Orchard Floor Management

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

Hort 421/521 -- Feb. 2014
Outline

• Orchard floor management basics
• Weed control
• Soil quality and soil biology
• Mulching and cover crops
• Management effects on pests, water
• Conclusions
• Questions and discussion
Mini Tatura Trellis on M.9
Washington

Standard System
Herbicide strip, grass alley
Apple Root Density

Length of root per area of soil surface (cm cm⁻²)

10⁴  10³  10²  10  1

herbaceous

Graminaceae

herbaceous

non-Graminaceae

woody plants

apple

(Neilson and Neilson, 2003)
## Orchard Floor Management

<table>
<thead>
<tr>
<th>Functions</th>
<th>Impacted by:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water intake/storage</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>Micro-climate</td>
<td>Organic inputs</td>
</tr>
</tbody>
</table>
Orchard Floor Management Review

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 0.5-1.0°C
- bare, compacted wet soil raised minimum air temperature by as much as 2°C
- dwarf rootstocks grow best at 14°C vs. up to 27°C for seedling rootstocks

(Skroch & Shribbs, 1986)
Orchard Floor Management Review

Soil quality:
• avoid cultivation
• favorable soil effects: legumes > grass > mulch > bare ground > cultivation

Water:
• soil moisture availability: mulch > bare soil > minimal cultivation > grass > legumes > continuous cultivation
• mowing decreases water use

(Skroch & Shribbs, 1986)
Weed Control

Why control weeds?

• Limit competition with young trees – nutrients, water
• Minimize rodent habitat
• Weeds as hosts for pests, disease inoculum

Why not?

Benefits to soil organisms
Enhance beneficial insects
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 trail length (cm/m²) for different treatments: LML, LMNL, SWL, SWNL, WC, CTL, WW. The graph compares trail length for 11/05 trails and 2/06 trails.](image)

Weeds don’t kill trees; rodents do.
## Area and Timing of Weed Control
### New York, ‘Imperial Gala/M.26

<table>
<thead>
<tr>
<th>Weed-free area (ft²)</th>
<th>Cum. Yield (kg/tree)</th>
<th>Cum. Growth TCSA (cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>14.9</td>
<td>20.0</td>
</tr>
<tr>
<td>22 (4.7’ x 4.7’)</td>
<td>41.0</td>
<td>25.5</td>
</tr>
<tr>
<td>43</td>
<td>38.2</td>
<td>25.6</td>
</tr>
<tr>
<td>65</td>
<td>41.1</td>
<td>24.7</td>
</tr>
<tr>
<td>LSD(.05)</td>
<td>11.0</td>
<td>5.1</td>
</tr>
</tbody>
</table>

- After 18 yr, no consistent yield trends
- Tree growth, soil C > in Mulch
- Optimal=transient weed suppression during growing season, live vegetation other times

*(Merwin & Ray, 1997; Atucha et al., 2011)*
Area and Timing of Weed Control
New York, ‘Imperial Gala/M.26’

<table>
<thead>
<tr>
<th>Weed Control Time</th>
<th>Cumulative Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>(days) (month)</td>
<td>(kg/tree)</td>
</tr>
<tr>
<td>0 check</td>
<td>15.0</td>
</tr>
<tr>
<td>30 May</td>
<td>34.4</td>
</tr>
<tr>
<td>30 June</td>
<td>34.5</td>
</tr>
<tr>
<td>30 July</td>
<td>30.7</td>
</tr>
<tr>
<td>30 August</td>
<td>36.6</td>
</tr>
<tr>
<td>60 May, June</td>
<td>46.3</td>
</tr>
<tr>
<td>60 June, July</td>
<td>42.7</td>
</tr>
<tr>
<td>60 July, Aug</td>
<td>40.5</td>
</tr>
<tr>
<td>90 May, June, July</td>
<td>51.9</td>
</tr>
<tr>
<td>90 June, July, Aug</td>
<td>46.0</td>
</tr>
</tbody>
</table>

(Merwin & Ray, 1997)
## Alternative Weed Control Costs

<table>
<thead>
<tr>
<th>Method</th>
<th>Rate</th>
<th>Freq.</th>
<th>Cost/ac/yr ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(ac)</td>
<td>Material</td>
<td>Appl.</td>
</tr>
<tr>
<td>Glyphos.</td>
<td>0.5 l</td>
<td>4/yr</td>
<td>24</td>
</tr>
<tr>
<td>Weed fabric</td>
<td>5’ x 3750’</td>
<td>1/6 yr</td>
<td>286</td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>8.5 ton</td>
<td>1/2 yr</td>
<td>319</td>
</tr>
<tr>
<td>Wood chip</td>
<td>100 yd³</td>
<td>1/3 yr</td>
<td>200</td>
</tr>
<tr>
<td>Spray on</td>
<td>3.4 ton</td>
<td>1/1.5 yr</td>
<td>234</td>
</tr>
<tr>
<td>Flaming</td>
<td>48 lb</td>
<td>3/yr</td>
<td>36</td>
</tr>
<tr>
<td>Tillage (WW)</td>
<td>0.25 hr</td>
<td>4/yr</td>
<td>0</td>
</tr>
</tbody>
</table>

(adapted from Hogue et al., 2002)
Flame Weeding

Brewster orchardist:
- Burn 4-5 ac/hr
- 10 gal propane/hr
- 4x per season
- Cost $70-80/ac

Dovex Orchard, June 2007
Wonder Weeder  440 ft/min

Can be cheaper than glyphosate

Weed Badger  20 ft/min
Weed Fabric

Swezey, 2005
Weed Fabric in Sweet Cherry

OSU, Hood River, OR – 2001-2007

• Fabric groundcover vs. bare ground in tree row

• 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

(Tomasini et al., 2007)
Wood Chip Mulch

- weed control
- increased fruit size & tree growth
Wonder Weeder results

All these practices can impact the soil

Spreading wood chip mulch
Soil Quality

Chemical

Biological  Physical

• Dynamic interplay of 3 aspects
• Short-term and long-term changes
• Influenced by environment (climate, geology, plants)
• Influenced by human activity (erosion, fertilization, irrigation, plants)
Carbon – the key ingredient

Carbon (C), the basis of Soil Organic Matter, which affects:

**Physical** – bulk density, aggregate stability, water-holding capacity

**Chemical** – cation exchange capacity, nutrient release

**Biological** – energy source for microbes, base of the soil food web, nutrient turnover, soil-borne diseases
Soil Organic Matter

Friends:
- No-till
- Mulching
- Organic amendments
- Cool temperatures
- Nutrient balance

Enemies:
- Tillage
- Erosion
- Fumigation
- Herbicides, bare ground
- Leaching, nutrient export

Goal: inputs > losses
Soil Organic Matter Change

0-20 cm depth after 5 yr, New York, apples

(Merwin, 2003)
Soil Organic Matter

![Graph showing the changes in soil organic matter from 1994 to 2003 for different treatments: CON, ORG, and INT. The graph indicates that ORG treatments consistently have higher organic matter levels compared to CON treatments.]

- **Topsoil (0-6 in) – Yakima**
- **Organic matter (%)**
- **CON**, **ORG**, **INT**

![Table showing soil properties for CA strawberries – paired fields for 1994 and 1995.]

<table>
<thead>
<tr>
<th>Soil property (0-10 cm)</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>

- **Compost** 0.4 t/ac
- **Tillage for weed control**

- **Compost (t/ac)**
  - CON: 5-6
  - ORG: 9-11

*Courtesy: P. Andrews*
**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**

*(Wooldridge and Harris, 1989)*

Reported problems with tillage:

- Loss of organic matter
- Less tree vigor
- Lower fruit yield, fruit size
- Trees falling over
# Tillage Effects

<table>
<thead>
<tr>
<th></th>
<th>Depth (in)</th>
<th>Length (in)</th>
<th>Root Conc. (in/in)</th>
<th>Weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tilled</strong>&lt;br&gt;(3” depth, 4x)</td>
<td>0-3</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>3-7</td>
<td>666</td>
<td>222</td>
<td>19.6</td>
</tr>
<tr>
<td></td>
<td>7-12</td>
<td>240</td>
<td>40</td>
<td>60.9</td>
</tr>
<tr>
<td></td>
<td>12-18</td>
<td>213</td>
<td>36</td>
<td>131.3</td>
</tr>
<tr>
<td><strong>Herb. Strip</strong></td>
<td>0-3</td>
<td>838</td>
<td>279</td>
<td>29.9</td>
</tr>
<tr>
<td></td>
<td>3-7</td>
<td>712</td>
<td>237</td>
<td>43.5</td>
</tr>
<tr>
<td></td>
<td>7-12</td>
<td>330</td>
<td>55</td>
<td>57.1</td>
</tr>
<tr>
<td></td>
<td>12-18</td>
<td>234</td>
<td>39</td>
<td>103.2</td>
</tr>
</tbody>
</table>

19-yr old pear

*(Cockroft & Wallbrink, 1966)*
Soil Biology

The last frontier?
The ultimate black box?

Microbe - Microbe
Microbe - Macrofauna
Microbe - Plant
Effect of Apple Replant Disease
Gala/M.26, Moxee, WA

- Growth after one year
- Trees 14’ apart, ‘virgin’ soil did not have apple previously
- No fumigation

Replant soil

‘Virgin’ soil

(M. Mazzola)
Growth of ‘Gala’ Apple Seedlings in Soil from Orchard Blocks of Varying Age

(M. Mazzola)
Changes in Relative Recovery of Specific Microorganisms with Increasing Age of Orchard Blocks

WVC Orchard, E. Wenatchee, WA

% of total isolates

NC 1 yr 2 yr 3 yr 4 yr 5 yr

P. putida P.f.bv3 R. solani

(M. Mazzola)
Growth of ‘Gala’ Apple Seedlings in CV Orchard Replant Soil Following Planting with Different Wheat Cultivars

(M. Mazzola)
Positive and negative effects of amendments on fine root development are indirect and likely function through the resident soil biology.

(Courtesy: M. Mazzola)
Microbial-induction of lateral root development

Inoculating soil with specific organisms may induce increased rooting.

(Courtesy: M. Mazzola)
Orchard Mulching

*Forest litter = mulch*

Mulches affect:

- Weeds
- Soil and orchard temperature
- Soil moisture, physical properties
- Soil C, N, other nutrients
- Soil biology, food web
- Tree performance
- Pests (rodents)
# Mulch Trial results

## 8-yr ‘Gala’/M.26 – Wenatchee, WA

<table>
<thead>
<tr>
<th>TRT</th>
<th>2005</th>
<th>2006</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fruit yield</td>
<td>Fruit Size 80-88</td>
</tr>
<tr>
<td>Wood chip</td>
<td>22.4</td>
<td>15.5 a</td>
</tr>
<tr>
<td>Control mow</td>
<td>20.4</td>
<td>6.6 b</td>
</tr>
<tr>
<td>Cultivator Z 3x</td>
<td>17.6</td>
<td>7.0 b</td>
</tr>
<tr>
<td>p=</td>
<td>0.150</td>
<td>0.014</td>
</tr>
</tbody>
</table>
Mulch Trial

- Mature commercial organic apple orchard
- Fine sandy loam soil, prone to moisture stress
- Tillage vs wood chip mulching in tree row
- Mulch effects:
  - +23% trunk growth (2 yr)
  - +40% fruit yield (cumulative 3 yr)
  - +35% gross revenue minus weed control cost (3 yr)
- Mulch had Net Present Value of $2152/ac over tillage
### Orchard Mulching Trials
Summerland, BC

**5th Leaf Spartan / M.9**

<table>
<thead>
<tr>
<th></th>
<th>TCSA (mm²)</th>
<th>Roots (g/0.018m³)</th>
<th>Yield (kg/tree)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Check (glyphosate)</td>
<td>1011 b</td>
<td>11.3 c</td>
<td>10.3 c</td>
</tr>
<tr>
<td>2. Biosolids (Vancouver)</td>
<td>1052 b</td>
<td>16.9 bc</td>
<td>11.2 bc</td>
</tr>
<tr>
<td>3. Paper mulch</td>
<td>1565 a</td>
<td>28.7 abc</td>
<td>13.0 ab</td>
</tr>
<tr>
<td>4. 2 + 3</td>
<td>1490 a</td>
<td>41.8 a</td>
<td>13.9 a</td>
</tr>
<tr>
<td>5. Composted biosolids + 3</td>
<td>1406 a</td>
<td>38.7 a</td>
<td>14.9 a</td>
</tr>
<tr>
<td>6. Alfalfa hay</td>
<td>1203 b</td>
<td>35.2 ab</td>
<td>14.0 a</td>
</tr>
<tr>
<td>7. Geotextile</td>
<td>1125 b</td>
<td>19.1 bc</td>
<td>12.7 abc</td>
</tr>
</tbody>
</table>

(Hogue et al., 2000)
Effect of Mulches on Nematodes in Orchard Soil - Summerland, BC

Increases in ‘benefical’ nematodes suppressed the pest root lesion nematode *P. penetrans*.
‘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/ft² DM
• About 10% of clippings retained after 2 yr
• 2x rate led to significant increase in tree growth
• Clippings add 25-50 lb K/ac; 50 bin/ac apple crop removes 56 lb
‘Mow & Blow’ Mulch Trial
Quincy, WA

16% increase in trunk growth
p=0.025

100 200 300 400
2012 2013 2-year

% Increase TCSA

0 1x 2x
Orchard Cover Crops

Cover crops affect:

- Weeds
- Soil and orchard temperature
- Soil moisture, physical properties
- Soil C, N, other nutrients (root exudates)
- Soil biology, food web
- Tree performance
- Pests (insect, disease, rodents)
- N fixation (legumes)
White clover living mulch

Rodents – the weak link for clover.
TCSA and Fruit Yield

WVC Orchard – Pinova/M7, 3rd leaf

Relative value (CTL=100)

- CTL
- WW
- WC
- SWL
- SWNL
- LML
- LMNL

- Trunk growth
- Fruit yield
Growing N in the Orchard

Side Discharge/Mulching Mower

- Reduced passes with mower
- Reduced passes with weed sprayer
- Reduced irrigation

(H. Huntley)
Year 3, 2010

39 days after mowing
Direct seeded
Morgan Orchard

Cumulative Cover Crop Biomass

Cover Crop Biomass, 2008-10

Add 30-50 lb avail. N/ac
$0.65/ lb N

Biomass DM (kg/ha)

Alfalfa  Grass  Kura  Ladino  Trefoil  Alfalfa  Grass  Kura  Ladino  Trefoil

Spray  No spray

2008  2009  2010
NRCS Cover Crop Trial
- 3 sites near Prosser, WA
- Planted Sept 2012
- USDA-NRCS Plant Materials Technical Note No. 23


Legume Cover Crops for N
Partial Cover Crop Nitrogen Contribution (N lb/ac) at Alvarez Orchard
Sampled 15 May, 20 July and 19 September 2013

Nitrogen Contribution
7' planted legume strip

40-50 lb/ac PAN
Alfalfas did well

(Pavek & Granatstein)
Pest Reduction

Cover crops can control tree vigor through regulation of N and water.

Apple (WV) – lower aphid populations in trees with cover crop than with herbicide strip; also 50% less powdery mildew, slightly less scab, and no fireblight with lower vigor (Brown & Schmitt, 1996)

Apple (BC) – much less aphid infestation with white clover/grass cover vs. rye, herbicide strip, weed barrier; clover mix competed with trees, reduced vigor, which reduced aphids (Haley & Hogue, 1990)
Pest Reduction

Successful examples usually involve a specific pest-predator relation.

Pecans (GA) – control of pecan aphid with convergent lady beetle; grow cover crop of hairy vetch; produced two generations of lady beetles, reaching 143,000/acre; migrated from ground cover (senescing) to pecan trees at time when aphids are reaching peak levels; effective biocontrol achieved (Tedders, 1983)

Citrus (China) – control of citrus red mite by natural enemies (Amblyseius spp.) encouraged on the weed Ageratum conyzoides; cover is planted or conserved; used on over 135,000 ha of citrus (Liang & Huang, 1994)
Syrphids to Control WAA

Attractiveness to Syrphids

- Marigold
- Alyssum
- Zinnia
- Cosmos
- Buckwheat
- Mustard

WAA=woolly apple aphid (E. Beers)
Insectary Plantings - Alyssum

L to R: Mike Hargrove, Betsy Beers, and Fred Plath in his orchard near Wapato planted with an alyssum cover crop (July 2009)

Blooming Alyssum

(E. Beers)
Effect of mowing on insect fauna in pears
Hood River, OR

(Horton, 1998)
Effect of mowing on insect fauna in pears
Hood River, OR

Effect of mowing on insect fauna in pears (Horton, 1998)

- Lygus
- Stinkbugs
- Aphids

Density (ratio to weekly mowing)

Pests

Floor

Unmowed Monthly

0 4 8 12 16 20 24 28 32 36 40
Effect of wood chip mulch and nematode species on codling moth larvae mortality - September

**Airblast Sprayer Application**

<table>
<thead>
<tr>
<th>Setting</th>
<th>Mean % mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under Mulch</td>
<td>94-99</td>
</tr>
<tr>
<td>Logs on trees</td>
<td>17-47</td>
</tr>
<tr>
<td>Tree bands</td>
<td>6-42</td>
</tr>
</tbody>
</table>
Water Conservation

Water shortages may be more common in the future.
Effect of Orchard Mulching on Soil Moisture Depletion

20-25% reduction in irrigation water

Moisture Depletion (mm)

Soil Depth (cm)

Mulch Unmulched
Goal: “Happy Trees”
Total Biomass
3-yr Pinova/EMLA.7
E. Wenatchee, WA

Yield Efficiency (g fruit/g tree DM)

LIVING MULCH 0.78
MULCH 0.41
TILL 0.50

(D. TerAvest)
Knowledge Gaps

• Is there an ideal soil quality?
• Manipulation of rhizosphere
• Nutrient flow through orchard
• Pest ecology in complex systems
• Pest / nutrition interactions
• Chemical ecology of plants
What we learned so far …

- No perfect system for weed control
- Ideal: avoid tillage, cover soil
- Need to try more combinations of tactics
- Can generate mulch internal to orchard, but will not provide sufficient weed control
- Can generate a large share of tree N need internally
- Rodents a major barrier
- Potential multiple benefits e.g. insect biocontrol, water

http://www.tfrec.wsu.edu/OrganicIFP
http://csanr.wsu.edu/pages/Organic_Agriculture