Finding Cost-Effective Weed and Nutrient Management Practices in Organic Pear Orchards

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Abstract

Four weed control treatments (in-row mowing, landscape fabric, wood chips, and organic herbicide) and three fertilizer treatments (chicken manure at 2 vs. 4 tons/acre, feather meal at 0.5 tons/acre) were compared in an organic, no-till Bosc orchard with solid-set sprinklers. Weed control in the landscape fabric and wood chip treatments was excellent through the season, and the five herbicide applications resulted in partial control. There were no significant yield differences between treatments, and mean fruit diameter for the fabric + 4 tons manure treatment was higher than the mow + no fertilizer treatment. There were no significant differences in trunk growth increase between treatments. The wood chip treatment had lower stem water potential than other treatments in August 2009. The N content of leaves in the mow + no fertilizer treatment was lower than that of the fabric and wood chip treatments (+ 4 tons manure) and the herbicide + 4 tons manure treatment. Wood chips and fabric had significantly fewer vole holes than in-row mowing. Assuming that landscape fabric lasts 8 years, landscape fabric is only somewhat more expensive per year than in-row mowing alone, even considering fabric repair costs. An organic herbicide program is more expensive because of the herbicide cost and the many applications required. Wood chips were by far the most expensive weed treatment because of the cost of chips and spreading them, as well as the need to reapply at least every two years. The use of 2 tons/acre of chicken manure was the cheapest fertilization strategy. Doubling that rate to 4 tons/acre doubled the total costs. The use of feather meal was over three times the use of 2 tons/acre manure for an equivalent amount of nitrogen. However, the limited availability and increasing costs of poultry manure make the use of feather meal the more feasible.

Introduction

Organically grown tree fruits generally sell for a substantially higher price than conventional produce; in 2008, organic Bosc pear prices were nearly 30 percent more than conventional Bosc pears. Whether the price premium increases profitability depends on yields, fruit size, and fruit quality, as well as using the most cost-effective growing practices. Successful organic production often requires more labor, bulkier fertilizers and amendments, and more monitoring than conventional production. In most years, growers find that in-row weed control and providing sufficient nitrogen are the greatest challenges, and the two are linked. Surveys conducted in Washington have shown that the top three production issues in organic tree fruit production were crop load management, weed control, and soil fertility (Granatstein, 2003).

Organic fertilizers

Organic fertilizers tend to have fairly low nitrogen (N) content. The most cost-effective fertilizer is often poultry manure, which generally includes wood shavings and/or rice hulls. It averages about 3% N, and also has phosphorus, potassium, calcium, and magnesium. Feather meal is sometimes used, especially in Pacific Northwest orchards. It has up to 13% N, but is still much more expensive than poultry manure and most other nutrients are present in lower amounts. Compost is an excellent soil amendment, but the N in it is largely unavailable during the first year. To maintain organic certification, uncomposted manures may not be applied within 90 days of harvest.

A portion of the N contained in manure and compost will volatilize into the atmosphere as ammonia if not disked into the soil – as much as 30 percent of the N may be lost (Chaney et al., 1992). With most orchards in this area being no-till, applied manure will lose N to the air, although less is lost if it is irrigated fairly quickly after application. Manure and compost also release plant-available N at different rates, which is largely based on the C:N ratio – the lower the ratio, the faster the release. With poultry manure, the majority of the N will be available to plants in the first year; poultry also has the highest volatilization potential, as evidenced by the strong ammonia smell. The "decay series" of manures was studied by UC researchers in the 1970s (Pratt et al., 1973), and the proportion of N availability over a 3-year period (years 1, 2, and 3) was shown to be:

- Chicken (.90, .10, .05)
- Dairy (.75, .15, .10)
- Feedlot (.35, .15, .10)

Thus chicken manure, for example, would have 90% of the nitrogen mineralized in the first year. In the second year 10% of the residual (that amount not previously mineralized) would be mineralized, and 5% of the residual would be mineralized in the third and subsequent years (Pang and Letey, 2000). These values may vary widely for any given manure based on many factors. N availability of composts is generally well below feedlot manure in year 1.

Cover crops often provide the most cost-effective way to add N. A vetch cover crop, often used with peas and/or bell beans, can supply up to 150 lbs. N/planted acre (Ingels et al., 2005). But this mix is usually used in disked orchards. The reseeding annual subterranean clover, with or without other annual clovers or medics, can provide similar amounts of N, but some N loss through volatilization can result from leaving the clippings on the soil surface. Perennial clovers have been shown to add large amounts of N also, but they are invasive and they compete with trees for water. All clovers also attract gophers.

Organic In-Row Weed Management

The greatest concentration of tree roots is under the canopy in the tree row, so weeds in the tree row compete with trees for nutrients and water. This competition is especially problematic for young trees, but yields and fruit size of mature trees can also be reduced by in-row weeds, especially warm-season grasses.

Organic weed management practices include mowers and cultivators that move around trunks and sprinklers, organic herbicides, flame or steam weeders, geese or sheep, and organic and synthetic mulches. **In-row mowers** are generally cost effective, but weeds still grow and compete with trees for nutrients and water. **In-row cultivation** can effectively control weeds, although tree roots near the surface can be damaged. Some implements, such as the Weed Badger, are hydraulically driven with a vertical axis cultivating head. Several organic tree crop growers in the Pacific Northwest use the Wonder Weeder, with simple rolling cultivators near the tree row and a spring blade that works in between the trunks. This implement is typically operated at about 5 mph but can be operated at speeds up to 8 mph.

Available **organic herbicides**, mostly based on clove or cinnamon oil, or acetic and citric acids, are effective mainly on very young weeds so they must be applied often, and they have limited efficacy on perennial weeds. **Flame weeders** are fairly effective on young weeds, but they often require multiple passes for some species, and they use substantial amounts of fuel. **Sheep or geese** can be very effective, and whereas they no longer must be removed 90 days before fruit harvest for organic certification, they do require fencing and they must be cared for and managed.

Mulches, either organic or landscape fabric, provide a practical – but expensive – method of preventing or greatly reducing weed growth in tree rows and improving the nutrient and moisture status of trees. Wood chips add organic matter and nutrients but they are more effective against annual weeds than perennial weeds.

A 2004-2006 Washington study showed that the total cost for applying a 5-foot wide, 6-inch thick layer of wood chips was $924/acre (Wiman et al., 2007). In this study, which compared two in-row tillage implements, in-row mowing, and wood chip mulch, wood chips provided the best weed control in all 3 years, although it needed reapplication in year 3. This treatment also produced the greatest tree growth and fruit size. In a related trial, a Gala apple block was used to compare a 4-inch wood chip mulch in the tree row with an herbicide strip (Granatstein and Mullinix, 2008). In the first year, mulched plots consistently had 15-20 percent higher soil moisture at the end of each irrigation cycle than the bare ground plots. In the second year, the two treatments were watered independently according to need, and mulching reduced cumulative irrigation application by 20-30 percent.

Synthetic fabric allows water penetration but it excludes light to act as an effective barrier to weed growth. A 3 to 4 ft. width of fabric is placed on either side of the row and they overlap and are pinned where they join, although weeds sometimes grow between the overlapped fabric. The outside edges are buried or pinned. Weed seeds may germinate on top of woven fabric and roots may grow through and establish in the soil, so some growers pull back the fabric each year and apply fertilizer or compost before re-pinning the fabric. Mulches, especially fabric, can also lead to the buildup of voles (D. Granatstein, personal communication).

In a 5-year study begun in a newly-planted, conventional cherry orchard in Hood River, OR, researchers reported over 30% greater tree growth and fruit yield where a 6-ft. wide, in-row strip of synthetic fabric was used compared to herbicide strip alone (Núñez-Elisea et al., 2005). Leaf N concentration was increased by 11 to 19 percent each year where groundcover was used, whereas leaf P, Ca, and Mg concentrations were reduced – a factor that was attributed to the dilution effect of increased tree growth (Yin et al., 2007). Although the polypropylene mulch resulted in substantially increased costs in all 5 years, gross returns from fruit sales were 218 and 43 percent greater where mulch was used than unmulched trees in the first 2 years of commercial harvest (years 4 and 5 of the study, respectively). Cumulative cash costs for the first 4 years before fruit production were $2,123/acre higher with mulch relative to no mulch; however, these costs were offset quickly by the increased returns from enhanced fruit yields

Objectives

1. To compare the effects of in-row mowing, landscape fabric, wood chip mulch, and organic herbicide on long-term suppression of weeds and on the leaf water potential of trees.
2. To determine the effects of feather meal vs. two rates of chicken manure on leaf and soil nutrient content.
3. To determine the effects of combinations of in-row weed management and fertilizer techniques on tree growth, number of fruit, fruit size, total yields.
4. To compare costs and evaluate cost effectiveness of various weed and nutrient management practices.

Methods and Materials

Treatment Descriptions

This trial was initiated in fall 2008 in a Golden Russet Bosc pear block (planted in 2001) at the Joe Greene Ranch on Lambert Rd. near Courtland, CA. Orchard spacing is 18 ft. between rows x 10 ft. between trees. The rootstock is Winter Nelis and the soil is a Valpac loam, a typical soil found along the Sacramento River in this area. The orchard is irrigated by solid set sprinklers, and nontillage is used, with middles mowed periodically through the year. The orchard became certified organic in June 2009.

The experiment was laid out in a randomized, complete block design, with 7 treatments and 5 replications. Each plot consists of 6 trees. Each experimental block consists of a single row, so each treatment is randomized down each of 5 rows (Figure 1). Treatments were begun in October 2008 and are shown below.

1. In-row mowing, no fertilizer
2. In-row mowing + chicken manure (2 tons/acre)
3. In-row mowing + chicken manure (4 tons/ acre)
4. In-row mowing + feather meal (0.5 ton/ acre)
5. Landscape fabric + chicken manure (4 tons/ acre)
6. Wood chips 4-6 in. + chicken manure (4 tons/ acre)
7. In-row mowing + herbicide strip (acetic acid) + chicken manure (4 tons/ acre)

Figure 1. Experimental design, showing six-tree treatments randomized down each of five rows.

Block (Row)	Treatments						
A	3	6	1	4	5	7	2
	Row Direction →						
B	1	4	5	7	3	2	6
C	7	4	2	3	6	1	5
D	6	3	1	2	4	5	7
E	5	7	2	6	1	3	4

<u>In-row mowing</u> was performed with a sidearm mower, in passes that were independent from middles mowing. The mower attachment is 24 in. wide, and it moves around trees and sprinkler risers by a spring mechanism. However, movement is restricted somewhat, and trunks of several trees were damaged by the mower.

Fertilizer application and weed control were performed on either side of 6 adjacent trees in each plot, halfway to the adjacent tree on each end. The **<u>manure and feather meal</u>** were spread before weed control was applied, in a manner that simulated the output by a tractor-mounted manure spreader (chicken manure) and fertilizer spreader (feather meal); that is, it was spread uniformly from the tree row out about 5 ft. on both sides of the row (total of a 10-ft. wide strip). The chicken manure contained about 21% moisture and 3.2% N. The feather meal contained about 12% N. Therefore, the 0.5 ton/acre application of feather meal contained about 128 lbs. N/acre and manure contained 132 lbs. (2 ton/acre) and 264 lbs. (4 tons/acre).

The fabric, wood chips, and herbicide strip extend from the tree row out about 2.5 ft. (total of a 5-ft. wide strip). The woven **<u>landscape fabric</u>** used was 3 ft. x 300 ft. Lumite Weed Barrier (Shaw Fabrics, Wellington, CO). The fabric was overlapped about 6 in. in the tree row, and 6-in.-long fabric pins were placed every 2 ft. along all edges.

The **<u>wood chips</u>** were very uniform in size, consisting of 1- to 3-in. pieces of mixed suburban tree species. They contained about 1% N and they had a C:N ratio of about 51:1. They were spread using a wood chip spreader on loan from a blueberry grower, then manually raked smooth to a depth of about 6 in. This resulted in a rate of about 25 cu. ft./tree, or 224 cu. yds./acre. Considering that wood chips weigh about 600 lbs./cu. yd., therefore, about 5.6 lbs. of actual N were applied per tree, or about 1,350 lbs. N/acre, the vast majority of which is temporarily tied up in the organic form.

The <u>herbicide</u> used was either GreenMatch at 10% concentration or vinegar (Fleischmann's 300 grain), which was applied at a 20% concentration by mixing two parts vinegar with one part water. Nu-Film P, an organic adjuvant, was added to all herbicide treatments at a 1% v/v concentration. Herbicide applications were made Oct. 22 (vinegar), Nov. 5 (vinegar), Nov. 19 (vinegar), Feb. 10 (GreenMatch), and June 23 (vinegar). Weeds were mowed using the sidearm mower as in treatments 1-4.

Evaluations and Measurements

Weed Evaluations. Weed control was visually evaluated (0 to 100 scale) periodically to assess treatment effects. Weed biomass was also assessed in summer 2009. Biomass was collected from two randomly placed $0.25m^2$ quadrats per plot, cutting all plants at ground level, separating plants by species, drying and weighing.

Harvest Evaluation. Prior to harvest, the diameters of 40 fruit in each plot were measured on two trees per plot (20 fruit/tree). Just before both commercial harvests (Aug. 12 and 24), two trees per plot were harvested and the fruit were weighed.

Tree Measurements. Tree growth in each plot is evaluated by measuring trunk cross-sectional area, about 6 in. above soil level. Circumference measurements were made in Nov. 2008, and there were no significant differences between treatments (Data not shown). A mark was placed on the trunk where measurements were made for uniform positioning in future years. Midday stem water potential was determined in four of the treatments (3, 5, 6, and 7) before and after a number of irrigations in late spring and summer to determine if in-row weed management practices affect tree water availability. Leaf analysis for N-P-K was done by sampling 80 non-fruiting spur blades per plot (20/tree) in July 2009.

Soil Nutrition. Soil was sampled at two depths in the tree row: 0-12 in. and 12-24 in. in each plot. Samples were analyzed by the UC DANR Analytical Lab for organic matter, total N, NO_3-N, NH_4-N, K, Ca, and Mg.

Vertebrate Pest Activity. Vole and gopher activity were determined by counting the number of holes and mounds in October 2009 and evaluating chewing damage by voles on trunks. Landscape fabric was pulled back for counting, but wood chips were not pulled back because vole holes were clearly visible on the surface of the chips.

Results

Weed Control. Weed control in the landscape fabric and wood chip treatments (#5 & 6) was excellent and statistically similar through the season (Table 1). The application of herbicides generally resulted in less weed control than mulch treatments, especially in spring and summer 2009, but far greater weed control than mowed treatments. Although weeds in the mow + no fertilizer treatment were generally smaller, weed cover was similar to mowed treatments with fertilizer applied.

Yields and Fruit Size. There were no significant yield differences between treatments (Table 3). The mean fruit diameter for the fabric + 4 tons manure treatment (#5) was significantly higher than the mow + no fertilizer treatment (#1).

Trunk Growth. There is a well-known direct correlation between trunk growth and total canopy growth. In both 2008 and 2009, there were no significant differences in trunk cross-sectional area between treatments (Table 3), nor were there differences in growth increase from 2008 to 2009.

Stem Water Potential. Four treatments were measured for stem water potential just before irrigation, all of which had 4 tons of manure applied. The wood chip treatment (#6) had significantly lower stem water potential than other treatments in August 2009 (Table 4). This treatment had lower means on other dates as well, but the differences were not significant.

Leaf and Soil Nutrient Status. The N content of leaves in the mow + no fertilizer treatment (#1) was significantly lower than that of the two mulch + 4 tons manure treatments (#5 & 6) and herbicide + 4 tons manure treatments (#7) (Table 5). Leaf N content between the 4 tons manure treatments (#3, 5, 6, & 7) was statistically similar. There were no significant differences between treatments in the other nutrients analyzed.

Analysis of soil samples shows that in the 0-12 in. depth, the only significant differences were found in soil pH (Table 6). The primary difference to note was that pH under wood chips was significantly higher than under landscape fabric. In the 12-24 in. depth, the only significant differences were in NH4-N, where the mean value for the mow + 4 tons manure treatment was significantly greater than fabric + 4 tons manure (Table 7).

Vertebrate Pest Activity. All the in-row mowing treatments had similar number of vole holes (Table 8). Herbicide-treated plots had half the mean number of holes, although there were not significantly fewer. Wood chips and fabric had significantly fewer holes than in-row mowing. Where tunnels were present next to tree trunks, we removed soil around the trunk to evaluate chewing damage from voles, but we found no damage. Although some gopher mounds were found in the middles, almost none were found under the tree canopies (data not shown).

Economic Evaluation. We determined the equipment and materials used for each operation. We calculated the time per acre needed for equipment operators and hand labor, as well as the costs and resource use in gallons of fuel and hours of labor for each alternative.

Total annual weed control costs per acre are substantially different among the various methods (Tables 9-12). Assuming that landscape fabric lasts 8 years, landscape fabric is only somewhat more expensive ($290) than in-row mowing alone ($219), even considering fabric repair costs. An organic herbicide program is far more expensive ($718) because of the cost of GreenMatch and the number of applications required (5) for even marginal weed control. Wood chips were by far the most expensive treatment ($1,040) because of the cost of chips and spreading them, as well as the need to reapply every two years (costs were amortized over 2 years).

Fertilizer costs also varied considerably (Tables 13-15). The use of 2 tons/acre of chicken manure was cheapest ($161). Doubling that rate to 4 tons/acre doubled the cost ($322). Although the cost of the feather meal product ($1,050/ton, or $525/acre) is about 10 times the cost of chicken manure ($8/yd., with approx. 3.25 yds./ton, or approx. $52/acre for 2 tons), the high cost of spreading the manure results in a total cost of $586/acre, only 3.6 times the total cost of chicken manure for an equivalent amount of nitrogen (~130 lbs. N/acre). Note that the manure used was very dry; manure with more moisture would have fewer yards per ton and therefore a lower cost per acre. However, using a higher rate in order to provide the same rate of N/acre would increase material and application costs proportionately.

Discussion

This trial will be conducted for three years, so we will learn more about the duration of fabric and wood chips, as well as the long-term effects of different fertilizer treatments. In year 1, the best weed control was obtained with landscape fabric. No weeds grew through the overlapped fabric strips, but weeds did grow next to some tree trunks. Weeds grew over the edges of the fabric, which helped reduce edge rips from mowing; nonetheless, some sections did rip and require repair.

The thick wood chip layer (6 in.) prevented virtually all seedling germination, but perennial weeds began to grow in the mulch, as can be seen on 6/22/09 (Table 1) and later in the season. It may be more effective to apply a thinner layer every year than a thick layer every other year. Although no treatments were under water stress at any point in the season, trees with wood chips had improved water status (less negative water potential) compared to the other treatments measured on Aug. 13. Other effects of applying wood chips may become apparent in future years, such as improved soil or tree nutrient status, or a further increase in soil pH below the wood chips.

Total costs among weed control treatments varied substantially. Wood chips are by far the most expensive and, although they largely controlled most weeds, in the first year they did not provide much benefit to the trees or yield. If landscape fabric lasts eight years, per-year costs will be similar to in-row mowing. Trunk damage by the sidearm mower will be eliminated with wood chip or fabric mulch. Organic herbicides are expensive and not very effective against summer weeds, particularly yellow foxtail.

Feather meal is one of the most concentrated organic fertilizers, so application costs are far lower than manure, but the total cost is still over three times higher than chicken manure. However, poultry manure is often not available and is often more expensive than the $8/yd. that we paid. Other livestock manures usually contain far lower N content, so the cost of spreading is much higher. If poultry or other manures are not available or are much more expensive, feather meal may be one of the most cost-effective organic fertilizers to use for large-scale fertilization.

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Table 1. Percent (%) weed control in 2008-09.

Treatment	12/3	12/9	2/12	3/25	5/6	6/22
1. Mow, no fertilizer	0.0 c	8.0 b	0.0 c	35.0 c	2.0 c	11.0 c
2. Mow, manure 2T	0.0 c	13.0 b	0.0 c	10.0 d	2.0 c	6.0 c
3. Mow, manure 4T	0.0 c	0.0 b	0.0 c	1.0 d	0.0 c	15.0 c
4. Mow, feather	0.0 c	0.0 b	0.0 c	0.0 d	0.0 c	16.0 c
5. Fabric, manure 4T	99.0 a	98.6 a	97.6 a	96.4 a	95.8 a	96.4 a
6. Chips, manure 4T	98.4 a	98.6 a	98.4 a	98.4 a	97.4 a	90.4 a
7. Herb., manure 4T	89.0 b	89.0 a	86.0 b	63.0 b	10.0 b	56.0 b

Means within a column followed by the same letter are not significantly different (Fishers Protected LSD test, P=0.05).

Table 2. 2009 yields and fruit size, both picks combined.

Treatment	Fruit Yield[1] Per Tree (lbs)	Fruit Yield[1] Per Acre (tons)	Fruit Diameters (in.)
1. Mow, no fertilizer	251.0 a[2]	30.4 a	2.75 b
2. Mow, manure 2T	256.2 a	31.0 a	2.79 ab
3. Mow, manure 4T	226.8 a	27.4 a	2.79 ab
4. Mow, feather	242.3 a	29.3 a	2.83 ab
5. Fabric, manure 4T	242.3 a	29.3 a	2.86 a
6. Chips, manure 4T	261.6 a	31.6 a	2.82 ab
7. Herb., manure 4T	234.0 a	28.3 a	2.82 ab

[1]Weight includes total of first and second pick.
[2]Means within a column followed by the same letter are not significantly different (Tukey HSD test, P≤0.05)

Table 3. Trunk cross-sectional area (TCSA) and TCSA increase, 2008-09.

Treatment	Nov. 2008 (cm^2)	Nov. 2009 (cm^2)	Increase, 2008-09 (cm^2)
1. Mow, no fertilizer	251.5	282.6	31.1
2. Mow, manure 2T	221.6	252.1	30.5
3. Mow, manure 4T	229.5	263.9	34.4
4. Mow, feather	243.2	271.3	28.1
5. Fabric, manure 4T	243.2	281.7	38.5
6. Chips, manure 4T	213.7	242.7	29.0
7. Herb., manure 4T	229.5	260.0	30.5

No significant differences (Tukey HSD test, P≤0.05).

Table 4. Stem water potentials in 2009.

Treatment	May 21	May 26	June 8	June 23	July 17	Aug. 13
3. Mow, manure 4T	9.2 a	7.0 a	6.4 a	7.7 a	7.3 a	7.6 a
5. Fabric, manure 4T	8.9 a	6.9 a	6.6 a	6.9 a	7.2 a	8.0 a
6. Chips, manure 4T	7.8 a	7.1 a	6.2 a	6.7 a	7.0 a	6.4 b
7. Herb., manure 4T	8.7 a	7.3 a	6.2 a	7.2 a	8.1 a	7.9 a

Means within a column followed by the same letter are not significantly different (Tukey HSD test, P≤0.05)

Table 5. Leaf nutrient analyses, leaves sampled July 20, 2009.

Treatment	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
1. Mow, no fertilizer	2.20 c	0.20 a	1.01 a	2.14 a	0.41 a
2. Mow, manure 2T	2.23 bc	0.18 a	0.91 a	2.05 a	0.42 a
3. Mow, manure 4T	2.29 abc	0.18 a	0.91 a	2.05 a	0.42 a
4. Mow, feather	2.23 bc	0.19 a	0.99 a	2.12 a	0.42 a
5. Fabric, manure 4T	2.41 a	0.16 a	0.93 a	2.08 a	0.43 a
6. Chips, manure 4T	2.38 ab	0.18 a	1.03 a	2.12 a	0.41 a
7. Herb., manure 4T	2.39 ab	0.17 a	0.91 a	2.05 a	0.41 a

Means within a column followed by the same letter are not significantly different (Tukey HSD test, $P \leq 0.05$)

Table 6. Soil analyses, 0-12 in. depth, sampled Aug. 24, 2009.

Treat-ment	pH	NH4-N	NO3-N	Total N	X-K	X-Ca	X-Mg	Organic Matter
		(ppm)		(%)	(meq/100g)			(%)
1	6.78 abc[1]	3.97	6.6	0.166	0.81	17.0	8.4	2.59
2	6.78 abc	3.74	7.2	0.172	1.00	17.5	8.9	2.61
3	6.74 bc	3.67	10.5	0.177	1.01	17.0	8.4	2.68
4	6.76 abc	3.57	7.7	0.172	0.93	17.5	8.8	2.77
5	6.64 c	3.07	11.7	0.170	0.96	17.6	9.4	2.78
6	6.90 a	3.69	8.1	0.170	0.94	17.2	9.2	2.77
7	6.84 ab	4.22	10.2	0.170	1.00	15.5	9.0	2.87
Signif.	**	NS	NS	NS	NS	NS	NS	NS

Means within a column followed by the same letter are not significantly different (Tukey HSD test, $P \leq 0.05$)

Table 7. Soil analyses, 12-24 in. depth, sampled Aug. 24, 2009.

Treat-ment	pH	NH4-N	NO3-N	Total N	X-K	X-Ca	X-Mg	Organic Matter
		(ppm)		(%)	(meq/100g)			(%)
1	6.88	3.39 ab	3.97	0.127	0.38	20.74	10.49	2.12
2	6.88	3.41 ab	4.85	0.122	0.42	21.52	11.55	2.08
3	6.90	3.94 a	7.95	0.128	0.39	21.28	10.64	2.26
4	6.92	3.45 ab	5.32	0.129	0.37	21.68	11.00	2.27
5	6.82	2.97 b	8.28	0.116	0.39	20.92	11.98	2.00
6	6.98	3.64 ab	5.80	0.125	0.37	20.66	10.90	2.35
7	6.92	3.49 ab	8.98	0.120	0.38	19.28	11.24	2.19
Signif.	NS	*	NS	NS	NS	NS	NS	NS

**Means within a column followed by the same letter are not significantly different (Tukey HSD test, $P \leq 0.05$)*

Table 8. Mean number of vole holes per six-tree plot (one side of tree row only), Oct. 21, 2009.

Treatment	No. of Holes
1. Mow, no fertilizer	35.0 a
2. Mow, manure 2T	30.0 ab
3. Mow, manure 4T	31.8 ab
4. Mow, feather	34.8 a
5. Fabric, manure 4T	12.2 bc
6. Chips, manure 4T	6.6 c
7. Herb., manure 4T	15.8 abc

Means within a column followed by the same letter are not significantly different (Tukey HSD test, $P \leq 0.05$).

Table 9. Costs per acre per year for in-row mowing.

Operating Costs	Quantity/ Acre	Unit	Cost/Unit	Cost/Acre
Labor: Machine	2.08	hrs	13.80	70
Labor: Non Machine	0.00	hrs	0.00	0
Fuel: Diesel	16.01	gal	3.70	59
Lube				9
Machinery Repair				35
Interest on Operating Capital				3
Total Operating Costs				176
Cash Overhead (taxes, insurance)				5
Non-Cash Overhead (equipment)				38
Total Costs per Acre				**219**

Table 10. Costs per acre per year for landscape fabric.

Operating Costs	Quantity/ Acre	Unit	Cost/Unit	Cost/Acre
Labor: Machine	1.37	hrs	13.80	19
Labor: Non Machine	1.00	hrs	11.75	12
Fuel: Diesel	4.33	gal	3.70	16
Lube				2
Machinery Repair				6
Interest on Operating Capital				1
Total Operating Costs				56
Cash Overhead (taxes, insurance)				27
Non-Cash Overhead (equipment, fabric, pins)				207
Total Costs per Acre				**290**

Table 11. Costs per acre per year for an organic herbicide program.

Operating Costs	Quantity/ Acre	Unit	Cost/Unit	Cost/Acre
GreenMatch	11.20	gal	55.60	623
Labor: Machine	2.05	hrs	13.80	28
Labor: Non Machine	0.00	hrs	0.00	0
Fuel: Diesel	6.46	gal	3.70	24
Lube				4
Machinery Repair				13
Interest on Operating Capital				7
Total Operating Costs				699
Cash Overhead (taxes, insurance)				2
Non-Cash Overhead (equipment)				17
Total Costs per Acre				**718**

Table 12. Costs per acre per year for wood chips.

Operating Costs	Quantity/ Acre	Unit	Cost/Unit	Cost/Acre
Labor: Machine	6.17	hrs	13.80	85
Labor: Non Machine	2.00	hrs	11.75	24
Fuel: Diesel	19.46	gal	3.70	72
Lube				11
Machinery Repair				46
Interest on Operating Capital				2
Total Operating Costs				240
Cash Overhead (taxes, insurance)				8
Non-Cash Overhead (equipment, chips)				792
Total Costs per Acre				**1,040**

Table 13. Costs per acre per year for fertilization with poultry manure (2 tons/acre).

Operating Costs	Quantity/ Acre	Unit	Cost/Unit	Cost/Acre
Poultry Manure	2.00	ton	48.75	98
Labor: Machine	1.20	hrs	13.80	17
Fuel: Diesel	3.78	gal	3.70	14
Lube				2
Machinery Repair				11
Interest on Operating Capital				1
Total Operating Costs				142
Cash Overhead (taxes, insurance)				2
Non-Cash Overhead (equipment)				17
Total Costs per Acre				**161**

Table 14. Costs per acre per year for fertilization with poultry manure (4 tons/acre).

Operating Costs	Quantity/ Acre	Unit	Cost/Unit	Cost/Acre
Poultry Manure	4.00	ton	48.75	195
Labor: Machine	2.40	hrs	13.80	33
Fuel: Diesel	7.56	gal	3.70	28
Lube				4
Machinery Repair				23
Interest on Operating Capital				1
Total Operating Costs				284
Cash Overhead (taxes, insurance)				4
Non-Cash Overhead (equipment)				34
Total Costs per Acre				**322**

Table 15. Costs per acre per year for fertilization with feather meal (0.5 tons/acre).

Operating Costs	Quantity/ Acre	Unit	Cost/Unit	Cost/Acre
Feather Meal	1,000.00		0.55	550
Labor: Machine	0.40	hrs	13.80	6
Fuel: Diesel	1.26	gal	3.70	5
Lube				1
Machinery Repair				3
Interest on Operating Capital				16
Total Operating Costs				580
Cash Overhead (taxes, insurance)				1
Non-Cash Overhead (equipment)				5
Total Costs per Acre				**586**