Influence of Whole Orchard Recycling on GHG Emissions and Soil Health in a New Almond Orchard

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Introduction

Whole orchard recycling (WOR) incorporates orchard waste on-site, without burning or moving the debris to another location, preventing the release of air pollutants into the atmosphere. When mulched into the soil, high carbon (C) containing amendments like woodchips increase soil organic matter (SOM). Agricultural research has found both decreases and increases in carbon dioxide (CO_2) and nitrous oxide (N_2O) greenhouse gas (GHG) emissions depending on the quality and quantity of amendments, fertilization rates and types, and soil biological and chemical characteristics. A study was initiated in fall 2017 to find what impact a high rate of recycled woodchips will have on N_2O and CO_2 emissions, soil factors, and tree establishment after planting.

Objectives

- Monitor field level nitrous oxide (N_2O) and carbon dioxide (CO_2) emissions, after a one-time WOR application in a newly established commercial almond orchard.
- Describe the effect of WOR on soil carbon and nitrogen cycling and identify the chemical and biological mechanisms.
- Identify optimal fertility rates for first year trees planted in recycled orchards

Methods

Orchard Establishment

Figure 1a. Excavated trees were chipped with a Peterson horizontal grinder and spread with modified manure spreader.

- Fall 2017, a commercial plum orchard (Parlier, Ca) was pushed over, chipped, and spread (Fig. 1a), deep ripped to 6 ft, stubble disked and scrapped to bury and distribute chips.
- Four half-acre (200 ft x 110 ft) control plots (did not receive any woodchip mulch) and four adjacent WOR plots of the same size were established.
- Baseline soil organic C, total N, pH, electrical conductivity (EC), and soluble and exchangeable cations were determined (data not shown).
- Woodchip biomass was estimated based on the dry weight of woodchips (>2 mm) in 1 ft^3 soil from several randomly selected locations within each plot in December 2017 and October 2018.

Figure 1b. WOR orchard, with berms and irrigation installed and trees planted.

- Planting berms were established, broadcast fumigated with chloropicrin, and double-line drip irrigation installed.
- In Jan. 2018, a 50-50 mix of Nonpareil and Monterey on Brights-5 rootstock were planted north to south with 17 x 20 ft spacing (Fig. 1b).
- ~12.2 and 17.3 inches water were applied in 2018 and 2019, irrigation provided an additional 1.5 lb N per acre inch applied (Table 1).

Table 1. N application shown as lbs N/ac and oz /tree) supplied by fertigation and irrigation in 2018 and 2019.

	lbs N / acre fertilizer		cumulative lbs N / acre from irrigation		Fertigation plus irrigation oz / tree	
	2018	2019	2018	2019	2018	2019
March	0	9.65	0.9	0.46	0.1	1.4
April	12.5	9.65	1.0	2.1	1.9	1.6
May	5.8	0	2.0	1.1	1.0	0.2
June	25	9.65	3.2	3.6	4.0	1.8
July	12.5	0	4.7	7.2	2.4	1.0
August	12.5	0	2.3	2.6	2.1	0.4
September-November	0	0	5.6	8.02	0.8	1.1
Total lbs N	**68.3**	**29.0**	**19.7**	**25.1**	**12.3**	**7.5**

Tree growth and nutrition

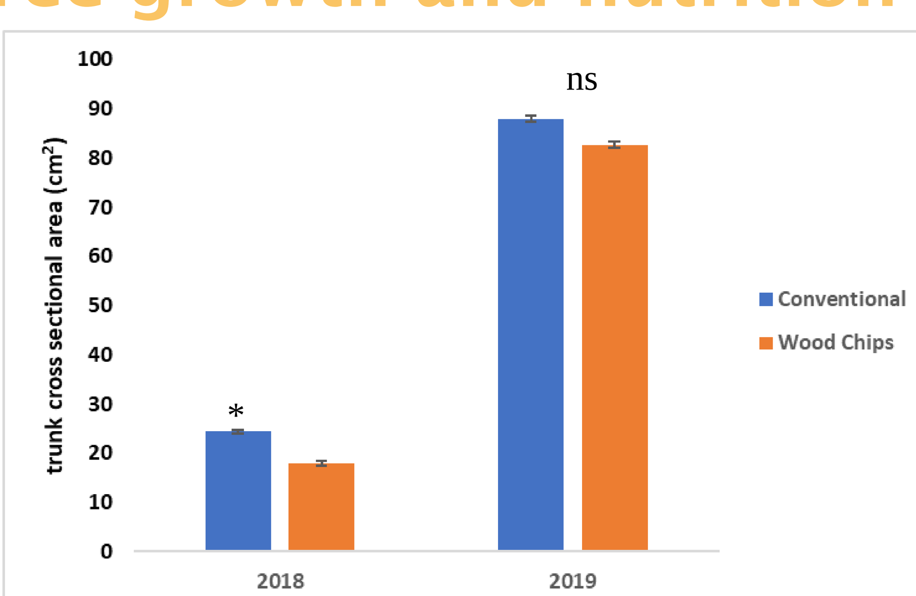


*Figure 2. tree growth expressed as trunk cross sectional area for conventionally established and trees planted after WOR. 1st year growth was significantly greater in conventional trees in 2018, but tree size was no different by the end of 2019. * Indicates a significant Tukey-Kramer adjusted P < 0.02*

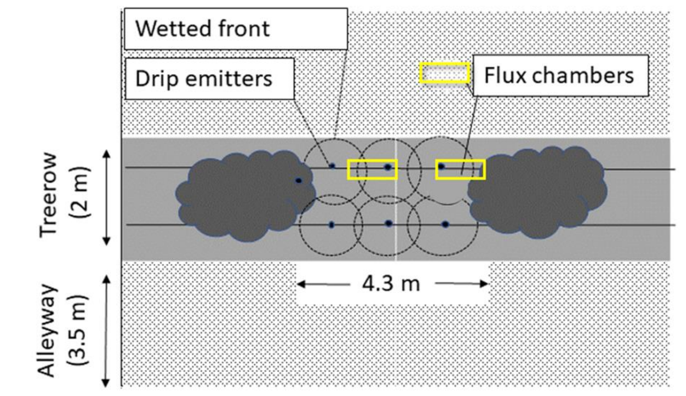
Table 2. Mid-summer leaf tissue sampling nutrient levels for control and woodchip treatments

	N	P	K	Ca	Mg	Zn	Fe	Mn	Cu	B	Mo
2018	%					ppm					
control	3.1	0.2	2.6	2.1	0.3	25.8	76.5	73.5	4.8	27.1	1.1
woodchip	3.1	0.3	2.8	1.9	0.3	32.3	79.5	71.3	5.4	25.6	1.1
2019											
control	2.1	0.1	3.4	3.7	0.5	30.5	112.3	88.0	11.4	45.3	0.2
woodchip	2.2	0.1	4.0	3.6	0.4	27.8	102.0	75.5	9.1	44.5	0.4

Figure 3. Almond trees replanted after WOR: 1st year November 30, 2018 (left) and 2nd year October 2019 (right).

Mid-summer nutrients were no different between control and woodchipped trees in 1st or 2nd year of growth. Trees reached satisfactory N content (3.1%) in 2018. N tissue levels were lower in 2019 but adequate for non-bearing trees (Table 2), no visible signs of nutrition stress were observed (Figure 3).

GHG Emissions and Soil Attributes



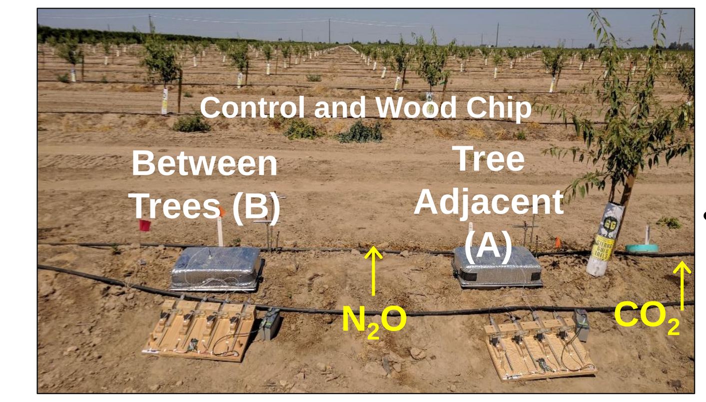


Fig. 4 static flux chambers have three locations: adjacent (A) and between trees (B), and in the alleyway.

- Gas flux chambers (Fig. 4) were installed to measure differences in GHG flux and soil N pools in the tree rootzone (A) and the inter-tree spaces (B) where applied nutrients are not taken up.
- Flux sampling is weekly at a minimum, and more frequently after fertigation and irrigation, and precipitation.
- Net changes in soil N and labile dissolved organic C pools (not shown) from 0-15 cm are measured monthly one day following fertigation.
- Year end emission factors (EF) were calculated as the ratio of N_2O emitted to fertilizer N applied from fertilizers and irrigation water.

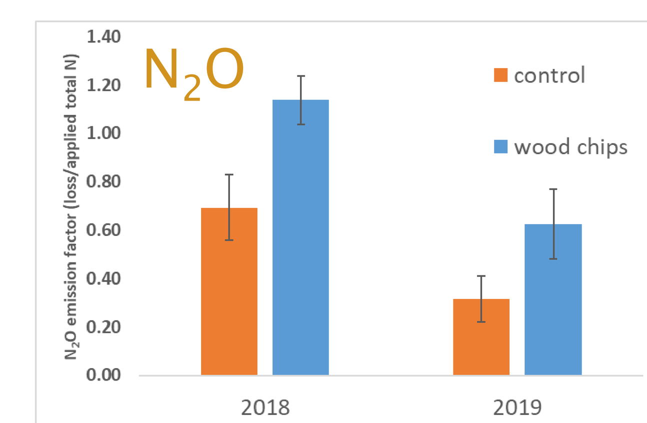


Figure 4. Nitrous oxide emission factors (EF) for the treerow berm for control and woodchip treatments. The EF is the ratio of surface N_2O emissions (kg/ha/yr) to total (kg/ha/yr applied (88 lb N/acre/yr 2018 and 54 lbs N/acre/yr 2019 (Table 1)

N_2O EF ranged from 0.69% in the control to 1.1% in woodchip plots in 2018 (Fig. 4), and 0.31% and 0.635% in 2019 suggesting a higher proportion of applied fertilizer was lost as N_2O in woodchip plots. Little difference in EF was observed within the tree-row A and B locations for either treatment. Flux peaks decreased after mid-summer both years (data not shown).

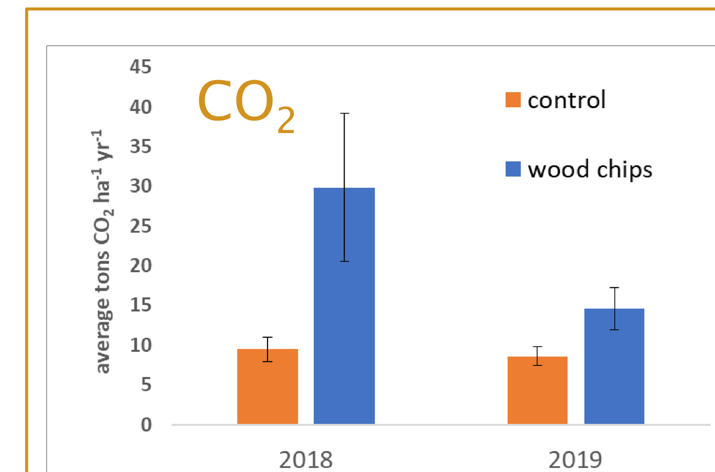


Figure 5. Estimated tons of CO_2 emissions from berm locations within control and woodchip treatments for the first season after replanting a new almond orchard.

Cumulative CO_2 losses were higher in the woodchip treatments and controls in 2018 and 2019. Woodchip CO_2 levels declined by more than half after June 2018 and remained steady in 2019 indicating a drop in emissions after readily degraded C sources were diminished. Higher CO_2 rates are consistent with higher levels of microbial biomass and activity associated with organic matter turnover as observed in other recent WOR trials.

Soil organic C and N

	Organic Matter LOI	Organic Carbon	Total N
	%		
Trial avg. (03/2018)	**2.26**	**1.21**	**0.11**
Trial avg. (12/2018)	**1.38**	**0.77**	**0.08**
Average by treatment and location December 2018			
control	**1.18**	**0.67**	**0.07**
tree root zone (A)	1.20	0.66	0.07
between trees (B)	1.25	0.69	0.08
alleyway	1.10	0.65	0.07
woodchip	**1.53**	**0.87**	**0.08**
tree root zone (A)	1.38	0.76	0.08
between trees (B)	1.68	0.95	0.09
alleyway	1.55	0.89	0.08
Type III Tests of Fixed Effects			
treatment (WC or CN)	0.1797	0.1091	0.4000
location (between trees, tree rootzone, alleyway)	0.6506	0.6355	0.5300
Month (Mar, Dec 2018)	<.0001	<.0001	0.0004

Table 3 Soil organic matter, organic C and total N levels soon after planting in March 2018 and at the end of the 1st growing season December 2018.

Soil organic matter, organic C and total N for the < 2 mm sieved soil fraction decreased significantly from the time of trial initiation, March 2018, to December 2018 (Table 3). Woodchip treatments had higher overall SOM and organic C at the end of the 1st growing season, but there was no significant treatment or location (A, B) differences for these variables.

Conclusions

Orchard N fertility applications were 2.4 times larger than the standard recommendation for newly planted orchards in the 1st year, however rates were reduced to half guideline rates in the 2nd year. Tree size was no different between conventionally managed and woodchipped trees by the end of 2019. This suggest managers may need additional fertilization at planting, but standard fertilization practices can resume in the 2nd year. Further research is needed to pinpoint the optimal timing and necessary season long fertility rates in the first growing season after recycling. Woodchip treatments had higher N_2O and CO_2 emissions compared to controls in the fertigated drip line during the first two years after orchard recycling. Compared to the control, higher N_2O fluxes in the woodchip treatment were observed during the first four days after fertigation; other times they were consistently similar. The woodchip N_2O EF ~1.1% (2018) and 0.634% (2019) was greater than the control, but comparable to levels reported for many crops. N_2O and CO_2 fluxes greatly declined after early to mid summer in the 1st year. Data collection and analysis of the impacts of WOR and orchard management on cumulative GHG emissions is ongoing. Soil organic matter and total N levels initially declined in the first year after replanting, but it is expected levels will increase in consecutive years as has been observed in long-term studies of the effects of WOR on soil conditions.

Acknowledgements

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