Almond Orchard Recycling

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Introduction

Whole orchard recycling (WOR), as an alternative to co-generation burning, could reduce net orchard greenhouse gas emissions by sequestering temporary carbon stored in tree biomass into soils. The woody residue generated by WOR, estimated to be 40-85 tons per acre depending on tree size, spacing, and varieties, could increase soil organic matter, soil fertility, soil water infiltration rates and soil water retention. Impacts of the orchard debris on incidence and severity of soil-borne diseases of almond are largely unexplored, but increases in soil organic matter content have resulted in favorable soil microbial community shifts, resulting in suppression of some soil-borne diseases and improved plant nutrient dynamics.

The overall goal of this project is to comprehensively assess two forms of whole orchard recycling (WOR), orchard chipping (WOR-C) with a wood chipper vs. orchard grinding (WOR-G) with an "Iron Wolf" rock crusher, compared to the standard practice of orchard removal for energy co-generation. In addition, we will continue to monitor impacts of WOR-G in the 2008 orchard recycling trial established by Holtz et al. at Kearney REC on soil and orchard health.

Our specific objectives are to:

1. Refine life cycle assessment (LCA) model for evaluation of carbon dynamics and balance.
2. Quantify effects of the treatments on the physical and chemical soil properties and tree nutrients.
3. Quantify effects of the treatments on biological soil properties.
4. Assess impacts of the treatments on replanted orchard growth, health, nutrition, production, and water relations.

The first orchard grinding trial at Kearney, established in 2008, compared WOR of stone fruit trees with the Iron Wolf, estimated, at 30 tons per acre, to burning and incorporating the ash. The orchard was replanted to almond. Ultimately, greater yields (Table 1), significantly more soil nutrients (Soil Analysis Table 2), organic matter, and total carbon were observed in the grind treatment when compared to the burn. Leaf petiole analysis also revealed higher nutrients levels in trees growing in the grind treatment, thus proving that the organic matter did not stunt replanted trees. Based on positive results from this trial and the closure of co-generation plants, we estimate almond growers ground and incorporated 1,500 acres in 2015 and 15,000 acres in 2016. Preliminary data from the Kearney deficit irrigation trial has shown less water stress from trees growing where the previous orchard was ground, suggesting increased water holding capacity with the additional organic matter (Figure 1).

Four additional orchard grinding trials with almond were established in 2016. A second trial with the Iron Wolf (Figure 2) was established with Agriland Farming in Chowchilla comparing Iron Wolf grinding (WOR-G) with wood chipping (WOR-C) (Figure 3) and spreading (Figure 4), with complete tree removal for electrical co-generation. WOR-C was estimated at 68 tons per acre. Third and Fourth trials were established with Wonderful Orchards, in Bakersfield and Shafter, where WOR-C was compared to complete tree removal, with and without fumigation and anaerobic soil disinfestation (Dr. Browne's replant disease project). WOR-C was estimated at 39 and 65 tons per acre respectively. A second study was established at UC Kearney where WOR-C was compared to orchard removal for cogeneration in plots 10 ft wide X 45 ft long microplots that also compared anaerobic soil disinfestation with fumigation. Wood chips were applied at a rate of 85 tons per acre (See M. Culumber's poster). The four WOR trials established in 2016 were fumigated and planted to second-generation almond trees in early 2017.

Results

Butte Variety, Kernel pounds/acre

Year	Grind	Burn	Difference
2011	687.40 lbs/ac	687.37 lbs/ac	0.03 lbs/ac (P= 0.49)
2012	1,472.40 lbs/ac	1,379.42 lbs/ac	92.98 lbs/ac (P=0.19)
2013	1909.64 lbs/ac	1667.91 lbs/ac	241.73 lbs/ac (P=0.05)
2014	2272.11 lbs/ac	1767.25 lbs/ac	504.86 lbs/ac (P=0.12)
2015	1,072.90 lbs/ac	877.54 lbs/ac	195.36 lbs/ac (P=0.11)
2016	1,341.97 lbs/ac	1,206.96 lbs/ac	135.01 lbs/ac (P=0.14)
2017	1956.01 lbs/ac	1539.17 lbs/ac	416.84 lbs/ac (P=0.07)
Total	**10,712.43 lbs/ac**	**9,125.62 lbs/ac**	**1,586.81 lbs/ac**

Table 1. Grinding vs. burning the first generation orchard on the second generation orchard yield.

Fig. 2. The 'Iron Wolf' 700 B, a 50-ton rock crusher, pushes trees over going forward while grinding branches and trunks. Then going in reverse the Iron Wolf can incorporate the wood, at a rate of 2 acres per day and at a of approximately cost $1,500 acre.

Figure 3. The Morbark horizontal chipper was used to chip up almond trees at Agriland for comparison with the Iron Wolf.

Figure 4. Kuhn & Knight Spreaders modified for spreading wood chips by G & F Ag Services in Ripon, CA.

Soil Analysis Table 2

	2010 Grind	2010 Burn	2011 Grind	2011 Burn	2012 Grind	2012 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-LOI	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

	2013 Grind	2013 Burn	2014 Grind	2014 Burn	2015 Grind	2015 Burn
Ca (meq/L)	3.78 a	3.25 b	7.55 a	5.45 b	4.02 a	1.36 b
Na (ppm)	2.74 a	1.90 b	3.41 a	2.34 b	2.32 a	1.21 b
Mn (ppm)	26.35 a	5.71 b	14.46 a	10.65 b	7.31 a	4.67 b
Fe (ppm)	32.56 a	20.38 b	38.58 a	29.30 b	24.29 a	17.21 b
Mg (ppm)	2.15 a	1.20 b	3.61 a	2.57 b	2.01 a	0.68 b
B (mg/L)	0.06	0.07	0.07 a	0.10 b	0.05 a	0.07 b
NO_3-N (ppm)	20.11	12.27	26.53 a	18.89 b	20.64 a	5.23 b
NH_4-N (ppm)	0.37	0.33	1.59 a	1.36 b	0.89 a	0.65 b
K (mg/L)	94.50	84.88	28.50 a	13.60 b	19.76 a	16.97 b
pH	7.39 a	7.53 b	6.95	7.06	7.27 a	7.60 b
EC (dS/m)	0.91 a	0.68 b	1.54 a	1.08 b	0.90 a	0.38 b
CEC(meq/100g)	9.54	10.16	7.78	8.30	5.16	5.14
OM %	1.55 a	1.06 b	1.21 a	0.93 b	1.37 a	1.08 b
C (total) %	0.87 a	0.51 b	0.71 a	0.54 b	0.66 a	0.50 b
C-Org-LOI	0.87 a	0.61 b	0.70 a	0.54 b	0.79 a	0.62 b
Cu (ppm)	8.26 a	7.11 b	8.03	7.73	7.51 a	7.03 b

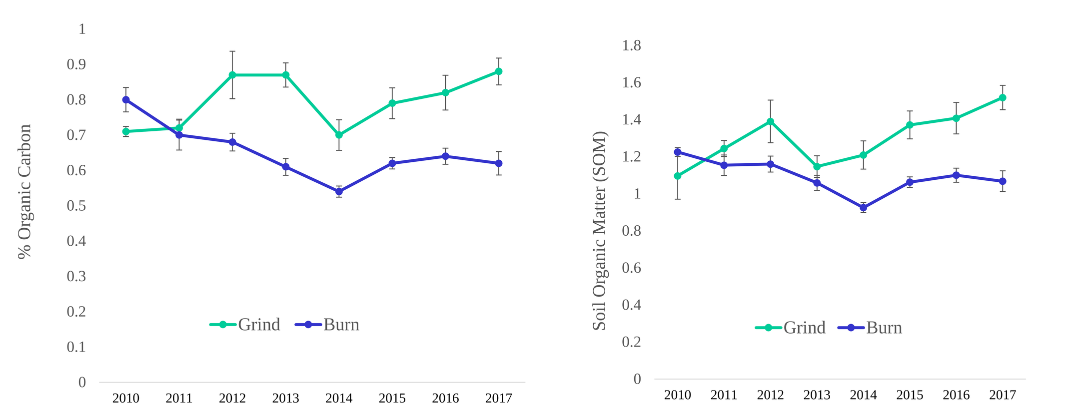
Blue Pair = grinding significantly less than burning

Yellow pair = grinding significantly greater than burning

Figure 5. Scraping wood chips to distribute evenly. Wood chips were analyzed for their nutrient content. The nitrogen content of the wood chips averaged 0.31 %, potassium 0.20 %, calcium 0.60 %, and carbon 50 %. When 64 tons of wood chips are returned to the soil per acre--that will give you 396 pounds of nitrogen, 768 pounds of calcium, 256 pounds of potassium, and 64,000 pounds of carbon per acre.

Trunk Diameter Butte Variety (cm)

Year	Grind	Burn	P value
2009	4.87	4.96	P= 0.19
2010	14.56	15.22	P=0.07
2011	22.39	22.72	P=0.38
2012	30.53	30.23	P=0.18
2013	38.52	37.73	P=0.09
2014	46.50 a	45.24 b	P=0.01
2015	55.71 a	53.79 b	P=0.01
2016	63.15 a	60.58 b	P=0.007



Figures 6 & 7. Percent organic carbon and soil organic matter (SOM) both increased significantly from 2010-2017.

Figure 7. This Duratech grinder is mobile and spreads the wood chips evenly as it grinds.

Soil Analysis Table 2. 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 2012-15 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 2011-15 the soil pH was significantly less in the burn treatment plots.

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