Orchard Carbon Recycling and Replant Disease

Brent Holtz[1], David Doll[2], and Greg Browne[3]

[1]University of California, 2101 E. Earhart Ave., Suite 200, Stockton, CA 95206
[2]University of California, 2145 West Wardrobe Ave, Merced CA 95340
[3]USDA-Agricultural Research Service, Department of Plant Pathology, UC Davis, Davis, CA

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:
Tree circumference measurements showed no effect in tree growth between trees growing in plots where whole tree grinding had been performed when compared to trees in burned plots. We were initially concerned that the carbon-nitrogen ratio would be critically out of balance in the tree grinding treatments, but an associated growth response was not detected. Sampling from these plots did not detect elevated pathogen levels associated with the 'whole tree grinding' treatment. Yields were determined in 2011 and 2012 and there were no differences between the grind and burn treatments. We initially observed more carbon, organic matter, and a greater cation exchange capacity in the burned plots when compared to the grind plots. The grind plots did however have greater levels of Tylenchidae nematodes (fungal feeding).

MATERIALS AND METHODS:
Experimental Orchard Design
Twenty-two rows of an experimental orchard on nemaguard rootstock (field #31) 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 50-ton rototiller) versus tree pushing and burning (completed March/April 2008). Subplots within these two main treatments above included tree site fumigation with Inline (61:33 ratio of 1,3-dichloropropene and Chloropicrin) through the micro-irrigation system versus a non-fumigated control (completed October 2008). There are 7 replications of each treatment and each replication or plot consists of 18 trees. Almond trees (Nonpareil, Carmel, Butte) were planted in January/February 2009. Tree growth was measured by trunk diameters and current season shoot growth twice throughout the year.

Chemical and physical properties of soil.
Samples of soil from around the trees of burn and whole tree grinding plots were dried for physical and chemical analyses in the ANR analytical laboratory at UC Davis. Samples were characterized for plant essential nutrients, texture, pH, electrical conductivity of soil extract, cation exchange capacity, and organic carbon. Sampling of each replicated treatment was made for a total of 14 samples.

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

Soil samples for nematode analysis. Sampling for plant pathogenic and bacterial and fungal feeding nematodes occurred in both the grind and burn plots. At the root zone of one tree in the center of each treatment block, soil approximately ~500 cm3 of soil was sampled at a depth of 5 inches. 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 (the first 100 encountered on a slide) were identified. Nematode abundances were used to calculate indices of ecological structure and function according to Bongers and Ferris (1999).

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

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

RESULTS AND DISCUSSION:
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 (3rd leaf trees) and 2012 and there were no significant differences between treatments burning or grinding. No significant differences were observed in mid-day leaf stem water potential readings between treatment trees.

Tree row after incorporation into the soil with the 'Iron Wolf'

	Ca meq/L		Na ppm		Mn ppm		Fe ppm		Mg (meq/L)		B (mg/L)		NO3-N (ppm)		NH4-N (ppm)	
	Grind	Burn	Grind	Burn	Grind	Burn	Grind	Burn	Grind	Burn	Grind	Burn	Grind	Burn	Grind	Burn
2010	4.06 a	4.40 b	19.43 a	28.14 b	11.83 a	8.86 b	32.47 a	26.59 b	0.76 a	1.52 b	0.08 a	0.07 a	3.90 a	14.34 b	1.03 a	1.06 a
2011	2.93 a	3.82 b	13.00 a	11.33 b	12.78 a	9.19 b	27.78 a	22.82 b	1.34 a	1.66 a	0.08 a	0.08 a	8.99 a	11.60 a	2.68 a	2.28 a
2012	4.27 a	3.17 b	11.67 a	12.67 a	29.82 a	15.82 b	62.48 a	36.17 b	2.05 a	1.46 b	0.08 a	0.05 b	19.97 a	10.80 b	1.09 a	1.06 a

	pH		EC (dS/m)		CEC meq/100g		OM % (LOI)		C (total) %		C-Org-LOI %		Cu ppm	
	Grind	Burn	Grind	Burn	Grind	Burn	Grind	Burn	Grind	Burn	Grind	Burn	Grind	Burn
2010	7.41	7.36	0.33 a	0.64 b	7.40 a	8.47 b	1.22 a	1.38 b	0.73 a	0.81 a	0.71 a	0.80 b	6.94 a	6.99 a
2011	6.96 a	7.15 b	0.53	0.64	8.04	7.88	1.24	1.20	0.79 a	0.73 a	0.72	0.70	7.94 a	7.54 a
2012	6.78 a	7.12 b	0.82 a	0.59 b	5.34	5.32	1.50 a	1.18 b	0.81 a	0.63 b	0.87 a	0.68 b	8.87 a	7.92 b

Table 1. In 2010 the Burn treatment plots had significantly more (blue paired numbers) organic matter (OM%) and carbon (C-Org%) in the top 5 inches. The electrical conductivity (EC), calcium (Ca meq/L), sodium (Na ppm), and cation exchange capacity (CEC meq/100g) were also significantly greater in the burn treatment plots. In 2011 the electrical conductivity (EC), cation exchange capacity (CEC meq/100g), organic matter (OM%), and carbon (C-Org%) were no longer significantly less in the grind treatment plots. In 2010 the Grind treatment plots had significantly more (yellow paired numbers) manganese (Mn ppm) and iron (Fe ppm) in the top 5 inches when compared to the burn treatment plots. In 2011 the Grind treatment plots had significantly more sodium (Na ppm), manganese (Mn ppm), and iron (Fe ppm) when compared to the burn treatment plots. By 2012 the Grind treatments plots had significantly more calcium (Ca meq/L), manganese (Mn ppm), iron (Fe ppm), magnesium (Mg meq/L), boron (B mg/L), nitrate (NO3-N ppm), copper (Cu ppm), electrical conductivity (EC dS/m), 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.

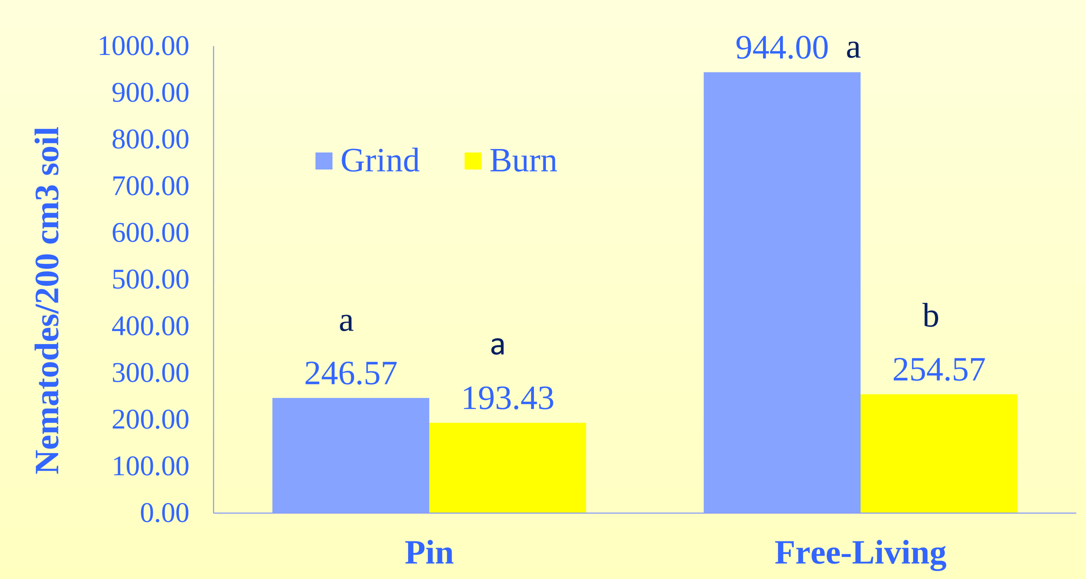

Figure 1. Significantly more 'free-living' nematodes in the family Tylenchidae, which primarily feed on algae and fungi and not almond, were observed in the grind plots, especially next to woody pieces in the soil (woody aggregates).

Woody aggregates, consisting of large pieces of wood debri and soil, were only found in the grind treatment plots. Fungal mycelium was readily observed colonizing woody aggregates and more basidiomycetes (mushrooms) were observed in the grind plots.

The whole tree grinding, estimated at 30 tons per acre organic matter, 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. Sampling from these plots showed elevated levels of nematodes from the family Tylenchidae which often feed on fungi, associated with the grind treatment and woody soil aggregates (Figure 1).

In 2010, two years after incorporation and burning of the first generation orchard, the burn treatment plots had significantly more organic matter and carbon in the top 5 inches than the grind treatment plots. The electrical conductivity, calcium, sodium, and cation exchange capacity were also significantly greater in the burn treatment plots. It appears that the carbon found in the ash from the burn treatment has been more readily detected in the soil analysis when compared to the carbon still captured in the large chunks of woody debri from the grind treatment not yet decomposed. The burn treatment and resulting ash may have released nutrients more quickly to the soil than the grind treatments.

In 2011 the electrical conductivity, cation exchange capacity, organic matter, and carbon were no longer significantly less in the grind treatment plots. In 2010 the Grind treatment plots had significantly more manganese and iron in the top 5 inches when compared to the burn treatment plots.

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

In 2011 the Grind treatment plots had significantly more sodium, manganese, and iron when compared to the burn treatment plots. 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.

By 2012 the Grind treatments plots had significantly more calcium (Ca meq/L), manganese (Mn ppm), iron (Fe ppm), magnesium (Mg meq/L), boron (B mg/L), nitrate (NO3-N ppm), copper (Cu ppm), electrical conductivity (EC dS/m), organic matter (OM%), carbon total (C %), and organic carbon (C-Org %). In 2011 and 2012 the soil pH was significantly less in the grind treatment plots.

Tree growth, disease incidence, and soil characteristics will continue to be monitored, but it appears that the soil incorporation of chipped tree and orcharde removal can sequester carbon without detrimental effects on young tree growth, and that substantial nutrients will ultimately be released for tree use.

ACKNOWLEDGEMENTS
This study would have been impossible without the cooperation of Chuck Boldwyn and Dale Pattigan and the financial contributions of the Kearney Research and Extension Center, University of California, Parlier, CA. This project is primarily supported by the Almond Board of California.