Orchard Carbon Recycling and Replant Disease

Project No.: 12-PREC3-Holtz

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Objectives:

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. 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 determine 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. 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.

Interpretive Summary:

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 with 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 comparison to burn treatment plots.

Materials and Methods:

Experimental orchard design. 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: grind treatment defined as whole tree grinding and incorporation into the soil with 'The Iron Wolf'(45,000 kg rototiller) versus burn treatment defined as tree pushing and burning (completed March/April 2008). There were 7 replications of each treatment and each plot of replication consists of 18 trees. Second generation almond trees (Nonpareil, Carmel, Butte) were planted in January/February 2009. Tree growth was measured annually by trunk circumference.

Chemical and physical properties of soil. Samples of bulk soil from around the trees of burn treatment and grind treatment plots were dried for physical and chemical analyses in the DANR Analytical Laboratory at UC Davis. Samples were characterized for plant essential nutrients, texture, pH, electrical conductivity of soil extract, and cation exchange capacity, with emphasis on an organic matter and carbon accumulation. Sampling of each replicated treatment was made for a total of 14 samples at one depth (approximately 5-6 inches).

Tree nutritional assays. Leaf samples were collected from the trees in mid-July. Leaves from six Nonpareil trees were sampled and pooled from each replicated treatment for a total of 14 samples. Samples were sent to the DANR Analytical Laboratory at UC Davis for analysis of all tree essential nutrients.

Identification of plant pathogenic and saprophytic fungi. Sampling for plant pathogenic and bacterial and fungal feeding nematodes occurred in both the grind and burn treatment plots in the root zone of replanted trees. Approximately 500 cm^3 of soil was sampled at a depth of 10-15 cm. In the laboratory, soil was passed through a coarse sieve to remove roots and rocks, and nematodes were extracted from 200 cm^3 by a modified sieving—Baermann funnel technique. The total number of nematodes in each sample was counted and a random subsample identified.

Basidiomycete analysis (mushroom counts). Basidiomycetes (mushrooms) were counted in the grind and burn treatment plots when observed, usually after fall or winter rain.

Results and Discussion:

Tree growth and yield. Tree circumference from second generation replanted trees showed no differences 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 and 2012 (3rd and 4th leaf) and there were no significant differences between treatments. No significant differences were observed in mid-day leaf stem water potential readings between treatment trees.

Fungal and bacterial feeding nematodes and soil nutrients. Sampling from plots showed elevated levels of fungal and bacterial feeding nematodes (Tylenchidae) associated with woody soil aggregates in the grind treatment (**Figure 1**). Fungal mycelium was readily observed colonizing woody aggregates and more basidiomycetes (mushrooms) were observed in the grind treatment plots. Yields were determined in 2011 and 2012, and there were no differences between grind and burn treatments. In 2010, more carbon, organic matter, and a greater cation exchange capacity were initially observed in the burn treatment plots, but by 2012 the grind treatment 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 comparison to burn treatment plots.

Whole tree grinding, estimated at 30 tons per acre (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 micro-irrigation systems, 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 of soil than the grind treatment plots (**Table 1**). 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 debris 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 debris are beginning to become available as shown in the soil analysis. Fungal decomposition of the organic matter may be contributing to the elevated levels of sodium, manganese, and iron, which would be gradually released as the woody aggregates are decomposed. We expect to see the grind (incorporated) treatment to ultimately sequester more carbon and have higher levels than the burn treatment.

Research Effort Recent Publications:

Holtz, B., Browne, G., Doll, D., Hodson, A., Brooks, K. 2010. Orchard removal carbon recycling and replant disease. Almond Board of California 2010 Research Update, p. 39.

Holtz, B.A., McKenry, M.V., and Caesar-TonThat, T.C. 2004. Wood chipping almond brush and its effect on the almond rhizosphere, soil aggregation, & soil nutrients. Acta Horticulturae 638:127-134.

Holtz, B.A. and Caesar-TonThat, T. 2004. Wood chipping almond brush to reduce air pollution as a sustainable alternative to burning that enhances soil quality and microbial diversity. Editors: Lartey, R.T., and Caesar, A.J., Emerging Concepts in Plant Health Management, 2004: pages 159-185, ISBN:81-7736-227-5, Research Signpost.

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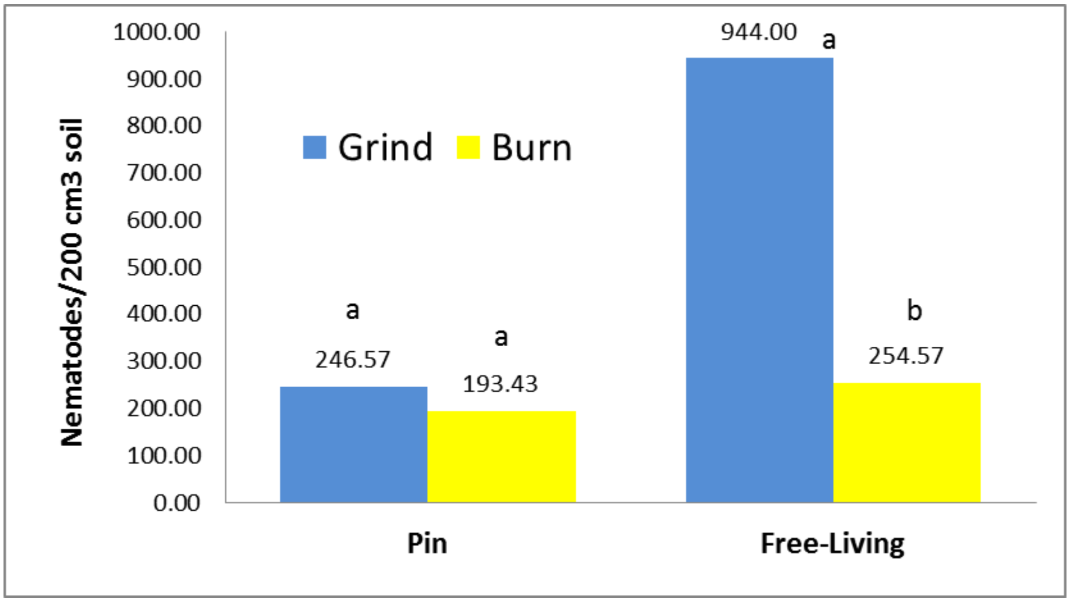

Figure 1. Significantly more 'free-living' nematodes in the family Tylenchidae were observed in the grind treatment plots, especially next to woody pieces in the soil (woody aggregates). Paired columns with different letters were statistically different when compared in a Student's T-test ($P < 0.05$).

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 of soil. 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 in comparison to grind treatment plots.

	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