td>16</td>
<td>378</td>
</tr>
<tr>
<td>Almond shell only</td>
<td>43</td>
<td>63</td>
<td>0.7</td>
<td>0.05</td>
<td>1.5</td>
<td>22</td>
<td>0.3</td>
<td>11.9</td>
<td>5.0</td>
<td>122</td>
<td>9</td>
<td>270</td>
</tr>
<tr>
<td>Whole orchard recycling chips</td>
<td>47</td>
<td>120.5</td>
<td>0.4</td>
<td>0.03</td>
<td>0.1</td>
<td>14</td>
<td>0.62</td>
<td>11.1</td>
<td>4.8</td>
<td>(507)</td>
<td>(39)</td>
<td>(156)</td>
</tr>
</tbody>
</table>
Process: spreading substrate
Process: substrate incorporation
Process: installing auxiliary irrigation system, tarp
Process: clean up, planting, assessment
Responses: soil parameters

During ASD process:
- ASD with high bran rate, wide strip
- Control

![Graph showing soil temperature and soil Eh over Julian days]

- Increase in soil temperature
- Decrease in redox potential
- Microbial community shifts
- Reduction of pest populations
- Gen. of organic acids, volatiles
- Reduction in soil pH

After ASD process:
- Microbial community shifts
- Some reduction in soil pH
- Reduced soil pest populations (weeds, pathogens)
- Increased levels of some nutrients (NPK)
Responses, orchards performance
KARE trials, planted 2014

Tree growth → Kernel yield

<table>
<thead>
<tr>
<th>Yield yr 1</th>
<th>Yield yr 2</th>
<th>Cumulative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>Fumig.</td>
<td>ASD-RB</td>
</tr>
</tbody>
</table>

lb/ac

0 1000 2000 3000 4000

Yield yr 1  Yield yr 2  Cumulative
### The cost challenge: $ estimates, ASD vs. Fumigation

<table>
<thead>
<tr>
<th>ASD Substrate</th>
<th>Material amounts and costs</th>
<th>Application costs ($/orchard acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rate (t/rt.ac)</td>
<td>Proportion</td>
</tr>
<tr>
<td>Rice bran</td>
<td>9</td>
<td>0.5</td>
</tr>
<tr>
<td>Ground almond hull and shell</td>
<td>9</td>
<td>0.5</td>
</tr>
</tbody>
</table>

### Fumigation Treatment

<table>
<thead>
<tr>
<th>Fumigation Treatment</th>
<th>Total cost ($/orchard acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telone II broadcast + Cpic 0.38 strip</td>
<td>1,278</td>
</tr>
<tr>
<td>Telone II broadcast + Cpic 0.15 spot</td>
<td>1,190</td>
</tr>
<tr>
<td>Telone II strip + Cpic 0.15 spot</td>
<td>797</td>
</tr>
<tr>
<td>Cpic 0.5 strip</td>
<td>614</td>
</tr>
</tbody>
</table>
Responses: Alternative substrates can work

Tree growth, KARE trial, planted 2017

Ex. 1, Yr. 1 w/ water and tarp
Ex. 2, Yr. 1 w/ water only
Ex. 1, Yr. 2 w/ water and tarp
Ex. 2, Yr. 2 w/ water only
Responses:
CSUF trials,

- More tests of alternative substrates, water, tarp.
- Tested with WOR chips
- Planted 2018
Responses to ground almond hull+shell vs. rice bran substrate

Tree growth at CSUF, yr 1

Trunk cross sect. area incr. (cm²)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>No water or tarp</th>
<th>Water only</th>
<th>Water + tarp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fum</td>
<td>20</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>Ctl</td>
<td>10</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Rice B</td>
<td>15</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>Ald hull/shell</td>
<td>10</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Ctl+W</td>
<td>12</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>Rice B+W</td>
<td>14</td>
<td>15</td>
<td>14</td>
</tr>
<tr>
<td>Ald hull/shell+W</td>
<td>10</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Ctl+WT</td>
<td>12</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>Rice B+WT</td>
<td>14</td>
<td>15</td>
<td>14</td>
</tr>
<tr>
<td>Ald hull/shell+WT</td>
<td>10</td>
<td>12</td>
<td>10</td>
</tr>
</tbody>
</table>
Negative growth impact of ASD based on ground almond hull and shell in one fumigation x WOR trial, Kern Co
Responses: to substrates, water and tarp; Chowchilla Trial, planted 2019
Responses: ASD / substrate trts. vs. postplant fertilizers
Chowchilla, planted 2019

Increase in TCSA cm²

ASD trial

Embedded fertilizer trial

Responses: ASD / substrate trts. vs. postplant fertilizers
Chowchilla, planted 2019

Increase in TCSA cm²

ASD trial

Embedded fertilizer trial
Summary, Outlook

- ASD is a multicomponent process with complex chemical and biological impacts
- ASD approached/matched fumigation for PRD control, but at sig. higher cost; more time needed to assess nematode control
- There is good potential to reduce cost of ASD
- Ground almond hull / shell a less expensive substrate than rice bran; worked well, but less dependably than rice bran
- ASD work suggests further N and P studies
- ASD is worth a try in buffer areas that can not be fumigated; treat in summer

Thank you!
gtbrowne@ucdavis.edu
Soil and tree responses to biosolarization using almond residue amendments

Christopher Simmons, PhD
Department of Food Science and Technology
University of California, Davis
A biosolarization field trial was conducted at a pre-plant orchard site in summer of 2017.

The trial was done in collaboration with Rory Crowley and George Nicolaus of the Nicolaus Nut Company at one of their Chico sites.
<table>
<thead>
<tr>
<th>NP = Nonpareil variety cultivated</th>
<th>B = Bennett-Hickman variety cultivated</th>
<th>M = Monterey variety cultivated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated (control)</td>
<td>Biosolarized using nonpareil variety residues and worm castings</td>
<td>Solarized without amendments</td>
</tr>
</tbody>
</table>
Root lesion nematode control observed within 9 days of biosolarization.
Nitrogen levels have been significantly elevated in both biosolarized treatments for almost 2 years.
Soil potassium

Potassium levels have been significantly elevated in both biosolarized treatments for almost 2 years.
Carbon levels have been significantly elevated in both biosolarized treatments for almost 2 years.
Tree growth

In the first year, trees in the biosolarized plots showed slower growth as they adapted to the soil.

In their second year, trees in biosolarized plots showed increased growth rate compared to trees in untreated soil.
Soil conditioning ahead of planting

Conditioning time is proportional to quantity of biomass amended to soil.
Soil conditioning ahead of planting

Conditioning time depends on both the type of amendment used and its particle size.
Challenges and future work

More data is needed to demonstrate broad spectrum control of all pests targeted by fumigation.

Additional data is needed regarding biosolarization/ASD performance across a variety of soil types, weather and climate conditions, and almond varieties.

Technoeconomic studies are needed to clarify the cost per acre to use biosolarization/ASD.
Alternatives for Managing Problematic Weeds

Brad Hanson, UC Davis
Inputs for weed management

- Herbicides
- Effort / labor
- Cultural practices / management
- Fuel
- Technology
CA almond herbicide use

<table>
<thead>
<tr>
<th>Top active ingredients</th>
<th>2017 treated acreage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 glyphosate</td>
<td>1,654,398</td>
</tr>
<tr>
<td>2 oxyfluorfen (Goal, Goaltender)</td>
<td>846,623</td>
</tr>
<tr>
<td>3 glufosinate (Rely)</td>
<td>625,175</td>
</tr>
<tr>
<td>4 paraquat (Gramoxone)</td>
<td>513,050</td>
</tr>
<tr>
<td>5 saflufenacil (Treevix)</td>
<td>508,432</td>
</tr>
<tr>
<td>6 indaziflam (Alion)</td>
<td>227,848</td>
</tr>
<tr>
<td>7 pendimethalin (Prowl H2O)</td>
<td>214,582</td>
</tr>
<tr>
<td>8 rimsulfuron (Matrix)</td>
<td>186,146</td>
</tr>
<tr>
<td>9 carfentrazone (Shark)</td>
<td>101,922</td>
</tr>
<tr>
<td>10 sethoxydim (Poast)</td>
<td>93,654</td>
</tr>
<tr>
<td>11 penoxsulam (PindarGT)</td>
<td>81,711</td>
</tr>
<tr>
<td>12 flumioxazin (Chateau)</td>
<td>73,143</td>
</tr>
<tr>
<td>12 pyraflufen (Venue)</td>
<td>69,630</td>
</tr>
<tr>
<td>14 2,4-D</td>
<td>63,689</td>
</tr>
<tr>
<td>15 clethodim (SelectMax)</td>
<td>50,410</td>
</tr>
<tr>
<td>16 oryzalin (Surflan)</td>
<td>43,176</td>
</tr>
</tbody>
</table>

~1.3 million total acres 2017
Herbicide-resistant weeds
Glyphosate resistance in CA orchards

Confirmed

• Broadleaves
  – Horseweed (mostly winter)
  – Fleabane (mostly winter)
  – Palmer amaranth (summer)

• Grasses
  – Ryegrass (fall/winter)
  – Annual bluegrass (fall/winter)
  – Junglerice (summer)

Suspected or questionable

• Broadleaves
  – Lambsquarters (summer)

• Grasses*
  – Threespike goosegrass (spring)
  – Feather fingergrass (summer)
  – Windmillgrass (summer)
  – Sprangletop (summer)
  – Witchgrass (summer)

*Resistance in the world in several other Elusine, Chloris, Leptocloa, Echinocloa, Eragrastis spp.
Multiple resistances

• Increasing issues with “stacked” resistance
• Widespread glyphosate-resistance in some species
• Starting to see gly-R plus resistance to some one or more other chemistries
  – Conyza, Lolium, Poa so far.
  – Paraquat, ACCase, some glufosinate reports
The future of almond weed management:
   - a series of challenges, risks, and some opportunities

- Economic
- Environment (pesticides, dust, water, carbon, emissions, etc)
- Losses of key tools
  - Market-driven
  - Regulatory-driven
- The “three R’s”
- System requirements and expectations
### Winter treatment
1. Alion
2. Alion + Prowl 4 qt/A
3. Alion fb Prowl 2 qt/A
4. Alion fb Prowl 4 qt/A
5. Alion + Prowl 2 qt/A fb Prowl 2 qt/A

### Spring treatment
1. Prowl 2 qt/A
2. Prowl 4 qt/A
3. Prowl 2 qt/A

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**Summer annual grass Weeds germinate**

**Herbicide residual threshold**

**Herbicide concentration in the soil**

*Background | Materials and Methods | Results | Conclusion*
Water management / Chemigation

• Can we use existing technology differently to address specific weed management issues (e.g. summer weeds)?
Cover crop opportunities

Soil mix

Kern County - March 2018
Merced County - March 2018
Tehama County - March 2018

Haring, Creze, Gaudin et al.
The “R” word (Roundup)

• Glyphosate classified as “probable carcinogen” in 2015

• IARC evaluation
  – New interpretation of existing data using a “hazard assessment”
  – Other agencies (USEPA, EU) previously interpreted these data – and more – differently using a “risk assessment” approach

• What does this mean for CA ag?
  – Added to CA Prop 65 list in 2017
  – I anticipate relatively little near term impact (ag) from a regulatory standpoint. But, considerable pressure from market forces in some sectors.

• Currently, a lot of litigation related to alleged glyphosate-caused cancer
  – Several important cases in CA state and Federal court jurisdictions
  – This will likely remain in the news for several years at least
Regulations

• Several important herbicides (and other pesticide classes) facing challenges driven by:
  – Toxicity and worker safety concerns (e.g. closed handling systems, applicator licensing changes)
  – Export market concerns with residues
  – Domestic market consumer/buyers leveraging changes to production systems
    • Organic, sustainably-produced, non-GMO, glyphosate-free and similar.
    • True also of other orchard-related goals (e.g. sustainability, healthy soils, etc).

• This is not likely to get easier for the grower! Sorry.
Robotics
Robotics

• Interesting work going on in autonomous vehicles for ag, including weed management tactics

• Likely will be opportunities for almond orchards

• Questions in my mind:
  – How are the weeds being controlled?
  – Can we use the technology to minimize our orchard weed control challenges and risks?
  – What is the trade off with regard to other challenges and risks?
• System requirements and grower/industry expectations
  - Extremely high expectations for weed control will be a major limitation to significant changes

• Autonomous vehicles (so far) will change “who” is doing the weed control practice but not yet the practices themselves.
• We cannot solve our problems with the same thinking we used when we created them.
  – Quote attributed to Albert Einstein
• Sometimes a bigger hammer isn’t the best solution for our orchard weed management challenges.
  – Quote attributed to Brad Hanson (who is, admittedly, no Albert Einstein)
Alternatives for Managing Replant Pests and Problematic Weeds