Technical Bulletin TB06-03 August 2006

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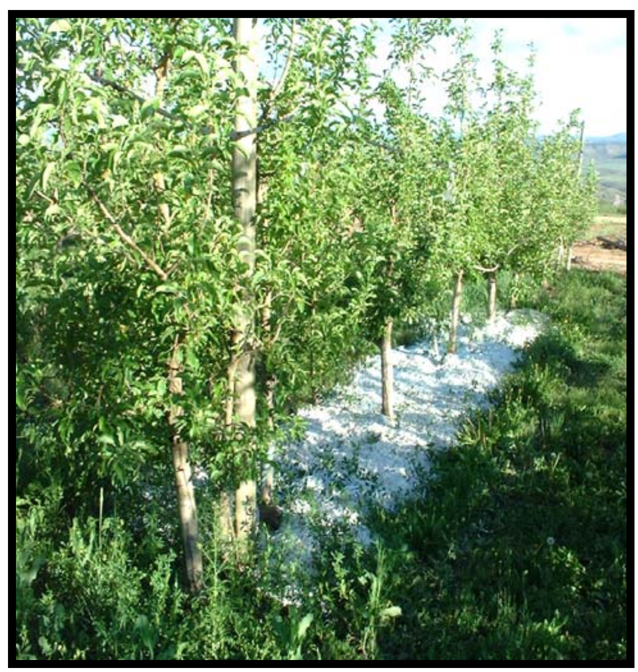
Organic Alternatives for Weed Control and Ground Cover Management: Effects on Tree Fruit Growth, Development and Productivity



Organic Alternatives for Weed Control and Ground Cover Management: Effects on Tree Fruit Growth, Development and Productivity

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A Cooperative Project

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Acknowledgements
The authors would like to thank the Organic Farming Research Foundation of Santa Cruz, California, for supporting this research.

Abstract

Production of organic fruit in western U.S. has been expanding for the past decade or more. Fresh market sales account for a majority of producer's income. In order to gain market acceptance and receive price premiums for their organic fruit, producers must grow large, flavorful, high quality fruit. Weeds compete strongly with young trees for water and nutrients, and there has been much research on the negative effects of weed pressure on young trees. However, little research has been done on the effects of weeds on older, mature orchards. The objectives of this research were to determine what, if any, effects weeds have on mature orchards and are one or more weed control methods more conducive to quality fruit production than others. This on-farm research was conducted at Silver Spruce Orchards near Hotchkiss, CO, on a nine-year-old Gala apple orchard with micro-sprinkler irrigation. This study included seven treatments with eight replications. The seven treatments were: 1) mowing (M), (2) propane weed flamer (F), 3) a weed barrier landscape fabric (LF), 4) shredded paper mulch (P), 5) mowing with material thrown into the tree row (M&T), 6) shredded bark mulch (B), and 7) farmer's favorite (FF), where no weed treatments were imposed and weeds were allowed to grow throughout the season. Results show that the mulch treatments (P and B) did suppress weeds and improve yield over the FF (control). However, three years of drought during the study may have skewed results towards treatments that benefited soil moisture retention, namely the mulching treatments, rather than as a direct effect of weed suppression only. The P treatment trees also retained higher fruit numbers until harvest and had the highest yields in two of the three years of the study. However, the M treatment only showed significantly lower yields in the third year and is much less labor intensive than manual application of the P treatment. Although the FF treatment showed significant impacts on yield due to unchecked weed pressure the M treatment appears to be a viable alternative over the P treatment. The M treatment yields were comparable to the P treatment yields in two of three years and do not incur the high labor cost of manual application of the P treatment.

Introduction

Organic fruit production in the US, especially the western regions, is expanding. The increase is occurring for both economic and ecological reasons. Current market conditions dictate that organic apple growers produce large, flavorful, high quality fruit. Large, high quality fruit receive price premiums and market acceptance whereas small fruit can be difficult to sell, even at lower prices. To grow large fruit, trees must be unstressed and provided with adequate water and nutrition. Weeds can compete with fruit trees for both water and nutrients. Research has demonstrated that weed competition in young fruit trees reduces tree growth and nutrient and water use efficiency, and therefore decreases fruit production and fruit size (Merwin and Stiles, 1994). Over time, reduced tree growth reduces tree volume and potential production. Thus, a standard orchard practice is to control weeds during the establishment and early growth of an orchard. However, the effect of weed competition on production and fruit size of mature fruit trees has not been studied.

Most experiments are conducted on young trees because stress on young trees reduces yearly production potential for the life of the tree, which could cost growers tens of thousands of dollars in income over the 20-30 year lifespan of the tree. Most commercial fruit, including both peaches and apples, are produced on mature trees. Thus it is important to understand the effects or lack of effects that weeds may have on a mature tree. This information could have significant impact on how orchards are managed along with the possibility of significantly reducing production cost.

Currently, organic growers spend considerable time and money controlling or removing weeds from their orchards based primarily on the research trials in young orchards. If weeds have only a minor effect on fruit size in mature trees, this time and money could be redirected to other parts of the operation. If weeds do have an effect, then the grower needs to know if one means of weed control is more effective than another. This study investigated the effects of several different weed control methods on fruit yield and size in mature apple trees. The information generated will give organic growers better knowledge as to how to manage weeds while producing large, marketable fruit.

Materials and Methods

This on-farm research was conducted at Silver Spruce Orchard (SSO), near Hotchkiss, Colorado. The research was conducted on a commercial, certified organic block of nine-year old Gala apples on EMLA 26 rootstock on an Aqua Fria clay loam soil [fine-loamy, mixed, mesic, Typic Haplargid]. The experimental design is a randomized complete block with seven treatments and eight replications; the experimental block had a border row of apple trees on either side. Plots consisted of five consecutive trees where treatments were applied. Within each plot, the three center trees were used for data collection with the two outside trees in each plot serving as buffer trees. The seven different treatments were applied in the tree row. The tree row consisted of a six foot wide strip, three feet on either side of the tree trunk. The trees are planted six feet apart within the row and there are 13 feet between rows. The weed control treatments were: 1) mowing (M), (2) propane weed flamer (F), 3) a weed barrier landscape fabric (LF), 4) shredded paper mulch (P), 5) mowing with material thrown into the tree row (M&T), 6) shredded bark mulch (B), and 7) farmer's favorite (FF), where no weed treatments were imposed and weeds were allowed to grow throughout the season.

The F and both mowing treatments were applied approximately every two weeks to one month as needed during the growing season. Mulches were renewed or replenished each spring in the tree row to a depth of approximately six inches. The P mulch consisted of shredded paper recycled from a local bank. The B mulch consisted of coarse bark from a local lumber mill. For the LF treatment, the fabric was removed, fertilizer applied, and the fabric replaced. The experimental plots were established during the summer of 2000 with data collection from 2001 through 2003.

Commercial organic fertilizer (12-0-0, derived from feather meal) was applied each spring at the rate of 25 lbs of nitrogen (N) ac^{-1}. In the treatments where mulches were applied (P and B) what remained of the mulches in the second and third springs was raked aside prior to fertilizer application. Following fertilizer application the old mulch was then raked back into the tree row over the organic fertilizer and new mulches applied.

Trees were pruned each winter by professional orchardists. Approximately two weeks after bloom, fruit were thinned to an approximate equivalent number of fruit per tree to establish a consistent starting crop load across all treatments. The orchards were micro-sprinkler irrigated every five to ten days as needed during the growing season. Data was collected for weed density, fruit yield and quality and tree growth.

Weed density, or the percentage of the tree row covered by weeds, was estimated on all plots prior to F and mowing treatments during the growing season, May through August. The weed density was then averaged over the growing season for each treatment. Fruit yield and quality was determined by counting and weighing the fruit from each of the three data trees within each plot at harvest. Average fruit size was calculated from total fruit weight and fruit number, as a measure of fruit quality. Tree growth was determined by measuring the circumference of each of the three data trees in each plot and calculating the total trunk cross-sectional area (TCA) at six inches above ground level. Tree growth measurements were taken prior to the initiation of the study and following the onset of dormancy each fall. Tree growth was evaluated on increase in TCA between the initial measurement and final measurement following the 2003 harvest. Data was analyzed using the general linear model with a least significant difference level of 0.05 (SAS Institute, 2001).

A permanent weather station is located at the Rogers Mesa Research Station (RM) (approximately one mile south SSO) where data is downloaded to a computer daily. A summary of average in-season climatic data can be found in Table 1. For evaluation of the weather data, the growing season was defined as April 1st to August 31st. All three years of the study were considered drought years due to well below average in-season precipitation (Table 1) and below average annual precipitation (data not shown). However, of the three drought years, 2002 was considered a severe drought year not only because of the very low precipitation amounts but also because of the extreme dryness (Min relative humidity (RH)) and extremely high maximum temperatures (Table 1). Average in-season precipitation at RM over the past 20 years is 4.85 inches and average maximum high temperature is approximately 80˚F (Table 1). In-season precipitation for both 2002 and 2003 was ½ inch or less and average maximum temperatures were above 85˚F and 83˚F, respectively.

Table 1. Average in-season climate data 2001-2003.

Year	MaxTemp (˚F)	Min Temp (˚F)	Vapor Pres. (mb)	Precip. (in)	Min RH (%)	GDD†	Ref ET‡ (in)
2001	82.7	49.7	9.4	1.1	20.2	1180	38.4
2002	85.4	49.6	7.5	0.4	13.9	1270	40.6
2003	83.4	49.6	8.9	0.5	17.4	1148	37.4
20 yr avg	79.8	48.2		4.85			28.0

† GDD = Growing degree days, based on the averaging method of calculating GDD with a maximum temperature cutoff of 97F and a minimum cutoff temperature of 41F, standard for apples.
‡ Ref ET = Reference evapotranspiration, computed using an alfalfa reference equation know as the 1982 Kimberly-Penman method, Wright, 1982. The average coefficient for apples from full bloom to harvest is 72% of Ref ET (U.S. Bureau of Reclamation website - AgriMet Crop Coefficients: Apples at http://www.usbr.gov/pn/agrimet/cropcurves/APPLcc.html.)

Results & Discussion

Results

Tree Growth

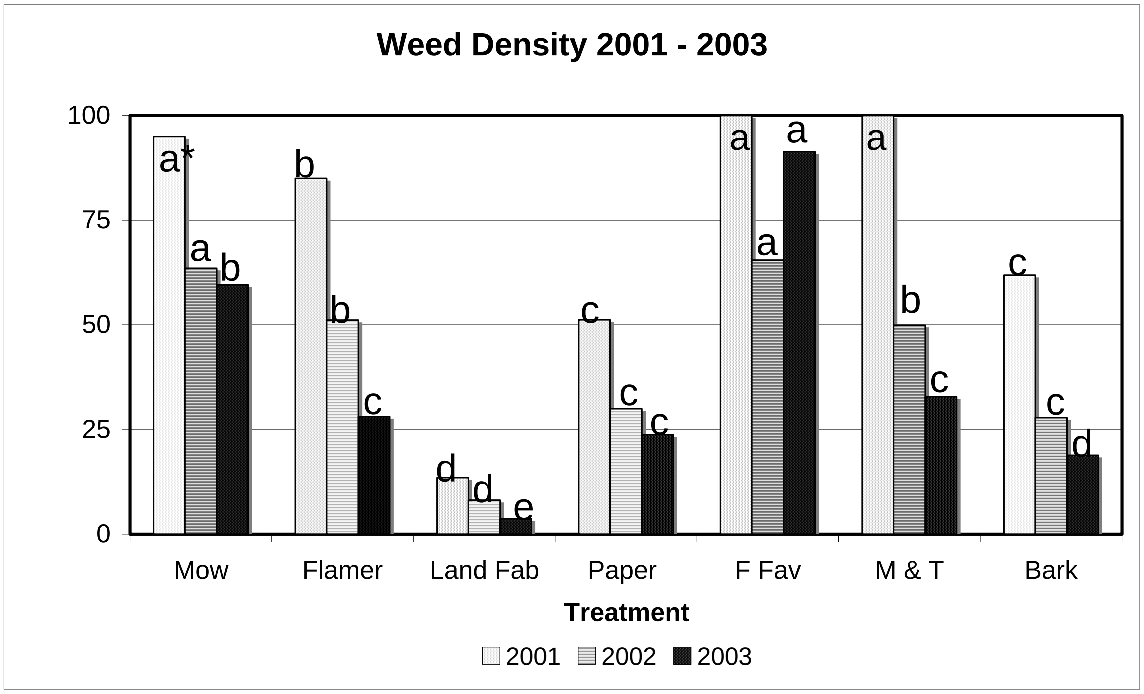
Treatments showed no significant differences in tree size at the start of the study in the spring of 2001, average TCA was 29.4 in^2. Over the three years of the study there were no significant difference in tree growth among any of the treatments and the average TCA in the fall of 2003 was 48.0 in^2. These data show that the treatments applied had no influence on tree growth. The lack of response may be due to equal amounts of N fertilizer applications across all treatments, which may have the most influence on tree growth and the mature stage of the trees.

Weed Density

The weed density data shows a significant treatment by year interaction; therefore, data was analyzed separately by year (Fig.1). Weed density was also affected by the severe drought in 2002 as can be seen in the FF treatment where weed density was near 100% in 2001 and 2003. However, weed density decreased to 65% in 2002 (Fig. 1).

In 2001, the M, FF and M & T treatments had significantly higher weed density than the other treatments, with the LF treatment having the fewest weeds. This would be expected, as the LF is a weed barrier with weeds only growing near tree trunks were the LF has slight openings (Fig. 1). In 2002, although weed density was much lower than the previous year for all treatments, the M and FF were significantly higher and the LF significantly lower than the other treatments (Fig. 1). In 2003, the weed density in the FF treatment was significantly higher than in all other treatments and the LF had a significantly lower weed density. In all treatments except FF, weed density was less each subsequent year, probably due to the cumulative effect of the treatments over the three years of the study. Although plots were irrigated on a regular basis, the extremely low relative humidity and very high maximum temperatures probably contributed to the reduced weed density in 2002. Overall the LF, P and B treatments showed the best weed suppression. The M, F and M&T treatments showed definite improvement from the first to third years of the study. The F, LF, P, and B treatments are more labor intensive than the other treatments and if yield or fruit quality does not increase to off-set the labor costs of these treatments, commercial fruit growers will not adapt the practice.

Figure 1. Weed Density, 2001-2003.



* Letter followed by a different letter in each year indicates significant differences between means at $P < 0.05$.

Fruit Number

Fruit number showed a significant treatment-by-year interaction; therefore, fruit numbers were analyzed individually by year (Table 2). Following bloom, fruit was thinned to approximately the same number of fruit per tree, however, the trees in some treatments had dropped significant numbers of fruit by harvest. This may be due to rapid soil moisture depletion following irrigation. In 2001, the trees in the P treatment had a significantly higher fruit number than the M, LF, FF and M & T treatments but were not significantly higher than the F or B treatments. The trees in the mulch treatments are retaining more fruit until harvest, possibly due to better soil moisture retention than the other treatments. The retention of higher numbers of fruit in the F treatment may be due to reduced weed competition for water and nutrients. However, these results appear to be an anomaly, as the results are not consistent with results for the remainder of the study (Table 2). Although the LF virtually eliminates weed pressure on the trees, the LF is black and is possibly causing higher soil temperatures thereby reducing available soil moisture.

In 2002, there were no significant differences in fruit number among any treatments. This is probably due to climatic stresses mentioned above. In 2003, the P treatment had significantly higher fruit numbers than any other treatments. The B treatment had the second highest number of fruit although not significantly higher than the other treatments. As in 2001, the P treatment retained the highest number of fruit and except for the LF had the lowest weed densities. In drought years, weed suppression combined with improved soil moisture retention afford by the P treatment may be the best way to retain fruit on the trees until harvest.

Table 2. Fruit number per tree, 2001 – 2003.

	Fruit number		
	---------------------fruit tree^{-1} --------------------		
Treatment	**2001**	**2002**	**2003**
Mow	62 bc*	68 a	72 b
Flamer	79 ab	61 a	59 b
Landscape Fabric	55 cd	75 a	67 b
Paper Mulch	86 a	56 a	96 a
Farmer's Favorite	44 cd	65 a	66 b
Mow & Throw	34 d	56 a	60 b
Bark Mulch	65 abc	52 a	74 b

* Letter followed by a different letter in each year indicates significant differences between means at P < 0.05.

Fruit Weight

For this study we used fruit weight as an indicator of fruit quality, with the assumption that heavier fruit are larger and more marketable. The data indicate that there was a significant treatment-by-year interaction; therefore, treatments were analyzed by year. This data shows that no treatment consistently produced significantly higher fruit weight than any other treatment over the three years of the study (Table 3). However, fruit weight was significantly different each year. The highest fruit weights were in 2001 and the least in the severe drought year of 2002. Presumably, the climate and growing conditions in each particular year had a more significant effect on fruit weight than any of the treatments imposed (Table 3). In 2001, the LF treatment had significantly higher fruit weight than the F treatment, while all other treatments were not significantly different than either treatment. In 2002, the M treatment had significantly higher fruit weight than the FF treatment. In 2003, there were no significant differences in fruit weight.

Table 3. Fruit weight, 2001-03.

	Fruit Weight		
	--------------------- g fruit^{-1} -------------------		
Treatment	**2001**	**2002**	**2003**
Mow	165 ab*	137 a	133 a
Flamer	149 b	121 ab	133 a
Landscape Fabric	166 a	117 ab	135 a
Paper Mulch	155 ab	116 ab	129 a
Farmer's Favorite	155 ab	111 b	126 a
Mow & Throw	156 ab	117 ab	123 a
Bark Mulch	161 ab	121 ab	123 a

* Letter followed by a different letter in each year indicates significant differences between means at P < 0.05.

Fruit Yield

Fruit yields also showed a year-by-treatment interaction and varied by year (Table 4). In 2001, the P treatment yielded more than all other treatments but not significantly higher than the M, F or B treatments. This is due to the combination of a higher number of fruit retained on the trees until harvest and a high fruit weight for these four treatments. Although yields of the M, F and B treatments were not significantly lower than the P treatment statistically, the F treatment yielded 1868 lbs ac^{-1} less than the P treatment. This difference may not be statistically significant, but it is economically significant. If the grower's income from the additional 1868 lbs is approximately \$0.50 lb^{-1}, the grower would realize approximately \$1000 more income per acre.

In 2002, there were no significant yield differences in any of the treatments (Table 4). This is probably due to the severe drought conditions that stressed the trees in general. The RH was very low and maximum temperatures were very high during the growing season in 2002, which probably had a major effect on yield regardless of irrigation water applied. In 2003, the P treatment yielded significantly higher than all other treatments (Table 4). Fruit weights were not significantly different in the P treatment in 2003 but fruit number were significantly higher, accounting for the significantly higher yields.

Table 4. Fruit yield, 2001 – 2003.

	Yield		
	---------------------lbs ac^{-1} -------------------		
Treatment	**2001**	**2002**	**2003**
Mow	12621 abc*	11006 a	11784 b
Flamer	14557 ab	9090 a	10000 b
Landscape Fabric	10954 bcd	10729 a	10682 b
Paper Mulch	16425 a	7926 a	15073 a
Farmer's Favorite	8453 cd	8969 a	10167 b
Mow & Throw	6556 d	8157 a	9101 b
Bark Mulch	12927 abc	7759 a	11198 b

* Letter followed by a different letter within each year indicates significant differences between means at $P < 0.05$.

<u>Discussion</u>

The M treatment yields were not significantly less than the P treatment except in the third year of the study. Mowing is a standard practice in most organic orchards and not as labor intensive as application of the P treatment and the labor needed is spread over the course of the growing season for the M treatment. The application of the P treatment requires large amounts of labor early in the season, as it must be hand applied when other orchard tasks are a high priority, such as fruit thinning. The F treatment also did not yield significantly less than the P treatment in the first two years of the study. However, the rising costs of propane in the past year or so has made the F treatment cost prohibitive for most growers.

The LF treatment yielded significantly less than the P treatment in two of the three years of the study. The lower yields coupled with the labor costs of removing the LF, applying fertilizer and reapplying the LF make this treatment cost prohibitive. It has since been learned that if the LF is not removed in the fall the LF makes for good winter habitat for mice, that tend to girdle fruit trees as a winter food source in the LF treatments (Steve Ela, et al. personal communication).

The FF treatment had consistently low yields throughout the study, indicating that unmanaged weeds do have an impact on mature trees likely by competing for water and nutrients. The M & T treatment did not yield well in any year; the reason for this is not understood at this time. The B treatment yielded well in the first and third years of the study but cost of material and labor for bark application, without a corresponding significant increase in yield does not make this treatment cost effective.

Conclusions

The results from this study are not definitive, probably due to drought conditions, and may also suggest that a three-year study may be too short in duration to conclusively determine meaningful outcomes from imposed treatments for organic perennial systems. The mitigating factor of climate appears to play a larger role in fruit tree production in drought years than imposed treatments. The data do show that the P mulch treatment reduced weed density and hence, weed pressure on the orchard, which likely led to the higher yields although the data are not consistent for the B mulch treatment.

In the third year of the study, the P treatment produced significantly higher yields but this is by no means conclusive. However, one conclusion that can be made is that organic perennial agricultural systems are highly buffered and very resistant to large changes over the short term, which is also the strength of organic systems compared to conventional systems. Since the M treatment is the standard practice for organic orchards and in light of the results of this study, growers will likely continue with this practice.

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