Optimizing Nitrogen and Water Use Efficiency in Replanted Orchards After Whole Orchard Recycling

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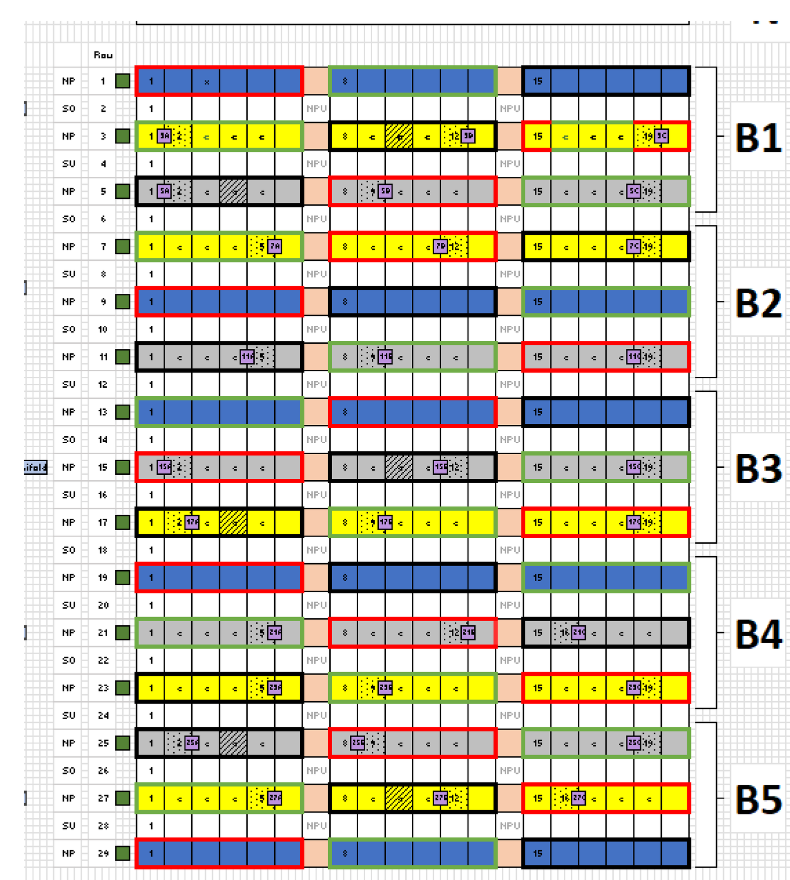
Abstract

Whole orchard recycling (WOR), the grinding and soil incorporation of whole trees during orchard removal, has been shown to be a sustainable method of tree removal that enhances soil and improves air quality. The woody residue generated by WOR, estimated to be 40-70 tons per acre (depending on tree size, spacing, and varieties) increases soil carbon, soil organic matter, soil fertility, soil water infiltration rates and soil water retention. Research is aimed at understanding the appropriate N fertility program and irrigation management strategies in replanted orchards after WOR.

Objectives

- Evaluate changes in soil physical, chemical, and biological properties, tree growth, and productivity in replanted orchards following WOR compared to controls with no soil amendments
- Determine if the WOR practice increases water and nitrogen use efficiency in replanted orchards from establishment to bearing



Methodology

A trial was established at the UC Kearney Agricultural Research Center (36.5966, -119.5176) in March 2019. The design is a split-plot block with three main plot treatments: WOR (60 tons/ac), WOR plus 15 tons/ac annual mulching application, and control (non-amended soil). Each main factor has three N fertilization rates (low, medium, and high) adjusted each year for growth and predicted yield (Table 1). Each split-plot treatment combination was replicated five times and planted in April 2019 with six Nonpareil on Cornerstone rootstock trees spaced 15 ft x 19.4 ft, with a pollinator buffer row separating each treatment plot. (Figure 1). Soil was sampled annually in the top 6 inches of the wetted dripline within the tree-row and in the alleyway to measure soil physiochemical changes with wetting and fertilizer applications. Tree mineral nutrition and growth were sampled annually at a minimum, and yield measured during the 3rd and 4th growing season.

Table 1 Nitrogen was applied as granular N-P-K (15-15-15) beginning in the 1st week of March, then as UAN32 and ammonium sulfate (NH4)2SO4 (21%)) monthly through July each season. To overcome the high nutrient immobilizing C:N ratio at planting, all N treatments were ~17 lbs (35%) above the UC recommendation for 1st leaf trees.

Nitrogen lbs / per acre								
	2019	2020	2021	2022	2023	2024	2025	2026
	1st leaf	2nd leaf	3rd leaf	4th leaf	5th leaf	6th leaf*	7th leaf*	8th leaf*
Nitrogen treatments								
Low	46.6	45	75	125	175	175	175	175
Middle	46.6	60	95	150	200	200	200	200
High	46.6	75	115	175	225	225	225	225
UC recommendation	30	55	116	174	232	237	210-255	210-255
Crop lbs/acre			750 lbs	1,750	2,750	2,900	2500-3,100	2500-3,100
N demand for leaves and wood	30	55	65	55	45	40	40	30

WOR decomposition enhances soil C and N levels

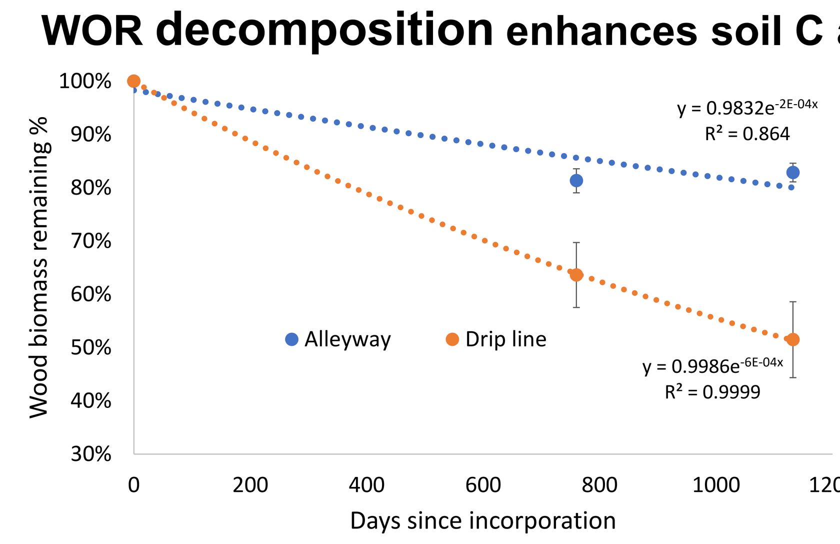
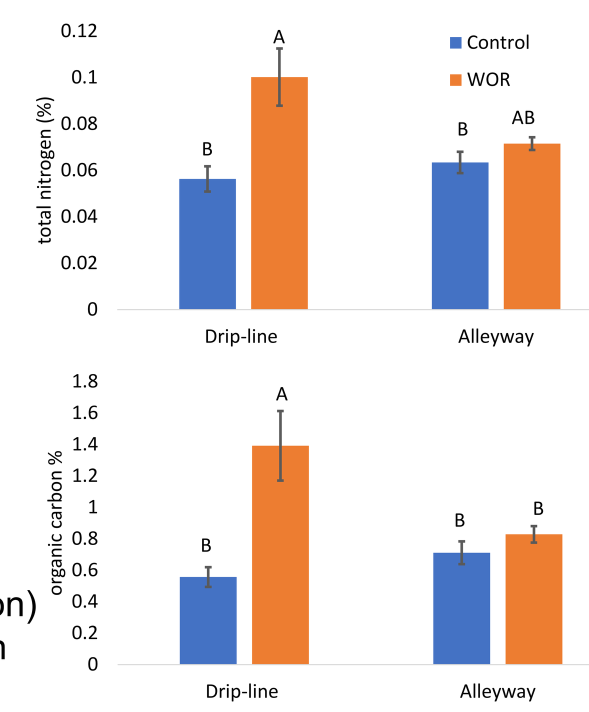


Figure 2 . Wood biomass decomposition in the wetted, fertilized dripline and the alleyway

Wood chips decomposed at a faster rate (~50%) in the wetted berm compared to the unirrigated, unfertilized alleyway (~18% decomposition) after 3 years (Figure 2). Total N and C % also increased significantly in the WOR dripline compared to the WOR alleyway and the Control (Figure 3). The rapid decomposition and increased soil C and N suggests higher mineralization in the in the wetted area where trees can utilize available N. As trees reached bearing age in the 3rd leaf, the 'high' N level rate matched the recommended 68 lbs N for every 1000 kernel pounds removed at harvest (Table 1).



Total N Type III Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
treatment	1	14	12.58	0.0032
location	1	14	2.15	0.1651
treatment*location	1	14	5.93	0.0288
year	1	14	0	0.9493
treatment*year	1	14	0.05	0.8244
location*year	1	14	0.56	0.4663
treatment*location*year	1	14	0.01	0.9067

Organic Carbon Type III Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
treatment	1	14	15.13	0.0016
location	1	14	2.79	0.1168
treatment*location	1	14	8.6	0.0109
year	1	14	0.02	0.8946
treatment*year	1	14	0.01	0.9126
location*year	1	14	0.06	0.8119
treatment*location*year	1	14	0.03	0.8693

Figure 3. Two-year average soil total N % and total C % in the drip-line and alleyway

Tree nutrition

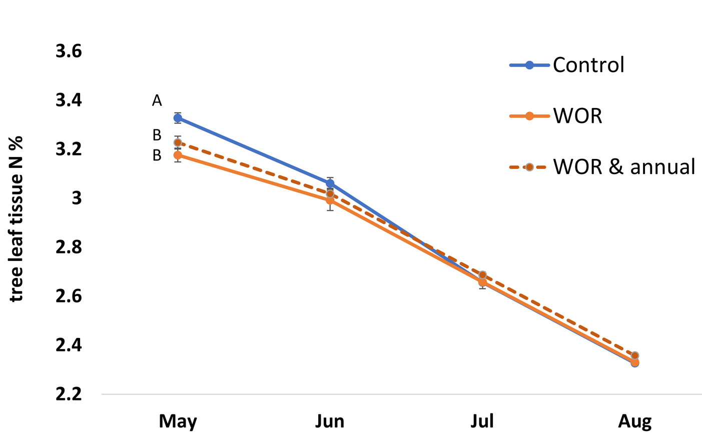


Figure 4

Type III Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
treatment	2	140	6.53	0.0019
N level	2	140	4.19	0.0171
month	3	140	1047.95	<.0001
treatment*N level	4	140	2.55	0.0421
treatment*month	6	140	3.51	0.0029
N level*month	6	140	0.97	0.4489
treatment*N level*month	12	140	0.56	0.8713

Tree leaf N nutrition was no different (avg. 2.6%) between treatments and N levels in July after all current season N fertilization applications were completed (data not shown). Monthly (May-August) leaf N during 2nd leaf was significant for treatment x month, where Control trees had higher N content than the WOR treatments early in the season. These results suggest N level did not greatly impact tree nutrition and that treatment effects (Control vs. WOR) are only observed early in the growing season during the 2nd leaf.

Tree growth, as trunk diameter, was measured in November annually. Tree size grew significantly for all treatments each year, with the WOR treatments consistently larger than the control treatment (Figure 5). No N level response was observed for growth.

Tree growth

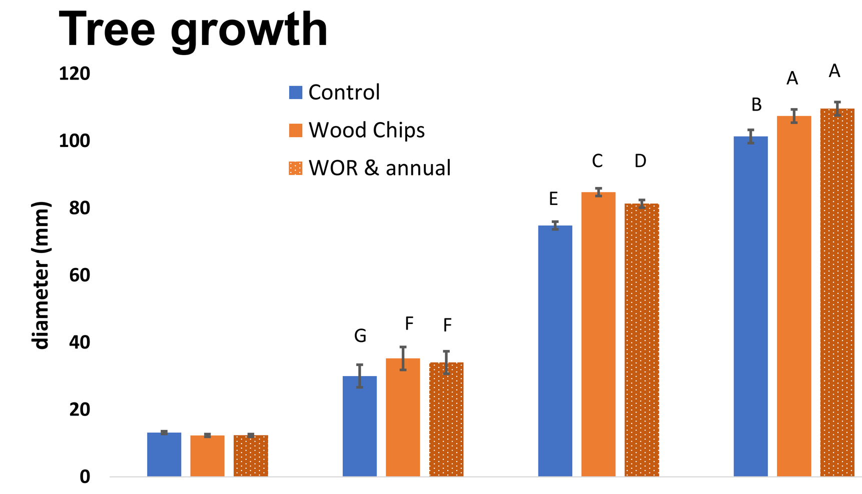


Figure 5

Type III Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Treatment	2	746	101.11	<.0001
N level	2	746	0.14	0.8709
Treatment*N level	4	746	3.41	0.0089
year	2	746	9319.18	<.0001
year*Treatment	4	746	7.12	<.0001
year*N level	4	746	0.29	0.8827
year*Treatment*N level	8	746	0.79	0.6108

Yield

No significant kernel lb/ac yield differences resulted in response to N level or WOR treatment in the 3rd or 4th leaf. WOR treatments yield trended higher than the control treatments, although not significantly. Evidence of wood chip decomposition, elevated soil C and N levels, tree growth, and yield data suggests greater N availability in the rootzone of WOR treatments soon after establishment. Excess N applications above the standard recommendation are not necessary in the early establishment and bearing years after the first season.

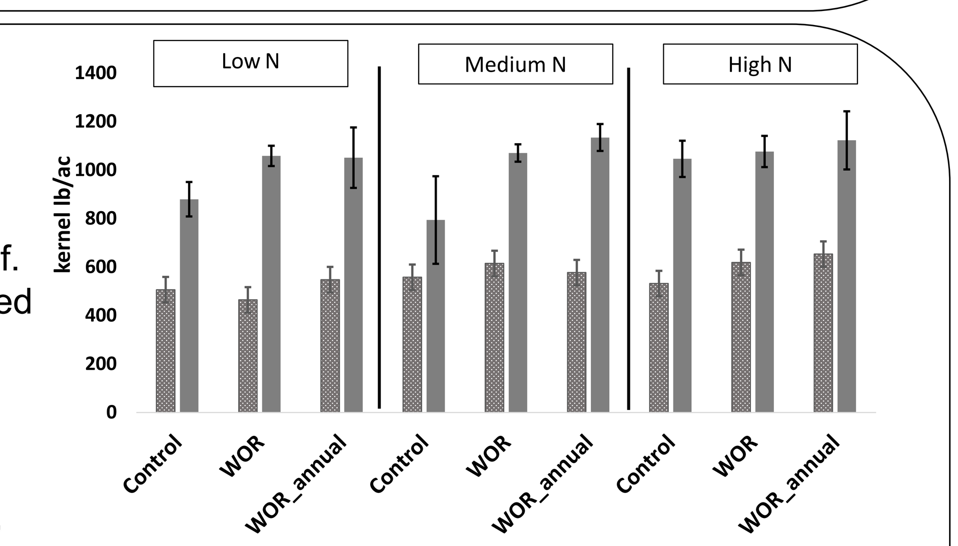
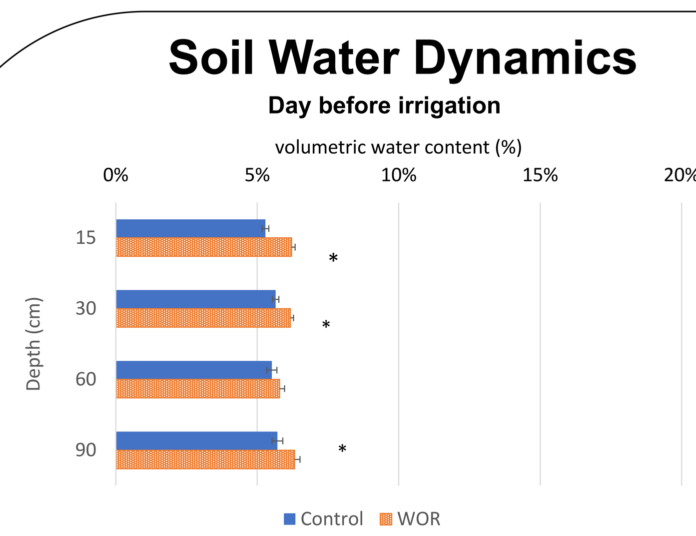


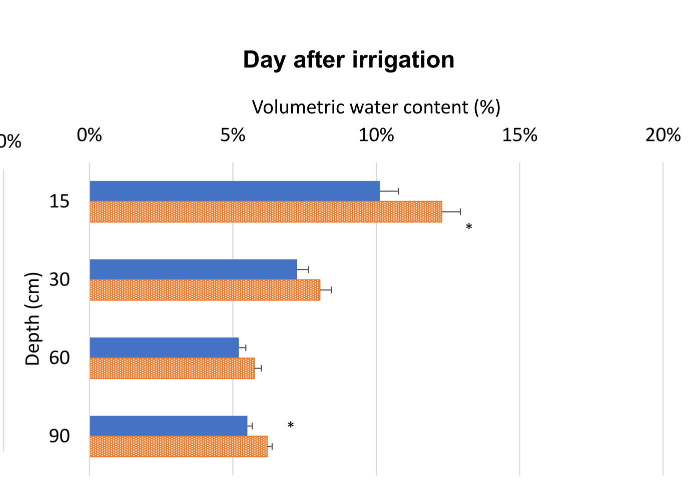
Figure 6

Type III Tests of Fixed Effects

	Num DF	Den DF	F Value	Pr > F
2021	2	8	0.92	0.4362
treatment	2	8	0.92	0.4362
N_level	2	24	2.57	0.0972
treatment*N_level	4	24	0.63	0.649
2022				
treatment	2	8	3.2	0.095
N_level	2	24	1.57	0.2282
treatment*N_level	4	24	1.28	0.3037

Soil Water Dynamics





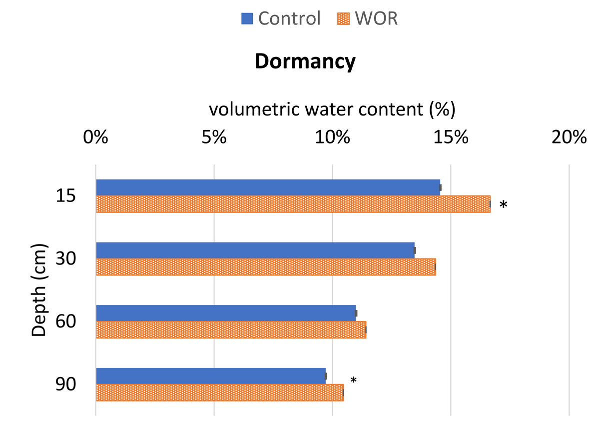
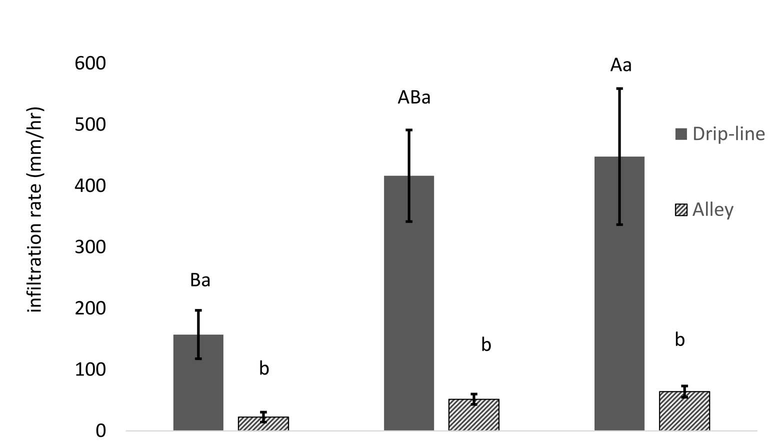


Figure 7. Soil moisture was monitored year-round including during dormancy, early in the season prior to the start of irrigation, and between irrigation events during the growing season with a neutron probe in 15 cm increments to 90 cm. Significantly higher water content resulted throughout the year in the top 15 cm of soil and at the deepest depth of 90 cm.

Significantly higher moisture levels observed at the deepest measured depth, suggests improved water permeability in the WOR treatments. Higher water content and sustained soil moisture between irrigation events could have significant cumulative water savings over the course of a season and through the lifetime of the orchard. Growers could potentially delay the first irrigation, as is possible after a wet winter, when a pressure chamber is used to confirm adequate plant water status.



Type III Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Treatment	2	8	3.37	0.0868
location	1	38	40.02	<.0001
Treatment*location	2	38	2.91	0.0664

Figure 8. soil infiltration rate (mm/hr) in the wetted berm and the alleyway

Soil infiltration rates were significantly higher in the WOR treatments compared to the control in the dripline, but no different in the alleyway. This suggests the repeated wetting and fertilization, and rapid turnover of the wood biomass is improving the soil structure allowing water to move into the soil and down through the rootzone

Conclusions

- Wood chips decompose rapidly in the wetted berm but enhanced soil C and N levels suggesting rapid mineralization following WOR and replanting
- 82% of the original alleyway biomass remained in the soil three years after incorporation, suggesting potential for long term C storage as wood biomass in the unirrigated, unfertilized portions of the orchard
- Soil C and N, soil moisture content, infiltration rates, tree growth, and yield show WOR treatment enhances soil function
- Trial data found no growth benefit from excess N applications. Improved nutrition and growth, and unchanged yield indicate standard fertilization practices can resume in the second growing season

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