Progress Report: Organic Cropping Research for the Northwest

TITLE: Integrated Multiple Mulch Trial

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ABSTRACT:
Balancing weed control, nutrient management, tree growth, and maintaining soil quality is an especially complex undertaking for organic fruit growers during the orchard establishment years. This study assessed potential weed control and management techniques and their effects on soil quality, fertility, and tree growth in a newly planted organic apple orchard. Treatments included "living mulches" of legume and nonlegume cover crop mixes, both in the entire weed strip and in the tree line only with tilled edges (Swiss "Sandwich" system), a Brassica meal application (*Sinapsis alba*), wood chip mulch, clean-tillage, and a bare ground undisturbed control, combined with three fertility levels using chicken manure compost. Weed, tree, and soil quality affects were quantified, and rodent presence was observed.. The "Wonder Weeder" cultivator has been found to provide low cost weed control (Granatstein 2004), so this was used for the clean-tilled and Sandwich system treatment. Cultivation can lead to improved tree growth during the first years when it controls weeds, but tillage can also increase leaching of nitrogen out of the rooting zone (Wiedenfeld 1999). Our results were in line with these findings, based on trunk growth and soil EC measures; however, tilled trees experienced significantly greatly leaning than untilled trees, possibly due to disruption of root anchoring during the first 2 years. The Sandwich system appears to provide a good compromise in this trial, with improved soil quality and tree growth over the clean cultivated treatments. Mulches have been found to control weeds and improve tree growth and yield (Neilsen et al. 2003, Granatstein 2006). However, by Year 2 of this study, weeds were abundant in the wood chip mulch plots, yet those trees had some of the largest growth. Living mulch cover crops show promise for weed control, soil quality, and fertility benefits, but clearly compete with trees and slow their growth. Vole presence was higher in living mulches in the first year, but the voles had almost completely disappeared by Year 2 despite a doubling of living mulch biomass. Brassica meal as a soil amendment increased nitrogen availability over the tilled treatment, but may have induced an iron deficiency in the trees (Hoagland 2006).

OBJECTIVES:

1. Evaluate the effectiveness of various weed management strategies, including wood chip mulch and cultivation, for organic orchards during the first two years of tree establishment.
2. Evaluate 'living mulch' species for their establishment, vigor, rodent usage, potential N contribution, and competitiveness with weeds.

PROCEDURES:

The Integrated Multiple Mulch (IMM) trial is a new Piñata™/M7 block planted in April 2005 (Year 1) with the following understory treatments: unfertilized control (CLT0), bare ground undisturbed control (CTL1), wood chip mulch (WC), cultivation (using Wonder Weeder, WW), Sandwich system (tillage each side of the tree line and a 45 cm strip of living mulch in the tree line, see Figure 1, SW), and a Living Mulch (LM) treatment filling the 150 cm wide tree row. The LM and Sandwich legume treatments consisted of a legume species seed mixture, LM nonlegume treatments consisted of a nonlegume seed mixture, and the Sandwich nonlegume treatment was transplanted with two groundcover species (Table 1). The species mixtures were hand-broadcast and raked into the tilled soil of the newly-planted orchard, while the sweet woodruff (*Galium odoratum*) and Corsican mint (*Mentha requenii*) were transplanted from plugs. Brassica seed meal (*Sinapsis alba*) (CTLB) was applied as a soil amendment, at 0.5 ton/ac in Year 1, and 1.5 ton/acre in Year 2. In addition, differing compost rates were applied to some of the treatments, denote 1x for the standard rate, 0.5x for half this rate, and 1.5x for 50% more. Experimental design is a Randomized Complete Block with 5 replicates. In Year 2, chicken manure compost was hand-applied around each tree at a 1x rate of 12 lb total per tree, with applications on 4/10/06, 5/9/06, 5/25/06, and 6/7/06. This provided a total of 208 lb N/ac, with an estimated 92 lb N available. Relative fertility levels of 0.5x, 1x, and 1.5x were retained in Year 2, but the 1x was increased to 3 times higher than the Year 1 rate. Living mulch was mowed at a 5" height approximately 12 times throughout the growing season in each year. Four tillage passes were conducted in tillage treatment plots (WW and SW). Irrigation was generally restricted to a 9 hr set to prevent leaching, based on two tensiometer stations monitoring 6, 12, and 24 inch depths. Fruit set was prevented by pinching off blossoms. Measurements included living mulch and weed biomass at peak stand, % N and C in the living mulches, % mulch and weed cover at several dates, tree trunk cross sectional area (TCSA), tree canopy volume, leaf SPAD, and soil moisture and water infiltration. A handheld EC probe was used in June 2006 for *in situ* measurements at 0, 6, 12, 18, and 24 inch depths, both next to trees (by the compost) and between the trees (Spectrum Technology, Plainfield, IL). In November 2006, soil cores were collected at 6", 12", 18" and 24" depths and tested with the EC probe. Samples were then analyzed for ammonium-N and nitrate-N from extractions of 10.0 g soil in 50 mL 1 M KCl on a Latchat FIA 8000 series autoanalyzer (Latchat Instruments, Milwaukee,WI). The samples were statistically analyzed with depth as repeated measure, and correlated with the EC data. Meadow vole (*Microtus pennsylvanicus*) presence was sampled using a grid of 36 intersection points three times in each plot; number of intersections that coincided with vole sign was counted, and runway length was measured for each grid area (Hansson 1979). Pocket gopher (*Thomomys talpoides*) traps were used throughout the spring and summer to protect the young trees (Sullivan 2001), and gopher sign was measured in November 2006. Statistical analyses were conducted using analysis of variance, and results compared with LSD ($p<0.05$) (SAS Institute, Inc.).

PROGRESS TOWARDS OBJECTIVES:

Weed Control and Vole Presence. Species in the living mulch mixtures established well in Year 1, but by Year 2 the species mixtures had changed. The LM and Sandwich legume treatment were mostly comprised of bentgrass (*Agrostis tenuis*) and birdsfoot trefoil (*Lotus corniculatus*) with a trace of black medic (*Medicago lupulina*) (Table 1). By Year 2, the Sandwich non-legume treatment was entirely composed of sweet woodruff (*Galium odoratum*) (Figure 5), and the LM nonlegume mix contained mostly bentgrass and mother of thyme (*Thymus serpyllum)* (Figure 6). Annual medics and subclovers were abundant in the first year, but emerged early and/or sparsely in Year 2, suggesting the perennial species were more vigorous as the season progressed. In Year 2, cover crop biomass was significantly higher in the LM legume and Sandwich nonlegume treatments, but there were no significant differences in weed biomass for all the LM species mixes (Figures 7 & 8). As expected, weed biomass and % cover in Year 2 were reduced due to cover crop competition and the absence of tillage. Birdsfoot trefoil was the most vigorous legume species over the two growing seasons (Figure 4), with bentgrass and sweet woodruff the most competitive nonlegume species. In addition, trefoil tissue had the highest % N of all living mulch treatments at the 1x fertility level (Table 2). The sweet woodruff (*Galium odoratum*) formed a good stand and very few weeds emerged through it (Figures 1 and 5), although the Corsican mint did not survive the first year due to disease. Warm season annual weeds heavily infested the site by August, but in Year 2 the cover crops competed with weeds more effectively than in Year 1 (Figures 7 & 8). Each clean tillage treatment led to germination of these warm season annual grass weeds (Figure 3). These treatments were kept weed free, but with significant cost and labor. The wood chip mulch did not control weeds well, possibly due to rapid decomposition, presence of weed seeds in the mulch, and/or favorable light and moisture conditions for seed germination.

Voles were at a high point in their cycle during winter 2005/2006, but populations dropped during 2006 and were very low by November 2006 (Table 3). Although vole trunk injury was measured, there was very little aboveground damage. There was significantly less vole presence in the *Galium* in February 2006 than the other cover crops, but more than the non-vegetated treatments.

Tree Growth. In Year 1, cover crop biomass negatively affected tree growth, but by Year 2 tree growth was excellent in all treatments (100-225% increase in TCSA, 3-5' leader growth, Table 4). Neither total per cent cover of understory vegetation nor total biomass showed any correlation with tree growth in Year 2 despite the near doubling of cover crop biomass. However, treatments with cover crops generally led to smaller trees (perhaps a carryover from the dramatic tree growth reduction by cover crops in Year 1), but the Sandwich non-legume trees grew as well as the best performing treatments (wood chip, tillage) (Figure 9). Poor overall tree growth in Year 1 was likely due to a combination of factors, including poor condition of transplants, stress from heading back, and some presence of root pathogens.

Tree leaf SPAD and trunk growth increment data suggest that the trees experienced little nitrogen stress in Year 2 (Table 4). There were no significant effects of fertility level on tree growth. However, cover crop tissue N did significantly increase with increasing compost rate, providing further evidence that the cover crops can outcompete the trees for the additional nutrients supplied by a higher compost rate. Clean tillage (WW) yielded the largest tree growth and greatest flower development, as well as the highest leaf % N (Table 6). SPAD measurements (leaf greenness) taken over time showed a lack of correlation with tree growth for some treatments such as wood chips, where trees grew well despite lower greenness. Living mulch trees had high leaf greenness but poorer tree growth, perhaps because their tree canopies were smaller and had fewer leaves to supply with N (Figure 14). A fertilizer response could also be seen with SPAD readings for the living mulch treatments and for wood chips. Over the course of the 2 year trial, the WW treatments yielded significantly more leaning trees, suggesting tillage may contribute to root pruning and reduced anchoring of free standing trees (Table 4, Figure 3).

Soil Quality. The direct soil EC readings from June 2006 correlated fairly well with lab nitrate analyses (R^2=0.74, Table 5). EC readings were much higher adjacent to the trees than between the trees; this was expected, as compost was placed around the trees. EC levels between the trees were closer to non-fertilized (CTL0) levels, and treatment differences for between-tree EC values were minimal. Generally, tillage led to higher EC, especially at the higher compost rates, suggesting that the incorporation was increasing N mineralization from compost, and possibly reducing volatile loss (Figures 10-12). Tillage also elevated EC readings between the trees, as did the Brassica meal (CTLB) which was broadcast across the entire plot. The unfertilized control (CTL0) had the lowest EC reading and was the same at all depths both next to and between the trees, providing a reliable background. No treatments had significantly higher EC at 24" depth by-tree than CTL0, suggesting that nitrate was being retained in the rooting zone; WW and WC had the highest levels (Table 5).

Fall soil nitrate was measured to 2' depth (Table 6), and a spring 2007 sampling is planned to better track movement of N over winter. For fall 2006, ammonium was similar for all depths and treatments, while nitrate was significantly different only among reps, despite some numerically large differences among treatments. The tillage (WW) 1.5x treatment consistently had the highest nitrate for each depth (not significant). Nitrate and ammonium were highest in the 0-6" depth of the soil column. Fall Year 2 available N was much lower than in fall Year 1, perhaps due to the August Year 1 fertilizer injection which elevated that year's soil N. Although we did have two elevated levels of available N in Year 2 soil nitrogen, there were similar treatment effects of the living mulch legume, cultivation, and sandwich treatments across compost rates on soil N. Our baseline treatment receiving no compost, CTL0, was consistently lowest in soil N, although not significantly. Generally, there was much higher overall soil N in Year 2 than Year 1, due to an increased base compost rate, which appears to have more of an influence than the orchard floor treatment. The influence of the living mulches on tree growth was highly correlated in Year 1 but not Year 2; but it is difficult to discern if reduced growth due to cover crops in Year 2 is simply a carryover affect from year 1 stunting or if living mulch cover continued to influence growth in Year 2.

Soil resistance data were collected in Year 1 but not Year 2 due to unavailability of the instrument. In Year 1, wood chip mulch had the lowest soil resistance of all treatments (Figure 15). At 15mm and 30 mm depth, soil resistance was significantly lower in the wood chip and LML plots than the control and WW plots. In both years abundant fungal hyphae development and root growth were observed in the wood chip layer throughout the trial. However, the wood chip treatment had lower water infiltration than the living mulch treatments (Table 5). Volumetric water content analyses showed that soil moisture was similar for all treatments, regardless of cover or tillage, for both years (Table 5).

Conclusions. This research is in progress for a third year (2007). Understory management had an influence on tree growth, illustrating the trade-offs in orchard system performance. No treatment yet provides optimum performance for tree growth, weed control, soil quality, and nutrient management. Based on the Year 2 results, living mulches are controlling weeds and improving some soil quality aspects, with reduced but still acceptable growth of trees. The legumes are adding N to the system, but may be competing with the trees for it. Vole presence is elevated in the living mulches, but no aboveground tree damage is obvious. The 'Sandwich' system, using *Galium odoratum,* appears to provide an acceptable compromise between the soil quality benefits of a cover crop and the competition-free tree growth with clean tillage (Figure 1). As trees mature, the *Galium* cover could potentially fill the entire weed strip, suppressing weeds and eliminating the need for tillage. This species seems less competitive with the trees than the bentgrass or birdsfoot trefoil, and it had significantly less vole activity compared to the other cover crops in 2005. Also, *Galium* plant tissue had the highest C:N ratio of all the living mulch treatments (Table 2). Future studies will need to combine strategies, building on the experimental results from this and other studies, and from the experiences of growers testing these same ideas in their orchards.

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Table 1. Integrated Multiple Mulch treatment list and management, years 1 & 2.

Treatment Code	Weed control/ Disturbance	Fertilizer 2006	Understory 2005	Understory 2006*
CTL0	No disturbance	No compost added	none or some sod	none or some sod
CTL1	Low disturbance	1x chicken manure compost (CMC)(12lb/tree)	none	none
CTL B	Low disturbance	0.5x CMC (6 lb/tree)	none or some sod; 0.5 ton/ac *B. alba* meal	none or some sod; 1.5 ton/ac *B. alba* meal
WW0.5	Wonder Weeder tillage 4x/season High disturbance	0.5x CMC (6 lb/tree)	none	none
WW1	Wonder Weeder tillage 4x/season High disturbance	1x CMC (12 lb/tree)	none	none
WW1.5	Wonder Weeder tillage 4x/season High disturbance	1.5x CMC (18 lb/tree)	none	none
WC1	Wood chip mulch No disturbance	1x CMC (12 lb/tree)	wood chip mulch, 6" layer	wood chip mulch, 6" layer
WC1.5	Wood chip mulch No disturbance	1.5x CMC (18 lb/tree)	wood chip mulch, 6" layer	wood chip mulch, 6" layer
LML0.5	Living mulch – legumes No disturbance after planting	0.5x CMC (6 lb/tree)	Afghan black medic, burr medic, birdsfoot trefoil, Mt. Barker subclover, and Colonial bentgrass	birdsfoot trefoil and bentgrass
LML1	Living mulch - legumes No disturbance after planting	1x CMC (12 lb/tree)	Afghan Black medic, burr medic, birdsfoot trefoil, Mt. Barker subclover, and Colonial bentgrass	birdsfoot trefoil and bentgrass
LMNL0.5	Living mulch - non-legumes No disturbance after planting	0.5x CMC (6 lb/tree)	Colonial bentgrass, sweet alyssum, five spot, mother of thyme	bentgrass, mother of thyme
LMNL1	Living mulch - non-legumes No disturbance after planting	1x CMC (12 lb/tree)	Colonial bentgrass, sweet alyssum, five spot, mother of thyme	bentgrass, mother of thyme
LMNL1.5	Living mulch - non-legumes No disturbance after planting	1.5x CMC (18 lb/tree)	Colonial bentgrass, sweet alyssum, five spot, mother of thyme	bentgrass, mother of thyme
SWL1	Sandwich system tillage on outside – legumes Moderate disturbance)	1x CMC (12 lb/tree)	Afghan black medic, burr medic, birdsfoot trefoil, Mt. Barker subclover, and Colonial bentgrass	birdsfoot trefoil and bentgrass
SWNL1	Sandwich system tillage on outside –non-legumes Moderate disturbance)	1x CMC (12 lb/tree)	Sweet woodruff and Corsican mint	Sweet woodruff

*Based on percent cover by individual species.

Table 2. Cover crop tissue composition.

Living Mulch trt	% Carbon	% Nitrogen	C:N
LM Legume 0.5x	44.2 a	2.6 ab	17.2 c
LM Legume 1x	43.9 a	2.8 a	15.9 c
LM Nonlegume 0.5x	42.5 b	2.1 c	20.8 b
LM Nonlegume 1x	42.9 b	2.4 b	18.1 c
LM Nonlegume 1.5x	42.5 b	2.7 a	16.1 c
SW Nonlegume 1x	40.2 c	1.5 d	27.0 a
p=	**<0.0001**	**<0.0001**	**<0.0001**

Table 3. Vole presence in tree row – 2006.

	February 2006 sampling			**October 2006 sampling**		
TRT	**Vole Sign Intersect Count**	**% Intersect**	**Vole Run length (cm/m^2)**	**Vole Sign Intersect Count**	**Vole Run length (cm/m^2)**	**Pocket gopher count**
Sandwich Legume	11.7 a	32.6	354 a	1.8 a	43	1.8
Living Mulch Legume	7.9 b	22.0	197 b	1.4 ab	51	2.0
LM Nonlegume	10.0 ab	27.8	286 ab	1.2 ab	45	0.8
Sandwich Nonlegume	3.1 c	8.7	90 c	1.9 a	63	0.3
Wood Chip Mulch	0.5 c	1.5	17 c	0.0 b	0	0.3
Control	0.2 c	0.6	4 c	0.0 b	0	0.0
Wonder Weeder	0.8 c	2.2	26 c	0.0 b	0	0.0
p=	**< 0.0001**		**0.0179**	**0.0749**	**0.1116**	**0.1644**

Table 4. Tree performance in Year 2 (2006).

Treatment	Yr 2 growth increment (cm^2)		Yr 2 trunk % increase	SPAD 5/31/06		SPAD 07/03/2006		SPAD 07/18/2006		% leaning trees	
Wonder Weeder 1.5x	9.6	a	217.9	37.8	abc	48.9	ab	49.2	ab		
Wonder Weeder 0.5x	9.2	ab	223.6	35.0	bc	47.3	abc	47.4	bcde		
Wood Chip 1.5x	8.7	ab	202.9	37.2	abc	47.0	bc	47.2	cde		
Wood Chip 1x	8.1	ab	206.7	36.2	abc	44.6	d	44.5	fg	10.0	b
Wonder Weeder 1x	8.0	ab	195.4	38.4	ab	48.0	abc	48.7	abc	53.3	a
Control Brassica	7.7	bc	184.9	30.5	d	45.9	dc	46.7	de		
Sandwich Nonlegume 1x	7.6	bc	209.6	38.4	ab	46.9	bc	48.2	abcd		
Sandwich Legume 1x	6.4	dc	179.1	37.9	abc	47.9	abc	48.8	abc	23.0	b
Control 1x	6.3	dc	162.8	35.6	bc	46.9	bc	47.2	cde	16.7	b
Living Mulch Nonlegume 1.5x	6.3	dc	173.4	37.9	abc	49.4	a	50.0	a		
Living Mulch Nonlegume 1x	5.6	d	169.5	37.3	abc	47.8	abc	48.2	abcd		
Living Mulch Legume 1x	5.2	de	149.6	39.6	a	48.8	ab	49.4	a	20.0	b
Living Mulch Legume 0.5x	5.0	de	145.8	36.6	abc	44.6	d	46.1	ef		
Living Mulch Nonlegume 0.5x	3.7	ef	115.5	34.3	c	44.0	d	44.2	g		
Control 0x	3.2	f	97.1	30.1	d	35.1	e	39.2	h		
p=	**<0.0001**			**0.0001**		**<0.0001**		**<0.0001**		**0.0036**	

Table 5. Soil parameters, measured midsummer 2006 (year 3).

Treatment	Soil Volumetric Water Content (%)	Electrical Conductivity- by tree (mS/cm) 0 in depth	6 in depth	12 in depth	18 in depth	24 in depth	Soil water infiltration 0.5 cm tension (ml/min)	2 cm tension (ml/min)
Control 0x	28.3	0.20 e	0.19 f	0.21 e	0.19 d	0.17		
Control 1x	24.6	0.32 cde	0.44 def	0.51 bcde	0.35 bcd	0.21	2.9 bc	1.7 ab
Brassica meal	33.0	0.40 bcde	0.51 cde	0.54 bcd	0.37 bcd	0.26		
LML 0.5x	29.2	0.28 cde	0.28 ef	0.27 de	0.21 d	0.23		
LML 1x	24.6	0.46 bcde	0.60 bcd	0.64 bc	0.37 bcd	0.23	4.6 a	1.8 a
LMNL 0.5x	26.3	0.34 bcde	0.38 def	0.36 cde	0.23 cd	0.19		
LMNL 1x	26.6	0.41 bcde	0.47 def	0.52 bcde	0.39 bcd	0.25	4.3 ab	2.0 a
LMNL 1.5x	28.2	0.53 abcde	0.60 bcd	0.55 bcd	0.44 bc	0.30		
Sandwich Legume 1x	28.2	0.53 abcde	0.80 abc	0.53 bcde	0.35 bcd	0.21		
Sandwich Nonlegume 1x	25.8	0.56 abcd	0.59 bcd	0.47 bcde	0.39 bcd	0.29		
Wood Chip mulch 1x	*	0.48 bcde	0.50 de	0.40 cde	0.30 cd	0.45	1.9 c	1.1 b
Wood Chip mulch 1.5x	*	0.67 ab	0.53 cde	0.36 cde	0.32 bcd	0.34		
Wonder Weeder 0.5x	27.9	0.24 de	0.37 def	0.46 cde	0.37 bcd	0.31		
Wonder Weeder 1x	25.7	0.82 a	0.85 ab	0.80 b	0.51 b	0.32	3.1 bc	1.4 ab
Wonder Weeder 1.5x	29.1	0.58 abc	1.01 a	1.15 a	0.87 a	0.45		
p=	**0.6931**	**0.0316**	**0.0001**	**0.0002**	**<0.0001**	**0.1253**	**0.0060**	**0.0411**

*Indicates probe could not penetrate soil to measure.
LML = living mulch legume; LMNL = living mulch non-legume

Table 6. Soil nitrogen and tree leaf nitrogen – 2006.

	Jul-06 0-10 cm	9/29/2006 0-10 cm	10/31/2006 0-15 cm	10/31/2006 0-60 cm			
treatment	**Soil avail N (ppm)**	**Soil avail N (ppm)**	**Soil avail N (ppm)**	**NH4-N (ppm)**	**NO3-N (ppm)**	**Soil avail N (ppm)**	**Tree leaf N (%)**
Control 0x	9.2 f	8.6 d	3.6	3.6	7.3	10.8	2.08 de
Control 1x	31.8 bc	17.9 abc	6.9	3.8	14.8	18.6	2.35 abc
Control Brassica	31.9 bc	22.7 a	5.9	3.9	12.4	16.3	2.25 cde
LML 0.5x	22.4 cdef	15.8 abc	5.6	3.7	11.1	14.8	2.24 cde
LML 1x	46.1 a	21.0 a	6.8	8.4	13.9	22.2	2.55 a
LLMNL 0.5x	32.1 bc	12.2 bcd	5.5	4.0	9.8	13.8	2.33 abc
LMNL 1x	28.0 bcd	12.7 bcd	6.5	4.3	11.6	15.9	2.50 ab
LMNL 1.5x	37.5 ab	21.8 a	10.0	5.9	33.9	39.8	2.34 abc
SW Legume 1x			4.9	3.0	9.6	12.5	2.33 abc
SW Nonlegume 1x			5.5	6.8	10.4	17.2	2.29 bcd
Wood Chip 1x	17.9 def	12.8 bcd	8.2	5.8	13.1	18.9	2.05 e
Wood Chip 1.5x	23.4 cde	12.0 bcd	5.0	6.4	12.2	18.6	2.26 cde
Wonder Weeder 0.5x	12.4 ef	11.3 cd	4.0	3.6	8.9	12.5	2.48 ab
Wonder Weeder 1x	22.9 cde	15.8 abc	6.5	2.7	16.4	19.1	2.45 ab
Wonder Weeder 1.5x	32.2 cde	18.5 ab	11.3	3.2	27.2	30.5	2.41 abc
p=	<0.05	<0.05	**0.5713**	**0.5888**	**0.2263**	**0.3434**	<0.05

LML = living mulch legume; LMNL = living mulch non-legume; SW = Sandwich system

Figures 1-4, IMM 2006. Clockwise from top left: 1. *Galium odoratum* in Sandwich nonlegume (SWNL). 2.Tree growth and summer annual weeds. 3. Clean cultivated (WW) treatment with leaning trees. 4. Biomass collection of living mulch legume (LML) treatment with birdsfoot trefoil (*Lotus corniculatus*).

Figure 5. Species composition of the Sandwich nonlegume treatment.

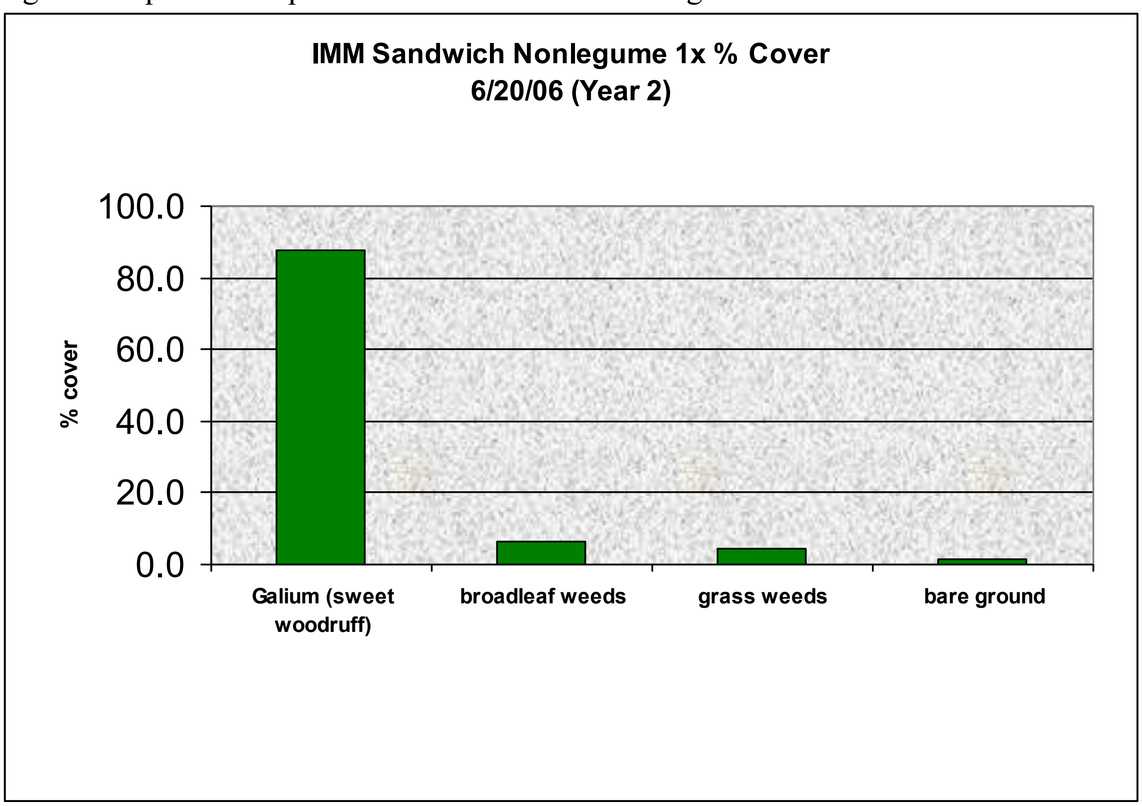


Figure 6. Species composition of the living mulch nonlegume treatment.

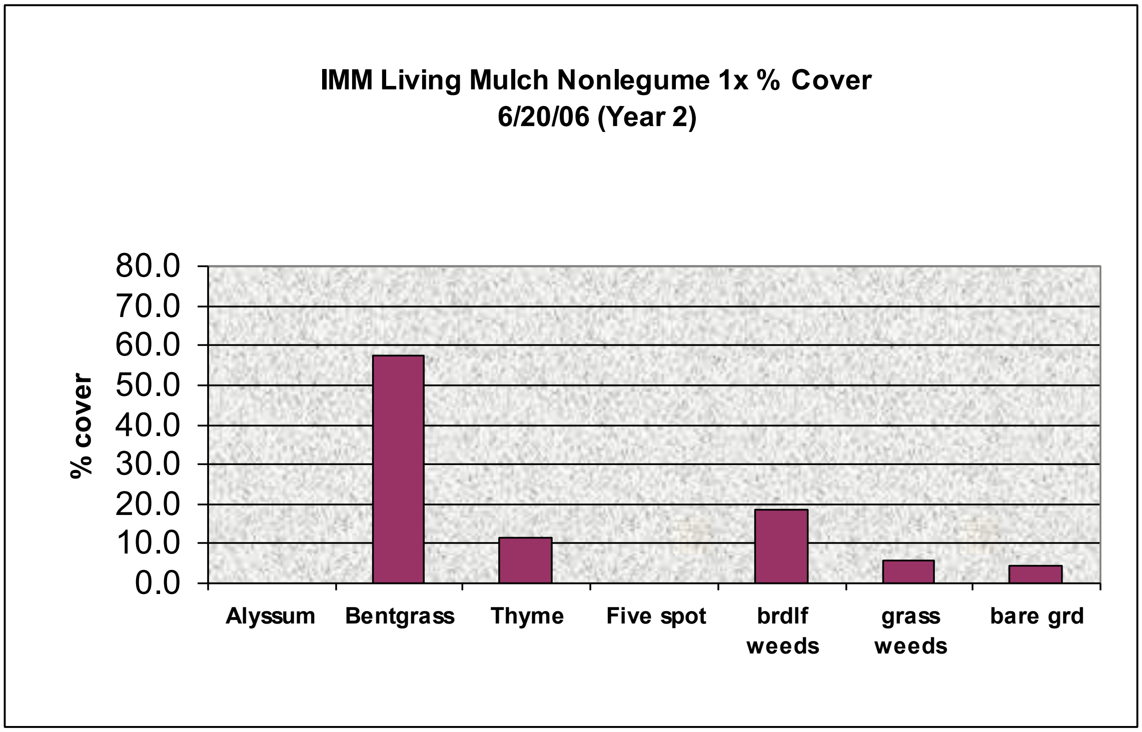


Figure 7. IMM cover crop, grass and weed biomass, July 2005.

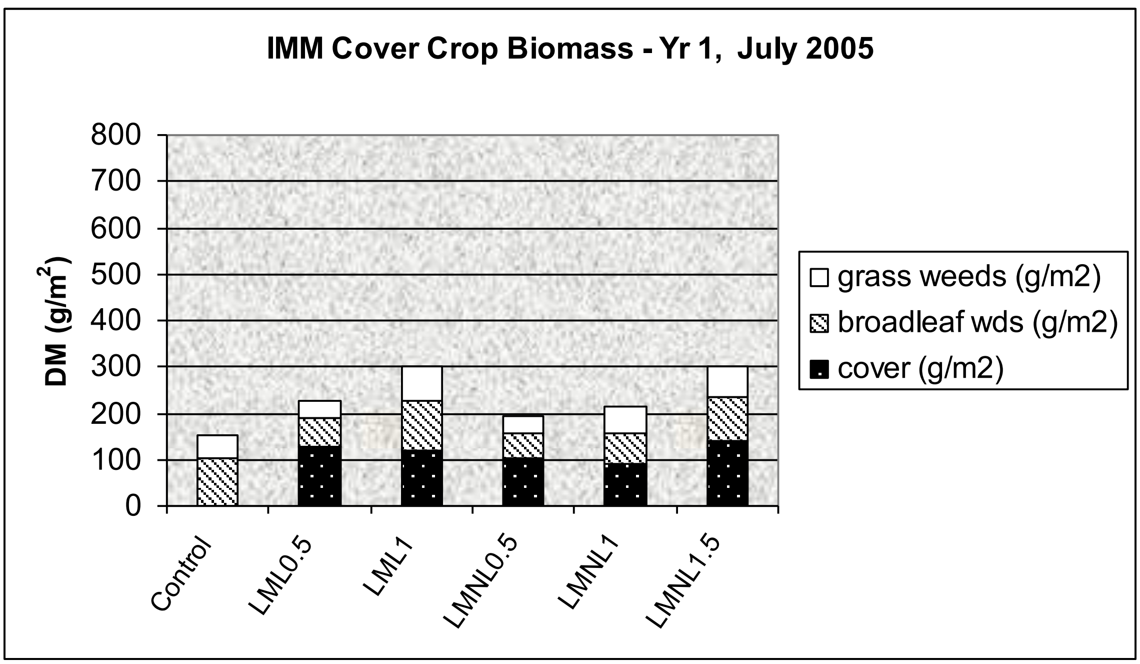


Figure 8. IMM cover crop, grass and weed biomass, July 2006.

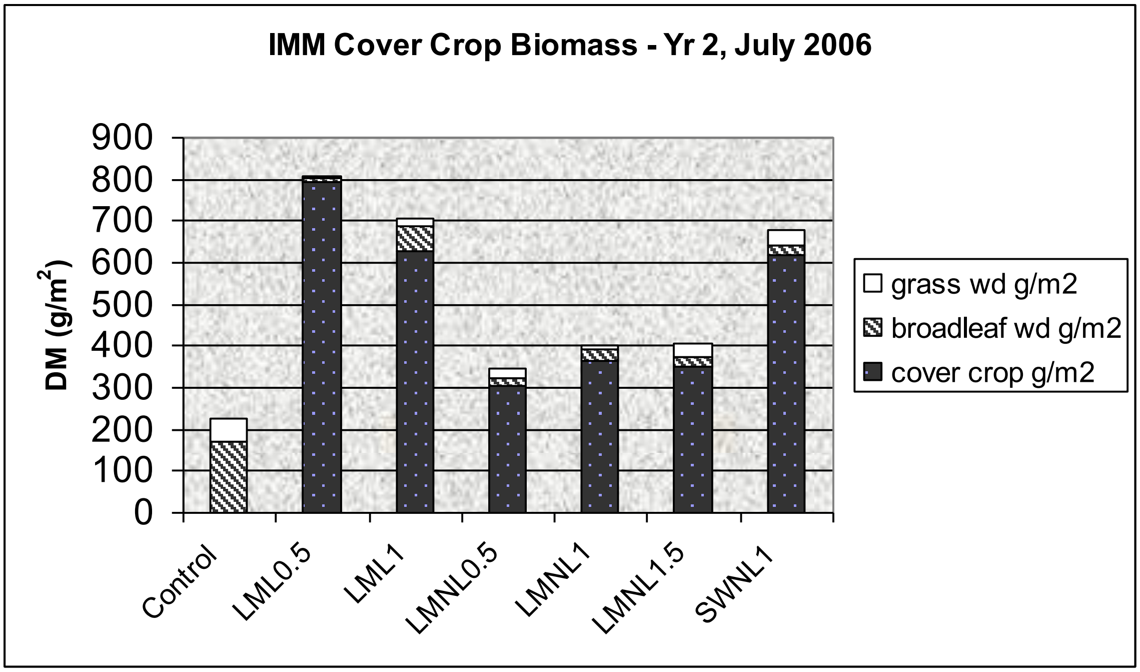
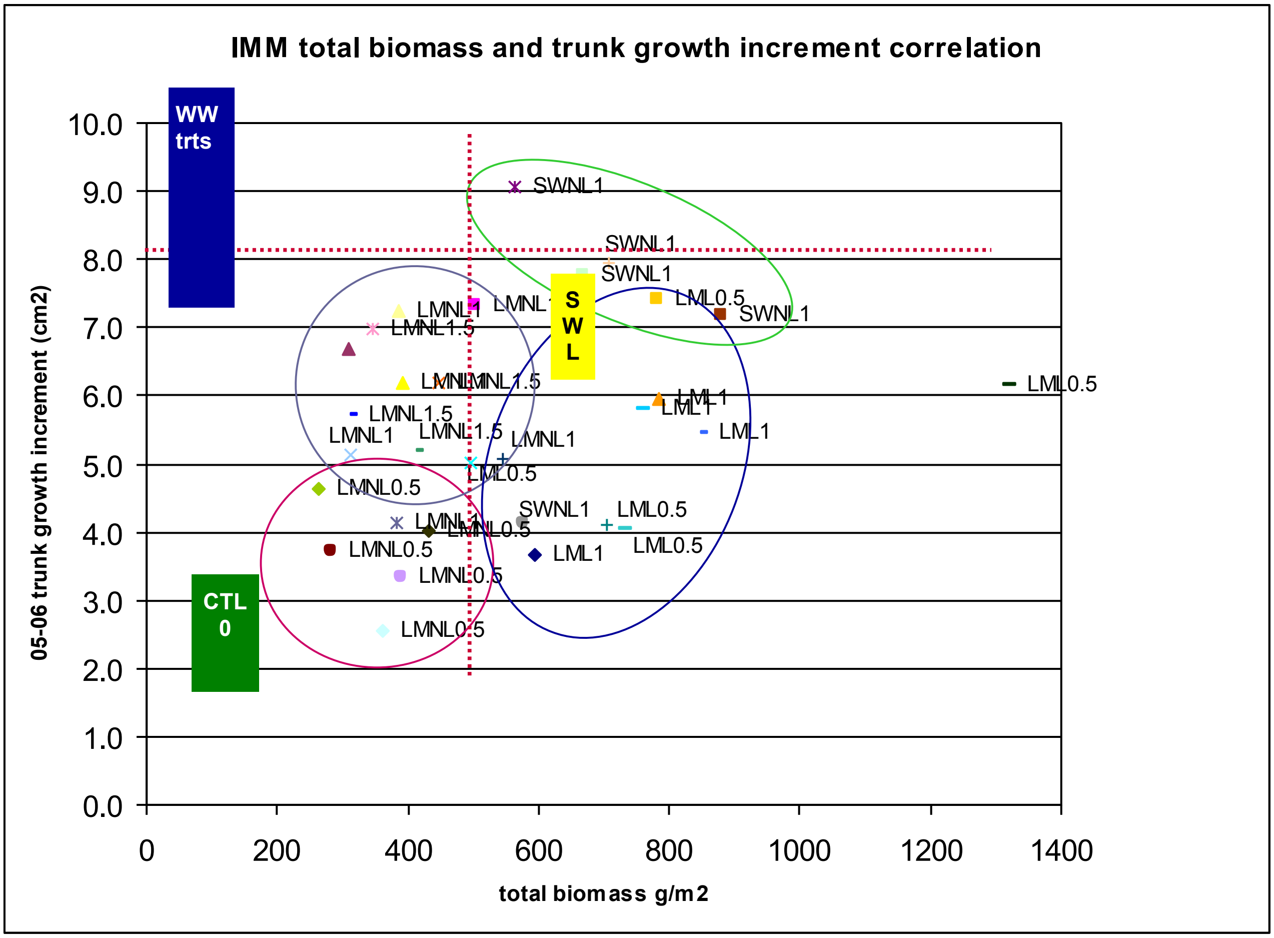
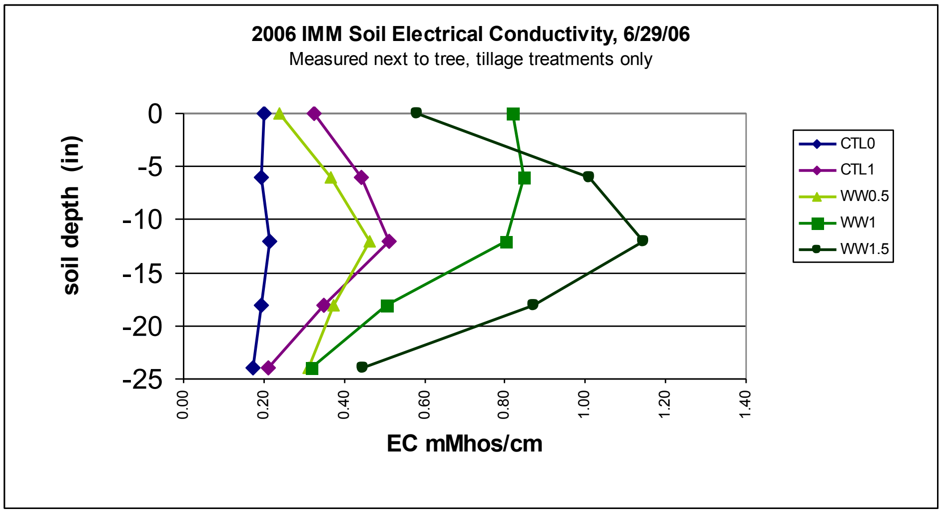
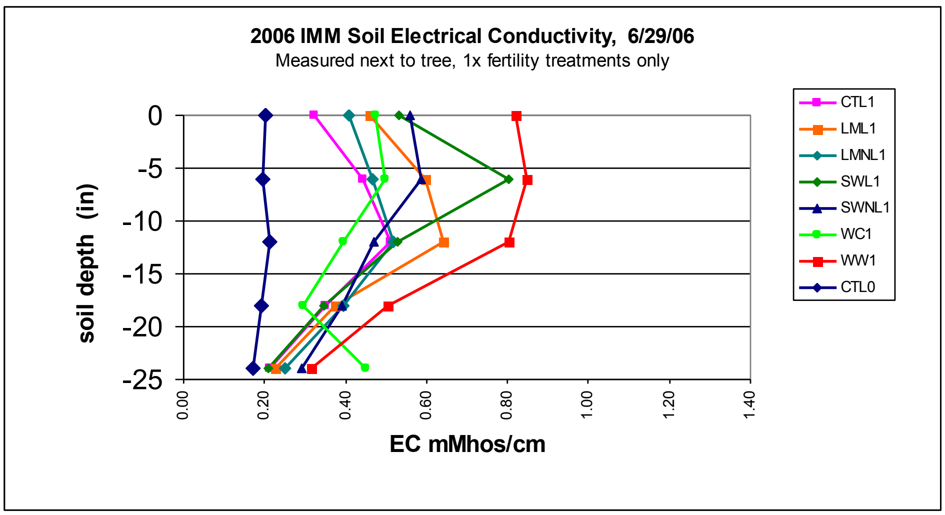


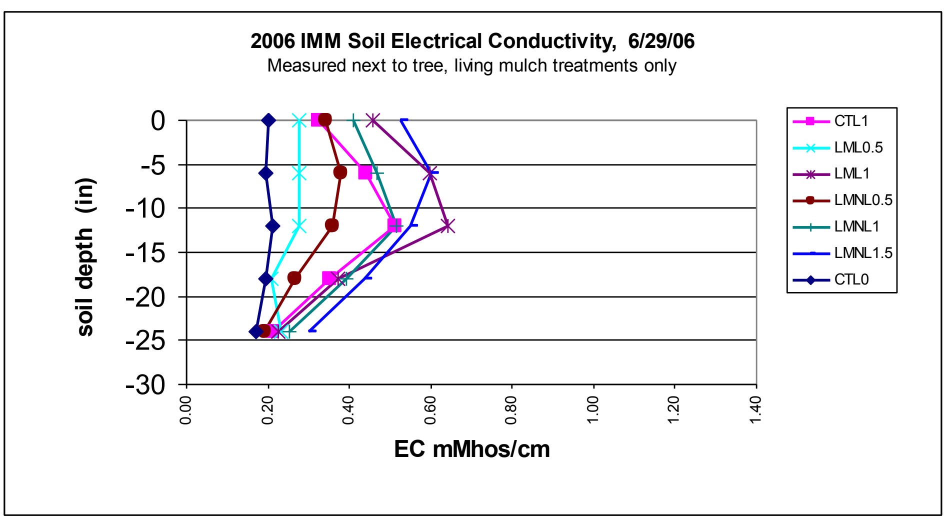
Figure 9. Year 2 relationship of total cover crop biomass and tree growth (expressed as trunk growth increment, or increase in trunk area (cm^2) from fall 2005 to fall 2006).



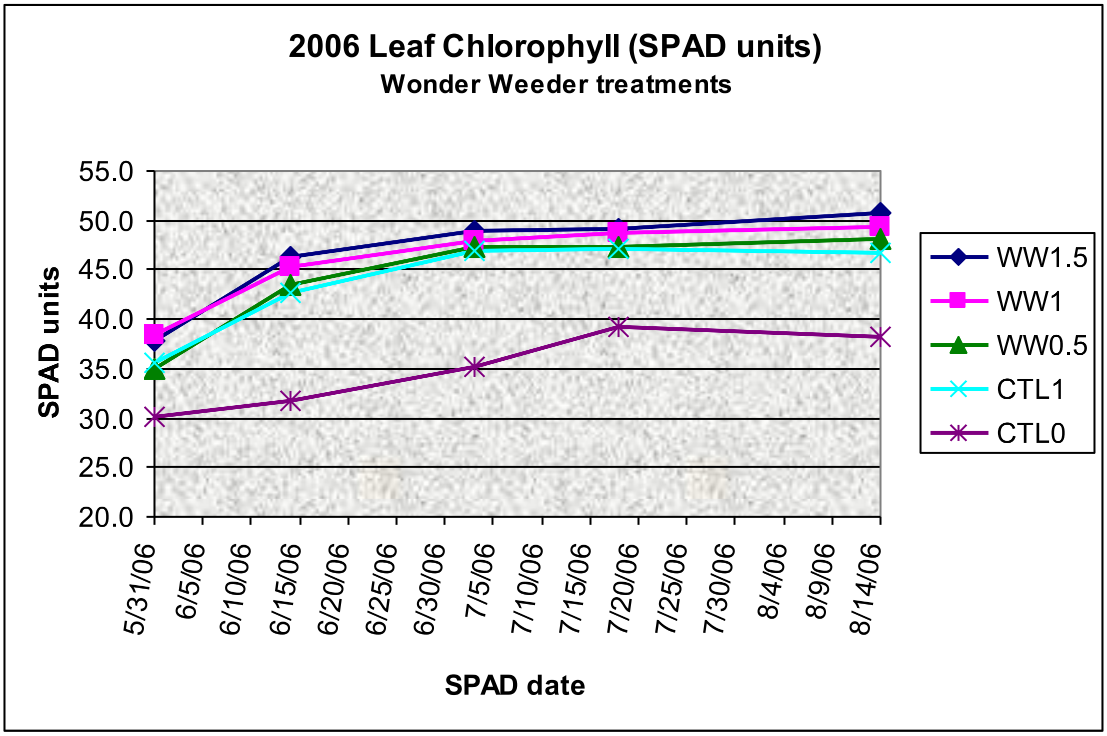
Figures 10-12. Direct soil EC measurements adjacent to trees to 24" depth (6/06)l







Figures 13 & 14. Year 2 tree leaf greenness measured with SPAD.



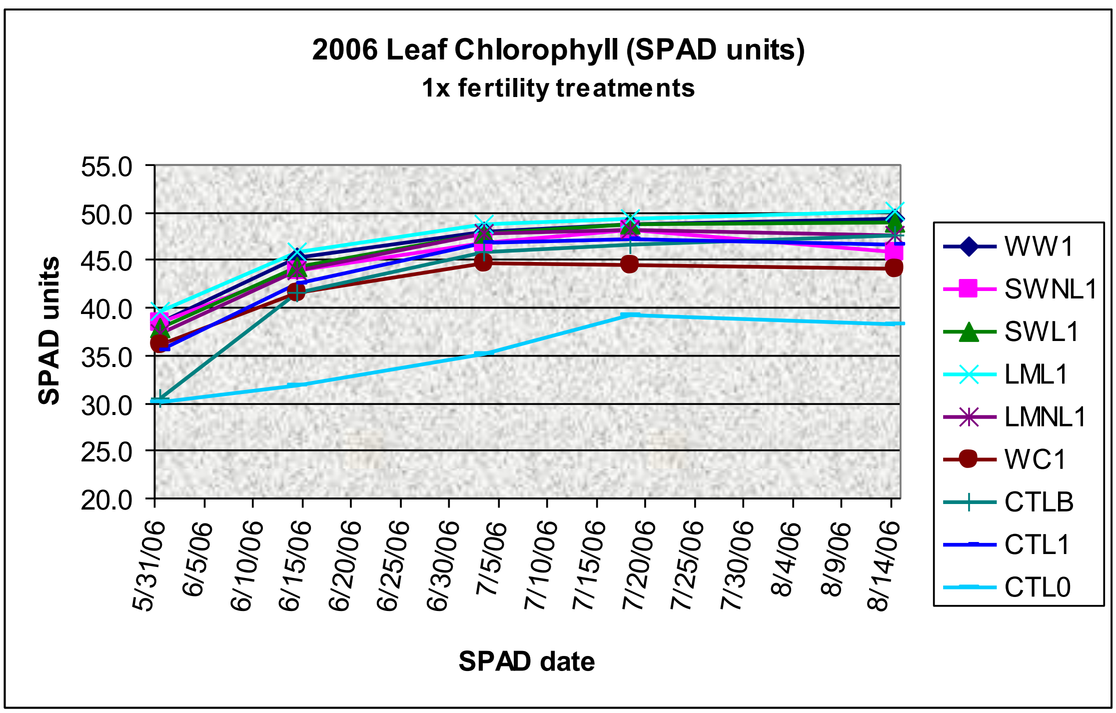


Figure 15. Year 1 soil resistance measured in the 1x fertility treatments.