Whole Almond Orchard Recycling and the Effect on Second Generation Tree Growth and Soil Fertility

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Abstract

The grinding and incorporating into soil of whole almond trees, during orchard removal, could provide a sustainable practice that could enhance air and soil quality. Removed orchards are typically either pushed out and burned or ground up and removed. Stored carbon is lost from the orchard site. Woody debris incorporated into soils could increase organic matter, enhance carbon sequestration, and improve soil quality and tree yield. The objective of this project was to compare the grinding up of whole trees with burning as a means of orchard removal. Twenty-two rows of an experimental orchard were used in a randomized blocked experiment with two main treatments, whole tree grinding and incorporation into the soil versus tree pushing and burning. The whole tree grinding did not stunt replanted tree growth. Sampling from plots showed elevated levels of fungal and bacterial feeding nematodes (Tylenchidae) associated woody soil aggregates in the grind treatment. Fungal mycelium was readily observed colonizing woody aggregates and significantly more basidiomycetes (mushrooms) were observed in the grind plots. No difference in yield was observed in 2011, however in 2012 and 2013 (P = 0.08) greater yields were observed in the grind treatment when compared to the burn. In 2010, more carbon, organic matter, and a greater cation exchange capacity were initially observed in the burned plots, but by 2012 and 2013 the grind plots had significantly more calcium, manganese, iron, magnesium, boron, nitrate, copper, electrical conductivity, organic matter, total carbon, and organic carbon. Soil pH was significantly less in the grind treatment plots. Leaf petiole analysis in 2013 showed significantly greater levels of nitrogen, potassium, phosphorus, manganese, and iron from trees growing in the grind treatment, while magnesium and sodium levels were significantly less.

Introduction:

The San Joaquin Valley Unified Air Pollution Control District restricts the burning of agricultural wastes. The wood chipping, shredding, or grinding of trees during orchard removal could provide an alternative to burning that could add valuable organic matter to San Joaquin Valley soils typically low in organic matter (Holtz et al., 2004). But growers fear that wood chips or grindings will take valuable nutrients away from their trees because of the high carbon to nitrogen ratio that could result. If wood grindings can be shown to not take valuable nutrients from trees, and not worsen replant disease or interfere with harvest, then growers would be more likely to adopt grinding and incorporating as an alternative to burning or removing debris from their orchards, especially if advantages to soil health and nutrition can be demonstrated. Since the Kyoto Protocol, participating countries have begun to examine the possibility of compensating growers that return high carbon amendments to soils as a means of off-setting industrial carbon emissions into the atmosphere. The objective of this project is to compare the grinding up of whole trees with burning as a means of orchard removal. We are examining second-generation orchard growth and replant disease between treatments (Holtz et al., 2009). We hypothesize that soils amended with woody debris will sequester carbon at a higher rate, have higher levels of soil organic matter, increased soil fertility, and increased water retention. We will examine the effect of whole tree grinding on the nitrogen to carbon soil ratio, soil organic matter, soil-plant nutrition, soil water holding potential, disease, and tree growth and yield. Analysis will also include the characterization of soil chemical and physical properties; extraction, quantification, and characterization of plant parasitic and non-parasitic nematodes; and the isolation and identification of plant disease causing bacteria and fungi.

“The Iron Wolf” (a 50-ton rototiller)

Tree being pushed over and ground in place by the ‘Iron Wolf’

MATERIALS AND METHODS

Twenty-two rows of an experimental orchard on nemaguard rootstock at the UC Kearney Agricultural Center, Parlier, CA were used in a randomized blocked experiment with two main treatments, whole tree grinding and incorporation into the soil with ‘The Iron Wolf,’ a 45,000 kg rototiller, versus tree pushing and burning (completed March/April 2008). There are 7 replications of each treatment and in each plot there are 18 trees. Second generation almond trees (Nonpareil, Carmel, Butte) were planted in January/February 2009. Tree growth was measured annually by trunk circumference. Samples of bulk soil from treatment plots were dried for physical and chemical analyses in the analytical laboratory at UC Davis. Samples were characterized for essential nutrients, texture, pH, electrical conductivity, cation exchange capacity, and organic carbon. Sampling for plant pathogenic and bacterial and fungal feeding nematodes occurred in both the grind and burn plots in the root zone of replanted trees, approximately 500 cm3 of soil was sampled at a depth of 10-15 cm. In the laboratory, soil was passed through a course sieve to remove roots and rocks and nematodes were extracted from 200 cm3 by a modified sieving—Baermann funnel technique. The total number of nematodes in each sample was counted and a random subsample identified. Leaf petiole samples were taken, washed, and dried for physical and chemical analyses in the analytical laboratory at UC Davis.

Tree row after incorporation into the soil with the ‘Iron Wolf’

RESULTS AND DISCUSSION:

Tree Growth and Yield

Tree circumference from second generation replanted trees showed no effect in tree growth between trees growing in plots where whole tree grinding had been performed when compared to trees in plots where the previous orchard had been burned. Yields were determined in 2011, 2012, and 2013 (3rd through 5th leaf). No difference in yield was observed in 2011, however in 2012 and 2013 (P = 0.08) greater yields were observed in the grind treatment when compared to the burn.

	2010		2011		2012	
	Grind	Burn	Grind	Burn	Grind	Burn
Ca (meq/L)	4.06 a	4.40 b	2.93 a	3.82 b	4.27 a	3.17 b
Na (ppm)	19.43 a	28.14 b	13.00 a	11.33 b	11.67 a	12.67 a
Mn (ppm)	11.83 a	8.86 b	12.78 a	9.19 b	29.82 a	15.82 b
Fe (ppm)	32.47 a	26.59 b	27.78 a	22.82 b	62.48 a	36.17 b
Mg (ppm)	0.76 a	1.52 b	1.34 a	1.66 a	2.05 a	1.46 b
B (mg/L)	0.08 a	0.07 a	0.08 a	0.08 a	0.08 a	0.05 b
NO_3-N (ppm)	3.90 a	14.34 b	8.99 a	11.60 a	19.97 a	10.80 b
NH_4-N (ppm)	1.03 a	1.06 a	2.68 a	2.28 a	1.09 a	1.06 a
pH	7.41	7.36	6.96 a	7.15 b	6.78 a	7.12 b
EC (dS/m)	0.33 a	0.64 b	0.53	0.64	0.82 a	0.59 b
CEC(meq/100g)	7.40 a	8.47 b	8.04	7.88	5.34	5.32
OM %	1.22 a	1.38 b	1.24	1.20	1.50 a	1.18 b
C (total) %	0.73 a	0.81 a	0.79 a	0.73 a	0.81 a	0.63 b
C-Org-LOl	0.71 a	0.80 b	0.72	0.70	0.87 a	0.68 b
Cu (ppm)	6.94 a	6.99 a	7.94 a	7.54 a	8.87 a	7.92 b

Table 1. Table 1. In 2010 the burn treatment plots had significantly more (blue paired numbers) organic matter (OM) and carbon (C) in the top 5 inches. The electrical conductivity (EC), calcium (Ca), sodium (Na), and cation exchange capacity (CEC) were also significantly greater in the burn treatment plots. By 2012 the grind treatments plots had significantly more (yellow paired numbers) calcium (Ca), manganese (Mn), iron (Fe), magnesium (Mg), boron (B), nitrate (NO3-N), copper (Cu), electrical conductivity (EC), organic matter (OM), carbon (C), and organic carbon (C-Org). In 2011 and 2012 the soil pH was significantly less in the burn treatment plots.

Fungal and bacterial feeding nematodes and soil and plant nutrients

Sampling from plots showed elevated levels of fungal and bacterial feeding nematodes (Tylenchidae) associated woody soil aggregates in the grind treatment. Fungal mycelium was readily observed colonizing woody aggregates and more basidiomycetes (mushrooms) were observed in the grind plots. Yields were determined in 2011 and 2012 and there were no differences between the grind and burn treatments. In 2010, more carbon, organic matter, and a greater cation exchange capacity were initially observed in the burned plots, but by 2012 the grind plots had significantly more calcium, manganese, iron, magnesium, boron, nitrate, copper, electrical conductivity, organic matter, total carbon, and organic carbon. The soil pH was significantly less in the grind treatment plots. In 2011 and 2012 leaf petiole analysis showed significantly greater levels of potassium from trees growing in the grind treatment, while magnesium and sodium levels were significantly less. In 2013 leaf petiole analysis showed significantly greater levels of nitrogen, potassium, phosphorus, manganese, and iron from trees growing in the grind treatment, while magnesium and sodium levels were again significantly less.

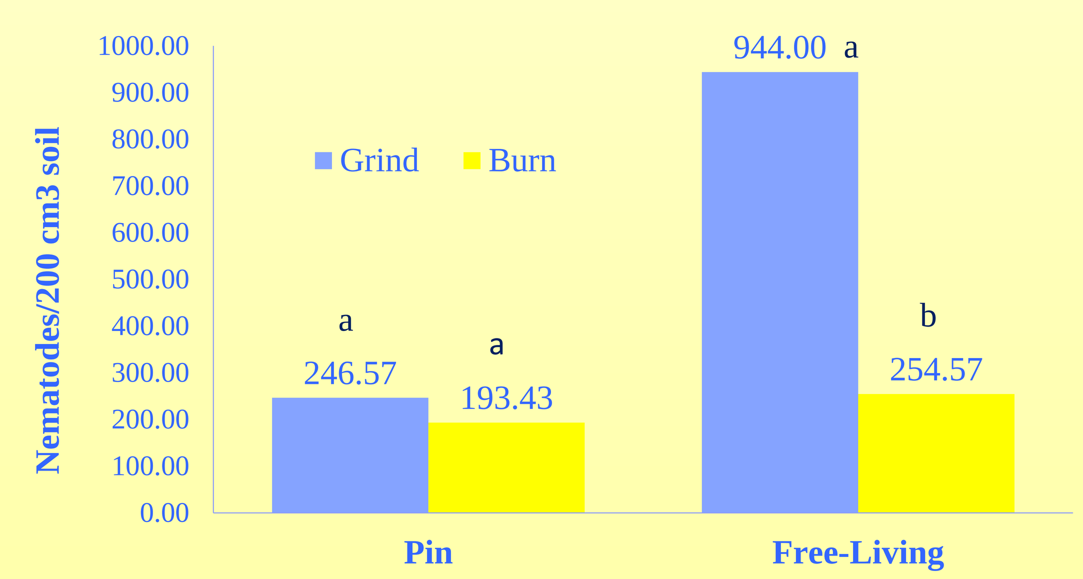

Figure 1. Significantly more ‘free-living’ nematodes in the family Tylenchidae, which primarily feed on algae and fungi and not almond, were observed in the grind plots, especially next to woody pieces in the soil (woody aggregates).

Yield lbs (kg) Green Weight per 6 tree plots			
Year	Grind	Burn	P value
2011	166.5 a (75.7 kg)	152.9 a (69.5 kg)	(P= 0.26)
2012	267. 5 a (121.6 kg)	253.4 a (115.1 kg)	(P = 0.20)
2013	347.2 a (157.8 kg)	306.3 b (139.2 kg)	(P = 0.08)
2014	467.7 (212.1 kg)	385.3 (174.8 kg)	(P = 0.08)
2015	264.4 (120.2 kg)	235.94 (107.3 kg)	(P = 0.17)

Table 3. No significant differences in yields were observed during the first three harvests. The grind treatment trees however have consistently had higher yields than the burn treatment trees, and in 2013 and 2014 the P value was very close to being significant (P = 0.08).

Fourth leaf second generation almond replants trees growing in grind and burn plots at the Kearney Agricultural Center.

CONCLUSIONS

The whole tree grinding, estimated at 61,000 kg per hectare, did not stunt replanted tree growth after the first three growing seasons. Replanted trees were given average nitrogen levels through the micro-irrigation system, never exceeding one ounce of actual nitrogen per tree per irrigation. Initially (2010) the burn treatment plots had significantly more organic matter, carbon, electrical conductivity, calcium, sodium, and cation exchange capacity in the top 10-15 cm than the grind treatment plots. Apparently the carbon and nutrients found in the ash from the burn treatment were more readily detected in the soil analysis when compared to the carbon and nutrients still captured in the large chunks of woody debri from the grind treatment not yet decomposed. The burn treatment and resulting ash most likely released nutrients more quickly into the soil than the grind treatment. However, two years later (2012) the grind treatment plots had significantly more calcium, manganese, iron, magnesium, boron, nitrate, copper, electrical conductivity, organic matter, total carbon, and organic carbon. Apparently the nutrients released by the decomposition of the woody debri are beginning to become available in soil analysis. Fungal decomposition of the organic matter may be contributing to available nutrient levels which would be gradually released as the woody aggregates are decomposed. We expect to see the grind or incorporated treatment to ultimately sequester more carbon and have higher levels than the burn treatment. Nutrients released by the organic matter decomposition appear to be accessible to the almond trees growing in the grind treatment plots as detectable differences in leaf petiole analysis have been observed when compared to trees growing in the burn treatment. By 2013 leaf petiole analysis showed significantly greater levels of nitrogen, potassium, phosphorus, manganese, and iron from trees growing in the grind treatment, while magnesium and sodium levels were again significantly less.

	Nitrogen %		Phosphorus %		Potassium %		Magnesium %		Manganese ppm		Iron ppm		Sodium ppm	
	Grind	Burn	Grind	Burn	Grind	Burn	Grind	Burn	Grind	Burn	Grind	Burn	Grind	Burn
2010	2.40 a	2.33 b	0.11 a	0.10 b	1.76 a	1.44 b	0.98 a	1.03 b	23.63 a	17.44 b	102.5	104.3	340.5 a	455.5 b
2011	2.58	2.58	0.14	0.14	1.92 a	1.67 b	0.66 a	0.71 b	25.70	24.91	91.34	93.75	19.38 a	54.00 b
2012	2.46	2.44	0.13	0.13	1.14 a	1.02 b	0.87	0.90	20.13	19.13	84.84	83.95	24.88 a	49.50 b
2013	2.57 a	2.49 b	0.112 a	0.106 b	0.94 a	0.73 b	1.04 a	1.12 b	27.83 a	23.25 b	113.59 a	102.79 b	634.6 a	957.5 b
2014	2.40 a	2.33 b	0.11 a	0.10 b	1.76 a	1.44 b	0.98 a	1.03 b	23.63 a	17.44 b	102.5	104.0	340.5 a	455.5 b
2015	2.42	2.39	0.12	0.11	1.66 a	1.43 b	0.97	1.01	23.96 a	17.88 b	142.5	148.22	243.8 a	358.22 b

Table 2. In 2011 and 2012 leaf petiole analysis showed significantly greater levels of potassium from trees growing in the grind treatment, while magnesium and sodium levels were significantly less. In 2013 and 2014 leaf petiole analysis showed significantly greater levels of nitrogen, potassium, phosphorus, manganese, and iron from trees growing in the grind treatment, while magnesium and sodium levels were again significantly less.

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Literature Cited

Holtz, B.A., Doll, D., Browne, G. 2014. Orchard carbon and nutrient recycling. Proceedings of the sixth international symposium on Almonds and Pistachios. Acta Horticulturae 1028: 347-350.