The Impacts of Organic Matter Amendments on Nutrient Availability and Food Safety

Project No.: **14-PREC7-Brown**

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Objectives:

1) To establish one non-bearing orchard site representative of almond farming in the North San Joaquin Valley for demonstration of the use of different sources of organic matter amendments and secure suppliers of composted manure and green waste compost
2) To measure initial soil nutrient content including total nitrogen (TN), nitrate (NO_3^--N), ammonium (NH_4^+-N), phosphate (PO_4^{3-}-P) and exchangeable potassium (K^+) from different sources of organic matter amendments and cumulative changes in the rooting zone of the soil (0 – 50 cm) under root exclusion between the beginning and end of the growing season
3) To demonstrate mass loss of different sources of organic matter amendments to determine decomposition rates during the growing season and changes in total soil organic carbon (TOC) and TN under root exclusion between the beginning and end of the growing season
4) To test the effect of mulching different sources of organic matter amendments on soil moisture under root exclusion after microsprinkler irrigation during the growing season
5) To measure initial TOC and soil nutrient content including TN, NH_4^+-N, NO_3^--N, PO_4^{3-}-P and K^+ of different sources of organic matter amendments and changes in those nutrients in the top soil (0 – 10 cm) under root exclusion during the growing season.
6) To monitor different sources of organic matter amendments for presence and absence of human pathogens including *Salmonella enterica*, *Escherichia coli* O157:H7, and *Listeria monocytogenes* and microbial population structure prior to application and in the top soil (0 – 10 cm) during the growing season.

Interpretive 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. Food safe integrated nutrient management of organic matter amendments offers a viable option to supplement conventional fertilizers. We examined the effects of composted manure and green waste compost on nutrient availability, soil moisture, and *human* pathogen persistence under root exclusion where almond tree roots where excluded from the soil during the duration of the experiment. We established a research trial in a non-bearing orchard representative of almond farming in the North San Joaquin Valley to test different sources of organic matter amendments and the timing of their application. We found significantly greater soil moisture in the early part of the growing season for green waste compost compared to the control. As decomposition continued throughout the growing season, these differences were no longer significant. There were no difference in the decomposition rate between composted manure and green waste compost of ~4.5 lbs dry mass $acre^{-1}$ day^{-1}

There were no differences in the amount of total inorganic nitrogen (NH_4^+-N + NO_3^--N) adsorbed to the surfaces of resin membranes in the top soil (0 – 10 cm) despite the added N input for the organic matter amendments. This result suggests that N immobilization may be an active process that increases soil N retention. Greater inputs of P and K from composted manure resulted in significantly greater adsorption of PO_4^{3-}-P and K^+ to surfaces of resin membranes compared to green waste compost and significantly greater adsorption of the same ions from green waste compost compared to the control. These results suggest that organic matter amendments play an important role in N immobilization that can retain N in the soil and reduce the risk of N leaching to groundwater. Furthermore, organic matter amendments contain readily available P and K nutrients that may be able to act as a substitute for other conventional P and K fertilizers and lead to cost savings for the grower.

Materials and Methods:

Objective 1) We established a research trial in a non-bearing almond orchard outside of Escalon, CA in San Joaquin County. 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 interplanted rows of ‘Aldridge’ and ‘Carmel’; all trees were grafted on ‘Hanson’ rootstock. The results of our exploratory project identified composted manure and green waste compost as organic matter amendments utilized by the majority of almond growers. These sources were compared to a standard practice without organic matter amendments and only conventional fertilizer as the control. The experimental design is a randomized complete 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 an untreated control for 12 main plots. Plots were maintained with *root exclusion* where almond tree roots were excluded for the duration of the experiment by maintaining trenches in the top soil (0 – 10 cm) around the plots and PVC pipe barriers in the rooting zone of the soil (0 – 50 cm). Each plot contained 3 subsamples that were aggregated for analysis. Conventional fertilizer was injected in split applications through a microsprinkler system and all plots received the same rate of conventional fertilizer. In total, 48 subplots were established to test the effect of different organic matter amendments on soil moisture, nutrient availability, and pathogen persistence.

Objective 2) At each of these microplots (~ 1 m^2 plots), thin-walled PVC pipe (4" diameter by 20" long) was driven into the soil to a depth of 50 cm on March 26th 2015. In order to construct the soil core-IER (ion exchange resin) system, the soil core in the PVC pipe was removed and a nylon-mesh bag containing mixed-bed ion exchange resins (IER) was secured to the bottom of the core with silicone glue. The cores were then returned to the hole. The purpose of the IER bag is to adsorb NH_4^+, NO_3^-, PO_4^{3-}, and K^+ and to quantify nutrient availability under root exclusion within the soil core but, still allowing water to pass freely out of the core (Hart and Firestone, 1989). The resin bags will be excavated at the end of the growing season.

Objective 3) Estimates of decomposition from organic matter amendments utilized a modified "litter bag" technique where composted manure and green waste compost were applied at the equivalent rate of *3 tons per acre* on the tree berm. The organic matter amendments were contained in a PVC pipe (4" diameter by 1" long) attached to coarse-mesh netting (1/32" openings) placed on top of the soil. This technique was used to estimate decomposition rates during the study period. Additionally, soil (0 – 10 cm and 0 – 50 cm depth) was sampled to analyze changes in total organic carbon (TOC) and total nitrogen (TN) between the beginning and end of the growing season.

Objective 4) In order to assess the effect of organic matter amendments on soil moisture, soil was sampled (0 – 10 cm depth) every two weeks during the growing season. Soil was sampled after removing the "litter bag" from the soil surface and analyzed for gravimetric water content. Values were converted to volumetric water content using bulk density.

Objective 5) Subsamples of the organic matter amendments were taken for chemical characterization prior to application (**Table 1**). Following the same sampling schedule as soil moisture, soil was extracted for nutrient analysis including NH_4^+, NO_3^-, PO_4^{3-}, and K^+. Each month PRS™ probes (Western Ag Innovations, Saskatoon, Canada) were deployed for one month where the surface of the resin membranes absorbed available nutrients.

Objective 6) We collected soil samples from the orchard before the application of organic matter amendments and analyzed them for the microbial population structure *via* 16S rRNA gene sequence analysis (McGarvey et al., 2014). We also collected samples of composted manure and green waste compost before application and examined them for their microbial populations using the same method. In addition to 16S rRNA gene sequence analysis, we examined all samples for the presence of the pathogens including *Salmonella enterica*, *Escherichia coli* O157:H7, and *Listeria monocytogenes* by cultural enrichment followed by immunomagnetic separation and growth on selective media (FDA, 1998).

Results and Discussion:

<u>Objective 1: Establish research trial and secure organic matter amendment suppliers</u>
During 2015, we established a research trial in a non-bearing almond orchard outside of Escalon, CA in San Joaquin County. The study site was secured as a result of grower interest from our survey conducted in 2013 - 2014. The results of that exploratory project also identified

composted manure and green waste compost as organic matter amendments utilized by the majority of almond growers. We designed a randomized complete block trial to compare these sources of organic matter amendments. We secured a supply of composted manure from a local dairy farmer and green waste compost from a major supplier to the San Joaquin Valley.

Objective 2: Cumulative changes in soil nutrients in the rooting zone (0 – 50 cm)

A total of 48 soil core-IER units were deployed on March 26th 2015 and will remain in the field until the planned excavation in September 2015. Upon excavation of the soil cores, we will analyze the soil in the rooting zone (0 – 50 cm), and ion exchange resins attached to the bottom of each soil core unit for NH_4^+, NO_3^-, PO_4^{3-}, and K^+. These results will be reported December 2015 at the annual Almond Conference in Sacramento.

Objective 3: Decomposition of organic matter amendments and changes in soil TOC and TN

Changes in mass loss from organic matter amendments were greater for green waste compost compared to composted manure; however these differences were not significant (**Figure 1**). After four months, 45% of the initial mass of the green waste compost remained compared to 53% of the composted manure. The average rate of mass loss was ~0.5 g m^{-2} day^{-1} *or* 4.5 lb. dry mass $acre^{-1}$ day^{-1} during the growing season. Initial soil samples were collected from the top soil (0 – 10 cm) and from the rooting zone (0 – 50 cm), and soil samples from the same depths are scheduled to be collected at the end of the growing season during September 2015. These samples will be analyzed for TOC and TN to calculate changes in these parameters between the beginning and end of the experiment. These results will be reported December 2015 at the annual Almond Conference in Sacramento.

Objective 4: Effects of organic matter amendments on soil moisture during the growing season

Sampling of soil moisture was conducted at biweekly intervals at 1 or 2 days before scheduled irrigations in order to assess volumetric water content at drier periods of the wetting cycle. Differences were detected during late April and early May where green waste compost was significantly greater in volumetric water content compared to the control while there were no differences between green waste compost and composted manure as well as composted manure and the control (**Figure 2**). The rate of decomposition between green waste compost and composted manure were not different (See Objective 3). The mulching effect of covering the soil and restricting evaporation would be the same for each material. We hypothesize that any differences may be attributed to differences in soil TOC between the green waste compost and the control (See Objective 3). As both sources of organic matter amendments decomposed during the growing season any differences in soil moisture were no longer significant. The combination of mulching and the addition of organic C may explain the greater volumetric water content in the top soil (0 – 10 cm) in the early part of the growing season.

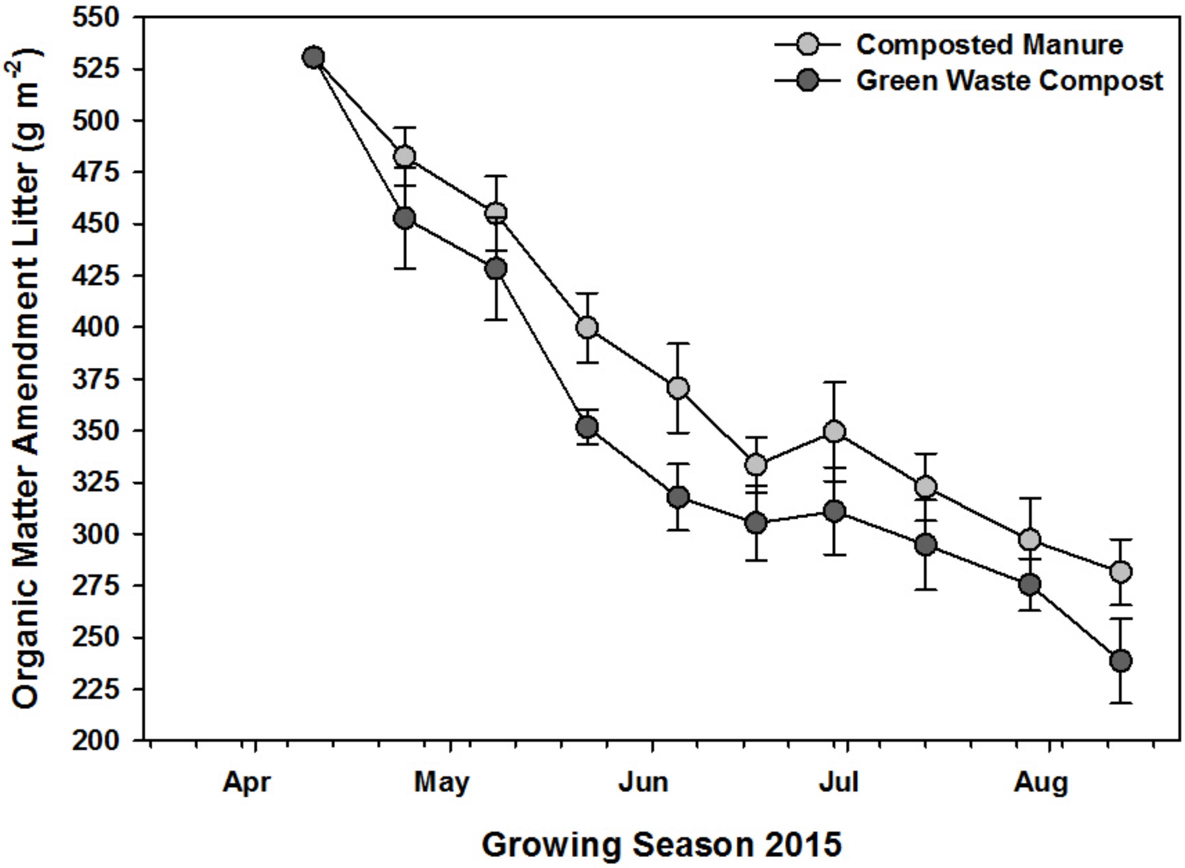

Figure 1. Changes in mass loss during 4-month incubation for different sources of organic matter amendments including composted manure and green waste compost placed on the tree berm under no-tillage, and watered and fertilized through microsprinkler irrigation. Values are means (n = 4) and bars are standard errors.

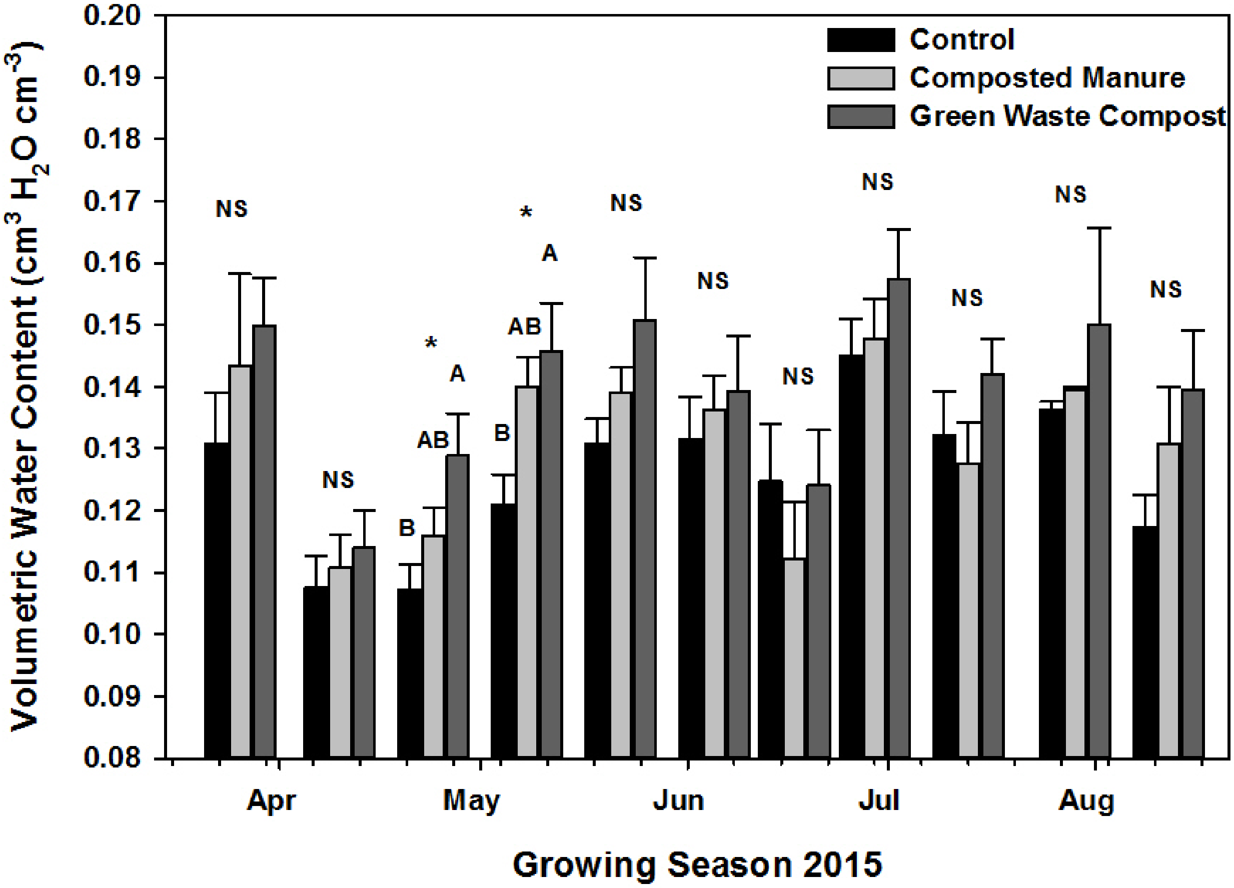

Figure 2. Volumetric water content from top soil (0 – 10 cm) applied with organic matter amendments of composted manure or green waste compost compared to an untreated control under root exclusion during the growing season. All plots received the same rate of conventional fertilizer. Values are means (n = 4) and bars are standard errors from daily samplings (each set of bars). Differences are reported as significant ($p < 0.05$) with an asterisk (*) or as not significant (NS) with mean comparisons using a Tukey test.

Objective 5) Chemical characterization of organic matter amendments was conducted prior to application. Differences were detected in various parameters with marked differences in pH, TN, NH_4^+, NO_3^-, PO_4^{3-}, and K^+ (**Table 1**). Sampling of soil was conducted at biweekly intervals at 1 or 2 days before scheduled irrigations in order to assess soil nutrient contents at drier periods of the wetting cycle. These samples will be analyzed for NH_4^+, NO_3^-, PO_4^{3-}, and K^+ to assess any changes in these parameters during the growing season. These results will be reported December 2015 at the annual Almond Conference in Sacramento.

Table 1. Chemical characteristics of composted manure and green waste compost prior to application including pH, electro conductivity (EC), total organic carbon (TOC), total nitrogen (TN), carbon to nitrogen ratio (C:N), ammonium (NH_4^+-N), nitrate (NO_3^--N), percentage moisture, Olsen orthophosphate (PO_4^{3-}-P), exchangeable potassium (K^+), calcium (Ca), magnesium (Mg), calcium to magnesium ration (Ca:Mg), sodium (Na), chloride (Cl), and boron (B).

	pH	EC dS/m	TOC %	TN %	C:N	NH_4^+-N mg/kg	NO_3^--N mg/kg	Moisture %
Composted Manure	7.93	29.1	28.3	2.35	12.1	351	223	37
Green Waste Compost	4.69	22.5	34.8	1.87	18.6	1250	6.80	36
	PO_4^{3-}-P mg/kg	K^+ mg/kg	Ca mg/kg	Mg mg/kg	Ca:Mg mg/kg	Na mg/kg	Cl mg/kg	B mg/kg
Composted Manure	2655	26895	0.68	0.62	1.09	5.63	13.3	0.04
Green Waste Compost	271	7410	8.95	7.53	1.19	5.44	11.6	0.04

Throughout the growing season total inorganic N (NH_4^+-N + NO_3^--N) adsorbed to the resin membranes of the PRS^{TM} probes were not significantly different between treatments. During late April green waste compost total inorganic N was greater than composted manure and the control possibly due to higher NH_4^+ content that may have been more readily available to the top soil (0 – 10 cm). In late May, June, and July the total adsorbed inorganic N was lower for composted manure despite ongoing decomposition (**Figure 3**). This result suggests that some level of N immobilization occurred where the C supply acts as a energy source even though there is a greater total N added compared to the control (Chalk et al., 2013). Furthermore, the higher inputs of PO_4^{3-} and K^+ from the composted manure resulted in significantly greater adsorption to resin members of PRS^{TM} probes compared to green waste compost and the control for nearly all sampling dates. The additional inputs of PO_4^{3-} and K^+ from the green waste compost resulted in significantly greater adsorption to resin members of PRS^{TM} probes compared to the control for many of the sampling dates (**Figures 4** and **5**). These results suggest that organic matter amendments play an important role in N immobilization that can retain N in the soil and reduce the risk of N leaching to groundwater. Furthermore, organic matter amendments contain readily available P and K nutrients that may be able to act as a substitute for other conventional P and K fertilizers and lead to cost savings for the grower.

Objective 6) 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*. We also performed coliform plate counts on all samples of organic matter amendments, none of which were over 2 log CFU gm^{-1}. Results of microbial population structure will be reported December 2015 at the annual Almond Conference in Sacramento.

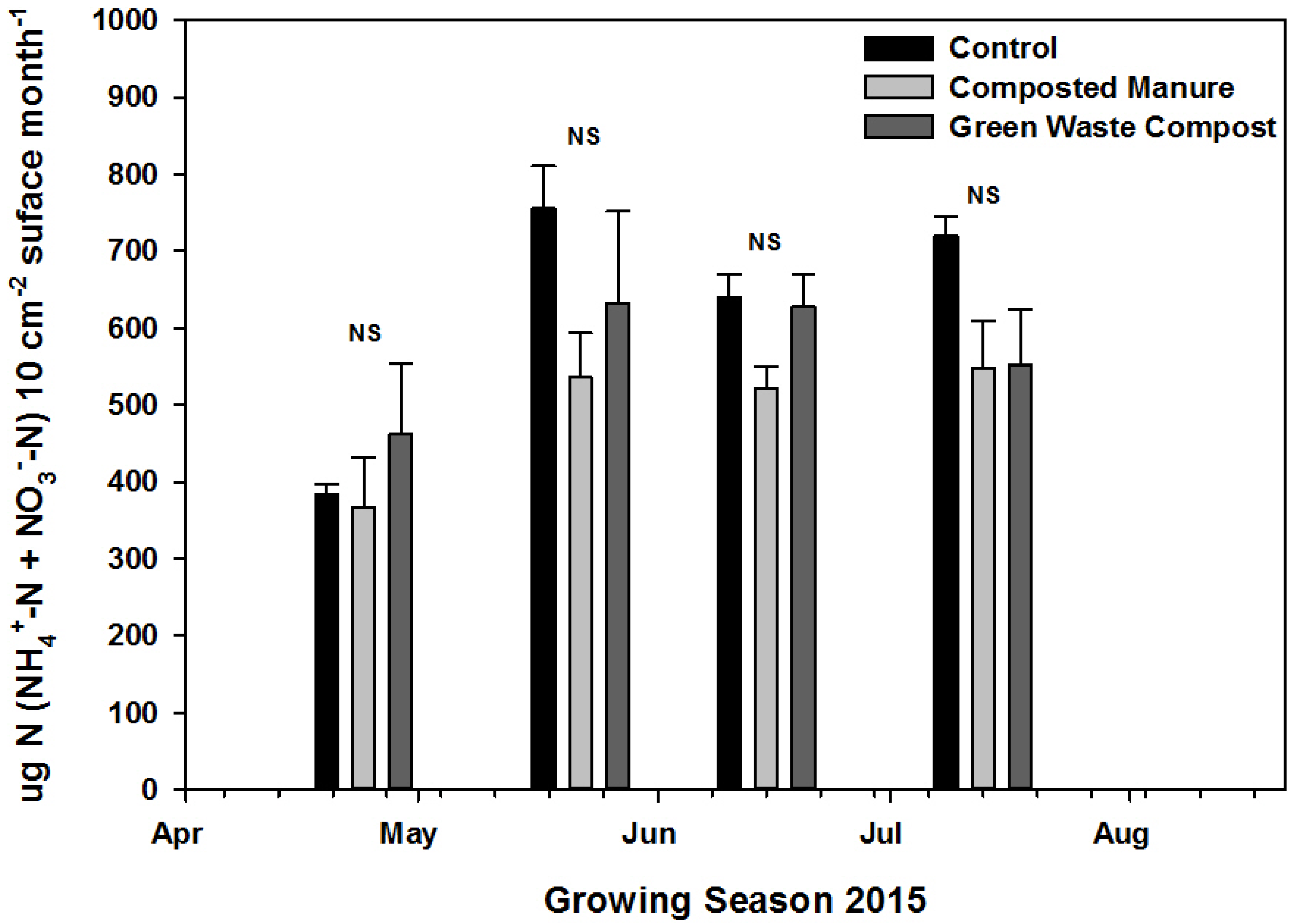

Figure 3. Total inorganic nitrogen (NH_4^+-N + NO_3^--N) per 10 cm^{-2} of resin membrane surface from PRS™ probes incubated for one month from top soil (0 – 10 cm) applied with organic matter amendments of composted manure or green waste compost compared to an untreated control under root exclusion during the growing season. All plots received the same rate of conventional fertilizer. Values are means (n = 4) and bars are standard errors from daily samplings (each set of bars). Differences are reported as significant ($p < 0.05$) with an asterisk (*) or as not significant (NS) with mean comparisons using a Tukey test.

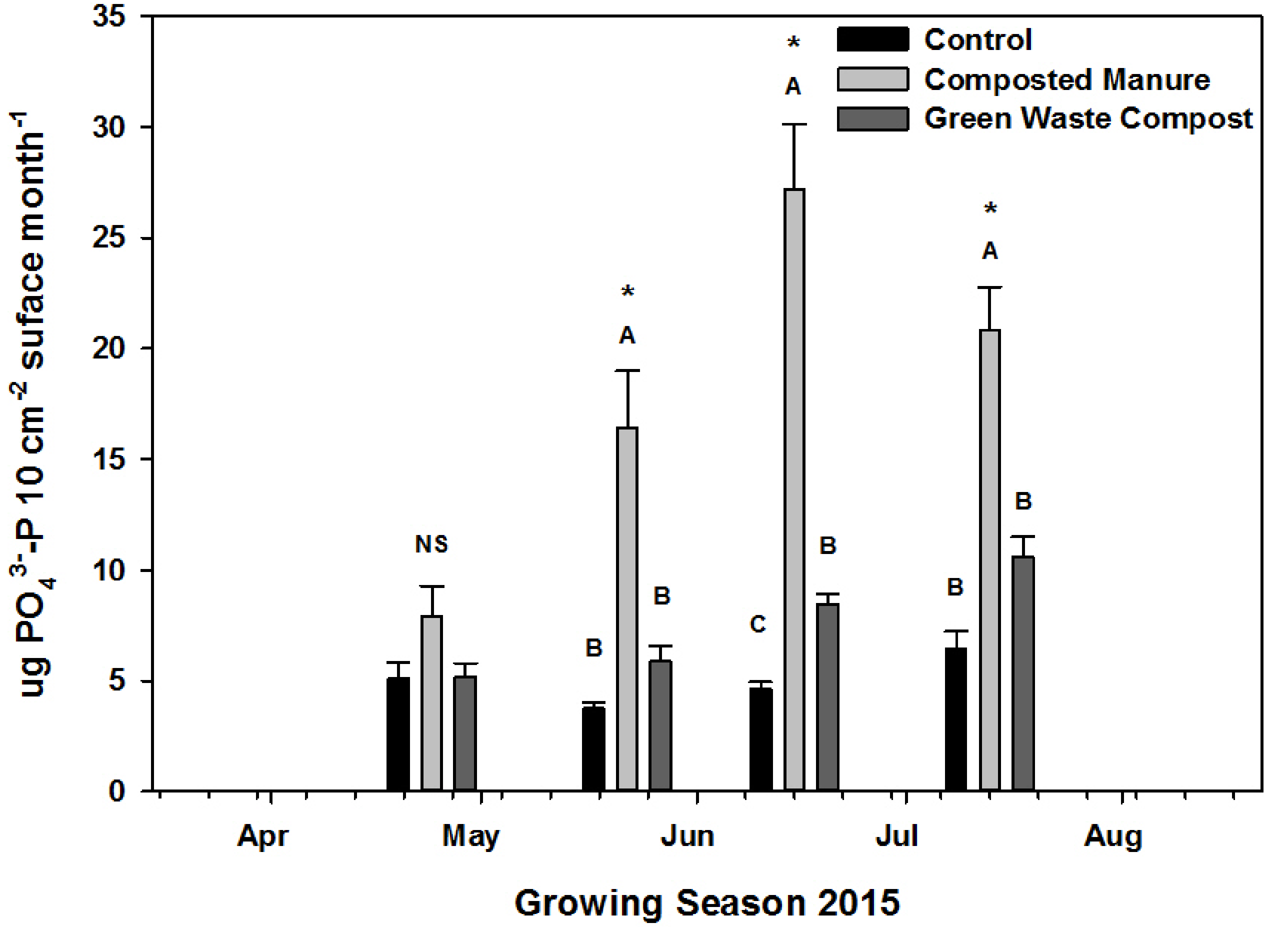

Figure 4. Total inorganic phosphorus (PO_4^{3-}-P) per 10 cm^{-2} of resin membrane surface from PRS^{TM} probes incubated for one month from top soil (0 – 10 cm) applied with organic matter amendments of composted manure or green waste compost compared to an untreated control under root exclusion during the growing season. All plots received the same rate of conventional fertilizer. Values are means (n = 4) and bars are standard errors from daily samplings (each set of bars). Differences are reported as significant ($p < 0.05$) with an asterisk (*) or as not significant (NS) with mean comparisons using a Tukey test.

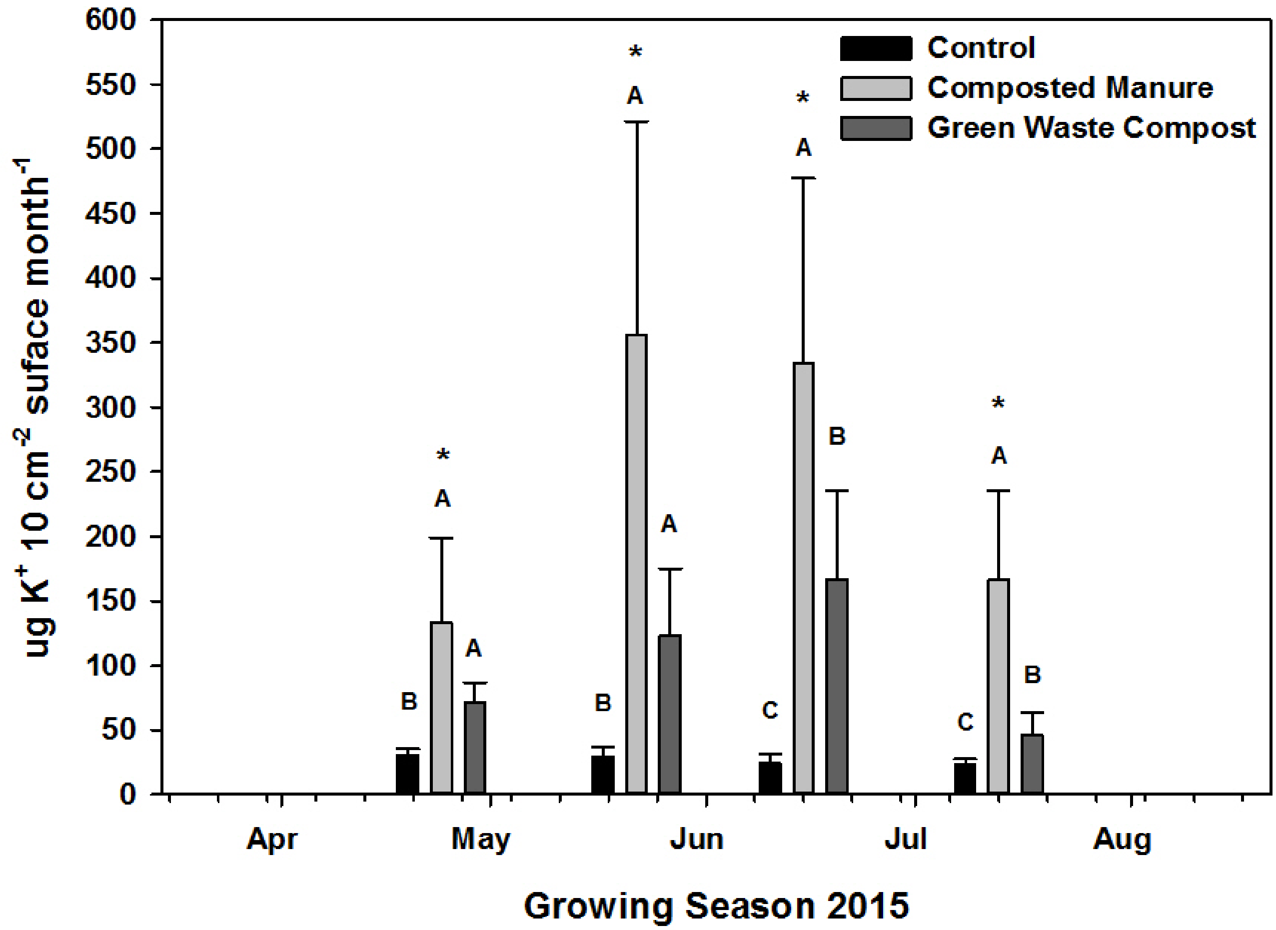

Figure 5. Total inorganic potassium (K^+) per 10 cm^{-2} of resin membrane surface from PRS^{TM} probes incubated for one month from top soil (0 – 10 cm) applied with organic matter amendments of composted manure or green waste compost compared to an untreated control under root exclusion during the growing season. Values are means (*n* = 4) and bars are standard errors from daily samplings (each set of bars). Differences are reported as significant ($p < 0.05$) with an asterisk (*) or as not significant (NS) with mean comparisons using a Tukey test.

Research Effort Recent Publications:

Schellenberg DL and PH Brown. 2015. Use of organic matter amendments in permanent crops – a grower oriented analysis. Plant and Soil Conference. California Chapter of the Agronomy Society of America, Fresno, CA. February 4th-5th

References Cited:

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. DOI: 10.1007/s11104-012-1358-5.

FDA. (1998) Bacteriological Analytical Manual, Department of Health and Human Services, Washington D.C.

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

McGarvey J.A., Connell J.H., Stanker L.H., Hnasko R. (2014) Bacterial population structure and dynamics during the development of almond drupes. J Appl Microbiol 116:1543-52. DOI: 10.1111/jam.12464 10.1111/jam.12464. Epub 2014 Mar 4.