UCCE Farm Advisor Projects, 2019-20 (Hort3.Jarvis-Shean)

Tree growth and soil health response to wood mulch incorporation in a newly established orchard.

Project No.: Hort3.Culumber

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Objectives:
Determine if wood chip amendment application rate of 85-90 tons/acre has a detrimental impact on establishment of young almond trees in comparison to other pre-plant agricultural waste product amendments and industry standard practices. Monitor soil biological and chemical shifts to identify mechanisms of nutritional deficiencies in trees planted with wood chips or other agricultural waste products.

Interpretive Summary:
Whole orchard recycling (WOR) incorporates orchard removal waste on-site, without burning or moving the debris to another location. The additional carbon (C) supplied by WOR mulch may lead to improvements in soil health that could be beneficial to orchard growth in the long term (Holtz et al. 2016). Our results show the high C composition of the wood chip (WC) treatment immobilized fertilizer N applications leading to reduced tree growth in the first three years after establishment. Almond tree size after an 85 ton/ac wood chip application may not catch up to other orchard management approaches unless fertilization rates and timing can overcome immobilization. Other WOR trials at lower application rates (30-60 tons/acre) have found trees attained the same size without significant impacts on yield.

Higher microbial biomass growth in WC treatments signals decomposition processes are turning over the high C containing wood chips faster in WC than all other treatments suggesting the carbon rich WC is stimulating microbial activity and development of communities that can assimilate cellulose and lignin in wood. Agricultural soils are dynamic systems. Soil biological and chemical composition shifts in response to the changing quality and quantity of decomposable residues, temperature, moisture, and pH among other factors, drive turnover of microbial biomass and increase nutrient mineralization. Increasing soil

organic C has been shown in many agricultural studies to have a positive impact on soil nutrient reservoirs and water holding capacity over time. We expect a similar balance of nutrient immobilizing and mineralizing processes may result in the WC treatments over a period of a few seasons.

Materials and Methods:

A trial was established in 2017 at the UC Kearney Agricultural Research Station in Parlier, CA in almond replant soil to test the tree growth and soil chemical and biological responses to three different organic amendments (Table 1), rice bran (RB), almond hull (AH), and wood chips (WC) as well as fumigated (FM) and a non-treated control (CN). The almond orchard was planted in February 2017 with Shasta on Nemaguard rootstock. Six trees were planted for each treatment plot with data collection taken from the three centermost trees.

Table 1. Pre-orchard planting organic amendments application rate at the plot and acre scale.

	Application rate	
Amendment	(lbs/plot) wet wt.	(tons/acre) wet wt.
Rice Bran	186	9
Almond Hulls	186	9
Wood Chips	1,770	85

The percentage increase in tree size (trunk cross-sectional area) from 2017 to 2019 was determined based on the circumference (cm^2) of the trunk 16 inches above the soil line in October. Total microbial biomass (ng/g soil), fungal to bacterial ratios, broad microbial community structure were determined at least once annually from 2017 to 2019, by method of phospholipid fatty acid analysis as described by Hamel et al. (2006) at the Ward Laboratory (Kearney, Nebraska). The PLFA biomarkers were aggregated into taxonomic groups. Only the reported biomass data for each taxon were used. The quantitative distribution of each taxon's biomass was examined visually using Q-Q plots against lognormal and Gamma fitted distributions.

Results and Discussion:

Wood Chip plot trees growth was significantly lower than all other treatments including the control after the first season and was still significantly smaller than FM and RB treatments after three years. Trees growing in the RB plot had the same increase in growth compared to fumigated treatments from 2017 to 2019 (Figure 1). The AH trees were as large as FM and RB by the end of 2019. A significant correlation ($r=0.8519$, $p<0.0001$) between soil organic C and total N levels, and greater organic C and total N were observed in the WC plot soils (Figure 2). Higher organic C levels in WC plots indicates decomposition of WC residues. Increasing total N can represent N in organic matter, mineralized N, or the immobilization inorganic N supplied by fertilizers, or a combination of all.

Total biomass (Figure 3a), undifferentiated biomass, total bacterial biomass (Figure 3b), and the biomass of each bacterial clade (Gram (+), Actinomycete, Gram (-), Rhizobia) were described by lognormal distributions, although in the cases of the larger taxonomic groups, Gamma distributions with shape parameters ranging from $k \sim 1.5$ to $k \sim 2.3$ also fit. Total fungal biomass (Figure 3c), saprophytic fungal biomass, A-M fungal biomass and protozoan biomass were best described by Gamma distributions with shape parameters ranging from k ~ 1 to k ~ 1.4. Lognormal fits for the biomass distribution of eukaryotic taxa could usually be rejected upon graphical examination. The lower shape parameters (k ~ 1) in the fit of Gamma distributions to fungal and protozoan biomasses reflect how eukaryotes are more likely to be

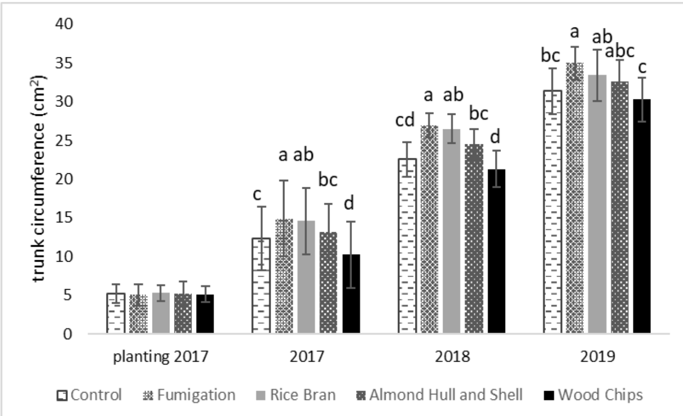

Figure 1. trunk cross sectional area from planting to end of 2019. Different letters indicate a significant difference at the p≤0.05 level

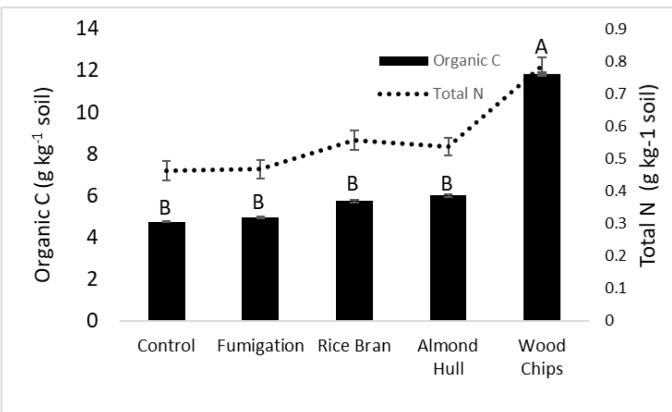

Figure 2. Season end average soil organic C and total N concentrations. Different upper case letters indicate differences between soil organic C and total N levels at the p≤0.05 level

present at low density, in contrast to bacteria, which are mainly present where they aggregate (k >> 1). Regarding the changes of biomass patterns over time, the control, fumigated, rice bran, and almond hull treatments began the trial with low microbial biomasses in 2017 and increased in the following years. The exception was the woodchip treatment, which consistently had the highest biomass for every taxon in every year. In 2017, the difference between the total biomass of the control treatment and the woodchip treatment was a factor of ~4, and microbial biomasses in the rice/almond hull treatments were significantly higher (~30%) than in the control/fumigated treatments. By 2019, this difference between the woodchip and control treatments had shrunk to a factor of ~2, and the difference between rice/almond hull and control/fumigated treatments had also diminished. This indicates microbial community biomass in each of the non-woodchip treatments are gradually recovering to pre-orchard establishment. Unfortunately, no baseline measurements for PLFA were sampled prior to orchard planting. Higher microbial biomass growth in WC treatments signals decomposition processes are turning over the high C containing wood chips. Agricultural soils are dynamic systems. Soil biological and chemical composition shifts in response to the changing quality and quantity of decomposable residues, temperature, moisture, and pH among other factors, drive turnover of microbial biomass and increase nutrient mineralization. Increasing soil organic C has been shown in many agricultural studies to have a positive impact on soil nutrient reservoirs and water holding capacity over time. We expect a similar balance of nutrient immobilizing and mineralizing processes may result in the WC treatments over a period of a few seasons.

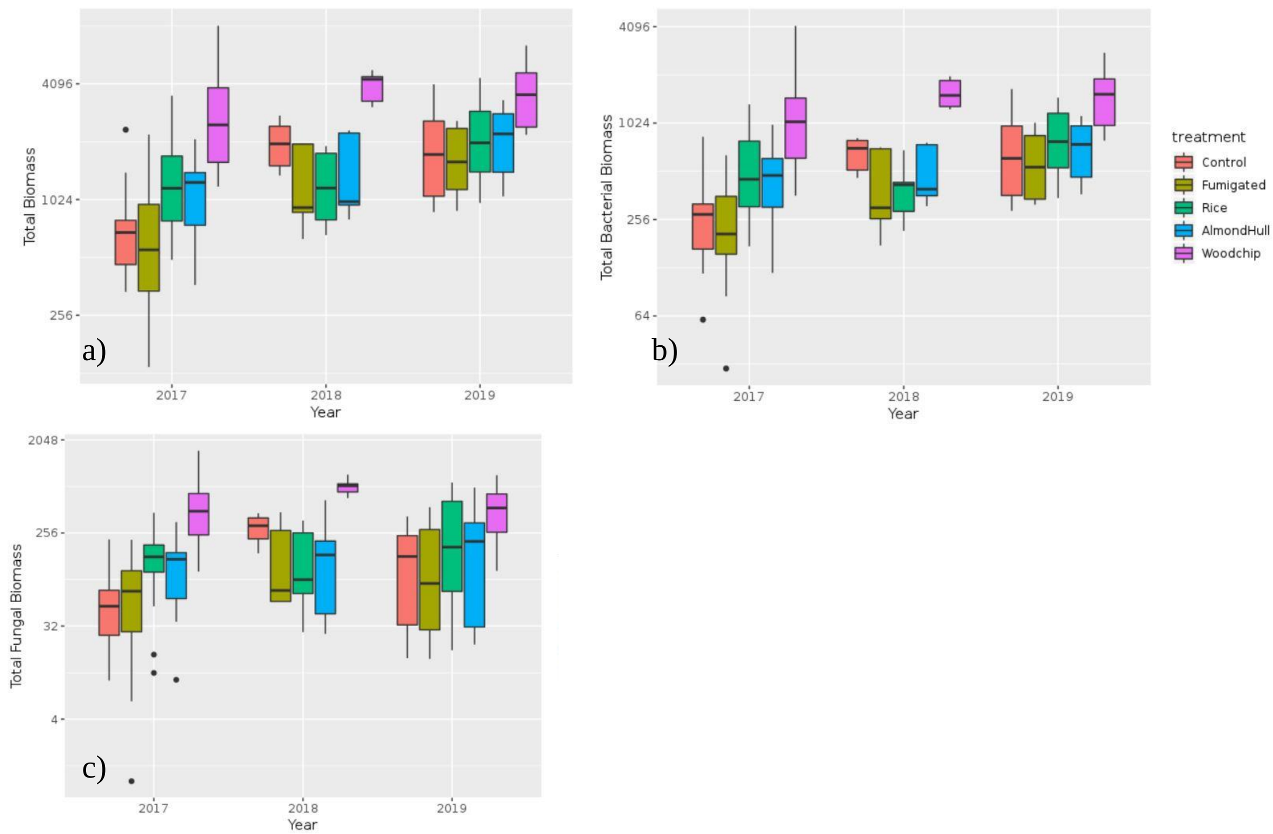

Figure 3. Phospholipid fatty acid (PFLA) of soil a) total microbial biomass, b) total bacterial biomass, and c) total fungal biomass collected from 0-15 cm depth for each organic amendment, fumigation and control treatments.

References Cited:

Hamel, C., Hanson, K., Selles, F., Cruz, A.F., Lemke, R., McConkey, B., Zentner, R., 2006. Seasonal and long-term resource-related variations in soil microbial communities in wheat-based rotations of the Canadian prairie. Soil Biol. Biochem. 38, 2104-2116.

Holtz, B.A., Doll, D.A, and G. Browne (2016). Whole orchard recycling and the effect on second generation tree growth, soil carbon, and fertility. ISHS 2016, DOI 10.17660, Acta Horticulturae 1112: 315-319.

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Documenting the Effects of Annually Applied Green Waste and Manure Composts on Almond Tree Performance

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Many studies have shown that soil applications of composted green waste or manure can increase the diversity and activity of soil microorganisms, soil water holding capacity, soil nutrients such as potassium and nitrogen, humic acid, organic matter and carbon sequestration. Despite these published reports on improvements in "soil health", few if any data have demonstrated enhancements in orchard performance. Despite the lack of data, government agencies including the California Department of Food & Agriculture and the USDA / Natural Resources Conservation Service are advocating that growers should apply organic matter such as composted green waste to their orchard soils. Current costs for purchase, delivery and application of composted green waste in the Modesto area is approximately $27 per ton. Common application rates range between five & ten tons of compost per acre, representing a significant investment to the grower. It is important to determine if almond growers can improve tree performance and/or yield enough to recover such a substantial input cost.

Two replicated field trials were established in 2015 to document the effects of composted green waste and manure on the performance of new almond orchards. Orchard A is planted in a Hanford sandy loam soil that has not been previously farmed. The variety is Nonpareil on Nemaguard rootstock and is irrigated with full coverage sprinklers. Orchard B is planted in a loamy sand in a replant site following an almond orchard removed four months prior and is irrigated with microsprinklers. The variety is Independence on Nemaguard rootstock. In both locations, 5.2 tons of compost per acre were applied to the berms in a concentrated band ca. 4 feet wide and incorporated into the soil at planting. An additional 0.5 tons / acre was applied to the soil surface at the base of the new trees after one month of growth. Each subsequent spring (2016 – 2019), approximately 10 tons of composted green waste or manure has been applied to the soil surface in a band approximately six feet wide. Trees are periodically monitored for stem water potential (water stress), and annually for leaf nutrients, nematodes, growth and yield.

Composted green waste and manure significantly affected July leaf levels of some elements (Table 1). Nitrogen and chloride levels were higher in both compost treatments compared to the unamended controls ($P \geq 0.05$). Leaf calcium was lower in the compost treatments. Potassium was increased in the composted manure treatment but not the green waste treatment. No other significant changes in leaf nutrients occurred. To date, compost treatments have not affected tree canopy size as measured by photosynthetically active radiation (PAR) (Table 2) or yield (Table 3). Compost treatments have not affected pathogenic nematode numbers (Table 4).

Conclusions: After five years of study, the application of composted green waste or manure has not increased growth or yield of almond trees whether grown in excellent, first generation orchard soil or very sandy, second generation orchard soil. Stem water potential measurements indicated that compost-amended trees tended to be slightly more water stressed than trees growing in unamended soil. This is contradictory to what was expected, and the reason is unclear. It is possible that high chloride in the composts may have resulted in higher water stress.

Costs for purchase and application of composts at 10 tons / acre were approximately $265 annually, or $1,325 per acre over the five-year period. After five years of study, it does not appear that application of composted green waste or manure is an economically sound practice in conventionally farmed almond orchards. Composts may be more beneficial in orchards deprived of commercial fertilizers although at a substantially higher cost. It is also possible that benefits may be very long term and not observable in just five years.

Table 1. Leaf Nutrients in July-Sampled Leaves from 4th-Leaf Trees in Compost-Amended and Non-Amended Orchard Soil. Independence on Nemaguard; Loamy Sand Replant Site.

	%N	%P	%K	%Ca	%Cl
Unamended	2.58 b	0.16 a	2.89 b	5.31 a	0.39 b
Green Waste	2.76 a	0.16 a	3.06 b	4.73 b	0.56 a
Manure	2.74 a	0.17 a	3.37 a	4.44 b	0.63 a
Additional Urea	2.58 b	0.15 a	3.12 b	5.33 a	0.39 b

Table 2. Photosynthetically Active Radiation (PAR) Measurements of 5th-Leaf Almond Trees Grown in Compost-Amended and Unamended Orchard Soil. July 2019

	Sandy Loam, 1rst Generation Orchard; Nemaguard Rootstock	Loamy Sand, Replant Site; Nemaguard Rootstock
Unamended	74.4	
Green Waste	74.1	
Manure	72.2	
Additional Urea	70.1	
	n.s.	

Table 3. Yield of Almond Trees with and Without Annual Compost Applications				
	Yield (kernel pounds per acre)			
	3rd Leaf	4th Leaf	5th Leaf	Cumulative Yield
	Orchard A. Nonpareil on Nemaguard; 1rst generation orchard, Hanford sandy loam soil			
Untreated	568 a	2148 a	3154 a	5870 a
Green Waste Compost	559 a	1992 a	2898 a	5449 a
Manure Compost	602 a	1977 a	2909 a	5488 a
Slow Release Urea	600 a	2121 a	3015 a	5736 a
	Orchard B. Independence on Nemaguard; replant site with sandy loam soil			
Untreated	-	1987 a	1779 a	3766 a
Green Waste Compost	-	2256 a	1788 a	4044 a
Manure Compost	-	1990 a	1859 a	3849 a
Slow Release Urea	-	2018 a	1554 a	3572 a

Table 4. Nematode Numbers in Rhizosphere of 5th-Leaf Almond Trees Grown in Compost-Amended and Unamended Orchard Soil. January 2019.				
	Nematodes per 250 cc Soil			
	Sandy Loam, 1rst Generation Orchard; Nemaguard Rootstock		Loamy Sand, Replant Site; Nemaguard Rootstock	
	Ring	Root Lesion	Ring	Root Lesion
Unamended	0	0	73	118
Green Waste	0	0	180	136
Manure	0	38	316	137
Urea	0	0	44	162
	n.s.	n.s.	n.s.	n.s.

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Reducing nut set to increase shoot growth?

Project No.: **HORT3.Niederholzer**

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Drew Wolter, UCCE Hort Intern, 2019

A. Summary: Heavy nut set can limit vegetative growth, reducing orchard yield potential. With limited labor available to remove flowers and/or prune, more options are needed to reduce cropload and, so, possiblty increase shoot growth and yield potential. Caustic fertilizers (ammonium thiosulfate or potassium thiosulfate) or fungicides (lime-sulfur) are used to thin fruit crops. A 1.5% (v/v) solution of potassium thiosulfate (KTS) was sprayed on 10th leaf Independence trees, planted at too wide a spacing for the site, at full bloom. Blossom counts showed a significantly reduced nut set (26% with KTS; 43% w/o KTS), but shoot growth and total kernel yield didn't change with KTS spray. Nut size, (nut count per oz) was increased in the KTS treated trees (25 ct/oz) compared to the untreated trees (28 ct/oz).

B. Objectives

1. Measure almond yield in a block which has not filled its space (2018)
2. Divide the study trees into 10x3 tree groups, based on 2018 yield.
3. Track bloom timing in each of the 10 groups.
4. Apply a caustic fertilizer to reduce nut set at full bloom to 5 of the 10 groups of 3 trees.
5. Measure nut set in the branches where flower progression was followed.
6. Measure yield in all blocks and compare between +KTS and –KTS.

C. Materials and Methods, Results and Discussion

1. Yield for 10x3 tree groups was measured at harvest, 2018, by shaking each 3 tree group and raking fallen nuts towards the center tree before moving on to the next tree, Field weights for each group of trees and a 4 lb subsample for crack-out was used to determine dry nut yield from the 3-tree groups.
2. The 10x3 tree groups were ranked by 2018 yield and adjacent yielding groups were paired as a block for the next season (Ranked 1st & Ranked 2nd; Ranked 3rd & Ranked 4th, etc.). Thinning (+KTS) or no thinning (-KTS) treatments were randomly assigned in each of the 3-tree groups in each block.
3. Bloom timing was tracked beginning on Feb. 22, 2019 by counting swelling buds on shoots around one tree in each of the ten groups. Open flowers were counted on Feb26, Mar2 and Mar4. All flowers were open on Mar4 and potassium

thiosulfate (1.5% v/v) was applied to all trees in 5 blocks using a volume equivalent to 200 gpa between 9-10PM that night to avoid harming bees.

4. Healthy nuts on each shoot section used to track bloom were counted on May 4 and %set determined. KTS treated trees showed significantly less nut set (26%) vs nut set in untreated trees (43%). The strong nut set for both treatments occurred despite less than 20 good bee hours (no rain, wind less than 10 MPH and temperature above 55^{o}F) during the 10 days of bloom.
5. At harvest, yield was again measured for each 3 tree group as in 2018. No yield difference existed between treated or untreated trees (p=0.53), but average nut size on the KTS treated trees (25 ct/oz) was significantly larger (p=0.02) than that on the untreated trees (28 ct/oz). There was no visible increase in shoot growth and no potential future yield increase is expected as a result. Late spring rains delayed nitrogen application until the first week of April. This may have played a role in lack of increased shoot growth in the KTS treated trees.
6. Future research efforts to increase shoot growth may include a thinning spray at 20-30% bloom in addition to one at 100% bloom along with timely spring nitrogen inputs. In addition, adding immediately after petalfall maybe part of a strategy to increase shoot growth in trees planted too far apart for the variety/site. KTS has a foliar fertilizer label beginning at petalfall, but is not labeled for flower thinning.

D. Outreach Activities

1. No outreach activities planned/conducted.

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Comparing navel orangeworm monitoring tools under mating disruption.

Project No.: HORT13.Rijal

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E. Summary

Navel orangeworm (NOW), *Amyelois transitella* is the most destructive pest of major nut crops, including almonds. NOW females lay eggs on hull-split nuts in which young larvae bore into and cause direct damage to the nutmeat. In addition, damaged nuts are highly susceptible to mold fungus, Aspergillus that can produce carcinogenic aflatoxin. A comprehensive IPM approach that combines various monitoring and control options is essential for the effective management of navel orangeworm. Recent studies showed that pheromone-based mating disruption can effectively be integrated into NOW management. However, pheromone traps are no longer useful in almond orchards that are under mating disruption influence. Based on the previous studies, a few attractants such as phenyl propionate (PPO), and oviposition bait (Peterson) may be used to monitor NOW activity in almond orchards. We tested two formulations of phenyl propionate and one ovibait attractants using delta trap in almond orchards with or without mating disruption influence. We found that both ovibait and PPO-based attractants can provide options to monitor navel orangeworm seasonal activities. In our study, the noncommercial formulation of PPO (PPO NC) seems to perform more consistently than the commercial version (PPO AMYTRA) under both with or without mating disruption influence.

F. Objectives

1. Testing new and registered mating disruption products and/or monitoring tools for navel orangeworm control in almonds.

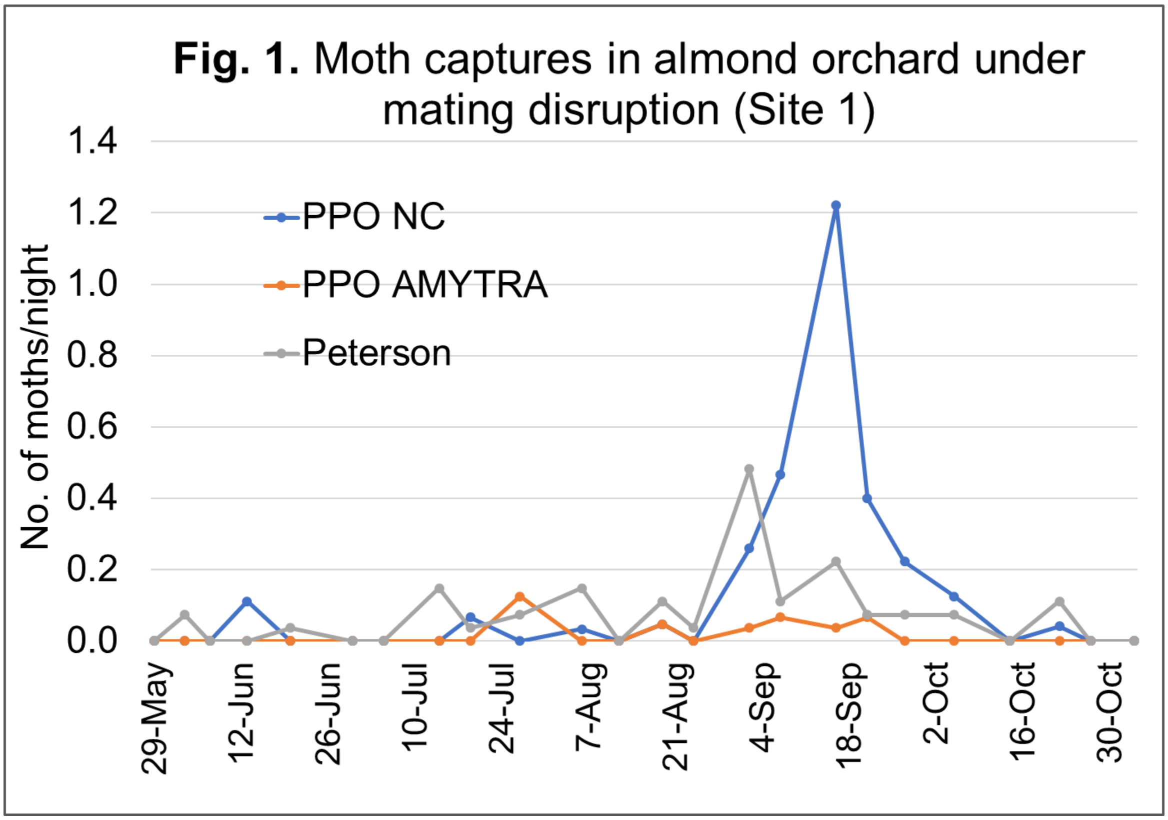
   (*Milestones:* A new navel orangeworm monitoring tool for almond orchards under mating disruption identified)

G. Annual Results and Discussion

The trapping study was conducted from the last week of May through October. Under mating disruption (Fig 1-3), the seasonal moth capture followed the same general trend across all three sites. PPO AMYTRA captured the least number of moths across the season.

The mean of the total number of moth captures between 30 June and 20 September period, which covers navel orangeworm population that attacks to hull split nuts, were compared among three attractant formulations. Data were combined across three almond orchard sites.

Under no mating disruption (Fig. 4, blue bars), a significantly greater number of moths (indicated by the different lower case letters) were captured in Peterson bait compared to two PPO lures (i.e., PPO NC and PPO AMYTRA) (ANOVA; p =<0.0004), and no difference between two PPO lure types. However, under mating disruption, the performance of PPO NC was statistically at par with the Peterson trap, and both of these lures were superior to PPO AMYTRA (ANOVA; p =<0.0007) (Fig. 4, red bars). Comparing three attractants separately with or without mating disruption (Fig. 4; blue vs. red bars), significantly more moths were captured in PPO NC traps under mating disruption compared to no mating disruption, but there was not a statistical difference in trap captures between with- and without mating disruption for PPO AMYTRA and Peterson lures.



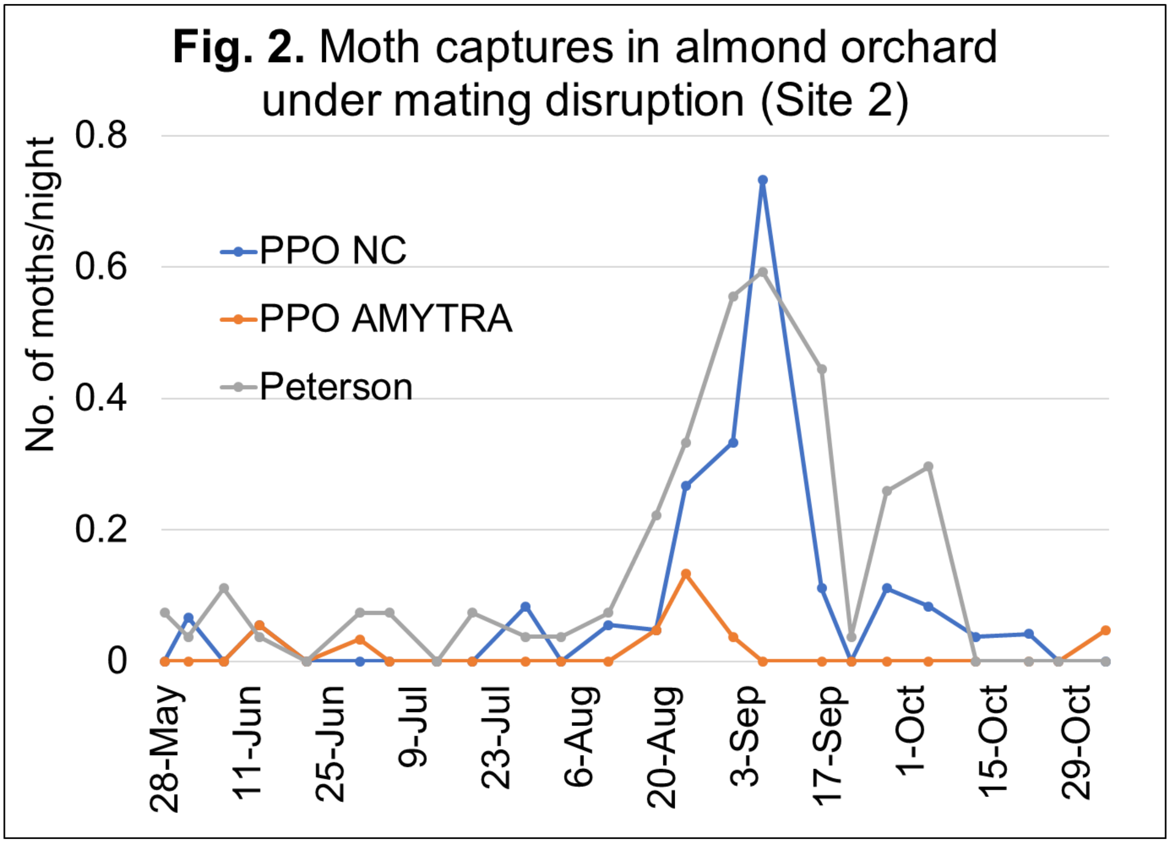


Fig. 2. Moth captures in almond orchard under mating disruption (Site 2)
No. of moths/night
0.8
0.6
0.4
0.2
0
PPO NC
PPO AMYTRA
Peterson
28-May
11-Jun
25-Jun
9-Jul
23-Jul
6-Aug
20-Aug
3-Sep
17-Sep
1-Oct
15-Oct
29-Oct

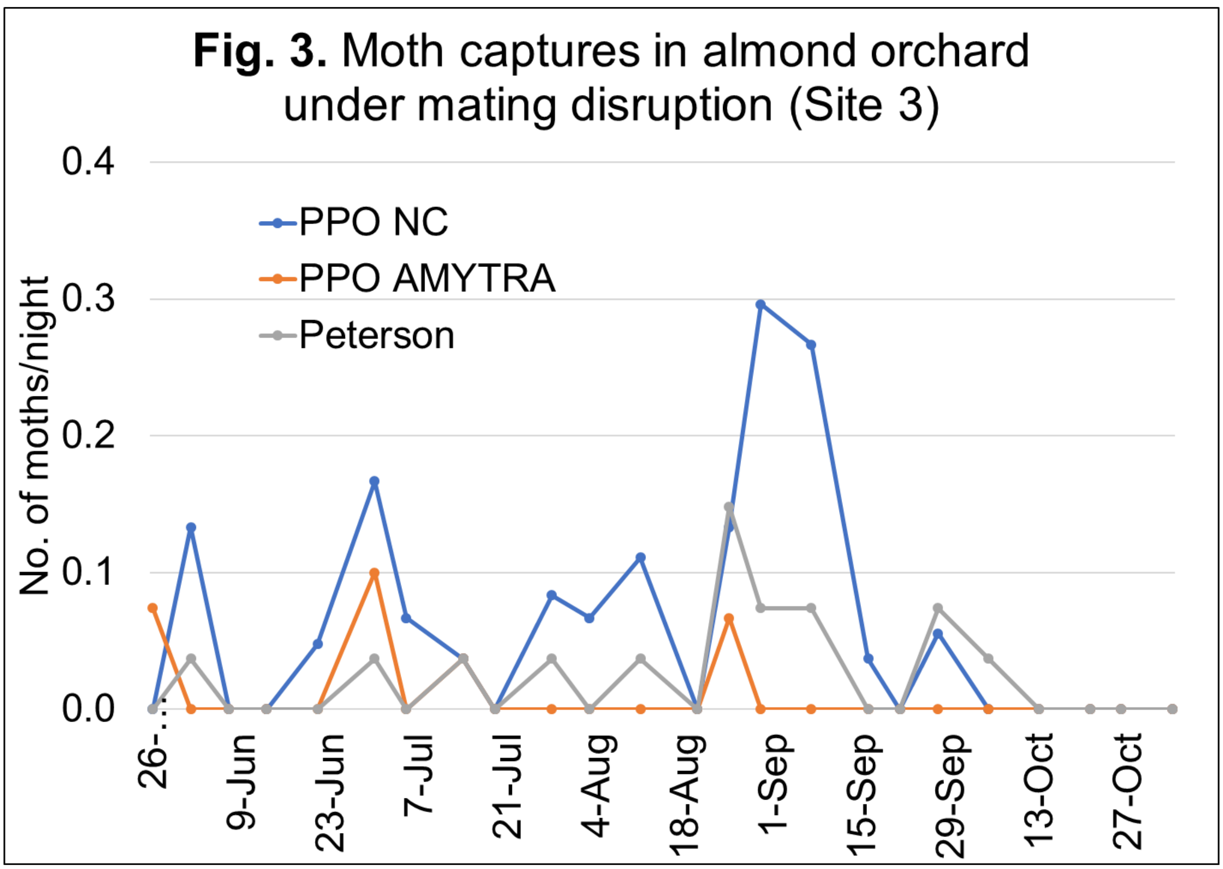
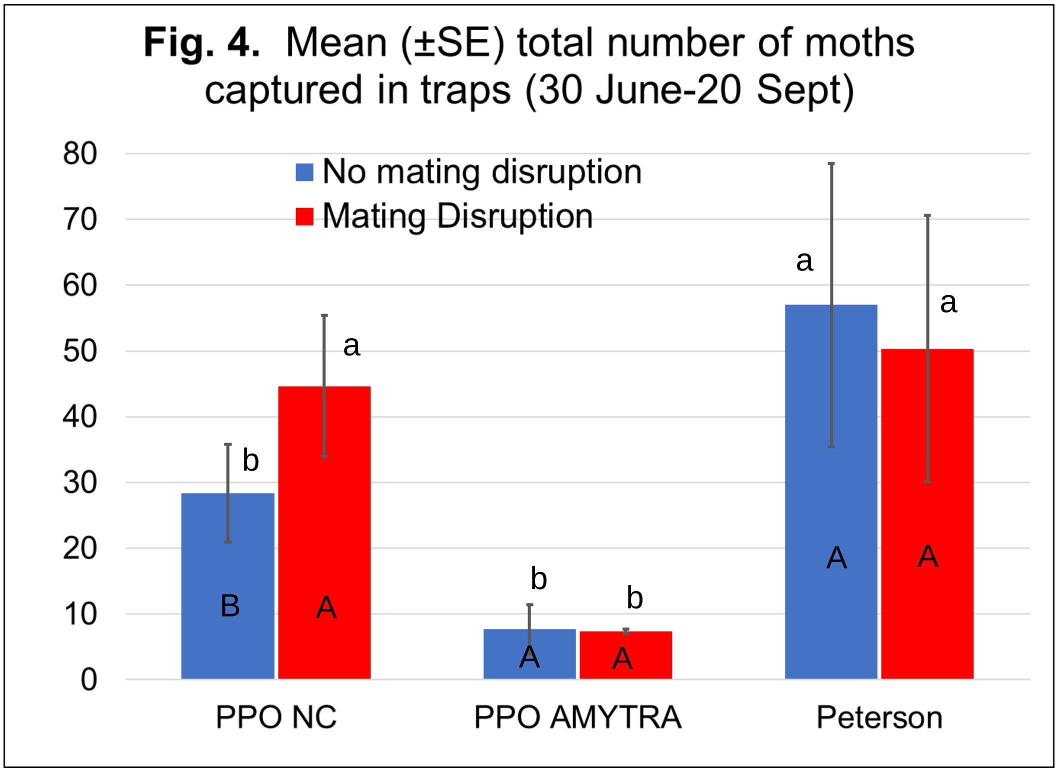


Fig. 3. Moth captures in almond orchard under mating disruption (Site 3)
No. of moths/night
0.4
0.3
0.2
0.1
0.0
PPO NC
PPO AMYTRA
Peterson
26-…
9-Jun
23-Jun
7-Jul
21-Jul
4-Aug
18-Aug
1-Sep
15-Sep
29-Sep
13-Oct
27-Oct



In Fig. 4, same lowercase letters above blue (without mating disruption) or red (with mating disruption) bars are not statistically different. Same upper case letters embedded on bars indicates no difference between with- and without mating disruption for each lure type

Our study showed that Ovibait and PPO-based traps could be used to monitor the navel orangeworm population in almond orchards, especially under the mating disruption. Burks et al. (2016) (*Ref:* J. Econ. Entomol. 109: 958–961) reported that PPO captures both males and females at about a 1:1 ratio. When PPO combined with the pheromone lure, the capture rate was higher, but the capture ratio was significantly male-biased (7.5 male: 1 female). It is also known that female capture in the trap is a better predictor of the crop damage by navel orangeworm compared to the male-based trap captures (Rosenheim et al. 2017; *Ref:* J. Econ. Entomol. 110: 2692–2698). Therefore, PPO only and Peterson trap catches might have better predictability of what is happening in the orchard. However, if the navel orangeworm pressure is extremely low and the moth counts in PPO traps may not reliably be used to track the flight, adding the pheromone lure to PPO might help to boost the overall trap catches, and provide more resolution to the seasonal flight activity. Trap capture rate can be improved by using wing traps which can provide more active space for the volatiles released from these lures and baits.

Ovibait traps have become more common among Pest Control Advisors due to the female-dominated capture, and the less variability in trap captures. PPO lures seem to be an additional monitoring tool for navel orangeworm in mating disrupted orchards. Further study to compare these products in addition to the pheromone and PPO-pheromone combo at various NOW densities, and also using wing traps is warranted.

H. Outreach Activities:

Rijal, J. 2019. Poster presented at the Annual Almond Board Conference, Sacramento, CA. Total attendees: >2000.

Rijal, J. 2020. Navel orangeworm management in almonds. Semios NOW Meeting, DoubleTree hotel, Modesto. 23 January. Total attendees: 23
Rijal, J. 2020. Biology and integrated management of navel orangeworm. North San Joaquin Valley Almond Day, 31 January. Total attendees: 400.

I. Materials and Methods:

We compared two formulations of phenyl propionate, 1) commercially available as Navel Orangeworm Female/Male Lure (PPO AMYTRA), 2) a non-commercial formulation of PPO lure (PPO NC), and one formulation of the oviposition bait commercially available as Peterson NOW Trap in three almond orchard locations. Attractants were tested in two blocks (with or without NOW mating disruption) of the same commercial planting (i.e., site, 60-90 acres), with a minimum separation distance of ~400 ft. between blocks. The study was conducted in three sites in Stanislaus county. Meso passive dispensers (NOW CIDETRAK, Trece, Inc.) were used @20 dispensers/acre. For each lure type, three orange delta traps with white sticky liners, and baited with these lures were used to capture moths in all six plots (3 sites with/without mating disruption). Attractants were hung at the center portion of the delta trap inside using a piece of the metal wire.

J. Publications that emerged from this work

Rijal, J. 2020. Comparing navel orangeworm monitoring tools under mating disruption. Annual Report submitted to the Almond Board of California.

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Using high resolution computed tomography (HRCT) to image almond spurs

Project No.: **HORT3.Fichtner**

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A. Summary

Traditionally botanists and plant anatomists visualize plant structures by dissecting plant material and capturing images using photomicrocopy. HRCT has been utilized extensively in the medical field to produce three dimensional images of human anatomical structures, but its use has recently been applied to botanical systems. HRCT is a valuable tool because it can be used to reconstruct three dimensional images that can be transposed into videos allowing a viewer to visually navigate through undisturbed plant tissue. Prior to the use of HRCT, cross-sectional images of plant tissues required serial sectioning and laborious microscopy. HRCT is particularly well suited for use on lignified tissues such as buds and nuts, and therefore may be of value for the development of educational materials for California nut growers.

Using the HRCT imaging facility at CSU Bakersfield, buds of the three major nut crops in California (walnut, pistachio, and almond) were imaged to develop educational tools for extension materials. In concert with the HRCT imaging, one-dimensional botanical illustrations of buds were created by H. Hartzog (USDA APHIS). The one- and three- dimensional images facilitate explanation of both growth and reproductive strategies of almond, and allow for comparison of growth dynamics between nut crops.

HRCT images and botanical illustations have since been utilized in extension education materials. They have been featured in oral presentations, extension newsletters, and trade journal articles.

B. Objectives *(300 words max.)*

1. HRCT images were generated of vegetative and flower buds of almond borne on spurs.
2. Botanical illustrations of almond buds were created to compliment the 3D images generated by HRCT.

C. Annual Results and Discussion

Our collaborative effort has generated 3D images of the following: a) two bud types (flower and vegetative) of almond, a monoecious crop with perfect flowers, b) two bud types (compound and catkin) of walnut, a monoecious crop with imperfect flowers, and c) three bud types (catkin, female flower, and vegetative) of pistachio, a dioecious crop with imperfect flowers. Examples of imagery are featured in Figure 1. Three dimensional videos were created to allow for navigation around and through each bud type, thus allowing for explanation of reproductive systems with the use of modern visual aids.

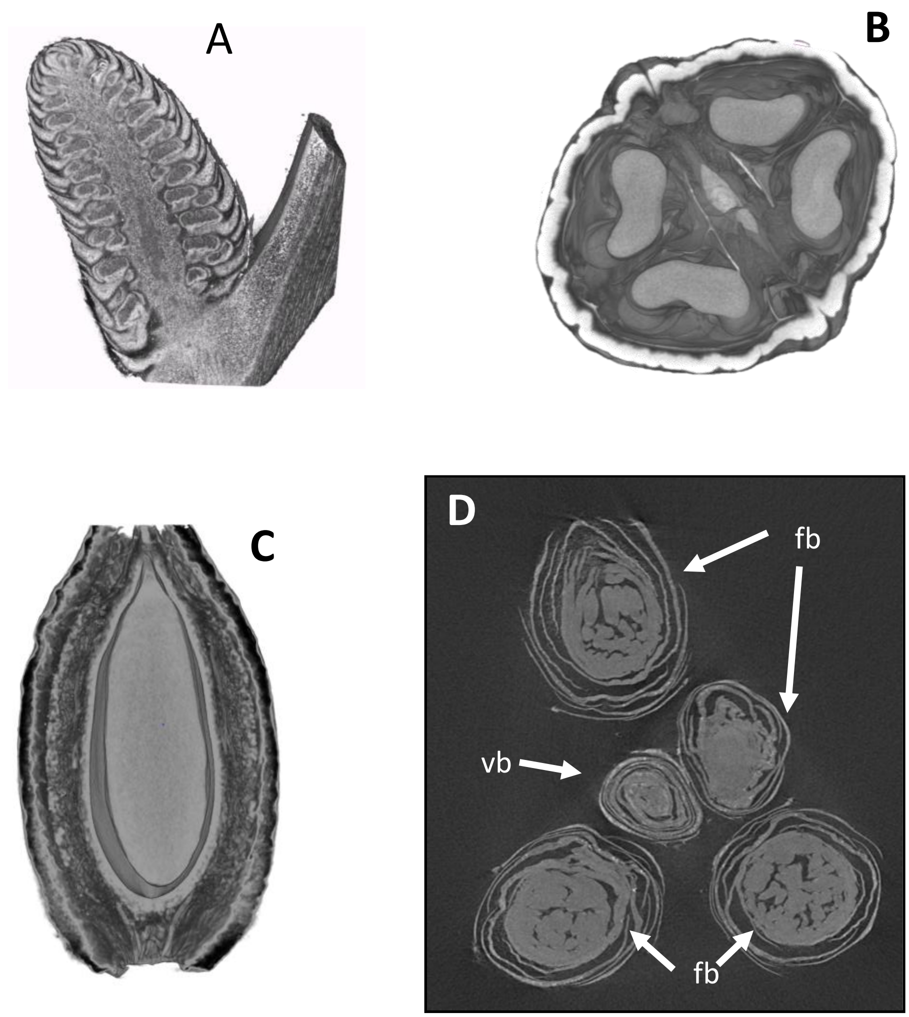

Figure 1. HRCT images were produced of a walnut catkin (A), a hulled walnut (B), an unhulled almond (C), and an almond spur (D) containing vegetative buds (vb) and flower buds (fb).

D. Outreach Activities

1. Oral presentations at the Fresno Almond Day (hosted by Jason Scott Marketing) and Kern Co. Almond Day (a UCCE event) were given in 2019. Both

presentations utilized the botanical illustrations and HRCT images generated on almond spurs and buds.

2. Botanical and HRCT images were used in a poster for the Almond Conference in December 2019 in Sacramento, CA.
3. Botanical illustrations were used in two trade journal articles (West Coast Nut) in 2019, as well as in UC ANR newsletters.
4. All UC ANR newsletter articles are posted online for future reference.

E. Materials and Methods *(500 word max.)***:**

Almond spurs were collected from commercial orchards in Tulare and Kings Counties pre-bloom. Similarly, dormant buds were collected from walnut and pistachio for coordinated imaging across nut crops. All plant materials were stored under refrigeration and transported to CSU Bakersfield within 24 hours of collection. Using the imaging facility at CSUB, buds were scanned with the x-ray and raw images were reconstructed into 3D models using InstaRecon (InstaRecon, Champaign, IL, USA), and videos using CTvox software (Bruker Corporation, Billerica, MA, USA. Both photographs and plant tissues were sent to H. Hartzon, a botanical illustrator, for creation of detailed one- dimensional illustrations of external twig and bud structures for use in print materials.

F. Publications that emerged from this work

Images generated by this project have already been utilized in two trade articles featured in West Coast Nut trade journal. Two more trade articles are expected to be composed in 2020.

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Can additional nutrition in first leaf trees alleviate symptoms of Prunus Replant Disease?

Project No.: **HORT3.Gordon**

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A. Summary

Trees were fertilized with urea (N) phosphorus (P) one of two formulations of a complete fertilizer (15-15-15 or Slow Release), or with a micronutrient only (Micro) fertilizer in a whole orchard recycled field and inserted into trial on Anaerobic Soil Disinfestation (ASD). Adding P, N, or complete fertilizers improved replanted almond tree growth over Micro only fertilizers or the grower control. The average circumference of trees fertilized with N, P, or complete fertilizers was comparable to some ASD treatments. Adding urea to ASD treatments statistically increased tree growth but the difference was horticulturally negligible. This trial shows promising results but the results need to be tested in a more statistically rigorous manner and compared to a fumigation control.

B. Objectives

The first objective of this trial was to determine whether applied fertilizers could replicate part of the growth response of Anaerobic Soil Disinfestation.

A sub objective of this trial was to evaluate the performance of phosphorus fertilizer on tree growth.

C. Results and Discussion

Due to experimental design limitations, we cannot perform a statistical comparison between the trunk circumference measurements of the full ASD trial to the fertilizer trial. However, we can observe that growth in the phosphorus, 15-15-15, slow release, and nitrogen-only fertilizer treatments was approximately as large as some moderately performing ASD treatments (Figures 1, 2). This is an important finding. The substrates and volumes used for ASD can add an extremely large nutrient load to soils, and the finding that fertilizers can improve the growth of replanted almond trees to the point of possibly rivalling some ASD treatments could explain some of the growth response of trees replanted in some ASD treatments. If these findings are replicatable, special attention to fertilization could allow growers to avoid preplant soil treatments in some sites where a nutrient boost may be as or more important than soil disinfestation.

Padre trees were larger than Butte (data not shown). There were no significant differences in October trunk circumference between the N, P, or either complete fertilizer (Figure 1), but they were significantly larger than the grower control or micronutrient blend. This indicates that nitrogen and phosphorus were both deficient, however the fact that the complete fertilizers did not show an additive growth effect is surprising. The researchers occasionally noticed that in some treatments that the applied fertilizer had not fully broken down, likely due to the emitter pattern of the microsprinklers, which applied several jets of water that sometimes missed the buried fertilizer. This also would result in less root proliferation around the fertilizer. Additionally, the repeated applications, which required digging into the soil several times and possibly disturbing tree roots, could have resulted in reduced uptake of nutrients in the repeat-application treatments. Thus, while we attempted to standardize fertilizer applications and apply immobile nutrients the the root zone, our methods could have resulted in uneven nutrient uptake. A more likely explanation was that the low rates of nitrogen applied by the grower, one applied two weeks before we began our treatments and the second in May, met much of the needs of the trees and decomposing wood chips and additional applied nitrogen resulted in very little growth. Previous research has found that in whole orchard recycled sites, nitrogen applications should start as soon as possible in the season. We may have seen a greater growth response had we started applications in March.

Adding urea to ASD treatments increased trunk circumference slightly; trees treated with urea had a trunk circumference of 13.6 cm, whereas those without urea treatments had a trunk circumference of 13.2 cm. While the difference is statistically significant, it may not be horticulturally significant. This could indicate that: 1) ASD treatments and/or grower fertilization provided almost all the nitrogen the trees needed, or 2) the application method or timing for urea treatments did not provide nitrogen at the right rate or right time. The first treatment in the ‘urea’ trial was in May, a month later than in the ‘fertilizer’ trial and two months later than recommended in whole orchard recycled orchards, and thus could have been applied too late to affect tree growth. Alternately, if breakdown of urea to ammonium began to occur before the urea was completely incorporated into the soil, the actual rate of applied nitrogen could have been reduced.

Leaf tissue results did not correspond to growth in the fertilizer trial (Table 1) and only leaf manganese levels were significantly different by the end of the season. Trees fertilized with the slow release treatment had significantly higher leaf manganese levels. The slow release fertilizer did contain some manganese, and it is possible that a complete fertilizer blend resulted in higher manganese uptake, which could also explain the July leaf manganese results. It is harder to explain the July potassium and calcium leaf tissue results; root disturbance from repeat applications of the P, N and 15-15-15 could explain the lower leaf tissue levels of those treatments. Regardless, these differences disappeared by September.

Potassium and calcium leaf tissue values corresponded with ASD treatments in the ASD trial (Table 2). While there were significant differences in leaf Mg, Mn, and Cu levels, they are far above leaf sufficiency values in bearing trees, though it should be emphasized that sufficiency standards should be viewed with caution in nonbearing trees. This is especially true for nutrients such as calcium, where leaf standards are developed on spur leaves that develop at the beginning of the season and accumulate calcium until leaves are sampled. This could explain the leaf calcium levels being far below leaf critical values despite no calcium deficiency symptoms being noted. Adding urea to trees in the ASD trial resulted in reduced leaf potassium, magnesium, calcium, and iron levels and increased leaf phosphorus and boron levels (Table 3).

Due to our inability to fumigate, we cannot fully determine whether fertilization can help boost tree growth in a replant situation. This trial should be repeated in a site where fertilization can be fully compared with fumigation and ASD treatments. However in many previous trials, ASD with a rice bran substrate was comparable to fumigation. More work needs to be done to tease out the role of nutrition in ASD and replant issues.

Table 1: 'Fertilizer Trial' leaf tissue results.

	July			**September**
Treatments	% K	% Ca	ppm Mn	ppm Mn
Slow release	1.69^{A}	1.09^{A}	116^{A}	72^{A}
Control	1.61^{A}	1.17^{A}	69^{BC}	51^{B}
Micros	1.55^{AB}	0.94^{AB}	57^{C}	47^{B}
Phosphorus	1.49^{ABC}	0.88^{AB}	56^{C}	53^{B}
15-15-15	1.29^{BC}	0.76^{B}	93^{AB}	57^{B}
Nitrogen	1.2^{C}	0.77^{B}	59^{C}	56^{B}

Reported results are for combined Butte and Padre leaves, sampled from one year old almond trees. The most recently matured leaves were sampled.

Table 2: Leaf tissue analysis of trees in ASD treatments

Treatment	% K	% Ca	% Mg	ppm Mn	ppm Cu
RBNoTarp	1.68^{A}	1.05^{A}	0.37^{BC}	52.8^{BC}	7.8^{C}
RBTarp	1.62^{AB}	1.1^{A}	0.39^{A}	99.3^{A}	10.8^{AB}
AlmNoTarp	1.60^{AB}	1.00^{AB}	0.36^{BCD}	49.3^{BC}	10.6^{AB}
CtlNodrip	1.53^{BC}	1.03^{A}	0.38^{AB}	57.5^{BC}	9.8^{B}
AlmTarp	1.47^{BC}	0.92^{BC}	0.35^{CD}	62.8^{B}	11.3^{A}
CtlTarp	1.38^{C}	0.90^{C}	0.34^{D}	40.0^{C}	9.8^{B}

Reported results are for combined Butte and Padre leaves, sampled from one year old almond trees. The most recently matured leaves were sampled.

Table 3: 'Urea Trial' Leaf tissue values for September

Treatment	% P	% K	%Ca	%Mg	ppm B	ppm Fe
Urea	0.28^{A}	1.34^{B}	0.88^{B}	0.36^{B}	171^{A}	200^{B}

Control	0.22^{B}	1.75^{A}	1.12^{A}	0.38^{A}	92^{B}	261^{A}

Reported results are for combined Butte and Padre leaves, sampled from one year old almond trees. The most recently matured leaves were sampled.

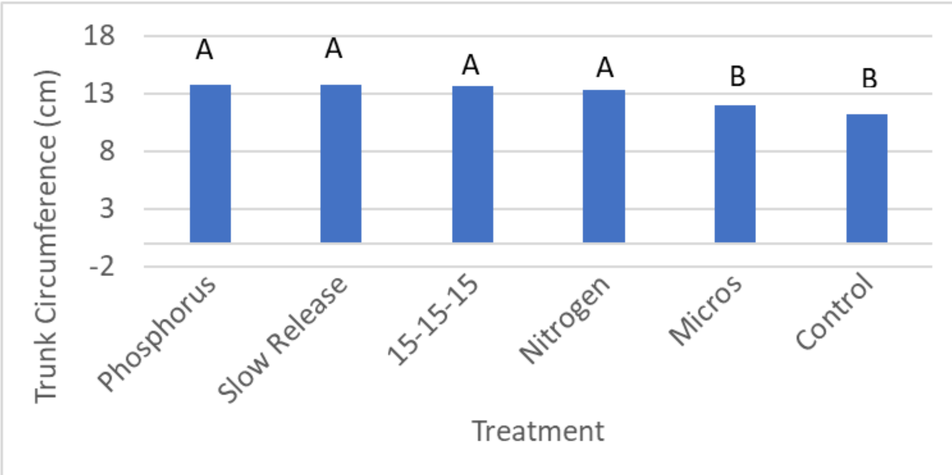

Figure 1: October trunk circumference of combined Butte and Padre trees fertilized with six fertilization treatments. Circumference was measured above the tree guard to standardize the measurements.

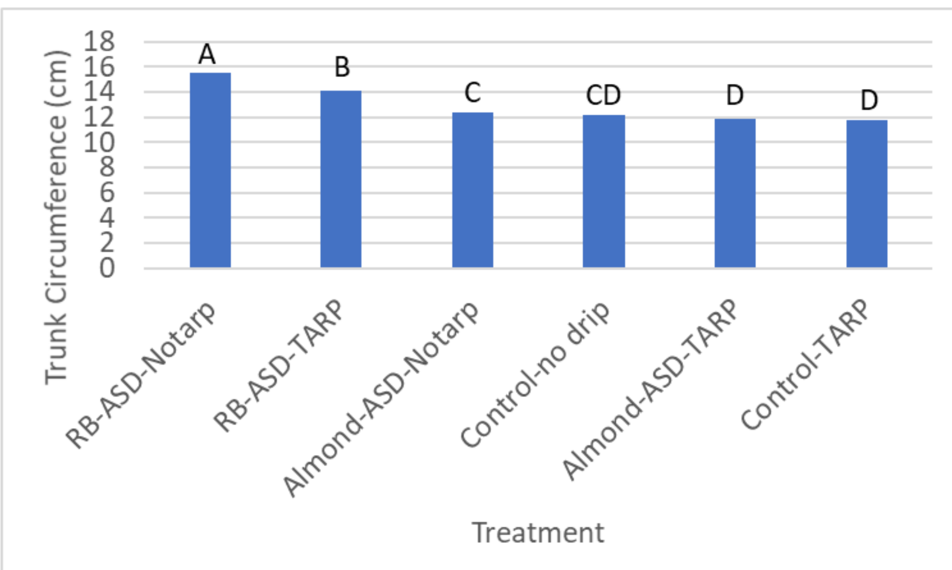

Figure 2: October trunk circumference of combined Butte and Padre trees fertilized with six fertilization treatments. Similar results also reported in PATH1-Brown; inclusion in this report is for comparison purposes. Circumference was measured above the tree guard to standardize the measurements. The reported results do not include trees from the 'urea' trial

D. Outreach Activities

The only outreach activity performed thus far has been an poster at the Almond Conference, and a discussion of preliminary results during a session of the field day at the Almond Short Course in November, 2019. The authors intend more extensive outreach to be done after planned followup work is completed.

E. Materials and Methods:

This trial was conducted in another Almond Board of California funded project on Anerobic Soil Disinfestation (PATH1-Browne). The previous generation orchard was recycled, wood chips incorporated into the soil, and in September 2018 the ASD treatments were initiated. Fumigation was unable to be performed due to the fall rains. Butte and Padre on Nemagard were planted in February 2019. The varieties were interplanted down the row. In April 2019, the fertilizer trial was begun. Treatments (Table 4) were applied to four trees in each nutrition row, replicated four times across the field. Applications consisted of digging a narrow trench approximately 12-18 inches from the base of all trees including the control, on the north and south side of the trees following the tree berms. The fertilizer was applied in the slot and buried. No fertilizer was applied to the control trees. This was done for all repeated fertilizer applications. The distance from the tree was selected to ensure the fertilizer was applied in the irrigation wetting pattern. The researchers accidentally skipped an application of fertilizer in June, thus the slow release fertilizer had higher application rates since all was applied at the beginning of the trial. Starting in May, urea was added to four trees in each ASD row (ASD*Urea trial). The urea trial was surface applied; the first application was done preceeding rain, and the remainder were applied to the wetting zone. The control consisted of the grower's fertilization practice, which was to apply 10.5 lbs N/acre (UN32) via fertigation split over two applications in early April and May, and 0.25 lbs of N, 0.6 lbs of P, and 1.2 lbs of K over two foliar applications. The grower's fertilization regieme was applied to all trees; fertilizer treatments were in addition to the grower's practices.

Leaf samples were collected from the Fertilizer trial in July, and leaf samples were collected from the Fertilizer trial and the ASD*Urea trial in September and submitted to DellaValle Laboratories (Fresno, California). Trunk circumference was measured in October. Leaves were not separated between variety due to insufficient biomass. Data was run in JMP version 14 as a Randomized Complete Block Design and significant differences were calculated with Student's t LSD.

Table 4: List of fertilizer formulations, amount per application, and total nutrient load applied.

	Fertilizer treatments	Amount per application	Total amount applied
Fertilizer Trial	Control	None	N/A
	15-15-15	6.66 oz, 5 applications	5 oz N, 5 oz P_2O_5, 5 oz K_2O
	Slow release 15-9-12+micros	40 oz, one application	6 oz N, 3.6 P_2O_5, 4.8 oz K_2O, .52 oz Mg, 2.4 oz S, .184 oz Fe, .024 oz Mn, trace amounts of B, Mo, Zn

	Phosphorus 0-46-0	2.17 oz, 5 applications	5 oz P_2O_5
	Pelletized urea 46-0-0	2.17 oz, 5 applications	5 oz N
	Micros	2.7 oz, one application	0.135 oz Ca, 0.275 oz Mg, 0.415 oz S, 0.012 oz Cu, 0.143 oz Fe, 0.027 oz Mn, 0.020 oz Zn, and 0.001 oz B
Urea Trial	Control	None	N/A
	Urea	2.17 oz, 4 applications	4 oz N

F. Publications that emerged from this work

None.