Orchard Floor Management

David Granatstein
WSU-Center for Sustaining Agriculture and Natural Resources
Wenatchee, WA

Organic Orchard Floor Management Workshop -- October 11, 2016
## Orchard Floor Management

<table>
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<th>Functions</th>
<th>Impacted by:</th>
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<tbody>
<tr>
<td>Microclimate</td>
<td>Understory species</td>
</tr>
<tr>
<td>Physical support</td>
<td>Understory canopy</td>
</tr>
<tr>
<td>Gas exchange for roots</td>
<td>Irrigation system</td>
</tr>
<tr>
<td>Nutrient cycling/storage</td>
<td>Nutrient inputs</td>
</tr>
<tr>
<td>Habitat (micro, macro)</td>
<td>Spray drip</td>
</tr>
<tr>
<td>Water intake/storage</td>
<td>Organic inputs</td>
</tr>
</tbody>
</table>
Microclimate

- soil temperature inverse to the amount of herbage or mulch
- plant mulch dampens extremes of daily soil temperature
- plant cover reduces minimum air temperature by 1-2°F
- bare, compacted wet soil raised minimum air temperature by as much as 4°F

(Skroch & Shribbs, 1986)
Microclimate

Soil Temperature:

• Proposed optimal temperatures for apple roots of 64-77°F. Above 86°F seemed to be deleterious. (Gur et al. 1974)

• Is a significant genetic component. M.9 died at 66, 77°F; Roots matured fast, browned, sloughed, and were infected by pathogen. (Nelson and Tukey, 1956)

• Soil temperature <59°F delayed bud break, fewer flower clusters on ‘Braeburn’/M.9. (Greer et al., 2006)
Root temperature study with Malling clones using water bath (°F)

(Nelson and Tukey, 1956)
Microclimate

Soil Temperature:

- Proposed optimal temperatures for apple roots of 64-77°F (18-25°C). Above 86°F (30°C) seemed to be deleterious. (Gur et al. 1974)
- Soil temperature <59°F (15°C) delayed bud break, less flower clusters on ‘Braeburn’/M.9 (Greer et al., 2006)
- Is a significant genetic component. M9 died at 66, 77°F; Roots matured fast, browned, sloughed, and were infected by pathogen (Nelson and Tukey, 1956)
- Black fabric in tree row of apple. Elevated soil temps, often daily maximum was >82°F at 8” depth. Negative effect on leaf Zn. Yield and tree growth same as herbicide strip. (Neilsen et al., 1986)
Neilsen et al., 1986. Accumulated degree days >10°C at 8” (20 cm) depth, Red Delicious/M.26, Summerland, BC

**Graph:**
- **X-axis:** Years (1981-1985)
- **Y-axis:** Accumulated Degree Days
- Lines represent different treatments:
  - **Herbicide strip** (Blue)
  - **Black plastic** (Red)
  - **Shallow till** (Green)
  - **Full ground cover** (Purple)

**Note:** Black plastic had similar effect at 38” (1 m) depth.
Mid-day Soil Temperature

WSU Sunrise Orchard,
August 2010

2” depth

Critical temp 30°C?

4” depth

Temperature (°C)

2-Aug 3-Aug 4-Aug 5-Aug 6-Aug

20 22 24 26 28 30 32

Bare ground
Wood chip
Fabric
Tillage

2-Aug 3-Aug 4-Aug 5-Aug 6-Aug

20 22 24 26 28 30 32

Bare ground
Wood chip
Fabric
Tillage
Air temperature 80F (26.7 C), 11am
Water Relations

- Soil moisture availability: mulch > bare soil > minimal cultivation > grass > legumes > continuous cultivation
- Mowing decreases water use
- Tillage dries soil
- ‘Golden Delicious’ midday stem water potential range -10 to -28 KPa; yield loss started around -15 KPa; Israel (Gur)
- ‘Gala’ in Geneva, NY; SWP -7 to -11 Kpa
- Evaporative effect lessens with increasing tree size, canopy

(Skroch & Shribbs, 1986; Naor et al., 1995)
Did not induce water stress by tilling trees for first time in August

Mulch consistently moister than bare ground; 20-25% water savings over season
Wood chip mulch led to 20-25% less moisture depletion between irrigations.
Rodents

- Limiting factor for many orchard floor practices
- Voles – need both habitat (cover) and food; food shifts to woodier material in winter
- Organic control options – minimize habitat; Vit D3; bait stations (e.g. oats + plaster of paris); mousetraps; raptor perches; cats; other??
- Risk management for 4-5 year population cycle, heavy snow winter
- Increased risk – mulches (straw, fabric); tall vegetation; legumes near tree trunks (e.g. white clover)
Vole Presence
IMM Trial, Winter 05/06
(Winter 06/07, too few to analyze)

- Wood chip (WC) = bare ground (CTL) = tilled (WW)
- *Galium* in Sandwich system (SWNL) significantly fewer voles than other in-row living mulches

![Graph showing vole trail length for different treatments.](image)

*Weeds don’t kill trees; rodents do.*
Weed Control

Why control weeds?

• Limit competition with young trees – nutrients, water
• Minimize rodent habitat
• Weeds as hosts for pests, disease inoculum
• Avoid blocked sprinklers
## Orchard Weed Control Options

(Granatstein & Mullinix, 2008)

<table>
<thead>
<tr>
<th></th>
<th>Pro</th>
<th>Con</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herbicides</td>
<td>Control weeds around trunk; rodents; no tree, root damage; low cost</td>
<td>Resistance, leaching, soil quality loss; effectiveness, cost (org herbicides)</td>
</tr>
<tr>
<td>Mowing</td>
<td>Fast, inexpensive</td>
<td>Short-term suppression; still have competition, habitat</td>
</tr>
<tr>
<td>Tillage</td>
<td>Effective; rodents; low cost</td>
<td>↓ tree growth, fruit size, soil quality; damage trees</td>
</tr>
<tr>
<td>Flaming</td>
<td>Control weeds around trunk; rodents; low cost</td>
<td>Tree injury, perennial weeds, fossil fuel</td>
</tr>
<tr>
<td>Inert mulches</td>
<td>Effective; soil quality; moisture</td>
<td>Costly; N tie up; soil quality</td>
</tr>
<tr>
<td>Living mulches</td>
<td>Add biodiversity; soil quality; fix N</td>
<td>Competition; rodents; persistence</td>
</tr>
</tbody>
</table>

How to combine strategies? Change system with age of orchard?
<table>
<thead>
<tr>
<th>Method</th>
<th>$/acre/yr</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flame weed + hand hoe</td>
<td>208</td>
<td>2014</td>
</tr>
<tr>
<td>Weed fabric (10 yr, open/close)</td>
<td>420</td>
<td>2014</td>
</tr>
<tr>
<td>Flaming (5x)</td>
<td>113</td>
<td>2012</td>
</tr>
<tr>
<td>Tillage (5x, Wonder Weeder)</td>
<td>115</td>
<td>2012</td>
</tr>
<tr>
<td>Wood chip mulch (3 yr life)</td>
<td>400</td>
<td>2012</td>
</tr>
<tr>
<td>Org. herbicide (4x)</td>
<td>508</td>
<td>2012</td>
</tr>
<tr>
<td>Mowing</td>
<td>210</td>
<td>2010</td>
</tr>
</tbody>
</table>

For more details, see the on line presentation [http://treefruit.wsu.edu/videos/weed-control-in-orchards/](http://treefruit.wsu.edu/videos/weed-control-in-orchards/)
Mulches

- Can impact soil (water, temperature, biology, nutrients), weeds, fauna (nematodes)
- Effects on trees: ↑ tree growth, ↑ fruit yield, ↑ fruit size, lower leaf N
- Generally more than pay for themselves
- Wood chips have had fewest problems
- Weed control variable, <1 to 3 yr; not effective for perennial weeds
- **Challenges**: finding the material, hauling, spreading
  - **Solution?** Mow and blow, utilize prunings; add flaming, “tillage” to extend weed control life
Spreading wood chip mulch
Weed biomass (dry matter) in the tree row. Columns with the same letter are not significantly different (p<0.05) for that orchard.
Yield Effects - WA

'Gala' apple

Fruit Yield (bins/acre) vs. Year for 'Gala' apple. Significant differences are indicated by lowercase letters (a, b).

- 2009: 0.08
- 2010: 0.07
- 2011: 0.02

'Anjou' pear

Fruit Yield (bins/acre) vs. Year for 'Anjou' pear. Significant differences are indicated by lowercase letters (a, b).

- 2010: 0.20
- 2011: 0.04

Commercial organic orchards, large-scale field plots

(Granatstein et al., 2014)
## Grower Returns

### 8+ yr ‘Gala’/M.26, sandy soil

<table>
<thead>
<tr>
<th></th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>3-Yr Rel to Till</th>
</tr>
</thead>
<tbody>
<tr>
<td><em><em>Apple Returns</em> ($/ac)</em>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mulch</td>
<td>2,320</td>
<td>8,440</td>
<td>12,764</td>
<td>+4,777</td>
</tr>
<tr>
<td>Herb/flame</td>
<td>1,971</td>
<td>6,193</td>
<td>9,638</td>
<td>-946</td>
</tr>
<tr>
<td>Tillage</td>
<td>2,942</td>
<td>6,843</td>
<td>8,963</td>
<td>0</td>
</tr>
</tbody>
</table>

### Mature ‘d’Anjou’ pears, good soil

<table>
<thead>
<tr>
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<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>3-Yr Rel to Till</th>
</tr>
</thead>
<tbody>
<tr>
<td><em><em>Pear Returns</em> ($/ac)</em>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mulch</td>
<td>9,580</td>
<td>12,636</td>
<td>9,377</td>
<td>+1,432</td>
</tr>
<tr>
<td>Herb/flame</td>
<td>10,274</td>
<td>10,621</td>
<td>8,141</td>
<td>-1,125</td>
</tr>
<tr>
<td>Tillage</td>
<td>10,676</td>
<td>11,182</td>
<td>8,302</td>
<td>0</td>
</tr>
</tbody>
</table>

*Gross bin returns minus weed control costs and picking costs  
(Granatstein et al. 2014)
Mulching Sweet Cherry

- The Dalles, OR; ‘Bing’/Mazzard block (32 yr old)
- Wood chip mulch with compost blend applied October 2014 every other row; total cost ~$1,600/acre (70 yd/acre = 1” depth in tree row)
- Increased cherry size next July 2015; added revenue $2,600/acre; net gain $1,000/ac
- Internal mulch; bought large flail mower to recycle larger pruning wood that being hauled out and burned; reduced costs of hauling prunings paid for flail in one season
‘Mow & Blow’ Mulch Trial
Quincy, WA

- ‘Fuji/M.9’ 2nd and 3rd leaf
- Tall fescue forage grass mix, mowed weekly
- 1x rate = 0.5-1.0 lb/ft^2 DM
- About 10% of clippings retained after 2 yr
- 2x rate led to 20% increase in tree growth
- Clippings add 25-50 lb K/ac; 50 bin/ac apple crop removes 56 lb
Nobili side delivery flail mower (Italy) and planted cover crop
Sweeping flailed prunings onto the tree row as an internal source of mulch.
Tillage

- Broad spectrum weed control
- Relatively low cost
- Incorporates organic amendments, speeds nutrient mineralization
- Helps disrupt rodent habitat
- **Challenges**: root pruning, trunk damage, soil OM oxidation, soil structure breakdown
  - **Solutions?** Lower disturbance machines (weed brush); organic amendments can compensate for OM loss; add “tillage” to mulching (hi-residue cultivators)
IMM clean cultivation: root pruning?

2006 tree leaning count

<table>
<thead>
<tr>
<th>Treatment</th>
<th>No. of leaning trees per 6 sample trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>1</td>
</tr>
<tr>
<td>Living Mulch Leg</td>
<td>1.5</td>
</tr>
<tr>
<td>Sandwich Leg</td>
<td>1.5</td>
</tr>
<tr>
<td>Wood Chip</td>
<td>0.5</td>
</tr>
<tr>
<td>Wonder Weeder</td>
<td>3.5</td>
</tr>
</tbody>
</table>
## Tillage Effects

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Stem Circ. (mm)</th>
<th>Pruning Mass (g/2 trees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herb. Strip</td>
<td>100.3 a</td>
<td>604 a</td>
</tr>
<tr>
<td>Mech. Cult.</td>
<td>85.2 b</td>
<td>234 b</td>
</tr>
</tbody>
</table>

3-yr old high density apple, South Africa

(Wooldridge and Harris, 1989)
Total Biomass
3-yr Pinova/EMLA.7
E. Wenatchee, WA

- LML
- WCM
- TILL

Dry weight (grams)
Soil Organic Matter

Year

Organic matter (%)


Topsoil (0-6 in) – Yakima

Con Org INT

- 0.4 t/ac compost
- Tillage for weed control

CA strawberries – paired fields

<table>
<thead>
<tr>
<th>Biological property</th>
<th>Con</th>
<th>Org</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total C (g C/kg soil)</td>
<td>8.25</td>
<td>10.04 *</td>
</tr>
<tr>
<td>Total N (g N/kg soil)</td>
<td>0.666</td>
<td>0.867 **</td>
</tr>
<tr>
<td>Organic matter (mg/kg soil)</td>
<td>1.46</td>
<td>1.84 *</td>
</tr>
<tr>
<td>Microbial biomass (µg CO₂-C/g soil)</td>
<td>96</td>
<td>249 ***</td>
</tr>
</tbody>
</table>

8-10 t/ac compost

Courtesy: P. Andrews
Weed Fabric

- Excellent weed control without soil disturbance
- Excellent habitat for voles
- Expensive to establish, but can increase early yields
- Mutually exclusive to other practices
- Challenges: excessive soil temperatures; no OM input unless opened; loss of soil quality; waste product at end of life
  - Solutions? Open fabric in winter; use white-on-black fabric to reduce heat, stimulate trees; biodegradable mulches; snakes!
Weed Fabric in Sweet Cherry

OSU, Hood River, OR – 2001-2007

• Fabric groundcover vs. bare ground in tree row (herb.)
• 2001-2004 – fabric $2125/acre increased costs
• 2004 – fabric trt. gross returns $3240/ac more than bare ground (1st yr of production)
• 2005 - $1633/ac more with fabric
• Fabric – trees produced more fruit at an earlier age, maintained higher yields

(Yin et al., 2007)
Sunrise Fabric Trial
- 2010-2012
- 6 yr old ‘Gala’/M9

<table>
<thead>
<tr>
<th></th>
<th>3 Yr Increase TCSA (%)</th>
<th>3 Yr Fruit Yield (kg/tree)</th>
<th>Fruit size 2011* (g)</th>
<th>Yield Eff. (kg/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>113</td>
<td>39.6</td>
<td>211</td>
<td>1.79</td>
</tr>
<tr>
<td>White-on-black</td>
<td>129</td>
<td>47.1</td>
<td>219</td>
<td>2.16</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>p=</td>
<td>0.13</td>
<td>0.08</td>
<td>0.05</td>
<td>0.005</td>
</tr>
</tbody>
</table>

*no fruit size difference in 2010, 2012

Makus 2007. White-on-black provided excellent weed control and raised anti-oxidant levels in blackberry.
Alley Vegetation
Legumes for N Fixation

Year 3, 2010

Alfalfa
Trefoil

39 days after mowing; initially direct seeded

Add 30-80 lb avail. N/ac/yr; US$0.70/lb N
What Might an Ideal OFM System Look Like?

- Narrow band cover crop - low competition, rodent repellent, beneficial insect habitat, bioremediation
- Mulch on row edges
- Legume in alley for N - mow and blow
- Recycle prunings back to tree row
What Might an Ideal OFM System Look Like?

- Thin mulch - mow and blow + flailed prunings
- Supplemental weed control - organic herbicide, hi-residue cultivator, thermal, microwave, or other non soil disruptive
- Limited other vegetation in tree row for specific period
  - \( \uparrow \) C input, soil biota; flowers for beneficials; N capture
- Legume as part of alley mix to fix some N.

OR

Cover crop mix in tree in row
- Repel rodents, exclude weeds, fix N, support natural enemies, provide active carbon to soil biota, provide bioremediation of replant
- Need growth suppression mechanism – herbicide, mowing, growth regulator, growth habit
**Summary**

- No perfect organic orchard floor management system
- All choices have trade-offs
- Need more clarity on effects of tillage on roots; new equipment options?
- Organic herbicide would be a game changer
- Can grow a portion of N need internally with legumes
- Need more work on novel plant-based solutions