PROGRESS REPORT: Organic Cropping Research for the Northwest

TITLE: Understory Management in Organic Tree Fruits

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ABSTRACT: Weed control and fertility management have been identified as priority research needs by Washington organic orchardists. Mechanical weed control has been the standard practice, often with high cost and potential degradation of soil quality. Mulches can control weeds and improve tree growth and yield, and do enhance codling moth mortality with entomopathogenic nematodes. Living mulches show promise for weed control, soil quality, and fertility benefits, but can compete with trees and increase rodent populations. A new cultivator provided less costly weed control than the standard, but with considerably more weeds than a mulch. Tillage did not show a detrimental effect on soil quality or tree performance. Living mulches generally did not provide adequate weed control and did increase the presence of voles. In a new planting, wood chips did not control weeds, nor did living mulches, which competed with the trees for nutrients. Only the bare ground treatments led to acceptable tree growth. A "Sandwich system" treatment was also included that combines tillage each side of the tree line and a living mulch in the tree line, and it performed similarly to the living mulch. An organic herbicide did control broadleaf weeds but not grasses. A treatment with Brassica meal did not lead to weed suppression. Wood chip mulch did enhance the mortality of codling moth larvae when treated with *Steinernema carpocapse* and *S. feltiae*.

OBJECTIVES:

1. Evaluate the effectiveness of various weed management strategies for organic orchards.
2. Evaluate 'living mulch' species for establishment, vigor and weed competitiveness.
3. Integrate promising practices into several understory management systems and compare their performance in a new apple planting.
4. Evaluate the potential for understory management to increase mortality of overwintering codling moth (*Cydia pomenella*) larvae.

PROCEDURES:

1. **Weed Control (WW) trial.** In April 2004, a 2-year trial was set out in an 8-yr old block of Gala/M26 in transition to organic certification. Treatments included control (no tillage, mowing to keep weeds down), wood chip mulch (6" thick), Cultivator Y (3x), Cultivator Z (2x), Cultivator Z (3x), and Cultivator Z (4x), with 5 replicates. In Year 2 Cultivator Y treatment was tilled once only, in early August. Cultivator Y is a hydraulically driven unit with a vertical axis cultivating head. Cultivator Z is a ground-driven rolling cultivator with a spring blade that works in between the trees. Data collected in both years included weed cover, weed biomass, infiltration and soil penetration resistance. In 2004 tractor time for operations, shoot extension, SPAD, and leaf nutrient

concentration were measured and soil samples were taken for pending organic matter tests. Fruit weight and yield were measured in 2005.

2. **Living Mulch (LM) trial.** The 2004 Living Mulch screening was monitored for a second season; stand cover, competition with weeds, height, bloom dates, and visual signs of rodent attractiveness were monitored and select biomass samples were taken in both year 1 and 2. Winter hardiness and reseeding ability of annuals were also monitored in Year 2. Tree growth parameters were not measured. Plots were mowed for supplemental weed control. In 2005, a second screening was established in a new Pinata/M7 apple block in transition to organic certification, where trees are more sensitive to competition and potential vole damage, and increased sunlight is available to the cover species during establishment. Selected species were planted as "Living Mulch" filling the 150cm wide understory weed strip, or as a 45cm "Sandwich" in the tree line with adjacent tillage in the remaining weed strip. Entries included both perennial landscape species and various legumes and non-legumes. Seedling emergence, stand establishment, % cover (LM and weeds), peak stand biomass and height were measured. Flowering dates and seed production were observed. Plots were mowed for supplemental weed control.

3. **Integrated mulch trial**. A trial was set up in the Pinata/M7 block to test the following understory treatments during orchard establishment: bare ground control, bare ground with Brassica meal, wood chip mulch, cultivation, Sandwich system (tillage each side of the tree line and a 45 cm strip of living mulch in the tree line), and a Living Mulch (LM) treatment filling the 150 cm wide tree row. Both LM and Sandwich legume treatments are a species mix of Mt. Barker subclover, black medic, burr medic, birdsfoot trefoil, and bentgrass. The Sandwich non-legume treatment is transplanted sweet woodruff and Corsican mint, while the living mulch non-legume mix contains sweet alyssum, five spot, mother of thyme and bentgrass. Pelleted chicken manure was broadcast and incorporated in the tree row at a 1x rate of 93 lb N/ac. Since our original trial plan was combined with that of the Reganold et al. project, tilled plots and LM non-legume plots have 0.5x, 1x, and 1.5x treatments, and wood chip and LM legume plots have 1x and 1.5x treatments. Trees were supplemented with foliar sprays (2.4 lb N/ac) and a late August liquid fertilizer injection (32 lb N/ac). Experimental design is a Randomized Complete Block with 5 replicates. Measurements included living mulch and weed biomass, % mulch cover, % weed cover, emergence count, tree TCSA and leaf SPAD, and soil moisture and resistance.

4. **Nematodes**. The trial was in an 8-yr old block of Gala/M26 in transition to organic certification, with main plots of mulch or bare ground (tillage), and split plots of water, *Steinernema feltiae*, and *S. carpocapsae*, with 5 replicates. Nematodes were applied at 1.0 billion nematodes/acre with a backpack sprayer to the weed strip on 9/21/04. Sentinel codling moth (CM) larvae in cardboard strips were placed in the plots prior to application, recovered 2 days later, and then evaluated for infection by the respective nematodes. In addition, sheet metal arenas were placed in the plots to test for the persistence of the nematodes and their ability to infect mobile CM larvae.

PROGRESS TOWARDS OBJECTIVES:

1. **Weed control (WW) trial.** While increasing tillage led to reduced weed pressure (Fig. 1), weed cover did appear to increase in 2005 (nearly 100%) versus 2004 (80%), suggesting an increase in the weed seed bank. Annual grasses predominated, and tillage did appear to stimulate these, in particular green foxtail (*Setaria viridis*) and large crabgrass (*Digitaria sanguinalis*), both warm-season grasses. Wood chip mulch provided good weed control for a second season with no additional management. Tillage had no negative effect on tree shoot growth, leaf SPAD or leaf nutrient levels in 2004 and no negative effect on yield, fruit weight or size in 2005. Wood chip

mulch provided a modest benefit to the trees. Leaf P levels were significantly higher (p=.002) for the wood chip treatment although all treatment levels were considered to be sufficient. Fruit weight (g/apple) and box size were significantly better for the wood chip treatment (Table 1). There was no consistent effect of any treatment on soil quality measured, although the control (untilled) did have higher infiltration at low tension, suggesting more macropores. The wood chip mulch did not appear to have modified the soil surface. Refer to on-line report for cost comparisons and other Year 1 information:
Effectiveness of Weed Management Strategies for Organic Orchards in Central Washington - 2004.
A similar Year 2 report will be produced this winter.

2. **Living mulch (LM) trial**. Weed pressure was severe. Sweet woodruff was the best performing perennial landscape type LM entry and provided early and season-long cover up to 90% by April. Year 2 growth of scotch moss, creeping thyme, and native beach strawberry was again too slow to suppress weeds. Bentgrass also provided complete early cover, out-competing both weeds and legumes planted as a mix; the grass likely competes with tree growth (Table 2). **Spring planted** alyssum, subclovers and burr medics did not re-establish stands in Year 2; heavy shade and duff contributed to low germination rate. Black medics had a biennial habit; the Afghanistan selection overwintered well and provided the earliest cover of the spring planted legume entries. White clover had better persistence than strawberry clover. Birdsfoot trefoils also performed well; low vigor kura clover failed to establish well in either year. **Fall planted** subclovers, birdsfoot trefoils, black medic (Afghanistan), and kura clover all over-wintered well. Mt. Barker subclover provided early spring cover of up to 70%. All varieties flowered, produced seed and died back in 2005. Fall planted burr medics and the Yugoslavian black medic did not survive the winter. Evidence of stripped stems indicated vole feeding; it is unknown if vole damage or lack of hardiness was the cause of mortality. **Vole trails** were mapped in March to observe winter damage. Trails were concentrated in Rep 1 white clover and bentgrass plots; the clovers showed heavy feeding activity while bentgrass appeared to provide cover rather than food. There was no evidence of vole damage to tree bark.

Expanded screening 2005. Overall, entries seeded in 2005 outperformed the 2004 screening, probably a result of improved light and irrigation and/or earlier planting date in the new block. Entries are listed in Table 3. Stand establishment was excellent for most species. Annual and biennial legumes, white clover, alyssum, and Norcen birdsfoot trefoil (BFT) exceeded 70% stand cover by six weeks post planting (Table 4). Bentgrass, Five spot and Canadian and South American BFTs ranged from 53-67% cover; kura clover and seeded thyme had low vigor. The quickly established annuals, particularly medics, had lower % weed cover. The medics and subclovers produced viable seed; fall emergence was present for all varieties. Perennial landscape entries performed variably. Thyme had significantly higher cover (93%) and lower weed cover (7%) at 6 weeks than other entries. Phlox and woodruff also established cover quickly; mint did not survive. Weed pressure was severe at this site. Cover crop and weed competition were detrimental to tree establishment and growth.

3. **Integrated mulch trial.** All cover crop species established well. However, by mid-July annual grass weeds infested the site and severely competed with both the cover crops and trees. The non-cover crop plots had better tree growth and higher leaf greenness than the cover crop (LM and Sandwich) treatments, and increasing fertilizer rate did not overcome this (Table 5). Both the legume and non-legume mixes did provide some early season weed suppression but also competed with the trees. An earlier and shorter mowing of the cover crops may have enhanced their competitiveness with the weeds. There may be a reduction in weed pressure in year 2 with the

absence of tillage in the cover crops. Supplemental fertilizer by injection in late August visually stimulated cover crop growth but not the trees in those plots. Wood chip mulch did not adequately control weeds in this trial, but did show the lowest soil penetration resistance of all treatments. Trees in the Sandwich plots are expected to improve next year when roots are able to move under the tilled area. Tests for soil nutrients and microbial status will be conducted this winter by Lori Hoagland.

4. **Nematodes**. The positive effect of the mulch on CM mortality was again evident in the fall 2004 test. Mulch had a bigger impact on the efficacy of *S. carpocapsae* (20% CM mortality on bare ground vs. 90% under mulch) than of *S. feltiae* (60% bare ground vs. 85% under mulch). Research is needed to determine the spatial distribution of overwintering CM larvae in modern high density orchards and the relative attractiveness of various mulches as overwintering sites for these larvae. If a mulch proved attractive to the larvae, it could act as a "trap location" that could be treated with nematodes while the larvae are relatively immobile, leading to significant mortality and thus reductions in spring populations.

OUTPUTS:
Several individuals and small groups viewed Cultivator Z in action. The study site was on the field tour of the National Organic Tree Fruit Research Symposium (NOTFRS), with over 100 people attending. Presentations were made at three grower meetings on the research. A manuscript has been submitted to the Journal of Entomological Science regarding the nematode experiments. A poster on the nematode trial was developed and presented at the "Bugs Work for You" symposium in Portland, OR in November 2004. An abstract is included in the proceedings. The poster was also presented at the Washington State Horticulture Association 2004 annual meeting in Yakima in December 2004, and at the National Organic Tree Fruit Research Symposium in Chelan in June 2005. The proceedings of this symposium were put on line at
http://organic.tfrec.wsu.edu/OrganicIFP/OrganicFruitProduction/PROCEED.FINAL.pdf
David Granatstein and Kent Mullinix were also organizers of the symposium.

IMPACT:
At least 6 growers have purchased Cultivator Z and are using it on over 300 acres of organic orchard, reducing their weed control expenses. There have been 11 grower inquiries about the weed control and cover crops being tested. Most were interested in the living mulch ideas and await further results before trying any of them. The NOTFRS symposium was very successful, reaching a mix of researchers, growers, and industry, and exposing them to the diversity of organic orchard research across the country.

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ORGANIC RESEARCH LAND (indicate number of acres on all that apply):

Station	____non-organic	____transitional	____certified
On-farm	____ non-organic	_2.5 transitional	____certified

FARMER COOPERATOR(S): Number_1__
Name(s): Amos Kukas

Table 1. Apple fruit yield, weight, size, and value – WW trial, 2005.

TRT	**Yield (kg/tree)**	**Fruit wt (g/apple)**	**Size 80 Fruit (%)**	**Fruit value ($/acre)**
Wood chip	22.4	**206.9a**	**15.5a**	13454a
Control (mow)	20.4	197.0b	6.6b	11579ab
Cultivator Y 1x	20.0	195. 8b	7.5b	11368b
Cultivator Z 2x	19.3	196.8b	6.0b	10952b
Cultivator Z 4x	18.7	194.9b	6.5b	10632b
Cultivator Z 3x	17.6	189.5b	7.0b	9799b
p=	**0.150**	**0.037**	**0.014**	**0.017**

Table 2. Percent cover potential in second year, LM trial (planted 2004).*

2004 Entry	**Scientific name**	**YR 2 % Cover LM -- 3/31/05**	**YR 2 % Cover LM -- 6/15/05**
Perennial Landscape* LM			
Sweet woodruff	*Galium odoratum*	95	90
Scotch/Irish moss	*Sagina subulata*	35	55
Creeping thyme	*Thymus praecox minus*	35	45
Native beach strawberry	*Fragaria chiloensis*	35	40
Spring Seeded LM**			
Bentgrass, Colonial	*Agrostis tenuis*	93	78
White clover, Dutch	*Trifolium repens*	53	73
Black medic, Afghanistan	*Medicago lupulina*	50	73
White clover, New Zealand	*Trifolium repens*	47	90
Birdsfoot trefoil, Norcen	*Lotus corniculatus*	38	72
Strawberry clover	*Trifolium fragiferum*	35	75
Birdsfoot trefoil, Kalo	*Lotus corniculatus*	27	70
Black medic, Yugoslavia	*Medicago lupulina*	10	33
Kura clover, Prairie	*Trifolium ambiguum*	5	17
Kura clover, Rhizo	*Trifolium ambiguum*	2	12
Fall Seeded LM**			
Subclover, Mt. Barker	*Trifolium subterraneum*	72	5
Subclover, Antas	*Trifolium subterraneum*	40	5
Subclover, Clare	*Trifolium subterraneum*	30	5
Subclover, Nungarin	*Trifolium subterraneum*	50	5
Birdsfoot trefoil, all	*Lotus corniculatus*	50	20
Black medic, Afghanistan	*Medicago lupulina*	15	15

** Best results*

** *Average of three reps*

Table 3. Living Mulch screening entries planted in 2005

Common Name	Scientfic name	Variety or Location	Life Cycle	System	Planting
Non-Legume Species					
Corsican mint	*Mentha requienii*	Corsican	Perennial	SW	Plugs
Bearberry, Kinnikinnick	*Arctostaphylos uva-ursi*		Perennial	LM	Plugs
Bentgrass	*Agrostis tenuis*	Colonial	Perennial	LM	Broadcast
Bugleweed	*Ajuga reptans*		Perennial	SW	Plugs
Chickweed	*Stellaria media*		Annual	SW	Plugs
Cinquefoil	*Potentilla neumanniana*	Nana	Perennial	SW	Plugs
Five spot	*Nemophila maculata*		Annual	LM	Rows
Moss pink	*Phlox subulata*		Perennial	SW	Plugs
Mother of thyme	*Thymus serpyllum*		Perennial	SW	Plugs
Mother of thyme	*Thymus serpyllum*		Perennial	LM	Rows
Speedwell	*Veronica repens*		Perennial	SW	Plugs
Sweet alyssum	*Lobularia maritima*		Annual	LM	Rows
Sweet woodruff	*Galium odoratum*		Perennial	SW	Plugs
Clovers					
Kura clover	*Trifolium ambiguum*	Prairie	Perennial	LM	Rows
Subclover	*Trifolium subterraneum*	Antas	Annual	LM	Rows
Subclover	*Trifolium subterraneum*	Clare	Annual	LM	Rows
Subclover	*Trifolium subterraneum*	Dalkieth	Annual	LM	Rows
Subclover	*Trifolium subterraneum*	Denmark	Annual	LM	Rows
Subclover	*Trifolium subterraneum*	Mt Barker	Annual	LM	Rows
Subclover	*Trifolium subterraneum*	Nungarin	Annual	LM	Rows
White clover	*Trifolium repens*	Dutch	Annual	SW	Broadcast
Medics					
Barrel medic	*Medicago truncatula*	Caliph	Annual	LM	Rows
Barrel medic	*Medicago truncatula*	Parabinga	Annual	LM	Rows
Burr medic	*Medicago polymorpha*	Santiago	Annual	LM	Rows
Burr medic	*Medicago polymorpha*	Scimitar	Annual	LM	Rows
Black medic	*Medicago lupulina*	VNS, Montana	Biennial	LM	Rows
Black medic	*Medicago lupulina*	Afghanistan	Biennial	LM	Rows
Black medic	*Medicago lupulina*	VNS, Montana	Biennial	SW	Broadcast
Subclover Mix	*Trifolium subterraneum*	Clare, Mt. Barker, Nungarin	Annual	SW	Broadcast
Trefoil					
Birdsfoot trefoil	*Lotus corniculatus*	Canada	Perennial	LM	Rows
Birdsfoot trefoil	*Lotus corniculatus*	Norcen	Perennial	LM	Rows
Birdsfoot trefoil	*Lotus corniculatus*	South America	Perennial	LM	Rows

Table 4. Growth of living mulches (LM) and weeds, 2005 planting.

Entry	Total Cover* (%)	Weed cover* (%)	LM peak stand biomass (g/m^2)	LM seedlings/ 100 cm^2**	Canopy Height*** (cm)
Seeded LMs					
Scimitar burr medic	95	5	264	5	32
Santiago burr medic	93	7	192	2	33
Caliph barrel medic	87	13	256	4	31
Blk medic Broadcast, SW	87	8		2	
Dutch White Broadcast, SW	87	10	299	16	
Blk medic VNS	85	15	211	4	34
Denmark subclover	83	17	222	3	20
Parabinga barrel medic	82	18	182	2	32
Alyssum	81	19	236	8	28
Antas subclover	78	22	281	3	21
Dalkieth subclover	78	22	156	4	19
Clare subclover	77	23	184	3	28
Mt Barker subclover	73	27	265	4	24
BFT Norcen	73	27	294	7	39
Blk medic Afg	72	28	133	9	31
Sub Mix Broadcast, SW	72	27	226	9	
Nungarin subclover	68	32	120	3	15
BFT Can	67	33	215	6	34
BFT SA	63	37	222	6	34
Five Spot	55	45	104	2	22
Bentgrass	53	47			27
Praire Kura Clover	25	75	62	7	15
Thyme	14	86	8	5	12
Perennial Transplants					
Thyme	93 a	7 d			
Phlox	67 b	23 c			
Woodruff	57 bc	na			
Ajuga	46 cd	33 bc			
Mint	38 de	na			
Veronica	30 ef	40 b			
Potentilla	18 fg	32 bc			
Kinnikinnick	10 g	90 a			
p=	**0.000**	**0.000**			

** 6 weeks post plant, **18 days post plant, ***2 months post plant*

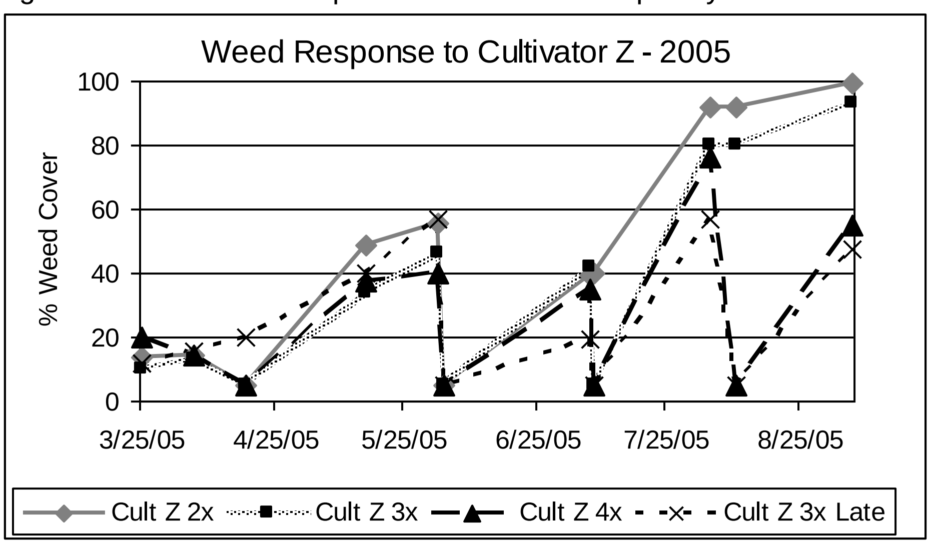
BFT= birdsfoot trefoil, SW=sandwich

Table 5. Leaf greenness and shoot growth, Integrated Mulch trial.

Treatment	SPAD 08/02/2005	SPAD 08/24/2005	SPAD 09/13/2005	% trees with new growth
Control 0x	30	33	36	47
Control 1x	32	36	40	77
Control Brassica	34	36	40	70
LM Legumes 0.5x	27	26	32	3
LM Legumes 1x	31	34	37	47
LM Non-legumes 0.5x	28	26	26	13
LM Non-legumes 1x	31	28	31	10
LM Non-legumes 1.5x	30	31	34	10
SW Legumes 1x	30	31	36	30
SW Non-legumes 1x	33	36	39	50
Wood Chips 1x	31	36	40	87
Wood Chips 1.5x	34	39	43	97
Cultivator Z 0.5x	32	40	43	93
Cultivator Z 1x	35	40	43	83
Cultivator Z 1.5x	35	40	44	77
p=	**0.030**	**0.000**	**0.000**	**0.000**
LSD=	**4.8**	**5.1**	**5.3**	**30.0**

SPAD meter used to measure leaf greenness.

Figure 1. Weed cover response to cultivation frequency – WW trial.



2005 Cultivator Z tillage dates: 4/18/05, 6/2/05, 7/8/05, 8/10/05

Figure 2. Soil resistance in Integrated Mulch trial – Sept. 2005.

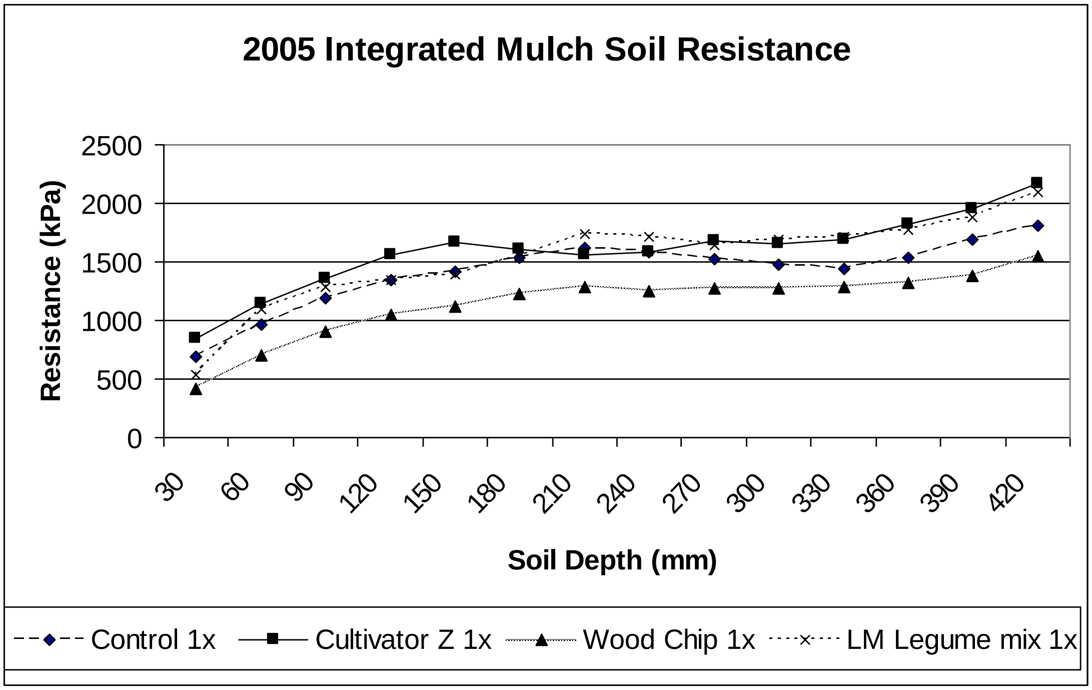


Figure 3. Effect of wood chip mulch and nematode species on codling moth larvae mortality - September 2004. Letters indicate differences between treatments; Fishers LSD at P < 0.05.