Tree Growth and Soil Nutrient Responses to Whole Orchard Recycling in a Newly Established Orchard

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Introduction

Whole orchard recycling (WOR) incorporates orchard removal waste on-site, without burning or moving the debris to another location. Slow adoption of WOR stems from concerns that incorporating a large volume of high carbon (C) to nitrogen (N) wood grindings before replanting could negatively affect tree nutrition. The additional C supplied by WOR mulch may lead to improvements in soil health that could be beneficial to orchard growth in the long term. Preliminary research comparing WOR of stone-fruit trees at **30 tons per acre** with burning and incorporating the ash resulted in significantly higher yields, soil nutrients, and organic carbon in the grind treatment when compared to the burn from 2008 to 2016 (Holtz et al. 2016). Almond orchards last about 10 to 15 years longer than a stone-fruit orchard, with significantly larger sized trees by the end of its productive life. We speculate a completely recycled higher-density almond orchard would incorporate **85-90 tons per acre**, nearly triple the volume applied in the grind/burn trial described above. It is unknown what impact a large application of wood grindings, matching the estimated volume of a recycled 20+ year old orchard will have on replanted almond tree nutrition and growth during the establishment years.

Objectives

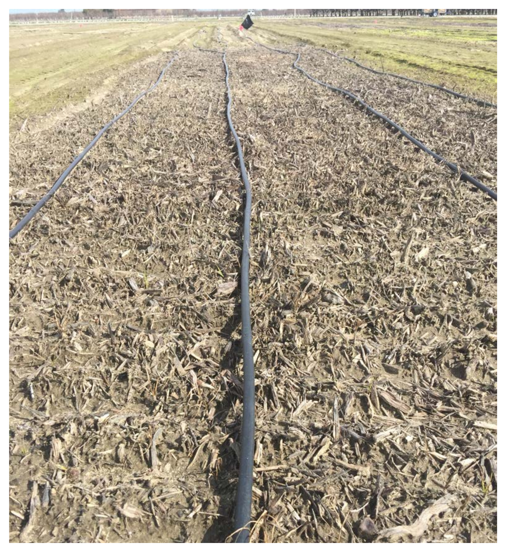
Determine if wood chip amendment application rate of 85-90 tons/acre has a detrimental impact on establishment of young almond trees in comparison to other pre-plant agricultural waste product amendments and industry standard practices. We expected tree growth will be adversely affected by wood chip amendments in the first growing season, but will recover by the third year corresponding to enhanced biological activity and soil fertility.

Methods

A trial was established in 2017 at the UC Kearney Agricultural Research Station in Parlier, CA in almond replant soil to test the tree growth and soil chemical and biological responses to three different organic amendments (Table 1), rice bran (RB), almond hull (AH), and wood chips (WC) as well as fumigated and a non-treated control. The almond orchard was planted in February 2017 with Shasta on Nemaguard rootstock. Six trees were planted for each treatment plot with data collection taken from the three centermost trees. Trees received approximately 1 ounce of N (0.06 lb N/tree) per fertigation application of UN32 from May to October.

Amendment	Application rate	
	(lbs/plot) wet wt	(tons/acre) wet wt
Rice Bran	186	9
Almond Hulls	186	9
Wood Chips	1,770	85

Table 1.



Tree and Soil Analyses

The percentage increase in tree size (trunk cross-sectional area) within the first growing season was determined based on the circumference (cm^2) of the trunk 16 inches above the soil line in February and October. Tree leaf nutrient levels were based on 15 leaves from each of the three centermost trees in each plot in July. The dried, ground material was analyzed for N, P, K, B, Ca, Zn, Cu, Fe, Mg, Mn, and S (ICP-AES). Composited soil sampling took place one day prior to and three days after fertigation each month. Analyses were performed on sieved moist samples within 4 days of sampling. Pre-fertigation measurements included: soil nitrate and ammonium levels at three depth increments (0-15, 15-3, 30-45 cm), total microbial biomass (ng/g soil), fungal to bacterial ratios, organic C, total N, available P, and K, EC, soluble cations, and gravimetric water content. Post fertigation sampling included soil inorganic N levels only. A general linear mixed model with repeated measures analysis of variance (ANOVA) was used in SAS (Proc Glimmix, SAS Version 9.4, SAS Institute). Natural log and square root transformations were used for analysis where necessary to meet model assumptions. A principal component analysis (PCA) was performed using PAST 3.17 software (University of Oslo) to model multi-factorial relationships between different soil indicators.

Results

Tree Growth and Nutrition

Wood Chip plot trees growth and nutrition was significantly lower than all other treatments including the control. Wood chip TCSA increased only by ~6.0 cm^2 in the first growing season. July nitrogen tree leaf % N was significantly lower than all other treatments, however the 2.5% N level in WC trees exceeds the sufficiency recommendation for almond.

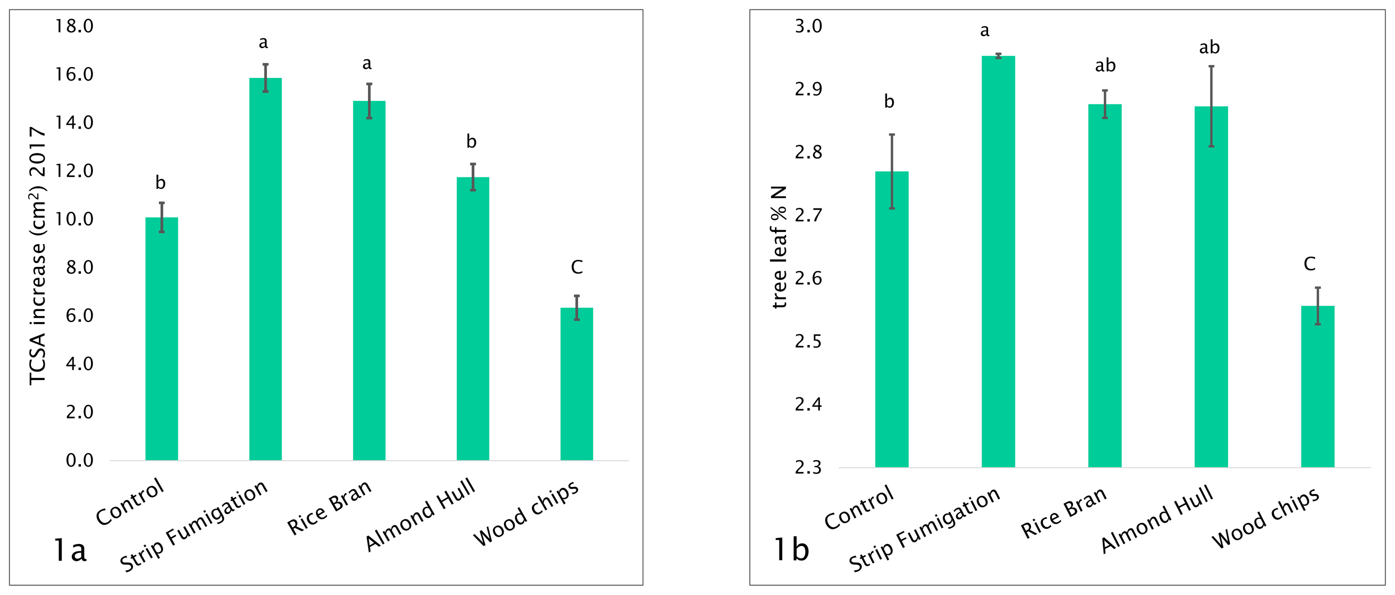


Figure 1 a). Average TCSA increase and b) % tree leaf nitrogen for five treatments. Different letters indicate a significant difference at the p≤0.05 level.

Soil Chemical and Biological Activity

Soil nitrate and ammonium nitrogen (NO_3^-N, and NH_4^+-N) levels collected prior to and after fertigation were significantly different among treatments. Thought not always significant, WC had the lowest overall pre fertigation NO_3-N and higher before and after fertigation NH_4^+ levels than the Fumigation and Control plots (Figure 2a and b). Lower pre-fertigation NO_3^-N suggests increased immobilization, and higher NH_4^+-N levels may indicate lower nitrification potential of ammonium supplied by UN32 fertigation in the WC treatment. The RB treatments had the highest post fertigation levels of NO_3^-N. Soil inorganic N levels varied by depth throughout the season (month*depth, p≤0.001). Early and late season concentrations were higher in the 0-15 cm range, although mid-season levels were generally no different from 0 to 45 cm, indicating N movement down in the soil profile (data not shown).

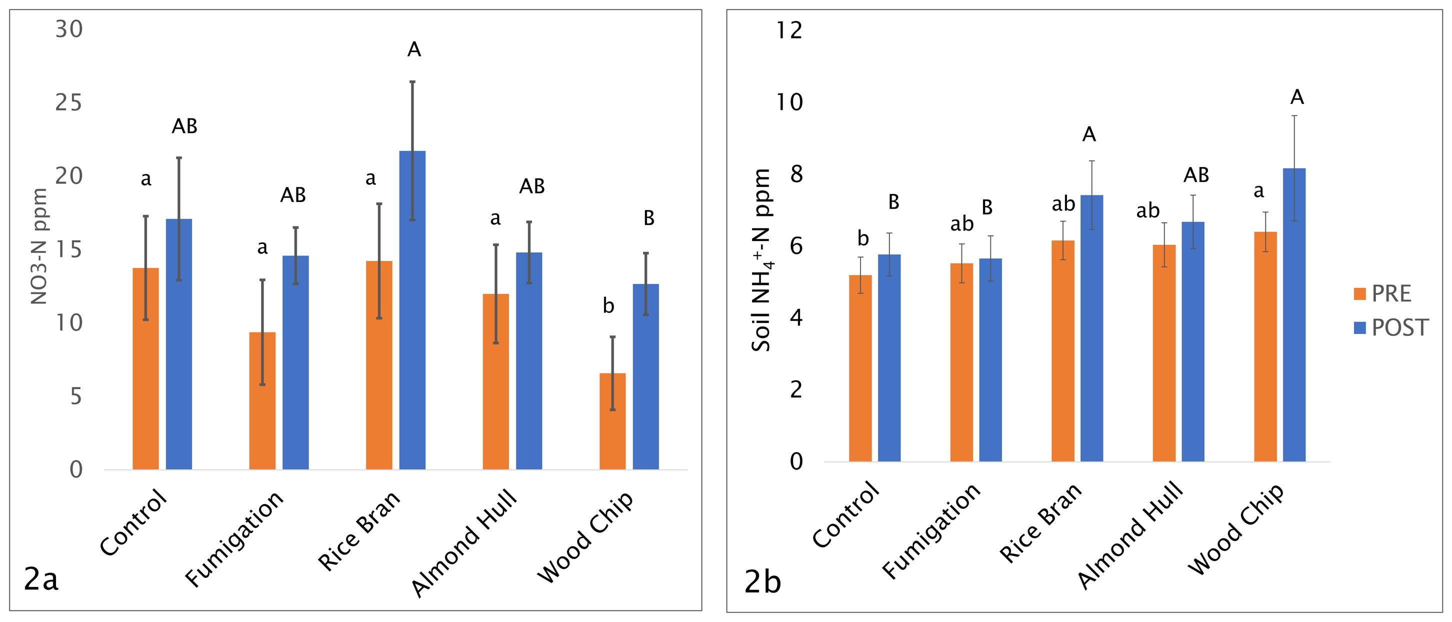


Figure 2a and 2b. Different lower case letters indicate differences between pre-fertigation NO3- -N and NH4+ concentrations and UPPER case letters indicate differences between treatments POST-fertigation at the p≤0.05 level. Reported means are for untransformed data.

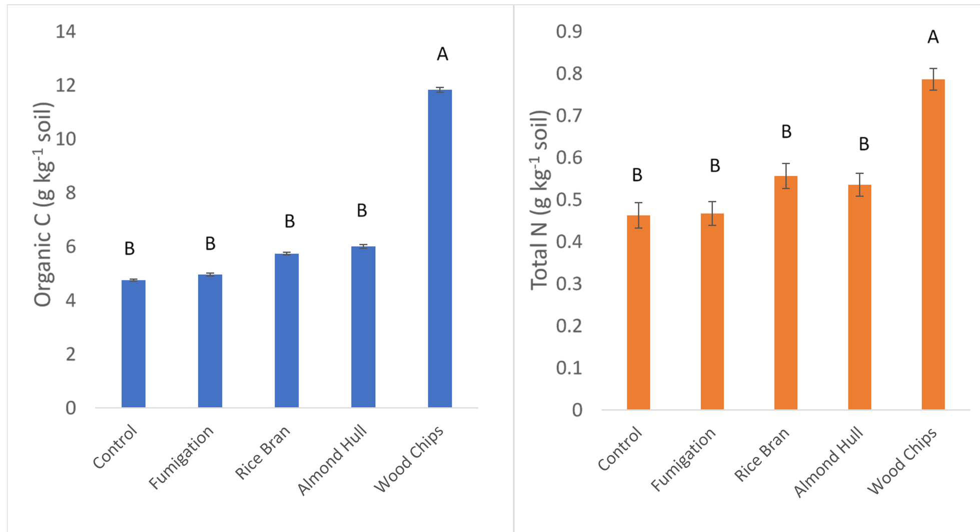
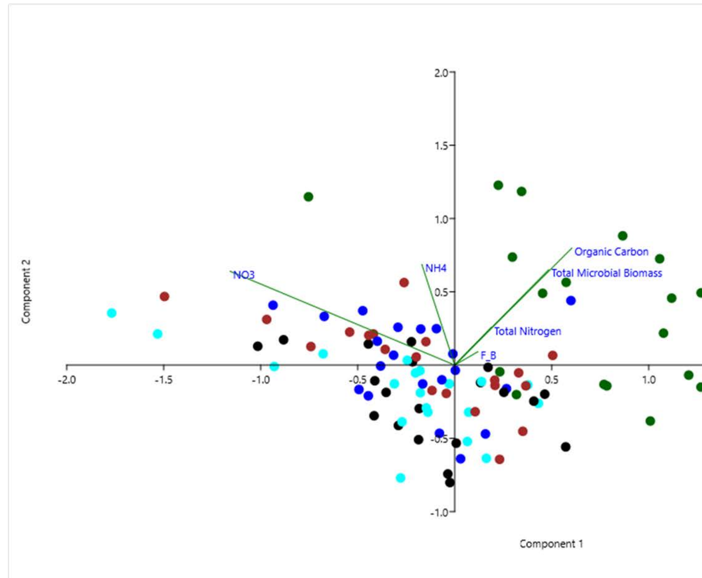


Figure 3a and 3b. Different upper case letters indicate differences between soil organic C and total N levels at the p≤0.05 level.

A significant correlation (r=0.8519, p<0.0001) between soil organic C and total N levels, and greater organic C and total N were observed in the WC plot soils (Figure 3). Higher organic C levels in WC plots indicates decomposition of WC residues. Increasing total N can represent N in organic matter, mineralized N, or the immobilization inorganic N supplied by fertilizers, or a combination of all.



	PC 1 (57.18%)	PC 2 (23.416%)
Total Microbial Biomass	0.34092	0.45842
F_B (Fungi:Bacteria)	0.08412	0.06459
Organic Carbon	0.42539	0.56220
Total Nitrogen	0.13232	0.18127
NO_3^--N	-0.81487	0.45061
NH_4^+-N	-0.11929	0.48343

Figure 4. Principal component analysis

Higher total soil microbial biomass (p<0.0001) and Fungal to Bacterial ratios (p<0.0100) resulted in WC than all other treatments, suggesting the carbon rich WC is stimulating microbial activity and development of communities that can assimilate cellulose and lignin in wood. The PCA of multiple soil indicators shows that although WC plots had the highest microbial biomass and organic C, increases in total N are likely explained by processes immobilizing fertilizer NO_3^-N, and NH_4^+-N.

Conclusions

Our results show the high C composition of the WC treatment facilitated the immobilization of fertilizer N applications leading to reduced tree growth and nutrition in the first year. Higher microbial biomass growth in WC treatments signals decomposition processes are turning over the high C containing wood chips. However despite frequent fertigation events, available N levels were limited. Agricultural soils are dynamic systems. Soil biological and chemical composition shifts in response to the changing quality and quantity of decomposable residues, temperature, moisture, and pH among other factors, which will drive turnover of microbial biomass and increase nutrient mineralization. Increasing soil organic C has been shown in many agricultural studies to have a positive impact on soil nutrient reservoirs and water holding capacity over time. Overcoming stunting in the first two years of growth, the first Grind and Burn trial demonstrated significantly higher cumulative yield over the lifetime of an almond orchard. Despite the same outcome for year one of this trial at the 85 ton/ac rate, we expect a similar balance of nutrient immobilizing and mineralizing processes may result in the WC treatments over a period of a few seasons, and that almond tree growth will catch up to other orchard management approaches without significant impacts on yield.

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