Nutrient Availability, Water Use and Food Safety of Organic Matter Amendments

Sat Darshan S. Khalsa[1], Hannah C. Lepsch[1], Stephen C. Hart[2], Jeffery A. McGarvey[3], Brent A. Holtz[4] and Patrick H. Brown[1]

[1]*Department of Plant Sciences University of California Davis*

[2]*School of Natural Sciences University of California Merced*

[3]*USDA ARS Food Toxin Prevention and Detection Unit Albany*

[4]*San Joaquin County Cooperative Extension University of California Agriculture and Natural Resources*

Significance and Project Summary

Use of conventional fertilizers for nitrogen (N), phosphorus (P), and potassium (K) nutrition results in beneficial outcomes for agronomic performance, but also comes with important economic and environmental costs. Water is a limiting resource in California and there is a critical need to optimize water use efficiency in orchard systems. Organic matter amendments (OMA) offer a viable option to supplement or partially substitute chemical fertilizers, and improve soil water retention and tree water stress.

We examined the effects of OMA source, composted manure and green waste compost, and timing treatments on tree growth and nutrient status, nutrient availability, food safety, soil moisture and tree water status. In 2015-2016, we scaled our trial to determine the impact of the treatments on the whole tree by measuring soil moisture to a depth of 6 ft, stem water potential, and monitoring trees for changes in trunk circumference and leaf nutrient status.

Objectives

- Screen organic matter amendments and almond fruit for human pathogens
- Estimate OMA decomposition and nutrient release rates and changes in total soil organic carbon (TOC) and nitrogen (TN)
- Measure nutrient availability in the top soil (0 – 4 in) from OMA sources
- Compare N availability in the active rooting zone (0 – 20 in) between OMA treatments
- Measure the effect of timing of composted manure on soil moisture and stem water potential

Materials and Methods

We established a research trial in a non-bearing almond orchard near Escalon, CA. The study site is a Manteca fine sandy loam planted in 2014 with 'Nonpareil' grafted on 'Hanson' rootstock. The experimental design is a randomized complete block design with three treatments including composted dairy manure (Nunes Dairy Farm Escalon, CA), green waste compost (Recology San Francisco, CA), and a control. We applied each OMA source in in either April or October at the equivalent rate of *4 tons per acre* at 37% moisture on the tree berm. All plots received the same amount of water and supplemental fertilizer. Plots were maintained with *root exclusion*.

We scaled our trial to determine the impact of the treatments on the whole tree and installed access tubes that extend 6 ft deep to monitor soil moisture in the soil profile. Each month PRS™ probes (Western Ag Innovations Saskatoon, Canada) were deployed where the resin membranes absorbed nutrients including NH_4^+, NO_3^-, PO_4^{3-}, and K^+. We integrated nutrient release curves for N availability in the top soil (0 – 4 in), active rooting zone (0 – 20 in) and potential leaching. We also began monitoring trees for changes in trunk circumference, leaf nutrient status and SWP. Samples of organic matter amendments and almond fruit were examined for the presence of the human pathogens using cultural methods.

Table 1. Total organic carbon (g C kg^{-1} soil) and total nitrogen (g N kg^{-1} soil) from soils (0 – 20 in) treated with composted manure, green waste compost or as an untreated control. Soils were sampled during April 2015 at the beginning and end of the experiment in October 2015. Values are means (n = 4). Significant (p < 0.05) differences between treatments using a Tukey test are reported by different letters within the same column.

	Total organic carbon				Total nitrogen			
	g C kg^{-1} soil				*g N kg^{-1} soil*			
	April		October		April		October	
Control	3.75	a	4.65	b	0.49	a	0.54	b
Composted Manure	3.04	a	5.94	a	0.44	a	0.65	a
Green Waste Compost	3.46	a	5.77	a	0.50	a	0.65	a
p value	0.360		*0.010*		0.790		*0.008*	

Table 2. Total inorganic nitrogen (NH_4^+ + NO_3^-), orthophosphate (PO_4^{3-}), exchangeable potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), iron (Fe^{2+}) and zinc (Zn^{2+}) per 10 cm^2 of resin membrane surface from PRS™ probes or resin stakes. Values are means (n = 4). Significant (p < 0.05) differences between treatments using a Tukey test and are reported by different letters within the same column.

	NH_4^++NO_3^-		PO_4^{3-}		K^+		Ca^{2+}		Mg^{2+}		Fe^{2+}		Zn^{2+}	
	ug ion 10 cm^{-2} membrane growing $season^{-1}$													
Control	3647	a	31.56	b	164.8	c	14070	a	3025	a	22.34	b	8.611	b
Composted M	2874	a	123.7	a	1343	a	12850	a	3058	a	23.22	b	14.09	a
GW Compost	3326	a	49.85	b	412.6	b	13240	a	2948	a	38.02	a	16.58	a
p value	0.177		*<0.001*		*<0.001*		0.053		0.581		*<0.001*		*0.001*	

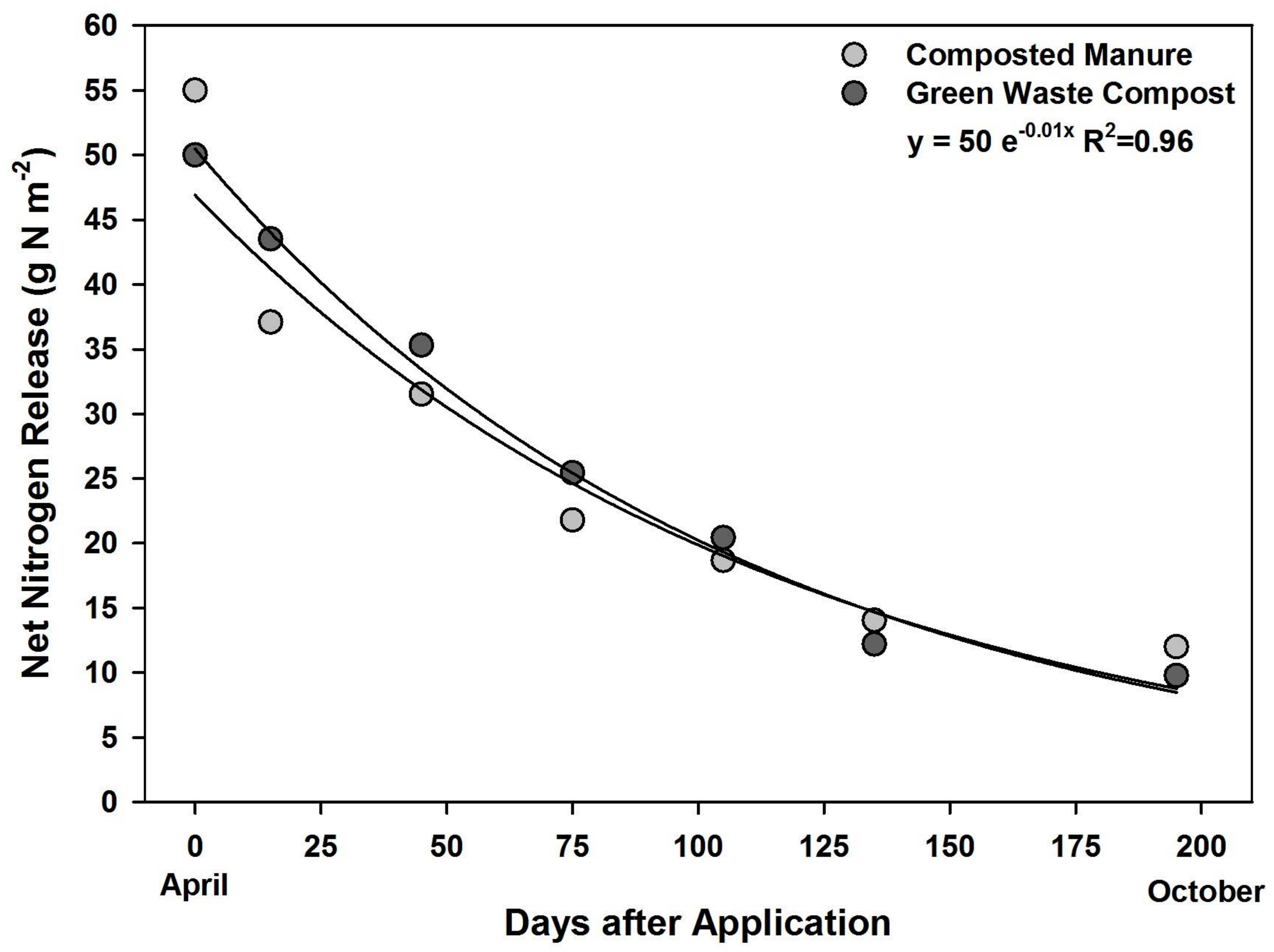

Figure 1. Net nitrogen (N) release represented by mass loss of N from organic matter amendments (g N m^{-2}) from composted manure and green waste compost from day 0 in April to day 200 in October is shown. Values for both organic matter amendments are fit to an exponential decay equation and reported with R^2 for goodness of fit.

Results

Chemical Characteristics and Human Pathogen Presence

All samples of composted manure and green waste compost were negative for all pathogens examined including *Salmonella enterica*, *Escherichia coli* O157:H7, and *Listeria monocytogenes*. Almond fruit was also screened and it is free of pathogens.

Decomposition and Nutrient Release

Both composted manure and green waste compost increased TOC and TN demonstrating that the decomposition of OMA results in the movement of organic C and N into the soil (Table 1). After 200 days in the field from April to October 2015, approximately 80% of the N from OMA was released. This process followed an exponential decay where N was released more rapidly in April and progressively decreased during the growing season (Figure 1).

Table 3. Soil moisture and stem water potential averages by treatment and season are shown. Treatments are composted manure (Composted M) applied in October 2015 or April 2016. The unit for soil moisture is hydroprobe counts. Stem water potential is in pressure bars. SE is standard error, and CI is confidence interval

Season	Treatment	Mean	SE	95% CI		Mean	SE	95% CI	
		Counts				*Bars*			
Spring	Control	7347	160.8	7028	7665	-9.45	0.40	-8.62	-10.3
	Composted M October	8252	126.9	8000	8503	-9.03	0.36	-8.28	-9.78
	Composted M April	8495	129.4	8239	8751	-8.15	0.44	-7.24	-9.05
Summer	Control	6387	117.1	6156	6618	-15.0	0.49	-14.0	-16.0
	Composted M October	7045	93.88	6860	7230	-13.2	0.48	-12.2	-14.2
	Composted M April	6655	93.17	6471	6839	-13.8	0.53	-12.7	-14.9

Table 4. Soil moisture and stem water potential averages by treatment and depth are shown. Treatments are composted manure (Composted M) in October 2015 or April 2016. The unit for soil moisture is Hydroprobe counts. Stem water potential is in pressure bars. SE is standard error, and CI is confidence interval.

Depth	Treatment	Mean	SE	95% CI	
		Counts			
4 – 24 in	Control	6488	98.35	6294	6682
	Composted M October	7309	111.4	7088	7529
	Composted M April	7202	117.1	6970	7433
24 – 60 in	Control	7036	167.6	6705	7367
	Composted M October	7724	120.5	7486	7962
	Composted M April	7576	138.4	7302	7849

Soil Moisture

Preliminary results indicate greater soil water retention with composted manure compared to the control. Average Hydroprobe soil moisture readings were higher for both April and October applications compared to the control, with the greatest effect observed from application timed in October (Table 3). Trees with OMA treatment had higher stem water potentials (SWP) than those in the control. These results indicate lower water stress for trees with OMA, which is supported by the correlation between SWP and soil moisture.

More Results

Nutrient Dynamics

Inorganic N adsorbed to resin stakes in the top soil (0 – 4 in) was not different between the normally fertilized control and OMA treatments. However there were significantly greater P, K, Fe and Zn availability from the OMA treatments (Table 2). Soil PO_4^{3-} was significantly greater for the composted manure compared to the green waste compost and the control. There were significant differences between green waste compost and the control for Fe^{2+} and Zn^{2+}. Exchangeable K^+ for OMA treatments was significantly greater than the control.

There were no significant differences in net N mineralization between OMA treatments and the control. Potential N leaching through the active rooting zone (0 – 20 in) did not significantly differ between OMA treatments and the control as determined by inorganic N adsorption to resin beads (Figure 2). Furthermore, there were no differences between net N mineralization and potential N leaching. These results suggest the N released from OMA is not being lost from the active rooting zone (0 – 20 in) at a rate greater than the control.

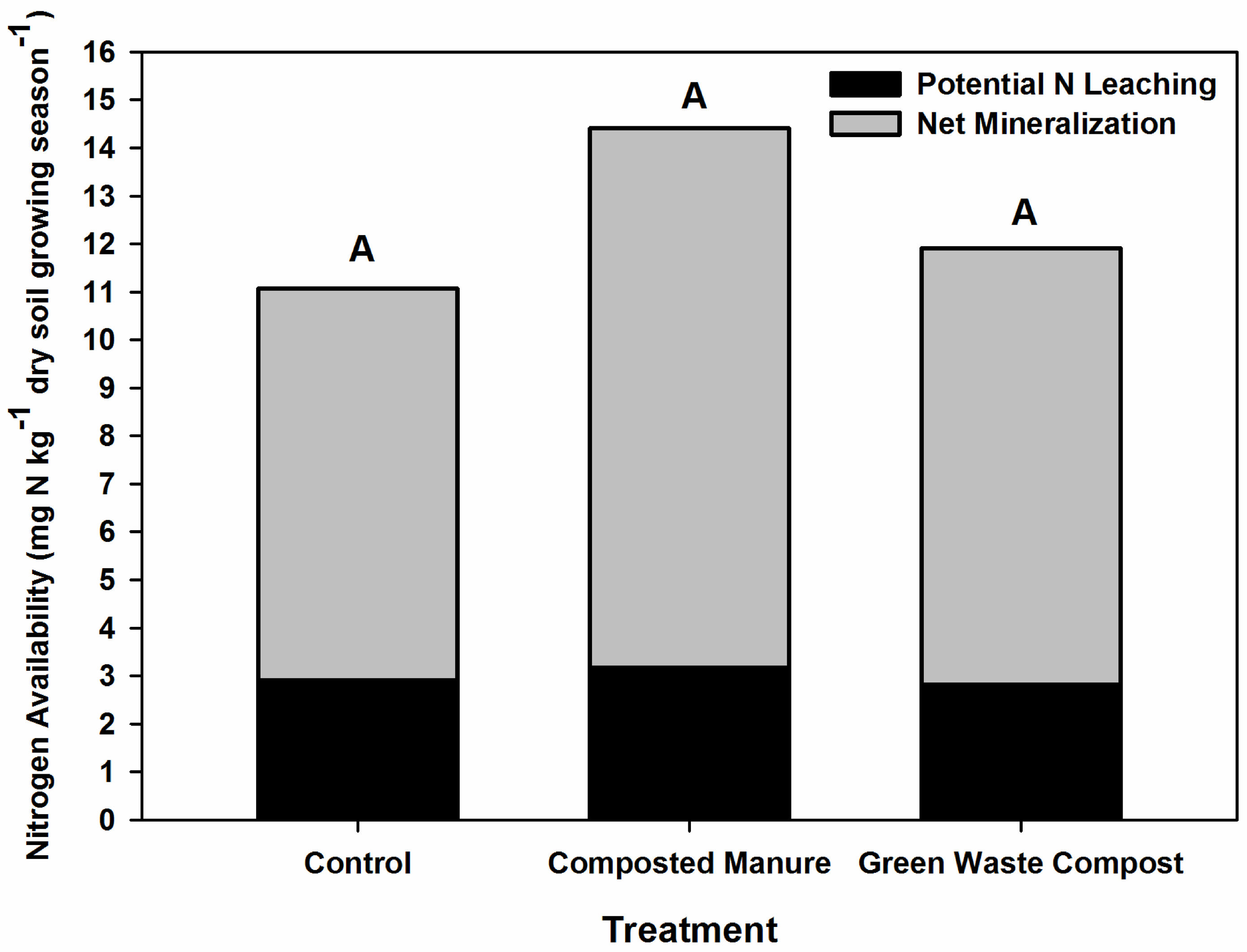

Figure 2. Nitrogen (N) availability (mg N kg^{-1} dry soil growing $season^{-1}$) from composted manure, green waste compost and an untreated control represented by the sum of potential N leaching and net N mineralization is shown. Potential N leaching was estimated by the adsorption of inorganic N (NH_4^+ + NO_3^-) to resin beads (0 – 20 in) attached to the base of a soil core under root exclusion during the growing season from April to October 2015. Net mineralization was estimated by changes in soil inorganic N (NH_4^+ + NO_3^-) within the same soil core (0 – 20 in) from April to October 2015. There were no significant differences between treatments.

Conclusions

Integrated nutrient management of organic matter amendments offers a viable option to supplement conventional fertilizers with other associated co-benefits. Composted manure and green waste compost significantly increased TOC and TN in the soil. N release rate did not differ between OMA sources and decreased exponentially through the growing season. Soil moisture in the rooting zone was higher with the composted manure treatment and trees with OMA treatment exhibited lower water stress. These results potentially indicate higher water infiltration and water availability due to improved soil quality.

Inorganic N in the top soil did not significantly differ between the control and OMA treatments, however both treatments were lower than the control. This result suggests that greater N immobilization occurred with OMA treatments. There were no differences in potential N leaching through the active rooting zone between OMA treatments and the control. Furthermore, no difference in N mineralization and potential N leaching was observed, suggesting that N released from OMA application is retained in the active rooting zone.

Acknowledgements

We express our gratitude to Ples Due, Matt Due, Matthew Read, Sam Metcalf, Dan Rivers, Abass Bella and Juliana Wu and acknowledge the Almond Board of California for funding this research.

Reference

Chalk P.M., Magalhaes A.M.T., Inacio C.T. (2013) Towards an understanding of the dynamics of compost N in the soil-plant-atmosphere system using N-15 tracer. Plant and Soil 362:373-388.