# Influence of Whole Orchard Recycling on GHG Emissions and Soil Health in a Newly Established Almond Orchard

**Project No.:** **17-AIR10-Culumber**

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**Objectives:**

1. Examine the benefits of applying a high carbon (C) containing amendment like wood chips to facilitate N immobilization and reduce losses of applied N to $N_2O$ emissions.
2. Soil chemical, physical, and biological conditions to examine potential benefits of WOR to short and long-term soil fertility, and the relationship to tree growth and nutrition.

**Interpretive Summary:**

Rising concerns about degrading air, soil, and water quality has led to increased regulations across California's Central Valley. These developments have motivated researchers to identify farming practices that mitigate soil health problems and reduce greenhouse gas (GHG) emissions. Soil organic matter (SOM) is an integral component of healthy soil, which provides nutrients, promotes good soil structure, improved drainage, and reduced erosion. However, the application of organic amendments to improve SOM content have resulted in a both decreases and increases in GHG emissions in agricultural systems highlighting the influence of local soil conditions, the quality and quantity of amendments, and the duration of amendment applications (years to decades) to these systems.

Burning restrictions and air quality regulations have coincided with a vast increase in the volume of orchard waste across the Central Valley. While open burning or removal of the orchard is carbon (C) neutral compared to co-generation plant disposal, burning will release air pollutants (i.e. soot) into the atmosphere. Whole orchard recycling (WOR) incorporates orchard removal waste on-site, without burning or moving the debris to another location.

When mulched into the soil, high carbon (C) containing amendments like wood chips have been shown to increase SOM (Holtz, 2016). Higher C to N ratios of organic amendments like wood chips can increase soil N immobilization leading to reduced availability of applied N fertilizers. Consequently, growers may need to apply fertilizer N at rates greater than what is recommended for trees in their first leaf, which may impact nitrous oxide ($N_2O$) emissions and the carbon-negative practice anticipated by WOR. Continued research is needed to quantify the effect of higher WOR application rates on GHG emissions, soil health, tree growth, and

productivity. This project is monitoring $N_2O$ and carbon dioxide ($CO_2$) emissions, soil C and N dynamics and soil health indicators for nearly three years after a one-time WOR mulching rate of 45 T/ac dry wt at a commercial almond farm in Parlier, Ca. Several field days will allow growers to view the impact of WOR on soil structure and tree orchard growth.

Efforts commenced in April 2018 to monitor field level variability of nitrous oxide and carbon dioxide emissions related to seasonality and orchard management practices. Gas flux chambers were installed in both wood chip mulched and control plots (no wood chips) to measure differences in GHG flux and soil N pools in the tree rootzone compared to the inter-tree spaces where applied nutrients are not taken up. In April and May, the peak nitrous oxide flux rate appeared to occur one to two days after application for both treatments. The soil nitrous oxide concentrations increased from 6 inches to 1.5 feet in woodchip treatments one day after the first fertigation, an increase was not observed in the control treatment. The increase in nitrous oxide concentration at 2.5 feet was minimal for both treatments. Carbon dioxide levels thus far are consistently higher in the woodchip treatment compared to the control. Statistical analysis has not yet been conducted to test for significance between experimental units.

**Materials and Methods:**

Field site description: After the previous orchard was pushed over and chipped in late 2017, four half-acre (60 m x 33.5 m) plots were established at random to serve as control plots and did not receive any wood chip mulch. The wood chip mulch treatment plots of the same size were established in an adjacent area to the controls. Planting berms were established and fumigated, the double line drip irrigation system was installed. A 50-50 mix of Nonpareil and Monterey almond varieties on Viking rootstock were planted in a 5.2 x 6.7 m square pattern, oriented in a north to south direction. Trees have been fertilized three times through the irrigation system at a rate of 1.73 ounces of 32% urea ammonium nitrate, (UAN)) and once with 15.8 % calcium ammonium nitrate (CAN) at a rate of 0.8 ounces per tree applied through the irrigation system (**Table 1**).

**Table 1**. Fertigation treatment specifications, rates, and application dates.

| Formula | Rate | Application dates |
|---|---|---|
| UAN (29-0-0-.72 Zn) | 4-gal ac<br>1.73 oz/tree | April 19<br>June 1<br>June 25 |
| CAN (15.8-0-0-8Ca-.04Zn) | 3-gal ac<br>0.8 oz/tree | May 15 |

Chamber, soil gas & gas chromatograph: The static chamber with an automatic sampler method is being used for $N_2O$ emission measurement (Gao et al., 2017). The chamber was constructed following the USDA Greenhouse Gas Reduction through Agricultural Carbon Enhancement Network (GRACENet) protocols. The chambers have dimensions of 102 mm × 324 mm × 527 mm (H × W × D) with a venting tube of a 3.2 mm ID. A sampling port (stainless steel tubing with a 1.6 mm ID) was installed at the center of the chamber. Connection between the chamber and four 20-mL syringes (collecting four subsamples) of the autosampler was made using Teflon® tubing through a perfusion manifold. A chamber base (collar) was made

from the same product as the chamber by cutting 51 mm off from the bottom and with rim up was inserted into the soil to a depth of 25 mm. An adhesive rubber tape (9.1 mm W × 7.9 mm H) was installed along the rim of the chamber. When the chamber was placed on the base, both rims are fastened together using large binder clips to ensure an air-tight seal. Samples are drawn upon chamber closure at 0, 30, 60, and 90 min, a linear $N_2O$ concentration increase with time was often observed. Each of the 20 mL sample was transferred to glass vials that were pre-flushed with ultra-purity of air to reduce background $N_2O$ contamination and preserved for instrumental analysis. The $N_2O$ concentration are determined with a gas chromatography (GC) Agilent Technologies 6890N (Agilent Technologies, Santa Clara, CA, USA) equipped with a micro electron capture detector (μECD), and a headspace sampler (G1888), and a capillary column [HP-PLOT Q, 0.53 mm (ID) × 30 m (length) × 40 μm (film thickness)]. The detection limit of the system is 0.03 μl $N_2O$ $L^{-1}$ or 0.034 ng $N_2O$-N $cm^{-3}$. Flux is calculated based on the slope, the chamber volume and surface area covered by the chamber. In addition to surface flux measurements, $N_2O$ concentrations in soil profiles were also monitored at 15, 50, and 80 cm depths at the same time when flux measurement was made. Soil gas probes were assembled using a capillary (1.6 mm diameter) stainless steel tubing, which was stabilized in a larger (9.53 mm) diameter stainless steel tubing. The probes were pushed into soil to the desired soil depth. Twenty mL of gas samples were withdrawn at each sampling time and preserved similarly as the emission samples for gas chromatography analysis. Carbon dioxide emissions are measured using a LI-8100A automated $CO_2$ flux System (LI-COR® Biosciences following the same schedule as the N2O emission measurements**.**

<u>$N_2O$ and $CO_2$ gas flux:</u> Gas flux sampling has been conducted weekly at a minimum, and more frequently during management events like tillage, fertigation and irrigation. Measurements are collected near the drip tape where fertilizer is applied at two locations on the treerow berm: adjacent to the tree, (location A) and half way between two trees (Location B) throughout the growing season. The second sampling location was added to the treerow berm to investigate differences in GHG flux and soil N pools in the tree rootzone compared to the inter-tree spaces where applied nutrients are not taken up. Spatial variation in the orchard was evaluated 2-3 times per year by adding two more locations in the alleyway midway between treerows **(Figure 1**).

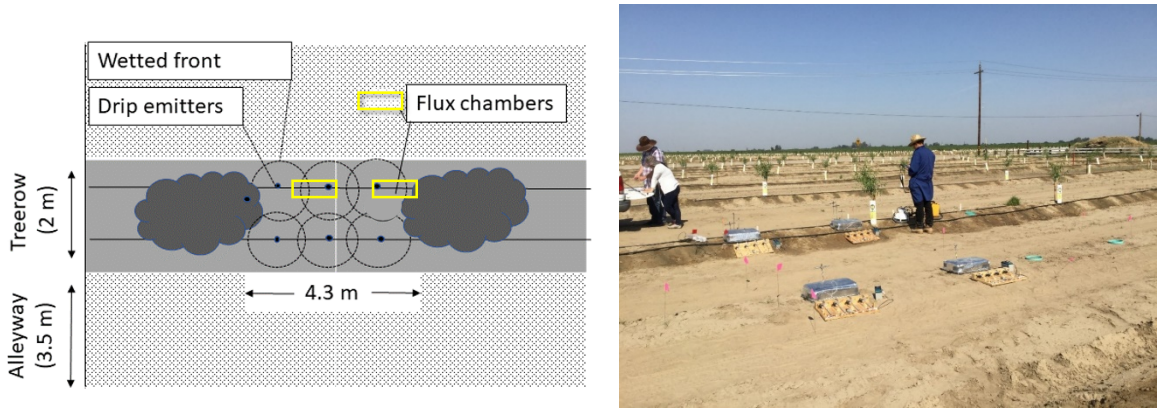


**Figure 1**. Illustration (left) and picture (right) demonstrating the location of N2O chambers in each treatment plot.

Soil attributes related to soil health & GHG emissions: Soil samples were collected in August 2017 to determine the baseline levels of soil organic matter (SOM) within the randomly assigned blocks prior to orchard recycling (**Figure 1**). Composite samples were collected from 6 locations within each block at 0-15 and 15-30 cm depth. The samples were analyzed for soil organic matter loss on ignition (%), pH, electrical conductivity, bulk density, total carbon and nitrogen, SOM%, available phosphorus (ppm) (Olsen P method), and soluble and exchangeable cations (**Table 2**). These attributes will be monitored in all experimental plots from 0-15, 30, 50, and 50-80 cm, once a year to capture changes over time resulting from the different orchard treatments. Net changes in soil inorganic N pools, labile dissolved organic C and N pools from 0-15 cm have been measured monthly one day following fertigation. Inorganic N concentrations were measured daily for four days after the June 25 fertigation event, coinciding with GHG measurements. The inorganic N and labile C and N pools will also be measured with depth (0-15, 15-30, 50, and 80 cm) annually. Potential net mineralization and nitrification, and denitrification by slurry (Hart et al., 1994; Robertson et al., 1999; Soon et al., 2007) at least once yearly. Three EM50 sensors (Meter Group, Pullman, WA) were installed to collect continuous soil moisture and temperature data at 15, 50, and 80 cm depth in both treatments within a half meter of the location B chamber.

Microbiological community and functional gene analysis: DNA has been extracted from eighty 0-15 cm soil samples for microbial community analyses: quantitative PCR and sequencing will be used to enumerate and identify microorganisms involved in denitrification and nitrification in soils. The soil was collected simultaneously with that for tracking net changes in soil chemical attributes following monthly fertigation events. DNA yields averaged 4 mg $g^{-1}$ wet soil. The pairing of microbial community data with detailed measurements of soil $N_2O$ fluxes, inorganic N, and dissolved organic C and N will allow assessment of the relative importance of different microbial groups in N cycling and GHG emissions in these soils. Data collection and analysis is ongoing.

**Table 2**. Average baseline values for control plots prior to orchard recycling of the stone fruit orchard.

| Test | units | Depth 0-15 cm (SE) | 15 - 30 cm (SE) |
|---|---|---|---|
| **pH** | | 7.05 (0.03) | 7.20 (0.00) |
| **EC** | dS/m | 0.19 (0.04) | 0.10 (0.01) |
| **Olsen P** | ppm | 31.48 (3.06) | 27.15 (4.08) |
| **Potassium** | ppm | 212 (26.2) | 148 (22.8) |
| **Ca** | ppm | 1350 (114) | 945 (110) |
| **Mg** | ppm | 202 (13.1) | 152.8 (21.2) |
| **Na** | ppm | 19.50 (2.50) | 23.0 (2.74) |
| **CEC** | meq/100g | 9.05 (0.71) | 6.48 (0.77) |
| **total nitrogen** | g $kg^{-1}$ soil | 1.04 (0.18) | 0.45 (0.09) |
| **total organic carbon** | g $kg^{-1}$ soil | 12.33 (1.77) | 4.80 (1.07) |
| **soil organic matter** | % LOI | 2.13 (0.25) | 1.10 (0.18) |
| **bulk density** | $g/cm^3$ | 1.33 (0.10) | 1.4 (0.07) |

Growth, Yield, C & N Partitioning: Baseline caliper measurements were taken for all tree within each block in February 2018. Tree leaves will be sampled in July 2018 to assess the tree nutrition in response to fertigation in the control and woodchip treatments, sample processing and analysis is ongoing.

## Results and Discussion:

Efforts commenced in April 2018 to monitor the spatial and temporal variability of nitrous oxide ($N_2O$) and carbon dioxide ($CO_2$) related to seasonality and orchard management practices. Gas flux chambers were installed in both wood chip mulched and control plots (no wood chips) to measure differences in GHG flux and soil N pools in the tree rootzone compared to the inter-tree spaces where applied nutrients are not taken up (**Figure 1**). The average daily soil $N_2O$ flux during April and May for control and woodchip treatments prior to and after two fertigation events are shown in (**Figure 2**). In April and May, the peak $N_2O$ flux rate (ug $m^{-2}$ $hr^{-1}$) appeared to occur one to two days after application for both treatments. The $N_2O$ concentrations increased an average 2.2 ng $cm^{-3}$ at 15 cm depth and 2.7 ng $cm^3$ at 50 cm depth in the control, and 5.3 ng $cm^{-3}$ at 15 cm depth and 4.9 ng $cm^{-3}$ at 50 cm depth in woodchip treatments one day after the first fertigation on April 19 (**Figure 3**). The increase in $N_2O$ concentration at 80 cm depth was minimal (<1.0 for both treatments). Carbon dioxide ($CO_2$) levels thus far are consistently higher in the woodchip treatment (13.9 +/- 4.2 µmol $m^{-2}$ $s^{-1}$) compared to the control (3.7 +/- 1.0 µmol $m^{-2}$ $s^{-1}$, **Figure 4**). Statistical analysis has not yet been conducted to test for significance between experimental units. More measurements during the growing and dormant season are necessary to make reliable interpretations about the impacts of WOR and standard orchard management on GHG emissions in a newly planted orchard.

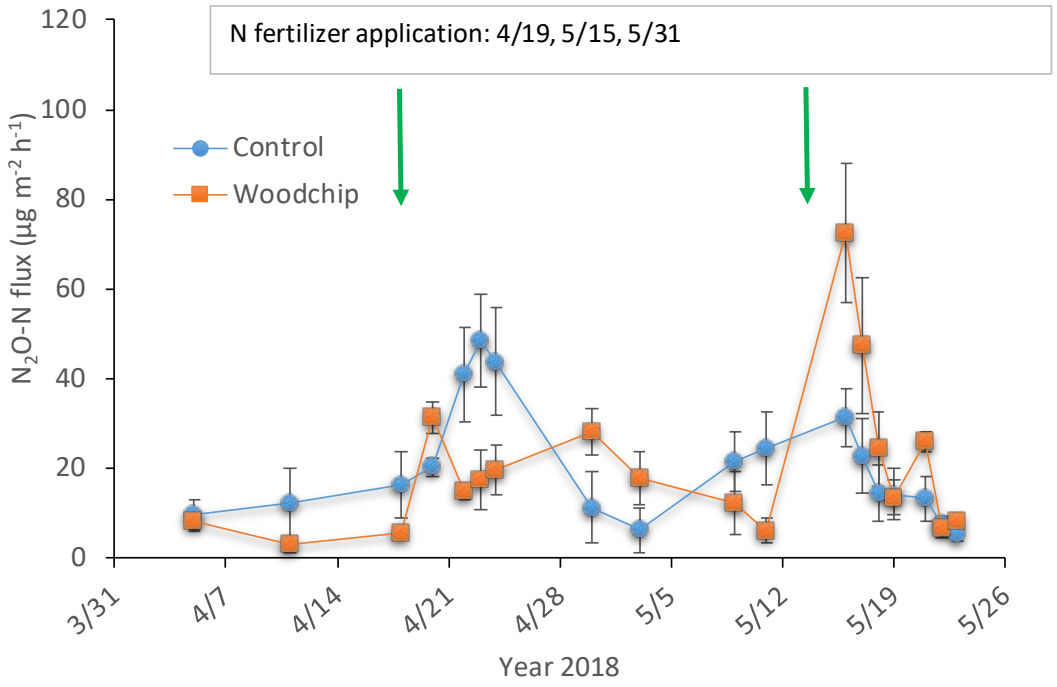


**Figure 2**. Average $N_2O$ flux from the treerow berm in control and woodchip treatment plots.

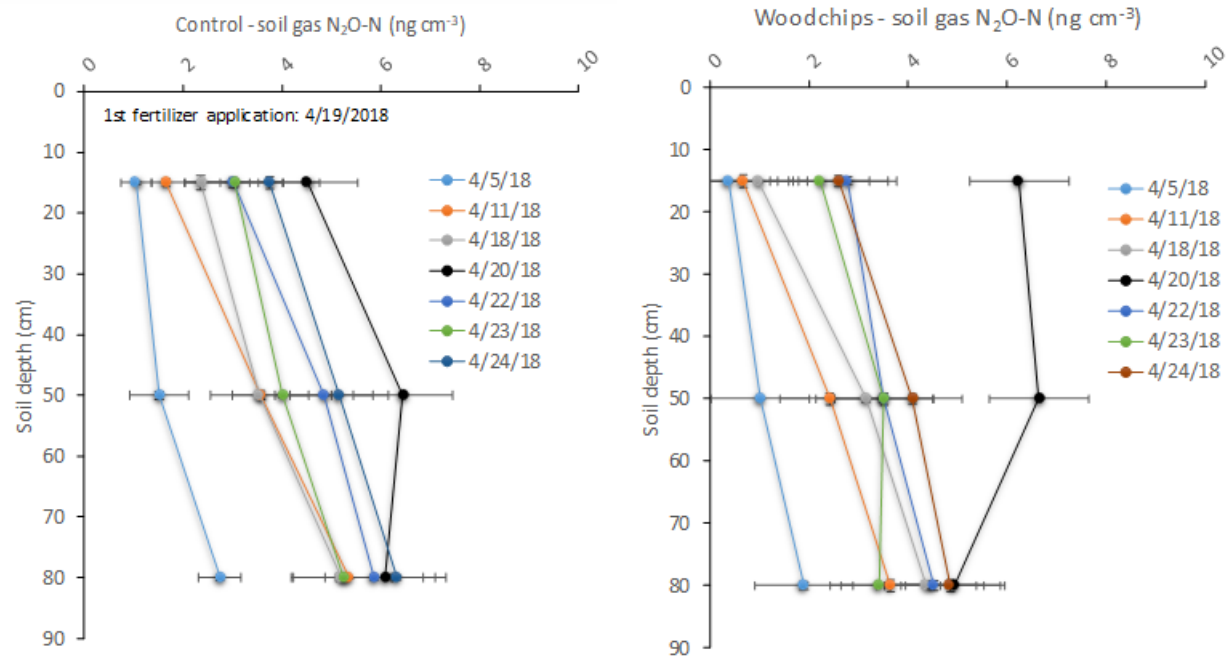


**Figure 3**. Soil $N_2O$ gas concentrations with depth over time in control and woodchip treatments before and after fertigation.

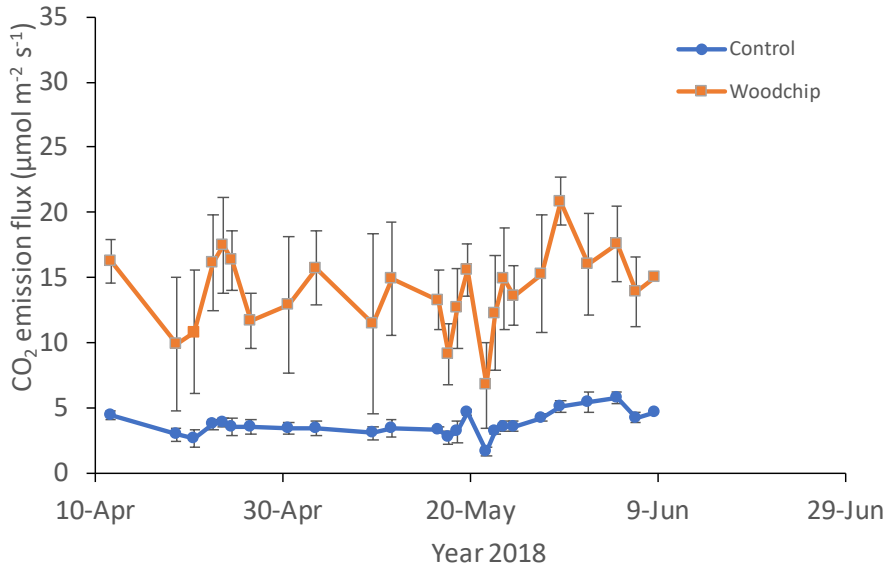


**Figure 4**. Average $CO_2$ emissions from the tree row berm in control and woodchip treatment plots.

## Research Effort Recent Publications:

Educational Outreach:

University of California cooperative Extension, Central Valley Almond Day. "Nitrogen considerations for second generation almond trees after whole orchard recycling," Fresno, CA. June 20, 2018.

## References Cited:


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