Progress Report: Organic Cropping Research for the Northwest

TITLE: Understory Management in Organic Tree Fruits

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KEYWORDS: mulch, living mulch, cover crop, legumes, sandwich system, mechanical weed control, apple, entomopathogenic nematodes, codling moth

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 enhance codling moth mortality with entomopathogenic nematodes (EPN). Living mulches show promise for weed control, soil quality, and fertility benefits but do compete with trees. In a mature orchard trial, wood chip mulch increased the percent of fruit in box size 80 and 88, thus paying for the mulch application. Wood chip mulch also controlled weeds well for two seasons in this trial. A new cultivator, the "Wonder Weeder," provided less costly weed control than the standard cultivator, but with considerably more weeds than the mulch. No clear effects of tillage on soil quality were measured, but tree growth and yield were reduced by Year 3. In a newly planted trial, wood chip mulch did not control weeds well, but tree growth under mulch was good and similar to the tilled plots. Living mulches generally did provide adequate weed control in the second year after planting, but tree growth was decreased. Vole activity was highest in the living mulches after the first season, but virtually absent in all plots after the second season. The 'Sandwich' system treatment showed promise as a compromise between tillage and living mulch, particularly with *Galium odoratum* as the cover. Tilled plots showed significantly more tree leaning in this untrellised orchard than other treatments, suggesting disruption of tree anchoring but not tree growth. 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.** For 2006, the trial was simplified to only maintain the control (mow), wood chip mulch, and Wonder Weeder 3x treatments (with 5 replications). Measurements included weed biomass and % cover, trunk cross-sectional area (TCSA), tree canopy volume, fruit yield and size, soil infiltration, and soil carbon (in progress).

2. **Living Mulch (LM) trial.** An initial living mulch trial was established in 2004 and maintained for 2 years in a mature Gala/M26 block. In 2005 an expanded cover species screening was planted in a first year Pinata/M7 apple block in transition to organic certification. 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. Results are on-line at Screening Annual and Perennial Ground Covers as In-Row Living Mulch - 2004 and 2005 Progress Report: Understory Management in Organic Tree Fruits. In 2006, living mulch and Sandwich covers were monitored a second year for stand renewal, percent cover, biomass, percent C and N (perennials), and rodent activity. Tree leaf SPAD and trunk cross sectional area (TCSA) were measured in the Sandwich screening by entry; average reference SPAD and TCSA were measured for the LM screening plots which were too small to measure by entry. Plots were mowed in both years for supplemental weed control.

3. **Integrated mulch trial**. First year treatments in the Pinata/M7 block were continued (Table 2) in 2006 (bare ground control, wood chip mulch, tillage, 'Sandwich' system; living mulch legume, living mulch non-legume, unfertilized control). See also the 2005 progress report for details. 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 214 lb N/ac, with 85 lb N available. Relative fertility levels of 0.5x, 1x, and 1.5x were retained, but the 1x was approximately 3 times higher than the previous year. Living mulch was mowed at a 5" height approximately 12 times throughout the growing season. Four tillage passes were conducted in tilled 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 18-inch depths. Fruit set was prevented by pinching off blossoms. Measurements included living mulch and weed biomass at peak stand, % mulch and weed cover at several dates, emergence count, tree TCSA, tree volume, leaf SPAD, soil moisture, and soil infiltration. In addition, soil nitrate was monitored with a handheld EC probe (Spectrum Technology) to evaluate this method, and soil samples were collected in November at 6", 12", 18" and 24" depths (analysis pending).

4. Nematodes. In October 2006, EPN treatments (*S. feltiae*, *S. carpocapsae*, and *H. megidis* at low and high rates [0.4 and 1 billion infective juveniles/acre]) were applied to 13' x 65' plots in an 8-year old Gala/M26 block with wood chip mulch using a commercial air-blast sprayer to examine results under grower conditions. Cocooned sentinel codling moth larvae in cardboard strips were placed under the tree row and covered with wood chip mulch, and infested logs and cardboard bands were placed on lower trunks. Plots were irrigated following application. Codling moth strips, bands, and logs were retrieved 2 days post application to assess larval infection and mortality rate.

PROGRESS TOWARDS OBJECTIVES:

1. Weed control (WW) trial. Wood chip mulch provided good weed control for the first two growing seasons, although it needed re-application of a 6-inch layer in April 2006. Tillage had no negative effect on tree shoot growth, leaf SPAD or leaf nutrient levels in Year 1 (2004), and no significant negative effect on fruit yield or size in either Year 2 or 3 relative to the control. However, trunk growth and canopy volume were significantly reduced with tillage by Year 3 (Table 1). Wood chip mulch improved fruit size in Year 2 and 3, increasing gross receipts to offset the cost of a single wood chip application. Wood chips also increased TCSA and canopy volume by Year 3. 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. Refer to on-line reports for cost comparisons and other Year 1and Year 2 information: Effectiveness of

Weed Management Strategies for Organic Orchards in Central Washington - 2004. Effectiveness of Weed Management Strategies for Organic Orchards in Central Washington - 2005.

2. Living mulch (LM) trial. The **Sandwich perennials** phlox and thyme performed well again in Year 2 suppressing weed growth all season; other perennials did not establish adequate cover. Woodruff (*Galium*) in the adjacent IMM trial again performed very well. Fall planted annual chickweed established an adequate stand but Dutch white clover, subclovers, and black medic failed to re-establish in Year 2. Most of the non-legume species do not contain a large amount of N, which suggests that they would not compete substantially with the trees for N. Tree leaf chlorophyll SPAD measured in September ranged from 49-51, indicating that tree growth was not limited by N. Percent increase of TCSA ranged from 176-250% in the second year. Statistical analyses have not been completed. **Living Mulch** entries performed variably in Year 2. Bentgrass, thyme, kura clover, and birdsfoot trefoil cultivars established excellent stands. Overall weed pressure in this trial was less than the previous year due to the absence of tillage. Birdsfoot trefoil and bentgrass were the most successful in suppressing weeds, however, the bentgrass is more aggressive and competitive than desired in this application. Alyssum, Five-spot, annual medics, black medics and subclovers did not re-establish. Although seed produced by these species in Year 1 did germinate, plant density was too low to suppress weeds. A late spring frost may have resulted in mortality of early emerged seedlings. Kinnikinnick was not able to overcome its limited growth in Year 1. Average percent increase in TCSA for LM was 200%, and average SPAD was 51. Biomass samples were analyzed for N and C (Table 3). Most samples were from the establishment year (2005); perennial biomass may be higher in succeeding years. For example, trefoil biomass ranged from 214-294 g/m^2 in the LM screening for 2005, while it ranged from 600-800 g/m^2 in the IMM trial for 2006 compared to 120 g/m^2 in the same plots in 2005. The 2006 IMM trefoil stand contained 50-60 lb N/ac.

3. Integrated mulch trial. Tree growth was excellent in Year 2 (100-225% increase in TCSA, 3-5' leader growth) despite the very poor growth in Year 1 (5-36% increase in TCSA, Jul.-Oct. 2006). Trees in the bare ground and wood chip treatments generally grew better than trees in the living mulch treatments, with 'Sandwich' plots intermediate. However, there was no correlation between cover crop competition (% cover, biomass) and tree growth (TCSA, canopy volume) as seen in Year 1, despite the more than doubling of cover crop biomass. Tree leaf SPAD data and tree growth suggest that the trees experienced little nitrogen stress in Year 2. There were no significant effects of fertility level on tree growth (Table 4), and soil moisture was similar in all treatments.

Weed control was very good in the cover crop treatments, but tillage again led to germination of the warm season annual grass weeds that were a problem last year. In addition, wood chips did not provide adequate weed control in this trial, despite a new layer being applied in May. Soil quality results will be reported by Lori Hoagland upon completion of her analyses. Fall soil nitrate analyses to 2' depth are in process, and a similar spring sampling is planned to better track movement of N over winter. Based on our Year 2 results, the living mulches are controlling weeds (Fig. 1) and improving some soil quality aspects, with reduced but still acceptable growth of trees (Fig. 2). The 'Sandwich' system appears to provide a reasonable compromise using *Galium odoratum*. As trees mature, the cover could be allowed to fill the entire weed strip and thus eliminate the need for tillage. This species seems less competitive with the trees than the grass or trefoil, and it did have significantly less vole activity compared to the other cover crops.

4. **Nematodes**. Codling moth larvae mortality was greatest in the strips under mulch compared to the logs and trunk bands. Under mulch, the low and high rate of *S. feltiae* both had 98-99% mortality, while *H. megidis* only provided 23-42% mortality. The high rate of *S. feltiae* produced

47% mortality on the logs versus 13% for the low rate, and about 40% mortality for both rates in the tree bands. *S. carpocapse* and *H. megidis* had 12-19% mortality on the logs, and 3-6% mortality on the bands. This trial illustrates the large benefit mulch provides for survival and searching by the nematodes, and the commercial feasibility of this practice.

OUTPUTS :

Vole populations, tree fruit orchards, and living mulches. 2006. Literature review by T. Sullivan on living mulches in orchards and the potential to cause a vole problem.

Lacey, L., Granatstein, D., Arthurs, S. Headrick,H., and R. Fritts, Jr. 2006. Use of entomopathogenic nematodes (Steinernematides) in conjunction with mulches for control of overwintering codling moth (Lepidoptera: Tortricidae). J. Entomol. Sci. 41:107-119.

Granatstein, D. and K. Mullinix. Organic tree fruit research developments. Presentation at Washington Tilth Producers annual meeting, Wenatchee, WA, Nov. 12, 2005.

Granatstein, D. Orchard floor management. Presentation at NW Wholesale grower meeting, Chelan, WA, Dec. 13, 2005.

Granatstein, D. and K. Mullinix. Optimizing understory management in Northwest organic orchards. Presentation at Amer. Soc. Hort. Science Annual Meeting, New Orleans, July 30, 2006. Paper submitted to HortScience.

Granatstein, D. and E. Kupferman. Sustainable horticulture in fruit production. Invited keynote presentation at Intl. Hort. Congress Sustainability Symposium, Seoul, Korea, Aug. 18, 2006. Paper submitted to Acta Horticulturae.

Granatstein, D. Optimizing understory management in Northwest orchards. Presentation at the 'Building Soils for Better Trees and Vines' workshop, The Dalles, OR, Nov. 9, 2006.

Five orchard tours for classes, EPA, and fruit company representatives.

IMPACT:

Organic tree fruit acreage is expected to double in the state and growers still rate fertility and weed control as two top research needs. Our work is leading to expanded use of mulches, Wonder Weeder, and cover crops. Several large orchards are in consultation with our program about deploying some of the understory management under study. More conventional orchards are also examining and testing practices such as mulching as their benefits are not restricted to organic systems.

INSTITUTION: Washington State University, Wenatchee Valley College, USDA-ARS,
STATE: WA
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FUNDING AMOUNT(S): $51,591 USDA; $5,000 WVC in-kind; $5,000 Becker Underwood.

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

	Station	____non-organic	____transitional	____certified
	On-farm	____ non-organic	1.5_ transitional	__1__certified
FARMER COOPERATOR(S):	Number _1_			
	Name(s): Amos Kukes			

Table 1. Apple fruit yield, weight, size, and value – Weed control trial.

TRT	2005			2006				
	Fruit yield	Fruit Size 80-88	Gross Fruit Value*	Fruit Yield	Fruit Size 80-88	Gross Fruit Value*	TCSA increase	Canopy volume
	kg/tree	%	$/acre	kg/tree	%	$/acre	cm^2	cu. ft./5 trees
Wood chip	22.4	15.5 a	14,354	14.7	39.0	11,032	3.7 a	1531 a
Control mow	20.4	6.6 b	12,003	14.3	33.5	9,748	3.0 b	1286 ab
Cultivator Z 3x	17.6	7.0 b	9,556	13.3	22.0	10,162	2.3 c	1059 b
p=	0.150	0.014		0.805	0.076		0.001	0.008

*Based on Gala WAXF #1 price, 9/1-10/30, reg. storage, domestic, conventional.

Table 2. 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
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 3. Living Mulch & Sandwich satellite trial individual entries, biomass and N content of cover crops.

Cover Crop Common Name	Life Cycle†	System	Peak stand cover crop dry weight (g/m^2)	Cover crop biomass * Kg/ha	%N	N in cover crop Kg/ha	C:N
Non-Legumes							
Corsican Mint	P	SW	N/A	N/A	N/A	N/A	N/A
Kinnikinnick	P	LM	N/A	N/A	N/A	N/A	N/A
Colonial Bentgrass	P	LM	464.0	1786.4	2.3	41.1	18.6
Ajuga reptans	P	SW	27.3	42.0	1.9	0.8	23.3
Chickweed	A	SW	160.7	247.5	2.5	6.2	16.0
Potentilla neumaniana	P	SW	N/A	N/A	N/A	N/A	N/A
Five Spot ‡	A	LM	104.3	401.6	1.7	6.6	24.7
Moss Pink, *Phlox subulata*	P	SW	529.0	814.7	1.5	12.2	28.7
Mother of Thyme	P	SW	600.7	925.1	2.0	18.5	23.6
Mother of Thyme	P	LM	376.0	1447.6	2.1	30.4	22.7
Veronica repens	P	SW	N/A	N/A	N/A	N/A	N/A
Sweet Alyssum ‡	A	LM	236.3	909.8	2.3	20.9	17.8
Sweet Woodruff	P	SW	617.9	951.6	1.5	14.3	27.0
Clovers							
Kura clover, 'Prairie'	P	LM	223.0	858.6	2.9	24.9	15.2
Subclover, 'Antas' ‡	A	LM	280.7	1080.7	1.9	20.5	23.6
Subclover, 'Clare' ‡	A	LM	183.7	707.2	2.8	19.8	16.0
Subclover, 'Dalkieth' ‡	A	LM	156.0	600.6	2.8	16.8	15.5
Subclover, 'Denmark' ‡	A	LM	222.3	855.9	2.8	24.0	15.6
Subclover, 'Mt. Barker' ‡	A	LM	264.7	1019.1	2.8	28.5	15.1
Subclover, 'Nungarin' ‡	A	LM	119.7	460.8	2.8	12.9	15.9
Subclover Mix ‡	A	SW	226.0	870.1	3.0	26.1	14.6
White clover, Dutch ‡	A	SW	299.3	1152.3	3.4	39.2	12.5
Medics							
Barrel medic, 'Caliph' ‡	A	LM	256.3	986.8	3.1	30.6	14.0
Barrel medic, 'Parabinga' ‡	A	LM	182.3	701.9	3.3	23.2	13.3
Burr medic, 'Santiago' ‡	A	LM	191.7	738.0	3.6	26.6	12.5
Burr medic, 'Scimitar' ‡	A	LM	264.3	1017.6	3.9	39.7	11.4
Black medic VNS ‡	BE	LM	211.0	812.4	3.6	29.2	12.3
Black medic, Afghan ‡	BE	LM	133.0	512.1	3.9	20.0	11.2
Black medic VNS ‡	BE	SW	N/A	N/A	N/A	N/A	N/A
Trefoils							
Birdsfoot trefoil, Canadian ‡	P	LM	214.7	826.6	2.9	24.0	15.7
Birdsfoot trefoil, 'Norcen' ‡	P	LM	294.0	1131.9	2.9	32.8	15.8
Birdsfoot trefoil, S. Amer. ‡	P	LM	222.3	855.9	2.5	21.4	18.6

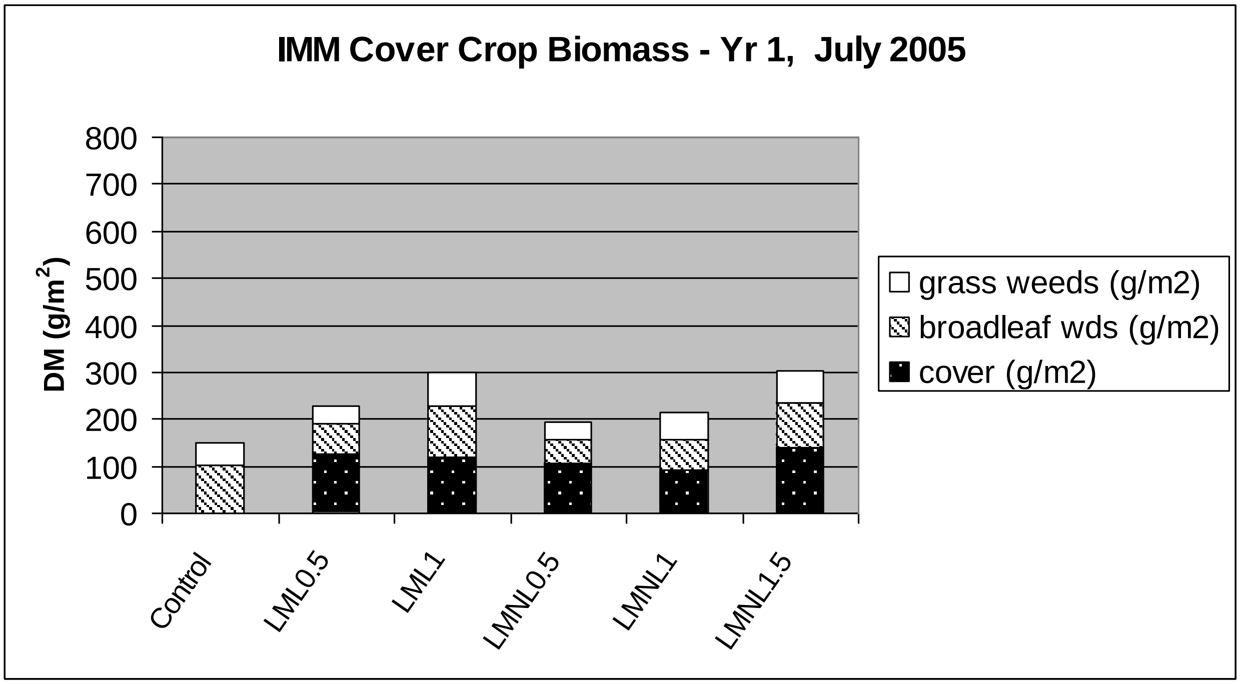
† Life Cycle code: A=annual, P=perennial, BE=Biennial
*LM system was 0.385 ac cover/acre orchard, SW system in tree row only was 0.154 ac cover/ac orchard.

‡ Samples were collected in the establishment year (2005).

Table 4 . IMM Trial. Trunk growth, leaf greenness* and canopy volume.

Treatment	Year 2 TCSA increase (cm^2)		Year 2 TCSA increase %	SPAD 07/18/2006		Canopy Volume (ft^3/tree)	
Living Mulch Legume 0.5x	5.0	de	146	46	ef	14.4	fg
Living Mulch Legume 1x	5.2	de	150	49	a	14.1	fg
Living Mulch Nonlegume 0.5x	3.7	ef	116	44	g	9.6	g
Living Mulch Nonlegume 1x	5.6	d	170	48	abcd	16.2	def
Living Mulch Nonlegume 1.5x	6.3	dc	173	50	a	15.4	ef
Sandwich Legume 1x	6.4	dc	179	49	abc	19.5	cde
Sandwich Nonlegume 1x	7.6	bc	210	48	abcd	22.6	bc
Wood Chip 1x	8.1	ab	207	45	fg	23.0	bc
Wood Chip 1.5x	8.7	ab	203	47	cde	24.6	b
Control 1x	6.3	dc	163	47	cde	19.9	bcde
Wonder Weeder 0.5x	9.2	ab	224	47	bcde	30.6	a
Wonder Weeder 1x	8.0	ab	195	49	abc	24.5	b
Wonder Weeder 1.5x	9.6	a	218	49	ab	29.6	a
Control 0x	3.2	f	97	39	h	11.4	fg
p=	**<0.0001**			**<0.0001**		**0.0001**	

*SPAD meter used to measure leaf greenness as a proxy of N content.



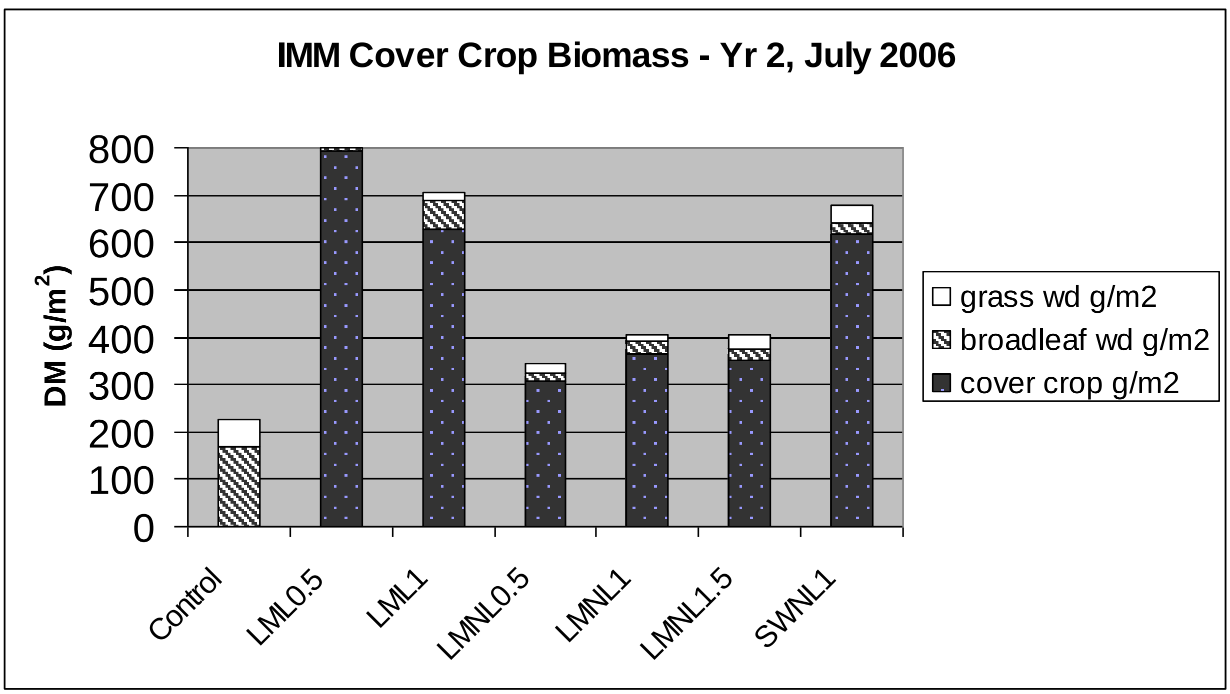


Figure 1. Cover crop and weed biomass in 2005 and 2006.

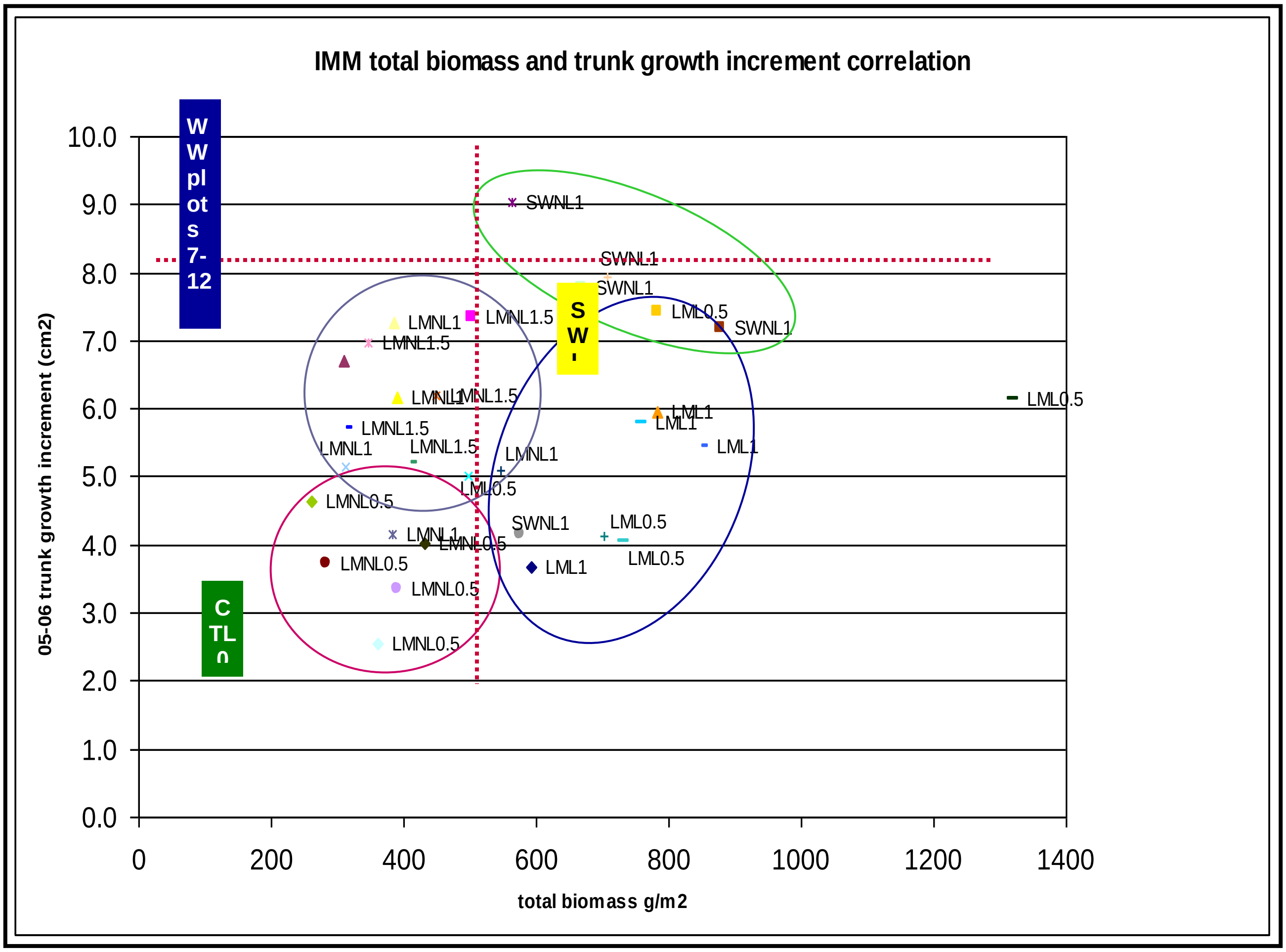


Figure 2. Relationship of total cover crop biomass and tree growth – 2006.