Cover Crops for Orchards

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Wenatchee, WA

In collaboration with Joan Davenport, Elizabeth Kirby, Michel Wiman, Amos Kukes, Kent Mullinix
Apple Root Density

Length of root per area of soil surface (cm cm$^{-2}$)

10$^4$  10$^3$  10$^2$  10  1

herbaceous

Graminaceae

herbaceous

non-Graminaceae

woody plants

apple

Neilsen and Neilsen, 2003
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)
Cover Crop Choices

Age of orchard, rootstock
Fruit harvest date
Irrigation system, water
Alley, tree row, ‘Sandwich’
Legume, grass, broadleaf
Species, cultivar
Annual or perennial
Nematode host?
Insect pest host?
Mulch?
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
- effects on humidity and disease? Russet?

*(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)
WA Peach

5 yr old trees

- Orchard grass – mowed late May
- Alfalfa – mowed late May, mid-summer
- Rye (winter cc) – disked late May, summer cult
- Vetch (winter cc) - disked late May, summer cult
- Mulch under tree
- Herbicide

- Alfalfa delayed maturity
- Highest yield with mulch
- N, water effects

(Proebsting, 1958)
MI Tart Cherry

Cover crop mix – crimson cl, annual ryegrass/hard fescue, berseem clover; no herbicides, mowed, irrigated

- Highest yields – mulch
- Cover crops, compost improved soil quality
- Fewest pest mites in cover crop; beneficial mites all year in red clover
- Cover crop + fertigation was among most profitable
- Nitrate leaching – most in season-long herbicide

(Edson et al., 2003)
MI Tart Cherry

Figure 3. Nitrate leaching/profitability trade-off:
Although Conventional was as profitable as the other two top profit treatments, it caused far more nitrate leaching.

(Edson et al., 2003)
NZ Apple

- 8 yr old apple trees
- Several species mixes
- Fixed N can replace harvest and leaching removal ($^{15}$N method)

Annual N fixed by understory

<table>
<thead>
<tr>
<th>Species</th>
<th>kg N/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red clover</td>
<td>33-84</td>
</tr>
<tr>
<td>Herb ley</td>
<td>12-105</td>
</tr>
</tbody>
</table>

(Goh et al., 1995)
NZ Apple

- Legumes – increased fruit N, delayed maturity; lower Brix and firmness than grass
- Mow and blow provided large inputs of nutrients; increased tree growth and fruit yield; did not increase fruit disorders

<table>
<thead>
<tr>
<th></th>
<th>Mow</th>
<th>Mow &amp; blow</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.1</td>
<td>6.8</td>
</tr>
<tr>
<td>N (%)</td>
<td>0.24</td>
<td>0.33</td>
</tr>
<tr>
<td>P (ppm)</td>
<td>28</td>
<td>37</td>
</tr>
<tr>
<td>K (ppm)</td>
<td>6</td>
<td>30</td>
</tr>
<tr>
<td>Ca (ppm)</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>Mg (ppm)</td>
<td>18</td>
<td>35</td>
</tr>
</tbody>
</table>

(Marsh et al., 1996)
## Legume Cover Crops
### Rio Negro, Argentina

5 yr old apple; 3.2 m drive alleys, mowed twice a year

<table>
<thead>
<tr>
<th></th>
<th>Leaf N (%)</th>
<th>TCSA (cm²)</th>
<th>Fruit Yield (tons/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strawberry Clover</td>
<td>1.98 a</td>
<td>113 a</td>
<td>54 a</td>
</tr>
<tr>
<td>Alfalfa/fescue</td>
<td>1.85 b</td>
<td>108 a</td>
<td>58 a</td>
</tr>
<tr>
<td>Vetch</td>
<td>2.00 a</td>
<td>105 a</td>
<td>57 a</td>
</tr>
<tr>
<td>Control</td>
<td>1.86 b</td>
<td>94 b</td>
<td>45 b</td>
</tr>
</tbody>
</table>

2 tons/ha 5-5-5 fertilizer

(Sanchez et al., 2007)
WA - White clover living mulch

- In-row
- Recycles P, K
- Root N contributions, but N fix suppressed
- Suppresses weeds
- Saves water
Grow Your Own N

Nitrogen release over 3 weeks from ambient soil with and without clover, root exclusion tubes, and tube covers.

Soil Nitrate

- **A** – control plot; tube + cover; no clover
- **B** – control plot; tube + cover; clover clippings added
- **C** – clover plot; tube + cover, clover clippings added
- **D** – clover plot; tube – cover, clover clippings added
- **E** – control plot; no tube
- **F** – clover plot, no tube

46% of clover N mineralized

Tree growth, fruit yield enhanced

7/24/2001

7/31/2001

8/7/2001
Late summer 2000

Early spring 2002

Rodents – the weak link for clover.
Vole Trail Length
WA IMM Trial, Winter 05/06
(Winter 06/07, too few to analyze)

![Bar chart showing trail length (cm/m²) for different treatments: LML, LMNL, SWL, SWNL, WC, CTL, WW. The chart includes bars for 11/05 trails and 2/06 trails. Notable groups include Other living mulches and Galium (sweet woodruff).]
Sweet Woodruff
(Galium odoratum)

Wenatchee area

Thyme
2008 Trial – Quincy, WA

• Legumes direct seeded in drive alley (4’ swath) – May 19
  ▪ Alfalfa cv. Radiant
  ▪ Jumbo Ladino white clover
  ▪ Kura clover
  ▪ Birdsfoot trefoil cv. Norcen

• SPRAY or NO SPRAY prior to seeding

• Mow and blow before apple harvest
Alfalfa after seeding
Drill - 8” spacing; narrower would be better

Single pass

Double pass
Year 1

Spray

Ladino clover

No spray
Ladino Clover – May, Yr 2
Alfalfa – May, Yr 2
Mow and Blow

Legume residue in tree row after mow and blow
Legume Biomass
(Yr 2, 2009, 4 cuttings)

% N of DM
- Alfalfa: 4.1%
- Trefoil: 3.4%
- Ladino: 3.9%
- Kura: 3.1%
- Grass: 2.3%

Biomass (DM kg/ha):
- Alfalfa
- Trefoil
- Ladino
- Kura
- Grass

Cuttings:
- 27-May
- 1-Jul
- 10-Aug
- 1-Oct
Effect of Pre-seeding Treatment on Biomass

<table>
<thead>
<tr>
<th></th>
<th>Sum of 8/08, 7/09, 8/09 cuttings</th>
<th>Legume only, 7/09</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sprayed</td>
<td>Unsprayed</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>759  a</td>
<td>685  a</td>
</tr>
<tr>
<td>Ladino</td>
<td>701  a</td>
<td>719  a</td>
</tr>
<tr>
<td>Trefoil</td>
<td>783  a</td>
<td>716  a</td>
</tr>
<tr>
<td>Kura</td>
<td>476  a</td>
<td>486  a</td>
</tr>
</tbody>
</table>

*Dry matter (kg/ha)*
Year 3, 2010

Alfalfa

Trefoil

39 days after mowing
Cover Crop Biomass, Yr 3

Morgan Orchard, Cover Crop Biomass 2010- Spray

Biomass (DM kg/ha)

Alfalfa  Trefoil  Ladino  Kura  Grass

- 6-May
- 14-Jun
- 12-Jul
- 24-Aug
- 24-Sep
Cumulative Cover Crop Biomass

Morgan Orchard

Cover Crop Biomass, 2008-10

<table>
<thead>
<tr>
<th>Biomass DM (kg/ha)</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa Spray</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grass Spray</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kura Spray</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ladino Spray</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trefoil Spray</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

No spray

<table>
<thead>
<tr>
<th>Alfalfa No spray</th>
<th>Grass No spray</th>
<th>Kura No spray</th>
<th>Ladino No spray</th>
<th>Trefoil No spray</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>2009</td>
<td>2010</td>
<td>2008</td>
<td>2009</td>
</tr>
</tbody>
</table>
% Cover of Legumes in Drive Alley
Grower Application

- Grafted ‘Fuji’ Young apple block
- Seeded mid May of 2010
- Direct seed drill directly into existing vegetation of grasses and weeds (flailed before seeding) -- double pass, high seeding rate
- Excellent establishment; ~7’ swath

Photos June 16, 2010
Direct-seeded Alfalfa

June 23, 2010
Red Clover

Tilled and seeded

June 14, 2010
# N Contribution

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(lb N/ac)</td>
<td>(ppm NO$_3^-$ N)</td>
<td>(ton/ac/yr)</td>
<td>(%)</td>
<td>(lb N/ac/yr)</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>38</td>
<td>251</td>
<td>3.56</td>
<td>4.11</td>
<td>46.9</td>
</tr>
<tr>
<td>Trefoil</td>
<td>26</td>
<td>179</td>
<td>3.60</td>
<td>3.40</td>
<td>39.2</td>
</tr>
<tr>
<td>Ladino</td>
<td>25</td>
<td>173</td>
<td>2.62</td>
<td>3.92</td>
<td>32.8</td>
</tr>
<tr>
<td>Kura</td>
<td>14</td>
<td>132</td>
<td>2.72</td>
<td>3.07</td>
<td>26.7</td>
</tr>
<tr>
<td>Grass</td>
<td>15</td>
<td>103</td>
<td>3.28</td>
<td>2.30</td>
<td>24.2</td>
</tr>
</tbody>
</table>

*Ave. 2009 and 2010. Yield on a full acre basis; actual strips are 0.16 of area (2.2’ strip)
## Economics

**Costs per acre of orchard, 4’ swath**

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herbicide</td>
<td>7.15</td>
</tr>
<tr>
<td>Tractor/sprayer</td>
<td>14.85</td>
</tr>
<tr>
<td>Tractor/seeder</td>
<td>29.70</td>
</tr>
<tr>
<td>Seed</td>
<td>32.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>83.90</strong></td>
</tr>
</tbody>
</table>

Planting good for at least 5 yr - $21/yr cost

Alfalfa – 3.5 ton/ac/yr @ 4% N = 280 lb N

<table>
<thead>
<tr>
<th>Width</th>
<th>N content</th>
<th>Fert. Value$^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>5’</td>
<td>101</td>
<td>$71</td>
</tr>
<tr>
<td>4’</td>
<td>81</td>
<td>$57</td>
</tr>
<tr>
<td>3’</td>
<td>59</td>
<td>$41</td>
</tr>
</tbody>
</table>

Over 4 yr, $84 cost / 130 lb N$^b$ = $0.65/lb

$^a$Estimate N fertilizer at $0.70/lb

$^b$40% avail., accounting for Nmin (50-70%), losses

[ 4’ swath, 81 lb N/yr x 4 yr x 0.4 avail = 130 ]
Sampling

Percent cover
Point intersect – stiff wire with 20 pts; place at 45° to seeding rows; at least 3 representative spots per plot

Biomass
Quadrat frame – 3-4 representative samples per plot; cut at mower height; dry, weigh; convert to lb/ac DM; can weigh wet sample first for moisture content estimate and future wet basis sampling
See OSU cover crop sampling instructions

Figure 1a. Placing the sampling frame.

Figure 1b. Working the frame through the canopy.

Figure 1c. Cutting plants rooted within the frame.

Figure 1d. One quadrat after sampling.
## Sampling

### Nitrogen

Ideal – C,N analyzer, by combustion

### Mow and Blow trial, Year 1 Tissue N

<table>
<thead>
<tr>
<th></th>
<th>% N</th>
<th>C:N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>4.06</td>
<td>10.6</td>
</tr>
<tr>
<td>Ladino</td>
<td>3.77</td>
<td>11.2</td>
</tr>
<tr>
<td>Trefoil</td>
<td>3.36</td>
<td>13.0</td>
</tr>
<tr>
<td>Kura</td>
<td>2.83</td>
<td>14.9</td>
</tr>
<tr>
<td>Grass</td>
<td>2.15</td>
<td>18.8</td>
</tr>
<tr>
<td>Non-legume</td>
<td>2.32</td>
<td>17.7</td>
</tr>
</tbody>
</table>
Sampling

Nitrogen

Ideal – C,N analyzer, by combustion
Total N analysis – reported as %N; e.g. alfalfa 4.11%
N content = 0.0411 x 7120 lb/ac DM = 293 lb N/ac

Need to adjust for area – 4’ strip, 14’ row spacing;
4/14 = 0.2857 x 293 = 83.6 lb N/ac of orchard

Need to adjust for N mineralization
Get C:N from tissue test e.g. alfalfa 10.6
83.6 lb x 0.40 = 33 lb avail N/ac orchard
OSU Organic Fertilizer & Cover Crop Calculator

This free online tool compares the nutrient value and cost of cover crops, organic and synthetic fertilizers and compost. Use this Excel Calculator to develop well balanced and cost effective nutrient management programs for your farm. Developed by Nick Andrews, Dan Sullivan, Jim Julian and Kristin Pool.

Quick Guide & Records Sheet The Quick Guide describes the main steps used to sample cover crops in the field, list the laboratory analyses required and describe how to use the Calculator.

Cover Crop Sampling Instructions These instructions describe the recommended method for sampling and analysing cover crops in more detail than the Quick Guide.

Organic Fertilizer & Cover Crop Calculator (per acre calculations for cover crops and fertilizers).

Small Farm/Garden Calculator (square foot calculations for fertilizers only).

Research Background This page links to research papers and other information that explains how the calculator was developed.

http://smallfarms.oregonstate.edu/calculator
Cover Crop N Mineralization


Courtesy: N. Andrews
Could perennial cover crop roots contribute more available nitrogen?

- Residues on surface, not incorporated.
- After 40 days surface applied legumes provided about 20% of the nitrogen provided by incorporated legumes.
- Orchard floor PAN release is probably lower than calculator estimates.
- Less control over timing of PAN release, e.g. decomposition slower on dry surface.

Courtesy: N. Andrews
Do legume roots provide short term PAN?

<table>
<thead>
<tr>
<th>Material</th>
<th>C/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hairy vetch tops</td>
<td>10</td>
</tr>
<tr>
<td>Hairy vetch roots</td>
<td>25-30</td>
</tr>
<tr>
<td>Break even point for short term N-mineralization</td>
<td>~20</td>
</tr>
</tbody>
</table>


Courtesy: N. Andrews
Perennial Cover Crops
– mowed, left on surface

Surface residues

• Legume C/N ~ 10-15
• Cereal C/N ~ 20-40
• Mixtures ~ 15-25
• Suggests that orchard floor residues may lose 0-5% of the total %N as NH₃

Dutch lab research, 37 day duration.

Courtesy: N. Andrews
What we learned so far ...

- Need multiple years to assess species; many novel species to test
- Shade, traffic affecting growth
- Spraying out grass helped, but all legumes had reasonable stands; compensate with double pass, higher seed rate
- Need greater growing surface to boost N contribution; net ~3’ with tires
- Combinations? Alfalfa + ladino + kura?

Thanks to USDA Organic Research Special Grant for funding.
Resources

UC Davis SAREP
http://www.sarep.ucdavis.edu/ccrop/
- Cover Cropping in Vineyards

Midwest Cover Crops Council
http://www.mccc.msu.edu/

USDA SARE Program
http://www.sare.org/
- Managing Cover Crops Profitably

WSU
- EB 2010 – Cover Crops for PNW Vineyards
- Orchard floor management
http://www.tfrec.wsu.edu/pages/organic/Orchard_Floor