Evaluation of Weed and Nutrient Management Practices in Organic Pear Orchards

Chuck Ingels
University of California Cooperative Extension
Sacramento, CA

Tom Lanini
Department of Plant Sciences, UC Davis
University of California
Davis, CA

Karen Klonsky and Rich Demoura
Agricultural and Resource Economics
University of California
Davis, CA

Ken Shackel
Department of Plant Sciences
University of California
Davis, CA

Keywords: Mowing, herbicide, wood chips, landscape fabric, fertilizer, manure, feather meal

Abstract

In 2009 and 2010, four weed control treatments (in-row mowing, landscape fabric, wood chips, and organic herbicide) and three fertilizer treatments (chicken manure at high vs. low rate, feather meal) were compared in an organic, no-till Bosc pear (*Pyrus communis*) orchard with solid-set sprinklers. Weed control in the landscape fabric and wood chip treatments was excellent through the season, and multiple herbicide applications per year resulted in partial control. There were no significant yield differences among treatments, and little difference in fruit diameter or weight. There were no significant differences in trunk growth between treatments. The wood chip treatment had significantly lower stem water potential than other treatments in August 2009 only. In both years, the N content of leaves in mow + no fertilizer was significantly lower than most high-rate manure treatments, and leaf P content followed the opposite trend. Wood chips and fabric tended to have fewer vole holes than in-row mowing, and the herbicide treatment was intermediate. Assuming that landscape fabric lasts 8 years, it is only slightly more expensive per year than in-row mowing alone. 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 treatment because of the cost of chips and spreading them, as well as the need to reapply every year. The use of a low rate of chicken manure was the cheapest fertilization strategy. Doubling that rate doubled the total costs, whereas the use of feather meal was about three times the cost of low-rate manure application for an equivalent amount of N.

INTRODUCTION

Organically grown tree fruits generally sell for a substantially higher price than conventional produce. 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; it usually has about 12% 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). Most orchards use nontillage, so 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 manure 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, 90% of the N in chicken manure would be 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. Mineralization of N in composts is generally well below that of feedlot manure in the first year.

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. Many 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.

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 (USA) study showed that the total cost of applying a 5-foot wide, 6-inch thick layer of wood chips was $924/acre (Wiman et al., 2007). In that 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% 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. The outside edges are buried or pinned.

In a 5-year study begun in a newly-planted, conventional cherry orchard in Hood River, OR (USA), 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). Although the polypropylene mulch resulted in substantially increased costs in all 5 years, gross returns from fruit sales were 218 and 43% greater where mulch was used than non-mulched 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.

MATERIALS AND METHODS

Treatments

This trial was initiated in fall 2008 in a Golden Russet Bosc pear block (planted in 2001) near Sacramento, CA (USA), and it will continue through 2011. Orchard spacing is 18 ft. between rows x 10 ft. between trees (242 trees/acre). The rootstock is Winter Nelis and the soil is Valpac loam. The orchard is irrigated by solid set sprinklers, and nontillage is used, with middles mowed periodically.

A randomized, complete block design was used, with 7 treatments and 5 replications. Each plot consisted of 6 trees. Each experimental block consisted of a single row, so each treatment was randomized down each of 5 rows. Treatments used were as follows:

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)

In-row mowing was performed with a single sidearm mower on one side of the row, and was 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 was restricted somewhat, and trunks of some trees were damaged by the mower. About five passes were made each year.

Fertilizer application and weed control were performed on either side of six adjacent trees in each plot, halfway to the adjacent tree on each end. The manure and feather meal were spread uniformly about 5 ft. on both sides of the row (total of a 10-ft. wide strip). Table 1 shows the fertilizer rates, timings, and rate of N application (based on % total N and % moisture). The values for manure are for the low rate, used for treatment 2; the values for treatments 3, 5, 6, and 7 are double these values. For the manure, allowance for some N volatilization and partial mineralization were used, which provided higher than normal N rates.

The fabric, wood chips, and herbicide strip cover a 5-ft. wide strip. The woven landscape fabric used was Lumite Weed Barrier (Shaw Fabrics, Wellington, CO, USA). The fabric was overlapped about 6 in. in the tree row, and fabric pins were placed every 2 ft. along all edges.

The wood chips 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. In October 2008, they were spread using a wood chip spreader, then manually raked smooth to a depth of about 6 in. (only 4 in. in April 2010). 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 tied up in the organic form.

The herbicide used was either GreenMatch at 10% concentration or vinegar (Fleischmann's 300 grain), which was applied with a backpack sprayer 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. Weeds were also mowed using the sidearm mower as in treatments 1-4.

Evaluations and Measurements

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.

Tree growth in each plot was evaluated by measuring trunk cross-sectional area, about 6 in. above soil level. 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 leaves per plot (20/tree) in July 2009 and 2010.

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

Vole and gopher activity were determined by counting the number of holes and mounds in October 2009 and September 2010, 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.

Prior to harvest, the diameters of 50 fruit in each plot were measured on each of two trees per plot. The middle four trees per plot were harvested (2 picks) and the fruit were weighed.

RESULTS

Key weed species included yellow foxtail (*Setaria pumila)* in the summer and California brome (*Bromus carinatus*) in spring. Weed control in the landscape fabric and wood chip treatments (5 & 6) was excellent and significantly better than other treatments at every evaluation (Fig. 1). The application of herbicides generally resulted in weed control that was less than mulch treatments but greater mowed treatments.

There were no significant differences in total yield among treatments (data not shown). Average yields for 2009 and 2010 were 29.6 and 26.4 tons per acre, respectively. Fruit diameters at harvest showed few differences among treatments; average diameters for 2009 and 2010 were 2.8 and 2.7 in., respectively. No significant differences were found among treatments for fruit weight (2010 average = 0.524 lb.), soluble solids, or fruit pressures.

There is a well-known direct correlation between trunk growth and total canopy growth. From 2008 to 2010, there were no significant differences in trunk cross-sectional area among treatments (average 2010 TCSA = 48.7 sq. in.), nor were there differences in growth increase.

Except for one date, there were no significant differences in stem water potential among treatments (data not shown). The wood chip treatment had significantly lower stem water potential than other treatments in August 2009. Means for this treatment were slightly lower on other dates as well, but the differences were not significant. The trees were never stressed in 2009 or 2010; water potentials ranged from 6.2 to 9.2 bars; trees wouldn't likely become stressed until about 12 bars.

In both 2009 and 2010, the N content of leaves in mow + no fertilizer (#1) was significantly lower than virtually all the high-rate manure treatments and not significantly different from the feather meal treatment (Table 2). Conversely, leaf P content of #1 tended to be higher than most high-rate manure treatments. There were no significant differences between treatments in leaf K content. It is interesting to note that N, P, and K levels tended to decline in 2010 compared to 2009.

Analysis of soil samples at 0-12 in. shows that soil pH tended to be higher under wood chips (#6) (Table 3). In 2010, NO_3-N tended to be lower in mow + no fertilizer (#1), and exchangeable K under wood chips (#6) was significantly higher than mow + no fertilizer (#1) and feather meal (#4). There were no significant differences among treatments in soil organic matter (data not shown), but wood chips (#6) had significantly more soil C than either mow + no fertilizer (#1) or fabric (#5).

In both 2009 and 2010, mulch treatments (#5-6), especially wood chips, tended to have fewer vole holes than mowed treatments (#1-4) (Table 4). Under the landscape fabric we counted runways as well as holes, since the fabric provided cover and tunnels were not necessary. At least two of the six trees in each treatment replicate had some sign of vole feeding on tree trunks except for wood chip plots, which had none (data not shown). Although some gopher mounds were found in the middles, almost none were found under the tree canopies (data not shown).

The equipment and materials used for each operation were determined. The time per acre needed for equipment operators and hand labor were calculated, 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 (Table 5). Assuming that landscape fabric lasts 8 years, landscape fabric is only somewhat more expensive per acre ($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 year. This cost study was based on reapplying the full amount of wood chips (6 in. deep) every other year and half the amount in the alternating years.

Fertilizer costs also varied considerably (Table 5). The use of 2 tons/acre of chicken manure was cheapest ($161). Doubling that rate to 4 tons/acre doubled the cost. Although the cost of feather meal ($1,050/ton, or $525/acre) is more than ten 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 delivery and spreading of 2 tons/acre of manure results in a final cost of only about three times that of feather meal for an equivalent amount of nitrogen.

DISCUSSION

This trial will be conducted through 2011, so we will learn more about the duration of fabric and wood chips, as well as the long-term effects of different fertilizer treatments. The best weed control was obtained with landscape fabric and wood chips. No weeds grew through the overlapped fabric strips, but weeds did grow next to some tree trunks. Weeds grow over the edges of the fabric, which helps reduce rips from mowing, but some sections did rip and require repair.

The thick wood chip layer prevented most seedling germination, but perennial weeds began to grow in some plots. Because of mulch breakdown over time, it is more effective to apply a thinner layer every year in the early spring than a thick layer every two years. 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 just before harvest in 2009, but not in 2010. 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, they have not provided a benefit in tree growth or yield. If landscape fabric lasts eight years, per-year costs will be similar to in-row mowing, and trunk damage by the sidearm mower will be eliminated. 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 three times higher than chicken manure. However, in recent years chicken manure is often not available, making feather meal the only practical alternative.

ACKNOWLEDGEMENTS

Thanks to California Pear Advisory Board and Organic Farming Research Foundation for providing funding for this project.

Literature Cited

Chaney, D.E., Drinkwater, L.E. and Pettygrove, G.S. 1992. Organic Soil Amendments and Fertilizers. Univ. of California Division of Agri. and Natural Resources, Pub. no. 21505.

Granatstein, D. 2003. Organic tree fruit research needs for Washington State. Center for Sustaining Agriculture and Natural Resources, Washington State Univ., Wenatchee. http://organic.tfrec.wsu.edu/OrganicIFP/OrganicFruitProduction/ Organic TF Research Summary Sept03.pdf

Granatstein, D. and Mullinix, K. 2008. Mulching options for northwest organic and conventional orchards. HortSci. 43:45-50.

Núñez-Elisea, R., Cahn, H., Caldeira, L. and Seavert, C. 2005. Polypropylene row covers greatly enhance growth and production of fourth-leaf sweet cherry trees. HortSci. 40:1129.

Pang, X.P. and Letey, J. 2000. Organic Framing: Challenge of Timing Nitrogen Availability to Crop Nitrogen Requirements. Soil Sci. Soc. Am. J. 64:247-253.

Pratt, P. F., Broadbent, E. and Martin, J. P. 1973. Using organic wastes as nitrogen fertilizers. Calif. Agric. 27:10–13.

Wiman, M., Granatstein, D., Kirby, E., Hogue, G. and Mullinix, K. 2007. Effectiveness of weed control strategies for organic orchards in Central Washington. Year 3 Report.

http://organic.tfrec.wsu.edu/OrganicIFP/OrchardFloorManagement/WW_Final_Report.pdf

Tables

Table 1. Rates and timings of fertilizer and rate of N application (based on % N and % moisture).

	Manure[1] (Low Rate)[2]			Feather Meal		
	Applied Rate (tons/acre)	Total N (%)	Total N (lbs./acre)	Applied Rate (tons/acre)	Total N (%)	Total N (lbs./acre)
10/14/08	2.0	3.2	103	0.50	11.0	103
9/30/09	2.0	2.6	83	0.50	7.7	74
4/14/10	1.0	2.9	47	0.38	12.0	88
Total applied N			233			265

[1]High rate treatment is twice the low rate treatment.
[2]Average percent moisture: manure = 20%, feather meal = 6%.

Table 2. Leaf nutrient analyses, leaves sampled July 20, 2009 and July 22, 2010.

	N (%)		P (%)		K (%)	
Treatment	2009	2010	2009	2010	2009	2010
1. Mow, no fertilizer	2.20 C[1]	2.08 C	0.200	0.169 A	1.01	0.78
2. Mow, manure low	2.23 BC	2.16 BC	0.182	0.161 AB	0.91	0.74
3. Mow, manure high	2.29 ABC	2.21 AB	0.176	0.148 BC	0.91	0.71
4. Mow, feather	2.23 BC	2.15 BC	0.192	0.146 BC	0.99	0.69
5. Fabric, manure high	2.41 A	2.26 A	0.158	0.142 C	0.93	0.66
6. Chips, manure high	2.38 AB	2.20 AB	0.182	0.158 ABC	1.03	0.74
7. Herb., manure high	2.39 AB	2.20 AB	0.172	0.148 BC	0.91	0.68

[1]Means separation within columns at 5% level (small letters) and 1% level (capital letters), Tukey HSD test.

Table 3. Soil analyses, 0-12 in. depth, sampled Aug. 21, 2009 and Sept. 9, 2010.

Treatment	pH		NO3-N (%)		Exchangeable K (meq/L)		Carbon (%)
	2009	2010	2009	2010	2009	2010	2010
1	6.78 ABC[1]	6.86 AB	6.6	7.9 b	0.38	0.85 bc	1.83 b
2	6.78 ABC	6.80 AB	7.2	10.7 ab	0.42	0.97 abc	2.01 ab
3	6.74 ABC	6.80 AB	10.5	12.4 ab	0.39	0.93 abc	1.93 ab
4	6.76 ABC	6.62 C	7.7	17.2 a	0.37	0.79 c	1.95 ab
5	6.64 C	6.74 ABC	11.7	15.3 a	0.39	0.92 abc	1.89 b
6	6.90 A	6.88 A	8.1	13.9 ab	0.37	1.19 a	2.43 a
7	6.84 AB	6.70 ABC	10.2	17.2 a	0.38	1.09 ab	2.03 ab

[1]Means separation within columns at 5% level (small letters) and 1% level (capital letters), Tukey HSD test.

Table 4. Mean number of vole holes per six-tree plot (one side of tree row only), 2009-10.

Treatment	No. of Holes 2009	2010
1. Mow, no fertilizer	35.0 a	27.8 ab
2. Mow, manure low	30.0 ab	23.0 abc
3. Mow, manure high	31.8 ab	32.4 a
4. Mow, feather	34.8 a	16.8 abc
5. Fabric, manure high	12.2 bc	9.2 bc
6. Chips, manure high	6.6 c	4.2 c
7. Herb., manure high	15.8 abc	12.4 abc

[1]Means separation within columns at 5% level (Tukey HSD test).

Table 5. Costs of weed control and fertilizer practices per acre.

	Total Operating Costs	Cash & Non-Cash Overhead Costs	Total Costs
Weed Control			
1. Mowing	176	43	219
2. Landscape fabric	56	234	290
3. Wood chips	240	800	1,040
4. Herbicide	699	19	718
Fertilizer			
1. Manure – low rate	142	19	161
2. Manure – high rate	284	38	322
3. Feather meal	580	6	586

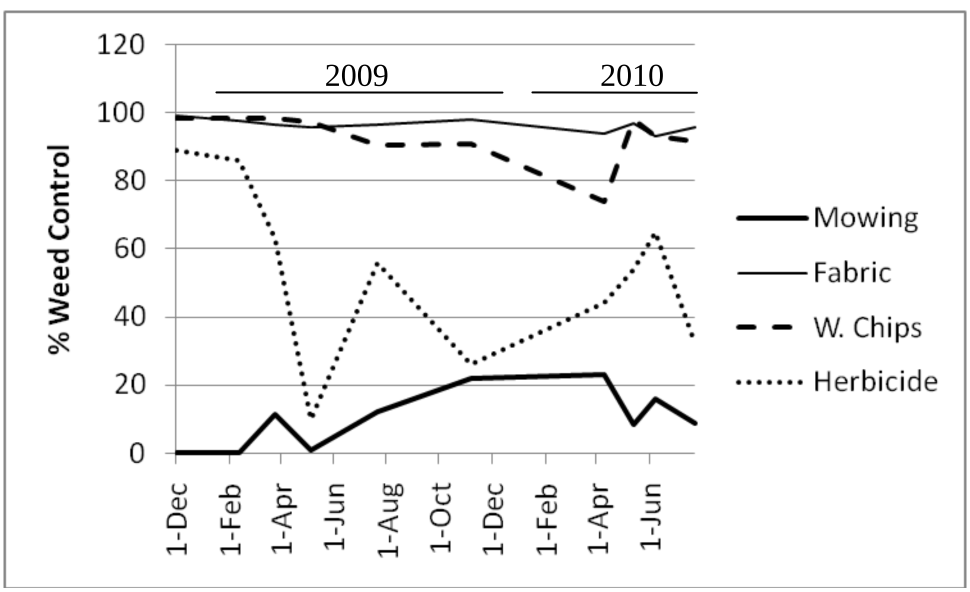

Fig. 1. Percent weed control of mowing alone (mean of 4 mowing treatments) vs. other methods.