Effects of Timing Food Safe Sources of Organic Matter Amendments on Nutrient Cycling and Water Use

Project Numbers: **17-PREC7-Brown/Khalsa**

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Objectives:

1) To measure the effects of timing different sources of food safe organic matter amendments on tree growth, leaf nutrient status, nutrient availability and water use
2) To compare the effects of food safe organic matter amendments on tree growth, leaf nutrient status and changes in soil nutrients across satellite trials (Funded by CDFA Specialty Crops Block Grant Program)
3) To evaluate nutrient availability of different sources of food safe organic matter amendments on different soil types (In partnership with UC Merced and funded by CDFA Specialty Crops Block Grant Program)
4) To monitor for human pathogens and microbial diversity on almond fruit (In partnership with USDA ARS)
5) To outreach the results of these projects to growers and other stakeholders during a field day and a workshop (Funded by CDFA Specialty Crops Block Grant Program)

Interpretive Summary:

Use of synthetic fertilizer for nitrogen (N), phosphorus (P), and potassium (K) nutrition results in beneficial outcomes for agronomic performance, but also comes with economic and

environmental costs. Organic matter amendments (OMA) offer a viable option to supplement or partially substitute synthetic fertilizers. We examined the effects of OMA source and timing treatments on tree growth and nutrient status, soil nutrient availability and water use. We applied composted manure and green waste compost in either fall or spring, and measured their effects on tree growth and nutrient status, nutrient availability, food safety, soil moisture and stem water potential (SWP). Multiple effects from OMA source and timing treatments were identified in this study and differences were identified between OMA source and timing treatment as well as between year one in 2016 and year two in 2017. There were no significant differences in tree growth between OMA treatments and the grower control. During 2016, leaf N, P and K concentrations from OMA sources were nearly equal or lower than the grower control while all leaf nutrient concentrations from the OMA sources were greater than the grower control in 2017 although not signficiantly different. This result shows an increase in nutrient availability and subsequent uptake from OMA during the transition from 2016 to 2017.

In 2016, soil total organic carbon (TOC) was significantly greater for green waste compost compared with other OMA treatments and the grower control. The effect on total nitrogen (TN) was the same but, without any significant differences. Overall, all the TOC and TN concentrations for OMA sources and the grower control decreased in 2017 suggesting soil organic matter built up during 2016 was rereleased in 2017. This result is consistent with the greater 2017 leaf nutrient concentrations. There were no significant differences in soil inorganic N in 2016 and 2017 between OMA sources and the grower control however, inorganic N increased from OMA sources relative to the grower control in 2017. This result demonstrates that N availability from OMA sources increased from 2016 to 2017. Soil inorganic P was influenced in 2016 by OMA sources compared to the grower control. In 2017, inorganic P from composted manure was greater than both green waste compost and the grower control although not significantly different. OMA sources were greater in soil exchangeable K compared to the grower control in 2016 and 2017. Furthermore, OMA applied in fall was significantly greater in exchangeable K in 2016, but OMA applied in spring was greater than fall in 2017. Nitrogen availability was significantly greater from OMA sources compared to the grower control in 2017. In 2016, N availability from OMA applied in spring was significantly greater than fall while the opposite was observed in 2017. These results further demonstrate N availability for OMA sources requires more than one year to become available.

Soil moisture measured by volumetric water content (VWC) averaged by month and treatment was 7.0% to 20% higher in the composted manure (CM) timing treatments compared to the grower control. The CM fall treatment had the highest mean VWC in the majority of months. We measured the largest difference in July 2016. Results from 2017 show similar trends, but treatments were no longer significant. This outcome could be related to greater application of irrigation water driving OMA mineralization. Tree SWP averaged by month and treatment was 0.03 to 1.50 MPa less negative in the CM treatments than the grower control in 2016 and 2017. Almond fruit from all OMA treatments contained no human pathogens. These results demonstrate that application of *composted* OMA with exclusion periods of greater than 120 days are a food safe practice. Results from satellite trials on different soil types funded by a CDFA Specialty Crop Block Grant are presented for comparison to the results of this trial.

Materials and Methods:

We completed the 2nd year of a field-scale OMA research trial in a 4th leaf almond orchard outside of Escalon, CA in San Joaquin County in 2017 (data presented herein) and repeated the same treatments and leaf/soil nutrient measurements (excluding resin cores) for a 3rd year in 2018. The study site is a Manteca fine sandy loam planted in 2014 with 18' tree and 22' row spacings to varieties of 'Nonpareil' and alternating pollinators grafted on 'Hanson' rootstock. OMA sources were compared to the grower control managed with synthetic fertilizer only. Fertilizer and water was delivered through a microsprinkler irrigation system. The experimental design is a randomized complete split block design with four blocks and three main plot treatments including composted dairy manure (Nunes Dairy Farm Escalon, CA), green waste compost (Recology San Francisco, CA), and the grower control (conventional management) and two timing split block treatments where OMA was applied as mulch in fall (October 2015, 2016 and 2017) or spring (April 2016, 2017 and 2018) at 4 tons per acre. For soil moisture and stem water potential, spring and fall applied composted manure treatments and untreated grower control plots were sampled. The same OMA source and grower control treatments were applied in February or April 2016, 2017 and 2018 at each of the four proximal satellite trials on different soil types and irrigation systems funded from 2015 – 2018 by the by a CDFA Specialty Crops Block Grant.

Measurements of trunk circumference from all data trees were made during January 2016, 2017 and 2018. The change in trunk circumference between the three sampling dates was conducted as an indicator of tree growth (cm yr^{-1}). In July 2016, 2017 and 2018, almond leaves were sampled, oven-dried and ground to pass through 60 mesh prior to analysis for total N, P and K (2014). During post-harvest (October 2016 and 2017), soils from a depth of 0 – 50 cm were sampled, ground, carbonates removed and analyzed for total organic carbon (TOC) and total nitrogen (TN). Soil aliquots were extracted in 2*M* KCl for analysis of ammonium (NH_4^+), nitrate (NO_3^-), in 0.5*M* Na_2CO_3 for Olsen phosphate (PO_4^{3-}) and in 1*M* NH_4-acetate for exchangeable K. In October 2015 and 2016, thin-walled PVC pipe (15 cm diameter and 50 cm long) was driven into the soil. The soil core in the PVC pipe was removed and a nylon-mesh bag containing mixed-bed ion exchange resin (IER) beads was secured to the bottom of the core with silicone glue. The soil cores were then returned to the hole. Resin beads adsorb NH_4^+ and NO_3^-, but still allow water to pass freely out of the core (Hart and Firestone, 1989). Cumulative N availability (mg N kg^{-1} soil yr^{-1}) was estimated by summing the amount of inorganic N ($NH_4^+ + NO_3^-$) adsorbed to resin beads after one year and changes between initial and final soil inorganic N within the same soil core. All analyses were conducted using a mixed effect model in SAS statistical software.

Soil moisture was measured using a CPN 503TDR Hydroprobe in duplicate in fall and spring timing treatments of composted manure and untreated grower control. During installation of access tubes, soil samples were taken to determine bulk density at 30 cm increments to 150 cm. Soil texture and irrigation emitter flow rate were measured to assess orchard uniformity. The probe measured soil moisture within a 20cm radius; and measurements are taken at 30 cm increments. Measurements were conducted every 2 weeks, 1 to 2 days before irrigation to reflect maximum soil moisture depletion. Whole tree transpiration was evaluated by measuring midday SWP between fall and spring timing treatments of composted manure and untreated grower control. SWP was measured using a Soil Moisture model 3000 pressure chamber on the same trees selected for soil water measurements. A non-transpiring leaf near the trunk was selected and bagged at a minimum of 10 minutes prior to taking the SWP measurement. Readings were taken between 1:00 pm – 3:30 pm and on the same day as soil moisture measurements. All analyses were conducted using a mixed effect model in SAS statistical software. OMA samples were collected prior to application and fruit samples were collected during harvest 2016 and 2017 and assayed for the presence of *Salmonella enterica*, *Escherichia coli* O157:H7, and *Listeria monocytogenes* by cultural enrichment followed by immunomagnetic separation and growth on selective media (FDA, 1998).

All data is presented for the Escalon trial funded by the Almond Board of California since 2015. Subsequent data for two of the four satellite trials funded by a CDFA Specialty Crop Block Grant are referred to in supplementary tables. The Patterson site is 'Nonpareil' on 4th leaf in 2017 located in West Stanislaus County on a Vernalis loam and the Denair site is 'Nonpareil' on 3rd leaf located in East Stanislaus County on a Madera sandy loam. Two additional satellite trials operated by Roger Duncan are located in Central Stanislaus County and those data have been collected and are being developed by Yocelyn Villa and Stephen Hart at UC Merced. Furthermore, a farm advisor field day was hosted on May 23rd at one of the satellite trials and a workshop was given on June 8th in Modesto. Both events were attended by 25 – 50 participants including farm advisors, growers, NRCS and RCD staff and UC graduate students.

Results and Discussion:

Tree status of young trees (3rd – 6th leaf) measured by trunk growth and leaf nutrient concentrations is one indicator for growers to evaluate agronomic performance of OMA use as a part of nutrient management programs. Over two years from January 2016 – 2018 the average change in trunk circumference for all trees was 9.33 cm yr^{-1} with no differences between OMA treatments and the grower control as well as at the satellite trials (**Tables 1 and S1**). Leaf nutrients of N, P and K were not significantly different between OMA sources and the grower control in 2016 and 2017 (**Table 2**). However, clear trends emerged during the transition from the first to the second year. During 2016, leaf N, P and K concentrations were nearly equal or lower than the grower control. While in 2017 all nutrient concentrations from the OMA sources were greater than the grower control. This result shows an increase in nutrient uptake from OMA during 2016 to 2017. Timing of OMA application in fall or spring was significantly different or nearly significantly different ($p = 0.06$) during 2016 and 2017 for all nutrients. There was no difference in OMA timing in 2016 for leaf N but, OMA applied in fall was greater than spring in 2017. For leaf P and K, OMA applied in spring was greater than fall in 2016 and the reverse was true for P in 2017. Spring applied OMA resulted in greater leaf K in 2017. OMA N and P require biological transformation to become plant available (Marinari et al., 2000). Spring applied OMA is more readily available while fall applied OMA incorporates into the soil organic matter and is released later. Greater nutrient uptake in 2017 may be driven from nutrient release of 2016 applied OMA during the 2017 production cycle. Finally, leaf K concentration may be facilitated by greater K availability from spring applied OMA on sandy soils. Greater leaf K concentrations from OMA sources were observed in Denair on a sandy loam comapred to a loamy soil in Patterson (**Table S2**).

Changes in soil organic matter measured by TOC and TN are the main soil parameters to determine if OMA are accumulating or depleting in orchard soil. In 2016, soil concentrations of

TOC from the active rooting zone (0 – 50 cm) were significantly greater for green waste compost compared to composted manure and the grower control and composted manure was greater than the grower control though not significantly different (**Table 3**). The same trends were apparent for TN but, without any significant differences. Furthermore, OMA applied in fall (October 2015) was significantly greater than OMA applied in spring (April 2016) most likely due to increased time for decomposition and incorporation into soil organic matter. However, the results in 2017 were no longer significant for TOC and the effect on TN lessened. Overall, all TOC and TN from OMA sources and the grower control decreased in 2017 suggesting that soil organic matter build up during 2016 was rereleased in 2017. This result is consistent with the increased 2017 leaf nutrient concentrations. An increase in grower applied irrigation water from 33 cm to 51 cm may have contributed to net mineralization of soil organic C and N as evidenced by the decrease in TOC and TN concentrations in both OMA treatments and the grower control. This outcome may justify a need to increase the OMA rate as the orchard matures. An increase in TOC and to a lesser extent TN was observed at both the Patterson and Denair satellite trials with a greater effect from composted manure (**Table S3**).

Concentrations of soil inorganic N (NH_4^+-N + NO_3^--N), inorganic P (PO_4^{3-}-P) and exchangeable K (K^+) sampled after harvest in the active rooting zone (0 – 50 cm) represent residual nutrient that may be at risk for loss (N) or may accumulate for the next growing season (P and K). There were no significant differences in inorganic N in 2016 and 2017 between OMA sources and the grower control however, inorganic N increased relative to the grower control in 2017 (**Table 4**). This result demonstrates that N availability from OMA sources increased from 2016 to 2017. In 2016, OMA applied in spring was significantly greater than fall while fall was greater than spring in 2017 although no significantly different. OMA applied in fall of 2016 is likely becoming more available in 2017 coupled with the OMA applied in fall of 2017 results in a cumulative effect. Inorganic P was nearly significantly different in 2016 due to greater concentrations from OMA sources compared to the grower control. In 2017, inorganic P concentrations from composted manure were greater than both green waste compost and the grower control although not significantly different. OMA applied in fall was significantly greater in inorganic P concentrations in 2016 and greater than OMA applied in spring in 2017 although no longer significantly different. These results coupled with leaf P concentrations that were significantly greater in spring in 2016 and fall in 2017 suggest P availability and uptake may be tightly coupled in 2016. Greater inorganic P from OMA applied in fall 2016 was retained in the active rooting zone and taken up during the following growing season in 2017. OMA sources were greater in exchangeable K compared to the grower control in 2016 and 2017, however only composted manure was significantly greater than the grower control in 2016. OMA applied in fall was significantly greater in exchangeable K in 2016, but OMA applied in spring was greater than OMA applied in fall in 2017. Availability of K for uptake may also be a function of soil type. In 2017, both satellite trials in Paterson and Denair showed higher exchangeable K from OMA sources while the impact on leaf K was greater in Denair than Patterson. More sandy soils with lower cation exchange capacity result in greater K availability for tree uptake compared to loamy soils where K derived from OMA sources is more likely to build up in the soil and become plant available in subsequent years. (**Table S4**).

Annual N availability equals the sum of net N mineralization measured by the change in soil inorganic N in the active rooting zone (0 – 50 cm) and N movement through the active rooting zone measured by N adsorption to resin beads. Nitrogen availability was greater from OMA sources compared to the grower control in 2016 and 2017, but only significantly different in 2017 (**Table 5**). OMA applied in spring in 2016 was more available than fall applied OMA, however OMA applied in fall of 2016 become available the next year during 2017. This observation is supported by a decrease in TN from 2016 to 2017. The lack of leaf N response in 2017 from OMA sources is likely due to sufficient N application leading to non-limiting N availability. Overtime increased N availability from OMA sources allows for an estimate of partial synthetic N fertilizer substitution with OMA sources. Estimates of N availability on different soil types are being developed by Yocelyn Villa and Stephen Hart at UC Merced.

Soil moisture (VWC) averaged to 160 cm depth and across treatments decreased by 46% over both the 2016 and 2017 growing seasons (**Figure 1**). In 2016 the VWC dropped 40% from April to June, and we observed dry soil conditions until October. In 2017 VWC decreased evenly from April to September. The overall 2016 mean VWC in 2016 was 23% than the overall mean in 2017. The mean monthly VWC ranged from 22 to 41% higher in 2017 compared to 2016 except in September when soil as dry. We observed a progressive loss of soil moisture during the 2016 and 2017 growing seasons. The VWC averaged by month and treatment was 7.4% - 20% higher in the CM treatments relative to the grower control. The CM fall treatment had the highest mean VWC in the majority of months, and it was significantly greater than the grower control in July to October 2016. We measured the largest significant difference between treatments in July 2016 with 25% higher VWC in the CM fall treatment compared to the grower control. Results from 2017 show similar trends, but treatment differences were smaller and not significant. The lack of significant difference in 2017 could be related to more water applied and in 2017 compared to 2016. The CM fall treatment had higher average VWC than the CM spring treatment in all months except April 2016. The differences in mean monthly VWC between timing treatments ranged from 18 % higher to 8.3% lower VWC in the CM fall compared to the CM spring treatment. The VWC in the tree root zone (0 – 90 cm) was significantly higher in the CM fall relative to CM spring treatments. We observed an 18% increase in VWC in the tree rooting zone in the CM fall versus spring treatments.

The seasonal pattern in SWP differed between the 2016 and 2017 growing seasons in all treatments (**Figure 2**). Average monthly SWP was 0.07 to 0.25 MPa more negative from May to August 2016 compared to the same period in 2017. In 2016, water stress peaked mid-season in July 2016 at -0.97 MPa below baseline. In the 2017, SWP was less -0.7 MPa below baseline for most of the growing season, and we recorded the most negative SWP (-1.07 MPa) in September 2017 at nut harvest. Tree SWP averaged by month and treatment was 0.03 to 1.5 MPa less negative in the CM treatments than the grower control in the majority of months of the 2016 and 2017 growing seasons, but the effects were not significant in any month. The CM fall treatment had the lowest water stress (least negative SWP) from June to September 2016 which was 15% less than the grower control. Monthly average SWP was similar for all treatments from May to August 2017 with no apparent trends among treatments. In September 2017, overall tree stress levels increased and trees with CM fall treatment were least stressed.

Almond fruit from all OMA source and timing treatments were sampled before harvest and tested for presence or absence of human pathogens. All samples were reported as negative.

Table 1. Trunk growth (cm yr^{-1}) from January 2016 – 2018 between organic matter amendment (OMA) sources of composted manure and green waste compost and a grower control and OMA timing of application in spring or fall. Values are means with significant ($p < 0.05$) differences between treatments using a Tukey test.

	Trunk growth *cm yr^{-1}*
Source	
Grower control	9.35 a
Composted manure	9.46 a
Green waste compost	9.18 a
p value	**0.77**
Timing	
Spring application	9.31 a
Fall application	9.33 a
p value	**0.91**

Table 2. Leaf N, P and K (%) sampled in July 2016 and 2017 between organic matter amendment (OMA) sources of composted manure and green waste compost and a grower control and OMA timing of application in spring or fall. Values are means with significant ($p < 0.05$) differences between treatments using a Tukey test.

	Leaf N *%*		Leaf P *%*		Leaf K *%*	
	2016	2017	2016	2017	2016	2017
Source						
Grower control	1.99 a	2.19 a	0.108 a	0.103 a	1.48 a	0.99 a
Composted manure	2.04 a	2.25 a	0.101 a	0.106 a	1.29 a	1.12 a
Green waste compost	1.97 a	2.22 a	0.100 a	0.108 a	1.36 a	1.08 a
p value	**0.37**	**0.41**	**0.20**	**0.20**	**0.30**	**0.17**
Timing						
Spring application	2.00 a	2.21 a	0.105 a	0.104 b	1.38 a	1.13 a
Fall application	2.01 a	2.26 a	0.096 b	0.110 a	1.27 b	1.07 a
p value	**0.63**	***0.06***	*<0.01*	*<0.01*	*<0.05*	***0.06***

Table 3. Total organic carbon (g C kg^{-1} soil) and nitrogen (g N kg^{-1} soil) sampled in October 2016 and 2017 from the active rooting zone (0 – 50 cm) between organic matter amendment (OMA) sources of composted manure and green waste compost and a grower control and OMA timing of application in spring or fall. Values are means with significant (p < 0.05) differences between treatments using a Tukey test.

	Total organic carbon *g C kg⁻¹ soil*		Total nitrogen *g N kg⁻¹ soil*	
	2016	2017	2016	2017
Source				
Grower control	4.74 b	4.28 a	0.50 a	0.43 a
Composted manure	5.21 b	4.70 a	0.54 a	0.46 a
Green waste compost	5.74 a	5.26 a	0.57 a	0.49 a
p value	*0.04*	**0.12**	**0.19**	**0.42**
Timing				
Spring application	5.16 b	4.65 a	0.54 a	0.46 a
Fall application	5.78 a	4.84 a	0.58 a	0.46 a
p value	*0.02*	**0.09**	**0.16**	**0.77**

Table 4. Soil ammonium (NH_4^+) and nitrate (NO_3^-), Olsen-phosphate (PO_4^{3-}), exchangeable potassium (K^+) sampled in October 2016 and 2017 from the active rooting zone (0 – 50 cm) between organic matter amendment (OMA) sources of composted manure and green waste compost and a grower control and OMA timing of application in spring or fall. Values are means with significant (p < 0.05) differences between treatments using a Tukey test.

	NH_4^+-N + NO_3^--N *mg N kg⁻¹ soil*		PO_4^{3-}-P *mg P kg⁻¹ soil*		K^+ *mg K kg⁻¹ soil*	
	2016	2017	2016	2017	2016	2017
Source						
Grower control	15.1 a	12.2 a	6.86 a	6.18 a	143 b	133 a
Composted manure	14.3 a	15.1 a	10.5 a	9.03 a	186 a	147 a
Green waste compost	16.4 a	16.4 a	10.0 a	6.60 a	167 ab	154 a
p value	**0.90**	**0.70**	***0.06***	**0.14**	*0.02*	**0.51**
Timing						
Spring application	21.4 a	14.1 a	8.07 b	7.01 a	156 b	155 a
Fall application	9.31 b	17.3 a	12.4 a	8.62 a	198 a	146 a
p value	*0.01*	**0.30**	*<0.01*	**0.26**	*0.01*	**0.65**

Table 5. Nitrogen (N) availability (mg N kg^{-1} soil yr^{-1}) sampled in October 2016 and 2017 represented by the sum of potential N leaching and net N mineralization for organic matter amendment (OMA) sources of composted manure and green waste compost and a grower control and OMA timing of application in spring or fall. Potential N leaching was estimated by the adsorption of inorganic N (NH_4^+ + NO_3^-) to resin beads (0 – 50 cm) attached to the base of a soil core. Net mineralization was estimated by changes in soil inorganic N (NH_4^+ + NO_3^-) within the same soil core. Values are means with significant (p < 0.05) differences between treatments using a Tukey test.

	N availability *mg N kg⁻¹ soil yr⁻¹*	
	2016	2017
Source		
Grower control	10.4 a	7.45 b
Composted manure	12.9 a	19.1 a
Green waste compost	14.2 a	19.2 a
p value	**0.60**	*0.02*
Timing		
Spring application	16.3 a	15.7 b
Fall application	10.8 b	22.1 a
p value	*<0.01*	*<0.01*

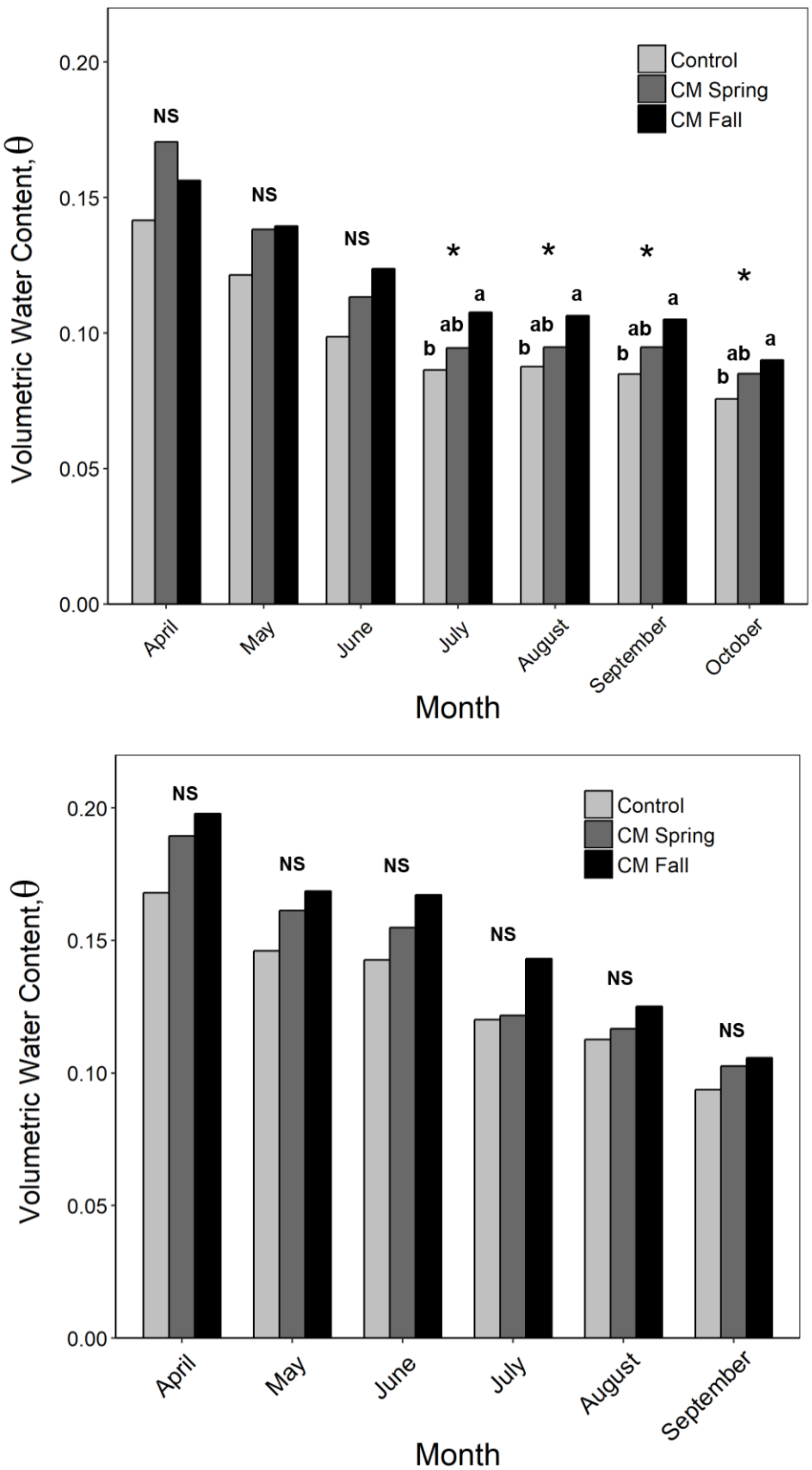

Figure 1. Soil moisture during the growing season from April to October 2016 and 2017 represented by monthly averages is shown. Treatments are composted manure applied in spring and fall. Soil moisture is the volumetric water content (Θ) of soil to 180 cm depth. Values represent least squared means and treatments sharing the same letter are not significantly different by Tukey comparisons. Asterisks * represent differences between treatments that were significant at $p < 0.05$. NS indicates no significant difference at $p > 0.05$.

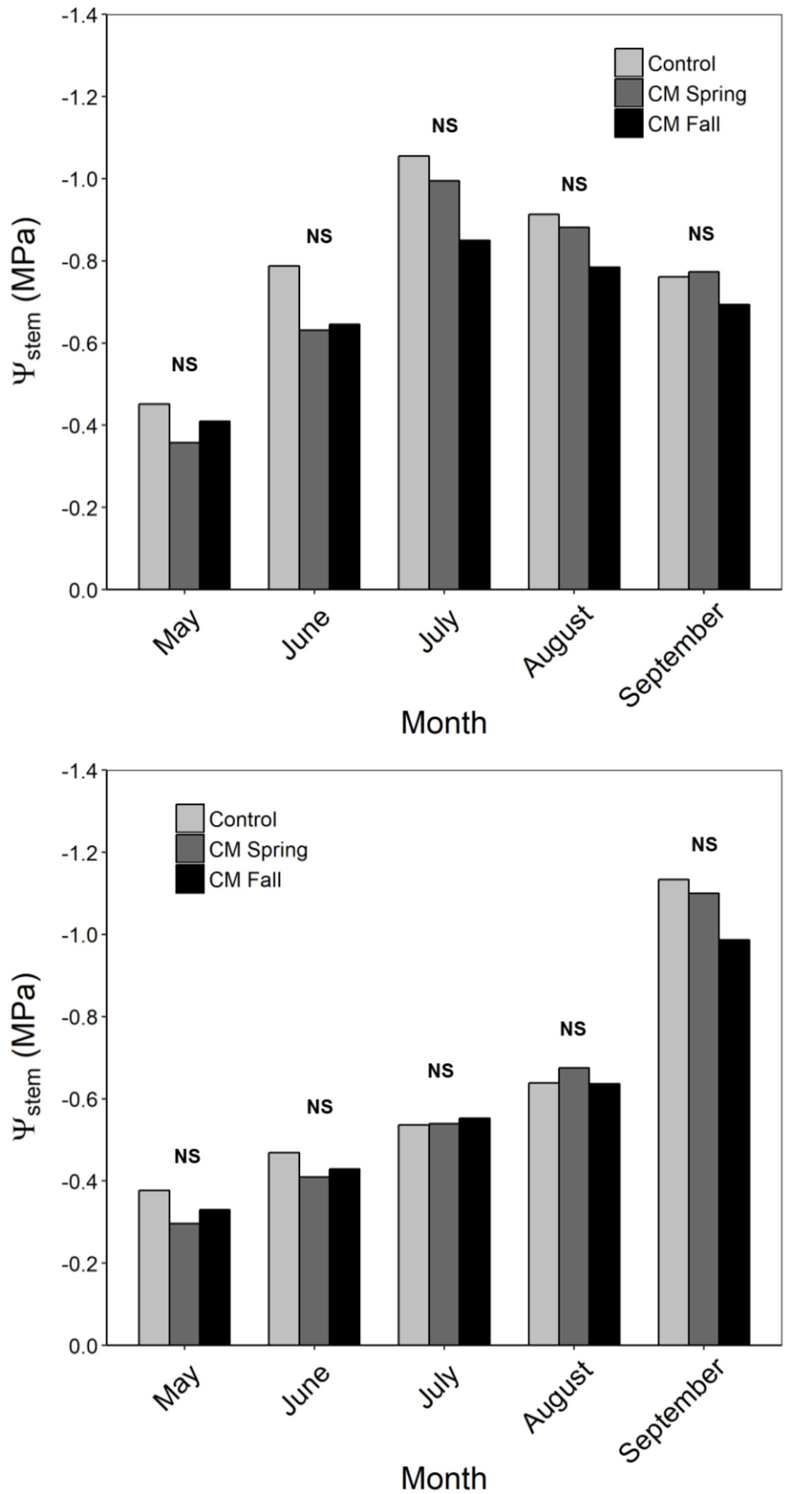

Figure 2. Stem water potential during the growing season from April to October 2016 and 2017 represented by monthly averages is shown. Treatments are composted manure applied in spring and fall. Stem water potential (Ψ) values are in pressure bars averaged by month from May to September 2016. Values represent least squared means and treatments sharing the same letter are not significantly different by Tukey comparisons. Asterisks * represent differences between treatments that were significant at $p < 0.05$. NS indicates no significant difference at $p > 0.05$.

Research Effort Recent Publications:

Khalsa S.D.S., Brown P.H. (In Press) Understanding nitrogen cycling in a deciduous irrigated permanent crop. Acta Horticultarae

Khalsa S.D.S., Brown P.H. (2017) Grower analysis of organic matter amendment in California orchards. Journal of Environmental Quality 46 (3), 649-658.

Khalsa S.D.S., Muhammad S., Brown P.H. (2017) Nitrogen budgeting in tree crops. Western Nutrient Management Conference 12, 43-46.

Khalsa S.D.S., Almanza C.A., Brown P.H., Smart D.R. (2016) Leaf litter C and N cycling from a deciduous permanent crop. Soil Science Plant Nutrition. 62:271-276.

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Hart S.C., Firestone M.K. (1989) Evaluation of three *in situ* soil nitrogen availability assays. Canadian Journal of Forest Research 19:185-191.

Marinari S., Masciandaro G., Ceccanti B., Grego S. (2000) Influence of organic and mineral fertilisers on soil biological and physical properties. Bioresour. Technol. 72:9-17.

Saa S., Brown P.H., Muhammad S., Olivos-Del Rio A., Sanden B.L., Laca E.A. (2014) Prediction of leaf nitrogen from early season samples and development of field sampling protocols for nitrogen management in almond (*Prunus dulcis* [Mill.] DA Webb). Plant Soil 380:153-163.

Supplementary Tables:

Table S1. Trunk growth (cm yr^{-1}) from January 2016 – 2018 between organic matter amendment (OMA) sources of composted manure and green waste compost and a grower control at two satellite trials on a Vernalis loam soil in Patterson, CA and a Madera sandy loam in Denair, CA. Values are means (n = 4) plus and minus (±) standard error.

2017	PATTERSON	DENAIR
	Trunk growth *cm yr^{-1}*	
Grower control	7.97 ± 0.39	10.8 ± 0.46
Composted manure	8.42 ± 0.67	10.5 ± 0.61
Green waste compost	9.22 ± 0.60	10.0 ± 0.44

Table S2. Leaf N, P and K (%) sampled in October 2017 between organic matter amendment (OMA) sources of composted manure and green waste compost and a grower control at two satellite trials on a Vernalis loam soil in Patterson, CA and a Madera sandy loam in Denair, CA. Values are means (n = 4) plus and minus (±) standard error.

2017	Leaf N	Leaf P	Leaf K
PATTERSON	*%*	*%*	*%*
Grower control	2.65 ± 0.03	0.12 ± 0.00	1.24 ± 0.09
Composted manure	2.72 ± 0.06	0.13 ± 0.00	1.25 ± 0.06
Green waste compost	2.70 ± 0.03	0.12 ± 0.00	1.36 ± 0.18
DENAIR			
Grower control	2.45 ± 0.03	0.13 ± 0.00	1.22 ± 0.09
Composted manure	2.54 ± 0.03	0.14 ± 0.00	1.55 ± 0.03
Green waste compost	2.52 ± 0.04	0.13 ± 0.00	1.47 ± 0.08

Table S3. Total organic carbon (g C kg^{-1} soil) and nitrogen (g N kg^{-1} soil) sampled in October 2017 from the active rooting zone (0 – 50 cm) between organic matter amendment (OMA) sources of composted manure and green waste compost and a grower control at two satellite trials on a Vernalis loam soil in Patterson, CA and a Madera sandy loam in Denair, CA. Values are means (n = 4) plus and minus (±) standard error.

2017	Total organic C	Total N
PATTERSON	*g C kg^{-1} soil*	*g N kg^{-1} soil*
Grower control	7.94 ± 0.30	0.95 ± 0.03
Composted manure	9.12 ± 0.31	1.06 ± 0.03
Green waste compost	8.37 ± 0.64	0.96 ± 0.07
DENAIR		
Groewr control	5.56 ± 0.75	0.59 ± 0.06
Composted manure	7.08 ± 0.33	0.67 ± 0.07
Green waste compost	5.29 ± 0.37	0.57 ± 0.03

Table S4. Soil ammonium (NH_4^+) and nitrate (NO_3^-), Olsen-phosphate (PO_4^{3-}), exchangeable potassium (K^+) sampled in October 2017 from the active rooting zone (0 – 50 cm) between organic matter amendment (OMA) sources of composted manure and green waste compost and a grower control at two satellite trials on a Vernalis loam soil in Patterson, CA and a Madera sandy loam in Denair, CA. Values are means (n = 4) plus and minus (±) standard error.

2017	NH_4^+-N + NO_3^--N	PO_4^{3-}-P	K^+
PATTERSON	*mg N kg^{-1} soil*	*mg P kg^{-1} soil*	*mg K kg^{-1} soil*
Grower control	19.4 ± 1.96	13.3 ± 1.75	215 ± 17.1
Composted manure	21.3 ± 3.42	15.5 ± 1.64	249 ± 20.6
Green waste compost	18.3 ± 3.14	16.0 ± 3.04	243 ± 28.0
DENAIR			
Grower control	5.42 ± 0.41	62.5 ± 4.43	59.0 ± 1.60
Composted manure	8.93 ± 1.22	66.4 ± 1.31	64.4 ± 2.82
Green waste compost	6.69 ± 1.49	58.3 ± 5.21	67.3 ± 3.57