Almond Culture and Orchard Management

Project No.: **17-HORT3-Yaghmour**

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Objectives:

The Almond Culture and Orchard Management report summarizes a series of projects conducted by University of California Cooperative Extension (UCCE) Farm Advisors to address local, regional, and/or statewide issues facing almond production throughout California.

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Objectives:

1. Using a 3rd leaf planting (Hansen rootstock, Nonpareil and Monterey scions) select 4 areas that range from 0.5 to 5 dS/m EC and ppm soluble boron.
2. Document differences in tree stature corresponding to these areas.

3. Correlate soil salinity and specific ion concentration with rootstock, scion and traditional leaf tissue samples to see if wood sampling provides an early indication of pending toxicity problems.

Interpretive Summary:

Problem and its Significance: Almond growers have been pushing the limits on almond salt tolerance for the last 10 years as land price and availability have skyrocketed while available surface water supplies have decreased, and groundwater salinity is increasing. Many of these plantings look good for several years and then hit the wall as one or more specific toxic ions (especially boron) finally reaches the critical level in the tree that can limit water/nutrient uptake, cause severe gumming, leaf burn, reduced growth and eventually death. There is no data documenting woody tissue deposition / concentration of these ions as a function of soil salinity to determine if sampling of the woody xylem tissue would give a grower an early warning sign of significant upcoming toxicity problems not yet showing in leaf tissues.

Kern survey/results: The selected Kern quarter section almond planting 5 miles NW of Lost Hills provides the perfect location to test this idea. Initial salinity in this block varies from an EC of 1.8 to 6.1 dS/m from the east to west side in 2015 and 3.6 to 4.8 dS/m in 2017. Due to the larger trees on the eastside of the block almost zero leaching fraction occurs which means the imported salt in the California Aqueduct irrigation water stays in the rootzone. Soluble soil boron in the same manner increases from 0.3 ppm in the east to 2.3 in the west. Despite these significant native soil salt differences across the field the salt tolerant Hansen rootstock has not really shown differential xylem wood or leaf tissue nutrient/salt concentrations for any of the areas – even though some trees in western Area 4 show visible gummosis on the scion. Although, a trend of higher scion xylem calcium with lower salinity is apparent.

Of course, the higher osmotic potential of the saline soils reduces water uptake and, therefore, tree trunk circumference, height and canopy volume and the 2017 5th leaf yield consistently decreased from east to west with increasing salinity. There is no replication for this survey and therefore no statistical analysis. In 2015, three popular surfactant/plant digest liquid materials were applied in replicated plots on the Westside to evaluate their benefit to the trees in the higher salinity area. None of the above growth indicators were improved using these materials. (See 2016-17 Symmes Annual Report for these results.)

Materials and Methods:

A 3rd leaf quarter section almond block in NW Kern County – 50/50 Nonpareil and Monterey was planted on Hanson rootstock in 2013. A significant gradient in increasing native salt load in this soil is obvious as you move from East to West despite having leached this ground with two foot of water using sprinklers prior to planting. The total soil salt load (EC), sodium (Na), chloride (Cl) and boron (B) increases 2 to 3-fold from Area 1 to 4 (**Figure 2**). Tissue and soil samples have been collected from the same 2 discreet trees since 2015 for each area at the end of the season. Nonpareil kernel yield is also taken from these trees. (**Figure 1**) illustrates the AREA layout along with CERES aerial imagery indicating increasing water stress from east to west.

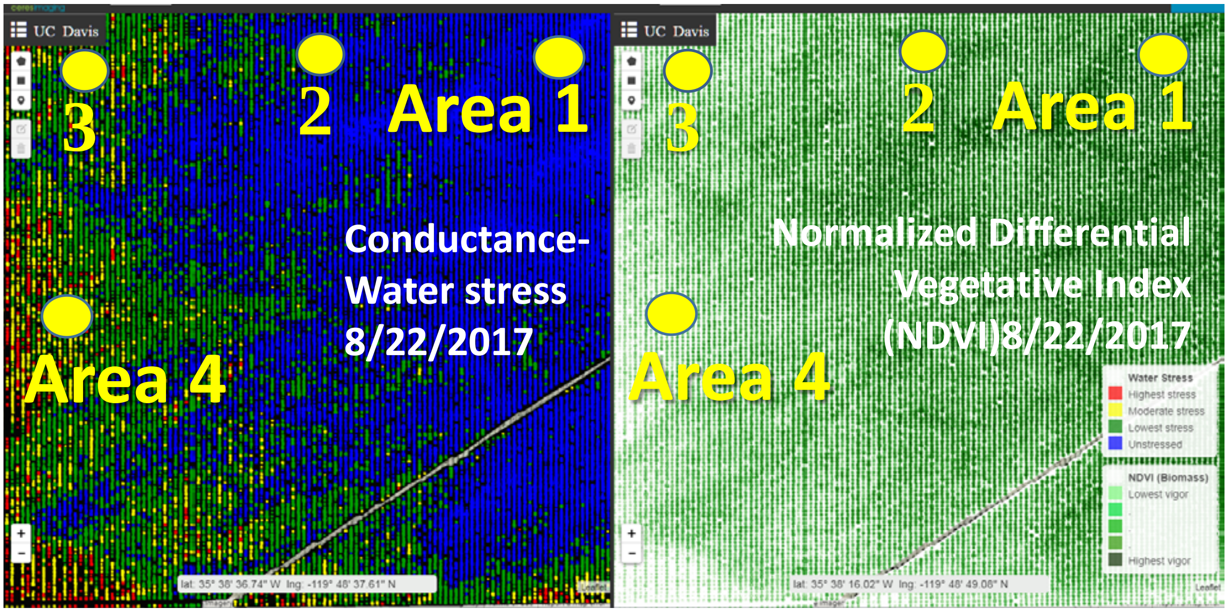


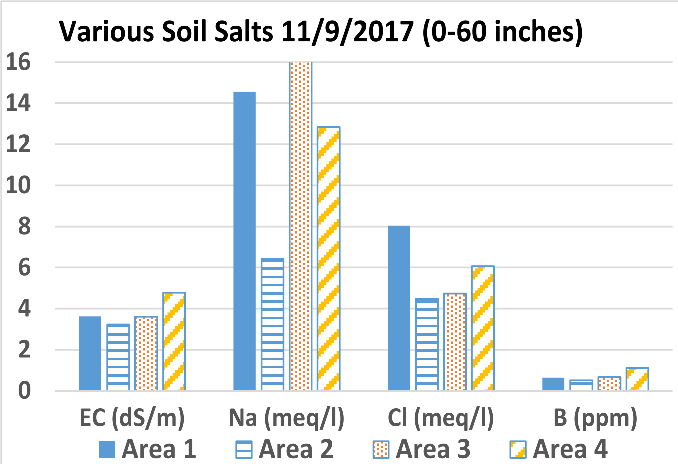
Figure 1. CERES aerial remotely sensed CONDUCTANCE (8/22/2017) and geographic locations of AREAS 1 to 4.

Excess sodium and the extremely fine particle size of many of these soils can cause poor aggregation, soil structure and, therefore, water movement. Efficient water penetration and leaching is critical to enable profitable production in these orchards.

Results and Discussion:

The first year (2015) all tissue samples for leaves, trunk corings and hull B showed no real difference with respect to Na, Cl and B. In 2016 the hull B of Area 4 at harvest was 58% higher (195 ppm) than Area 1 (124 ppm). For 2017, however, the hull B of Area 1 was 180 ppm compared to 155 ppm for Area 4 (**Figure 7**). Calcium scion xylem concentration increased with decreasing salinity (**Figures 3, 4, 5**). There does appear to be more sporadic gummosis on the occasional tree in Areas 3 and 4 compared to Area 1. The elevated salt load and associated osmotic resistance to water uptake has decreased tree size in Area 4, but the usual marginal salt burn associated with this is basically absent. Surfactant amendments made no difference in tree water stress (CONDUCTANCE) or growth/vigor (NDVI) in the small plot companion test in the elevated salinity zone of Area 4.

The trunk circumference of Area 4 was 19% less than Area 1 the end of 2015 and still 16% less the end of 2017. The 3rd leaf yield was very low even for the low salinity Area 1 @ 312 lb./ac and 137 lb./ac for Area 4, a 56% decrease. The 5th leaf yield was 3708 lb./ac for Area 1 and 1616 lb./ac for Area 4, still a 56% decrease (**Figure 6**).



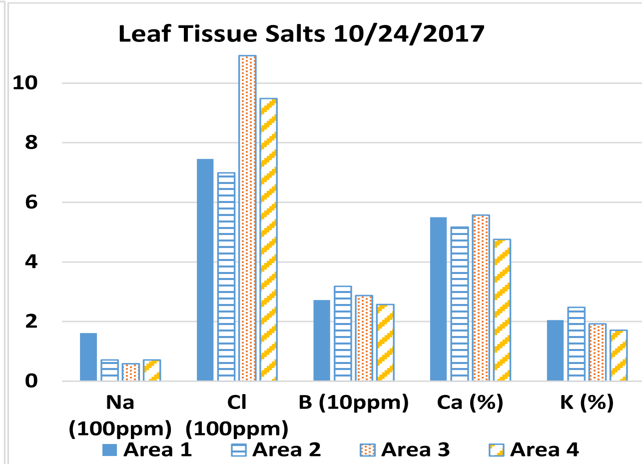
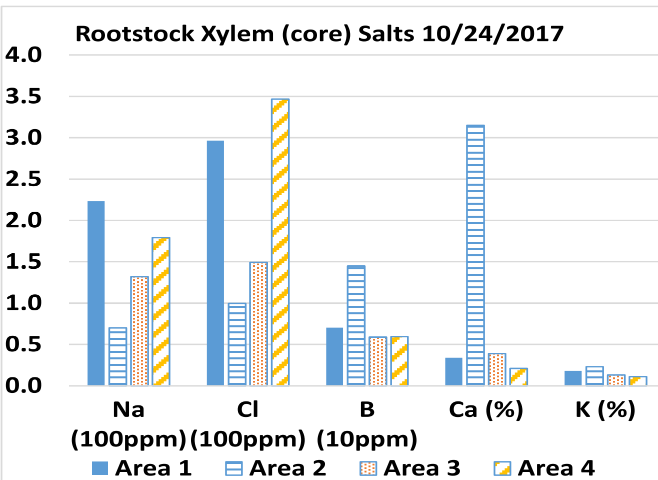


Figure 2. Selected soil salt concentrations to 60”.

Figure 3. End of season leaf tissue Na, Cl, B, Ca, K.



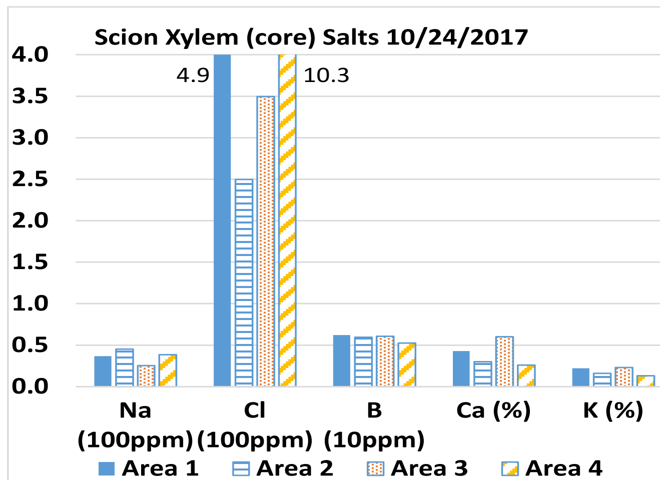
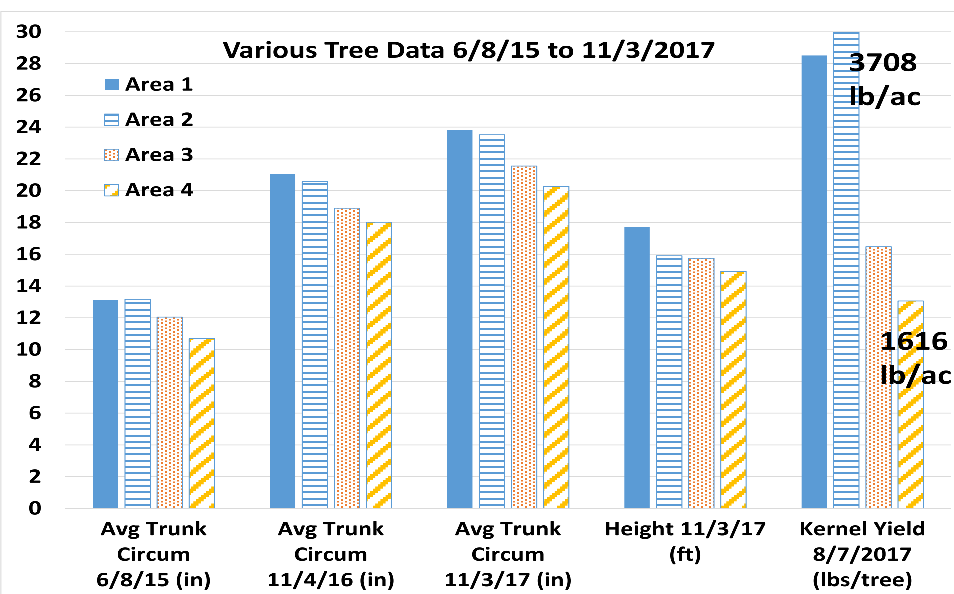


Figure 4. End of season rootstock Na, Cl, B, Ca, K.

Figure 5. End of season scion Na, Cl, B, Ca, K.



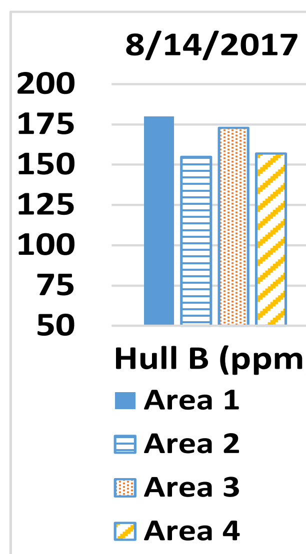


Figure 6. Scion circumference, tree height and kernel yield for all areas.

Figure 7. Hull B at harvest.

Research Effort Recent Publications:

None

References Cited:

None

Project Title: **Almond Bloom Disease Control Trials**

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Problem and its Significance: Brown Rot, Shot Hole, Scab
There are several fungal diseases that can infect almond trees during bloom, infecting and killing blossoms and ultimately reducing yield. Fungicides are commonly sprayed on almond trees, and other stone fruits, during bloom to prevent disease. In some instances, fungicide resistance has developed in pathogen populations. Resistance to single site-specific fungicides (Strobilurins) have been reported. These new fungicides have low residual activity and are environmentally safe, but since they are single-site specific, resistance can also develop to them. Thus, it is important that growers practice a fungicide rotation program where different classes of fungicides are used so that pathogen resistance will not build up in response to the over use of any one fungicide or class of fungicides. It is also important that these new and previously registered fungicides are evaluated for disease efficacy by unbiased personnel that can extend such information to growers and PCAs.

Objectives:

1) Consideration should be given to develop a disease management program that avoids developing fungicide resistance not only with Brown Rot, Shot Hole, and Scab but other fungal diseases sprayed during the same timing period, such as Anthracnose and Alternaria. We evaluated conventional, organic, and developmental unregistered fungicides for their efficacy to control brown rot, shot hole, and scab bloom diseases of almond.

Materials and Methods:

Replicated and randomized block experiments were placed in an experimental orchard at the Kearney Research and Extension Center to evaluate fungicide efficacy. Single tree replications were used since crop destruct is necessary when unregistered materials are studied. Different almond varieties are chosen for specific studies because some varieties are more resistant to certain diseases than others. Fungicide trials are rated for disease a few weeks after bloom when symptoms are visible. Fungicides are grouped into their respective chemical classes and rated for their efficacy to control certain diseases at a particular stage in bloom development.

Results and Discussion:

Sequential treatments' of Aproach (Picoxystrobin + Cyproconazole), Fontelis (penthiopyrad), Quadris Top (difenoconazole + azoxystrobin), Bravo Weather Stick (chlorothalonil), Inspire EC (difenoconazole), experimental products from DuPont Crop Protection, Syngenta Crop Protection, and Nichino America, along with organic products Timorex Gold (tea tree oil), Microthiol Disperse (micronized wettable sulfur), and Regalia (extract of Reynoutria sachalinensis) in tank-mixtures and in various combinations and timings for the control of almond brown rot and scab. Most treatments significantly reduced the incidence and severity of brown rot and scab when compared to our two untreated controls.

Project Title: **Tree Growth and Soil Health Response to Wood Mulch Incorporation in a Newly Established Orchard**

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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 C supplied by WOR mulch may lead to improvements in soil health that could be beneficial to orchard growth in the long term. Preliminary research comparing WOR of stone-fruit trees at 30 tons per acre with burning and incorporating the ash resulted in significantly higher yields, soil nutrients, and organic carbon in the grind treatment when compared to the burn from 2008 to 2016 (Holtz et al. 2016). Almond orchards last about 10 to 15 years longer than a stone-fruit orchard, with significantly larger sized trees by the end of its productive life. We speculate a completely recycled higher-density almond orchard would incorporate 85-90 tons per acre, nearly triple the volume applied in the earlier study (Holtz et al. 2016). It is unknown what impact a large application of wood grindings, matching the estimated volume of a recycled 20+ year old orchard will have on replanted almond tree nutrition and growth during the establishment years.

Our results show the high C composition of the WC treatment facilitated the immobilization of fertilizer N applications leading to reduced tree growth and nutrition in the first year. Higher microbial biomass growth in WC treatments signals decomposition processes are turning over the high C containing wood chips. Despite frequent fertigation events, available N levels were limited. 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, which will 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. Overcoming stunting in the first two years of growth, the first Grind and Burn trial demonstrated significantly higher cumulative yield over the lifetime of an almond orchard. Despite the same outcome for year one of this trial at the 85 ton/ac rate, we expect a similar balance of nutrient immobilizing and mineralizing processes may result in the WC treatments over a period of a few seasons, and that almond tree growth will catch up to other orchard management approaches without significant impacts on yield.

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 and a non-treated control. 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. Trees received approximately 1 ounce of N (0.06 lb. N/tree) per fertigation application of UN32 from May to October.

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) within the first growing season was determined based on the circumference (cm^2) of the trunk 16 inches above the soil line in February and October. Tree leaf nutrient levels were based on 15 leaves from each of the three centermost trees in each plot in July. The dried, ground material was analyzed for N, P, K, B, Ca, Zn, Cu, Fe, Mg, Mn, and S (ICP-AES). Composited soil sampling took place one day prior to and three days after fertigation each month. Analyses were performed on sieved moist samples within 4 days of sampling. Pre-fertigation measurements included: soil nitrate and ammonium levels at three depth increments (0-15, 15-3, 30-45 cm), organic C, total N, available P, and K, EC, soluble cations, and gravimetric water content. Post fertigation sampling included soil inorganic N levels only. Total microbial biomass (ng/g soil), fungal to bacterial ratios, broad microbial community structure was determined five times throughout the 2017 growing season, prior to fertigation, by method of phospholipid fatty acid analysis as described by Hamel et al. (2006) at the Ward Laboratory (Kearney, Nebraska). A general linear mixed model with repeated measures analysis of variance (ANOVA) was used in SAS (Proc Glimmix, SAS Version 9.4, SAS Institute). Natural log and square root transformations were used for analysis where necessary to meet model assumptions. A principal component analysis (PCA) was performed using PAST 3.17 software (University of Oslo) to model multi-factorial relationships between different soil indicators.

Results and Discussion:

Wood Chip plot trees growth and nutrition was significantly lower than all other treatments including the control. Wood chip TCSA increased only by ~6.0 cm^2 in the first growing season (**Table 2**). July nitrogen tree leaf % N was significantly lower than all other treatments, however the 2.5% N level in WC trees exceeds the sufficiency recommendation for almond. Trees growing in the RB plot had the same increase in growth compared to fumigated treatments (**Table 2**).

Soil nitrate and ammonium nitrogen (NO_3—N, and NH_4^+-N) levels collected prior to and after fertigation were significantly different among treatments. Thought not always significant, WC had the lowest overall pre-fertigation NO_3-N and higher before and after fertigation NH_4^+ levels than the fumigation and control plots (**Figure 1**). Lower pre-fertigation NO_3—N suggests increased immobilization, and higher NH_4^+-N levels may indicate lower nitrification potential of ammonium supplied by UN32 fertigation in the WC treatment. The RB treatments had the highest post fertigation levels of NO_3—N. Soil inorganic N levels varied by depth throughout the season (month*depth, $p \leq 0.001$). Early and late season concentrations were higher in the 0-15 cm range, although mid-season levels were generally no different from 0 to 45 cm, indicating N movement down in the soil profile (data not shown).

Table 2. Average increase in growth expressed as trunk cross sectional area (TCSA) nd July average leaf % nitrogen for three organic amendment treatments compared to strip fumigation and untreated control. Treatment standard error is reported in (). Different letters indicate a significant difference at the $p \leq 0.05$ level.

Treatment	TCSA increase (cm^2)	Leaf tissue % N
Control	10.09b (0.60)	2.77b (0.06)
Strip Fumigation	15.87a (0.56)	2.95ab (0.00)
Rice Bran	14.91a (0.71)	2.88ab (0.02)
Almond Hull	11.76b (0.54)	2.87ab (0.06)
Wood chips	6.34 (0.49) c	2.56c (0.03)

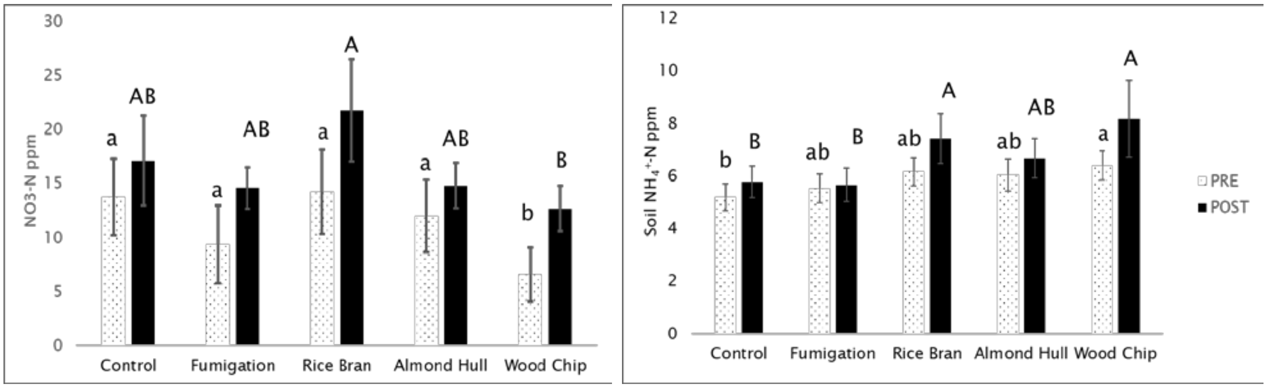

Figure 1. Montly average pre and post fertigation inorganic N levels. Different lower-case letters indicate differences between pre-fertigation NO3- -N and NH4+ concentrations and UPPER-case letters indicate differences between treatments POST-fertigation at the p≤0.05 level. Reported means are for untransformed data.

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. Evaluation of soil phospholipid fatty acid (PFLA) under the different amendments resulted significantly higher overall fungal (p<0.0112) and bacterial biomass (p<0.0017), arbuscular mycorrhizae (p<0.0001), saprophytes (p<0.0015), actinomycetes (p<0.0003), rhizobia (p<0.0103), and protozoan (p<0.0130) populations (**Figure 3**). Higher total soil microbial biomass (p<0.0001) and fungal to bacterial ratios (p<0.0100) resulted 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.

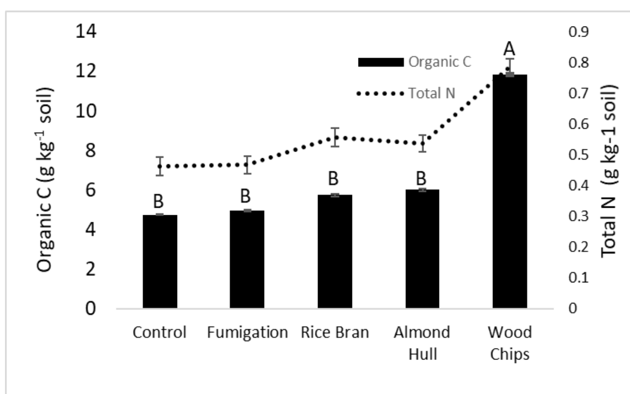

Figure 2. Season end average soil organic C and total N concentrations. Different upper case letters indicate differences between soil organic C and total N levels at the p≤0.05 level

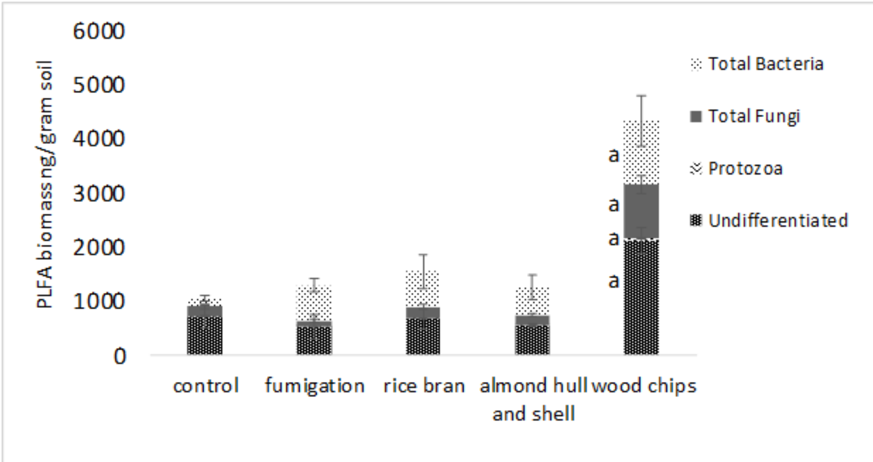

Figure 3. Phospholipid fatty acid (PFLA) of soil collected from 0-15 cm depth for each organic amendment, fumigation and control treatments. Different letters indicate a significant difference between wood chips and all other treatments at the p<0.01 level.

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.

Project Title: **Mechanical Topping of Almond Trees During the Second Dormant Season**

Project Leader: Dani Lightle
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Objectives:

1) Compare early yields from trees mechanically topped during the second dormant season to trees left un-topped.

Interpretive Summary:

Some growers in the northern Sacramento Valley have adopted the practice of mechanically topping almond trees during the second dormant season. The rationale behind this practice is to attempt to produce greater numbers of spurs during the 3rd leaf growing season than an un-topped tree, resulting in a greater yield in 4th leaf. A side benefit to this practice may be reduced wind-throw while the root system is continuing to establish.

This study is following two orchards that were planted winter 2014/15; one planted on Nemaguard and the other on Hansen. The trees were flat-topped at a height of approximately 9 feet in November 2016. The estimated cost for the mechanical topping treatment (including topping and brush removal) was approximately $90 per acre. At a price of $2.50/lb., yields in 4th leaf on topped trees would need to be equivalent to any yield loss in 3rd leaf, plus an additional 36lbs/ac. Yield data from Nonpareils were collected in 2017 (3rd leaf) and will be collected again in 2018. There were no yield differences between treatments in 2017.

Materials and Methods:

The replicated trial was established in two separate orchards in November 2016. Both orchards were planted in winter 2014/15 as potted trees. Trees were headed at planting. During 1st dormant, the grower selected 3-4 scaffolds per tree and tipped them. During 2nd leaf, any crossing limbs were removed. The mechanical topper was run through both orchards in November 2016 and topped the trees at a 9-foot height.

Orchard 1 is a Nonpareil, Butte & Carmel orchard on Nemaguard on a Tehama loam soil. Each block contains 40 trees per variety; 20 trees were mechanically topped, and 20 trees were left untopped. The treatments were replicated three times.

Orchard 2 is a Nonpareil & Monterey orchard on Hansen, planted in a Cortina gravelly sandy loam soil. Each block contains 40 trees per variety with 20 mechanically topped and 20 trees untopped. The treatments were replicated four times.

Results and Discussion:

A topped tree next to an untopped tree in February and May 2017 are shown in (**Figure 1**). There were no differences in yield between topped and untopped Nonpareil trees in either block in 2017 (**Table 1**).

The incurred costs for mechanical topping were estimated by the grower and shown in (**Table 2**). Costs include the topper machinery, brush stacking and brush removal.

Figure 1. An untopped tree (left) next to a topped tree (right) during bloom 2017 (top photo) and in May 2017 (bottom photo).

Table 1. Average yield (lbs./ac) in 2017. There were no yield differences between topped and untopped trees within an orchard.

	Topped	**Untopped**
Orchard 1	1157 ± 238	1149 ± 248
Orchard 2	304 ± 11	308 ± 46

Table 2. Estimated expenses associated with mechanical topping during the 2nd dormant season. Expenses were estimated by the grower cooperator in this study.

Estimated Costs per Acre in 2015	
Machine Topping	$50
Brush Stacking	$20
Brush Removal	$20
Total Cost	**$90**

Project Title: **Survey to Determine Frequency of Prunus Necrotic Ringspot Virus and other Ilarviruses in Newly Established Almond Orchards**

Project Leader: David Doll
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Introduction:

Prunus necrotic ringspot virus (PNRSV) is a member of the Ilarvirus group and can infect many *Prunus* species including almond. Certain strains, such as the almond calico strain can cause infectious bud failure and impact tree productivity. These viruses are pollen transmitted but are not venereal. Infection is indirect and requires thrips to wound the flower to allow virus entry. Therefore, PNRSV can spread through an orchard, albeit slowly. More commonly, however, PNRSV is transmitted by grafting when infected tissue is grafted to healthy trees.
PNRSV is commonly found in almond orchards world-wide and is a major limiter of production. Within California, however, occurrence has been limited due to quarantine services and clean stock programs within nurseries. Infected tissue utilized as bud wood can spread the virus to new locations. Once infected tissue is in the field, transmission to non-infected trees occurs. Since the virus is pollen born and is spread through flowers, newly planted trees typically are disease free until they flower. The exception is if the virus was transmitted in bud wood or rootstock tissue produced via cuttings.

There are several strains of PNRSV that impact almond trees differently. Some strains are symptomless, while others can cause severe crop loss. Symptoms are characterized yellow spotting on leaves that are typically only observed in the springtime when viral concentrations are high. Leaf symptoms may be mottled (yellow spots), yellow, or have the presence of ring-looking spots. Fruiting bud loss can occur, reducing yield, leading to a willow-like appearance to the tree. Similar symptoms may occur with boron deficiency (BD) and non-infectious bud failure (NIFB). BD can be confirmed with a hull analysis. Terminal vegetative buds do not usually grow with NIFB.

Recently, there has been an increase in young to middle aged almond plantings testing positive for PNRSV. Although the initial source of infections is unknown, there is a high possibility that these orchard infections originated with infected nursery material.

Objectives and Methods:

One-year-old trees that have not flowered were surveyed to determine the frequency of PNRSV infection. Two to three leaves from 10-12 trees of the same variety were selected, pooled, and sent to a commercial lab to screen for PNRSV. Tree source and variety were kept anonymous for the report, but results were shared with the respective nursery if any viruses were detected. Twenty orchards were sampled and submitted 41 samples for analysis. Screening for two other Ilarviruses (Tomato Ringspot Virus (ToRSV) and Prune Dwarf Virus (PDV)) also occurred.

Results and Discussion:

Four out of 41 samples tested positive for PNRSV from three different sites and three different nurseries (**Table 1**). Nurseries with positive results were contacted to screen their respective budwood source trees. The other viruses were not detected.

The occurrence of this virus at a nearly 10% occurrence within newly planted orchards warrants further investigation. Within the study, the occurrence was limited to three nurseries all which have participated in viral indexing programs through State agencies. This suggests that either false negatives occur or budwood is selected from trees that aren't tested. Budwood sourcing from non-tested trees has happened in the past during periods of high planting. From a grower's perspective, the presence of PNRSV within newly planted trees is concerning. Infected trees that are planted will most likely have low production and serve as a reservoir of the pathogen. Over time, the pathogen will spread to unaffected trees within an orchard, resulting in lower productivity and eventual orchard removal. Considering that this pathogen is a virus and is spread by thrips, there is no economical chemical control besides prevention of disease establishment.

To prevent disease establishment and spread within an orchard, trees should be certified disease free. Check with the nursery to see if they are participating in State virus screening programs, and if not, choose another nursery. Newly planted trees can be checked by pulling leaf tissue in mid-April through May. Mature "bull trees" or any other low yielding tree should be checked for leaf symptoms in the spring and tested. If positive, trees should be removed prior to bloom the following year to reduce transmission to healthy trees.

Acknowledgement:
I would like to thank AL&L Crop Solutions Laboratories for providing discounted virus testing for this study.

Table 1: Test results for three different Ilarviruses from 20 different new orchard plantings within Merced County. The label “nd” given if the virus was not detected.

Sample ID	Sample Location	Material	Variety	Rootstock	PNRSV	PDV	ToRSV
DD1	1	Potted	Aldrich	Hansen 536	nd	nd	nd
DD2	1	Potted	Nonpareil	Hansen 536	nd	nd	nd
DD3	1	Bare root	Nonpareil	Nemaguard	nd	nd	nd
DD4	1	Bare root	Aldrich	Nemaguard	nd	nd	nd
DD5	2	Bare root	Independence	Viking	nd	nd	nd
DD6	2	Potted	Independence	Viking	nd	nd	nd
DD7	3	Bare root	Independence	Viking	nd	nd	nd
DD8	3	Bare root	Independence	Viking	nd	nd	nd
DD9	3	Potted	Independence	Viking	nd	nd	nd
DD10	4	Bare root	Nonpareil	Nemaguard	nd	nd	nd
DD11	4	Bare root	Monterey	Nemaguard	nd	nd	nd
DD12	5	Bare root	Aldrich	Krysmk-86	nd	nd	nd
DD13	5	Bare root	Nonpareil	Krysmk-86	nd	nd	nd
DD14	5	Bare root	Wood Colony	Krysmk-86	nd	nd	nd
DD15	6	Bare root	Aldrich	Viking	nd	nd	nd
DD16	7	Bare root	Nonpareil	Nemaguard	nd	nd	nd
DD17	7	Bare root	Wood Colony	Nemaguard	nd	nd	nd
DD18	7	Bare root	Supareil	Nemaguard	nd	nd	nd
DD19	7	Bare root	Aldrich	Nemaguard	nd	nd	nd
DD20	8	Bare root	Nonpareil	Nemaguard	nd	nd	nd
DD21	8	Bare root	Monterey	Nemaguard	nd	nd	nd
DD22	9	Bare root	Nonpareil	Nemaguard	nd	nd	nd
DD23	9	Bare root	Wood Colony	Nemaguard	nd	nd	nd
DD24	9	Bare root	Nonpareil	Nemaguard	nd	nd	nd
DD25	10	Bare root	Nonpareil	Krymsk-86	nd	nd	nd
DD26	10	Bare root	Monterey	Krymsk-86	POSITIVE	nd	nd
DD27	11	Bare root	Independence	Lovell	nd	nd	nd
DD28	12	Bare root	Independence	Lovell	nd	nd	nd
DD29	13	Bare root	Independence	Nemaguard	nd	nd	nd
DD30	14	Bare root	Independence	Nemaguard	nd	nd	nd
DD31	15	Bare root	Independence	Nemaguard	nd	nd	nd
DD32	16	Potted	Monterey	Nemaguard	nd	nd	nd
DD33	17	Bare root	Nonpareil	Hybrid	POSITIVE	nd	nd
DD34	17	Bare root	Carmel	Hybrid	POSITIVE	nd	nd
DD35	18	Bare root	Nonpareil	Nemaguard	nd	nd	nd
DD36	18	Bare root	Fritz	Nemaguard	POSITIVE	nd	nd
DD37	19	Potted	Nonpareil	Krymsk-86	nd	nd	nd
DD38	19	Potted	Monterey	Krymsk-86	nd	nd	nd
DD39	19	Potted	Carmel	Krymsk-86	nd	nd	nd
DD40	20	Bare root	Butte	Nemaguard	nd	nd	nd
DD41	20	Bare root	Padre	Nemaguard	nd	nd	nd

Project Title: **Sacramento Valley Pest Monitoring and IPM Updates**

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Objectives:

1) Monitor the activity of key almond pests in the Sacramento Valley almond production region.
2) Disseminate pest activity reports and pest management information via the Sacramento Valley Orchard Source website, clientele email list-serves, and other traditional and novel extension methods.
3) Maintain historical records of pest activity in almonds in the Sacramento Valley.

Interpretive Summary:

Orchard sites in throughout the Sacramento Valley continue to be used as University of California pest monitoring locations to provide local area Farm Advisors, Pest Control Advisers, Certified Crop Advisers, farm managers, and growers with timely pest activity updates, as well as maintain historical records of pest activity in the Sacramento Valley. This ongoing research will allow University of California Cooperative Extension Advisors to maintain an ongoing dialogue with almond decision-makers (growers and their pest control/crop advisers) and continue to refine integrated pest management (IPM) programs. In 2017, monitoring and data analyses focused on the key arthropod pest in almonds, navel orangeworm (NOW). Specifically, various types of traps and trap-lure combinations continue to be evaluated for their utility in pest management decision-support. In addition, pest phenology (flight patterns, generation timing) continues to be evaluated in relation to environmental conditions (i.e., onset of spring activity, degree day accumulations).

Materials and Methods:

Throughout the 2017 almond growing season, multiple commercial almond orchards representing distinct areas within the Sacramento Valley growing region were monitored for key arthropod pest activity (Tehama, Glenn, and Colusa counties).

Data summarized here is focused on monitoring of the key Lepidopteran pest in almonds, navel orangeworm (NOW). A combination of egg, pheromone, and kairomone traps were used based on orchard size and location. Egg traps (4 Tehama, 8 Colusa, 18 Glenn), used to track female ovipositional activity, were baited with ground almond meal (Trécé, Inc). Pheromone traps (2 Colusa, 18 Glenn), used to track adult male flight activity, were baited with Pherocon® L2 lures (Trécé, Inc). Kairomone traps (18 Glenn), used to track adult female flight activity, were baited with ground pistachio and almond culls (Peterson Trap Co.).

Results and Discussion:

Navel orangeworm (NOW) Sacramento Valley regional egg biofix dates and degree day model predictions (2015-2017) are shown for comparison in (**Table 1**) and (**Figure 1**). Fourth flights (typically thought to be less common in the Sacramento Valley) are becoming increasingly common due to earlier biofixes (e.g., 2015) and increased summer heat unit accumulation (e.g, 2017).

Low numbers of eggs were detected on egg traps in all locations, with the exception of a substantial peak at the Colusa site in August (please note that Glenn and Tehama data are plotted on a different scale than Colusa) (**Figure 2**). This large peak in August is unusual, as egg traps typically lose attractiveness once the in-season crop splits and becomes highly attractive to ovipositing females. Due to difficulties with sanitation in the winter of 2016-2017, large numbers of mummies were present in many orchards. It is likely that egg traps are less attractive to the early flights of female moths when significant “mummy-competition” is present, particularly when mummies have been previously infested by NOW. Kairomone trap activity largely coincided with egg trap activity at the Glenn county site and provided more resolution (i.e., greater numbers/trap) than egg traps in 2017 (**Figure 3**).

Pest monitoring and degree-day data, along with University of California best practices guidelines for Integrated Pest Management (IPM) approaches targeting relevant pests was disseminated season-long throughout the Sacramento Valley via a combination of traditional and novel methods. These included: website posts at www.sacvalleyorchards.com, email updates to clientele list serves (march through October), monthly IPM breakfast meetings (February through November), field workshop (May) co-sponsored by the Almond Board, post-harvest IPM workshop (November), social media posts, and personal contacts with growers, PCAs, and CCAs throughout the season.

Table 1. Degree day model predictions and dates for navel orangeworm (NOW) in the Sacramento Valley (Durham.A CIMIS #12) 2015-2017.

	Predicted Degree Days	2015	2016	2017
Spring Egg Biofix (1st flight)	--	March 27	April 13	April 21
F1 Biofix (2nd flight)	1056	June 21	June 29	June 28
“Hull Split Spray” timing	1200	June 28	July 6	July 4
F2 Biofix (3rd flight)	1779	July 27	August 6	July 30
F3 Biofix (4th flight)	2502	September 3	September 17	August 31

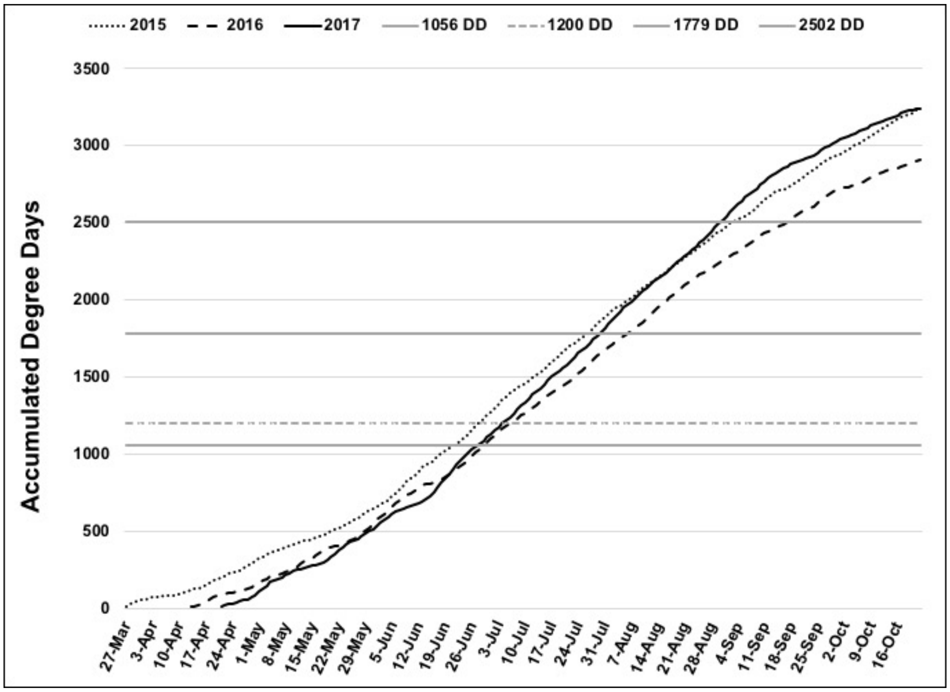

Figure 1. Degree day accumulation for navel orangeworm (NOW) in the Sacramento Valley (Durham.A CIMIS #12) 2015-2017. Horizontal gray lines represent DD model predictions for each generation (flight). The horizontal dashed gray line represents DD-based hull split spray timing.

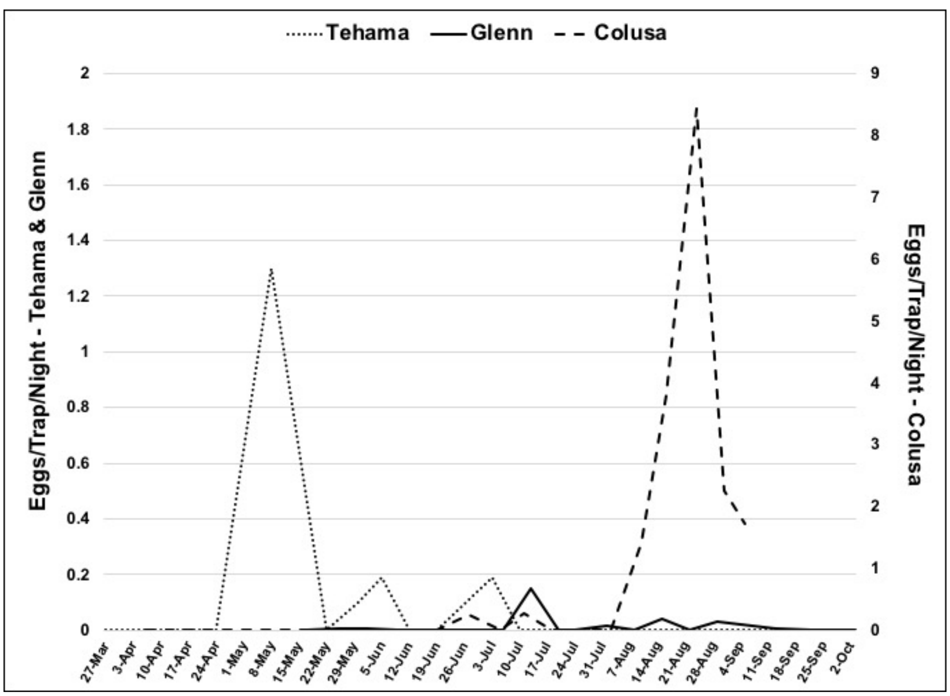

Figure 2. Egg trap data expressed as eggs/trap/night for monitoring sites in Tehama, Glenn, and Colusa counties. Tehama and Glenn counties data are plotted on the primary axis. Colusa county data are plotted on the secondary axis.

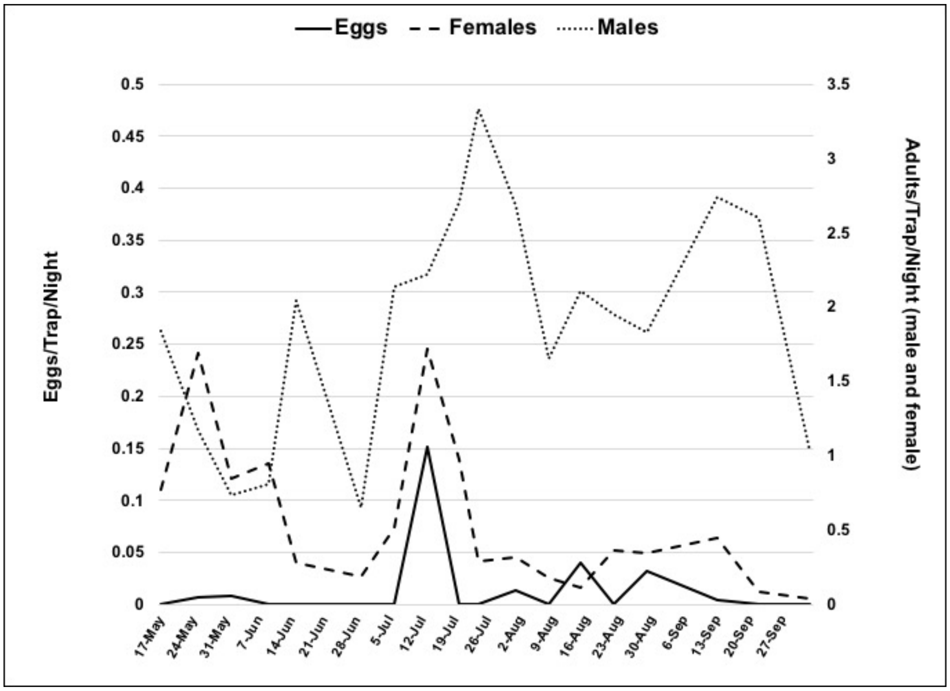

Figure 3. Egg, pheromone, and kairomone trap data at the Glenn county site. Egg trap data are plotted on the primary ax

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Project Title: **Does fall nitrogen application improve almond yield?**

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Objectives:

Determine if mature, adequately fertilized Non-pareil or Aldrich almond trees in the Sacramento Valley showed yield improvement the year following postharvest soil applied nitrogen (N) fertilizer.

Interpretive Summary:

Late fall (mid October) application of 30 lbs. N/acre or 60 lbs. N/acre (as UN32 and/or ammonium sulfate solid under micros) did not increase Non-pareil yield compared to untreated (no fall N application) trees.

Materials and Methods:

The study block is 50% Nonpareil, with Monterey (20%), Carmel (10%) Aldrich (10%) and Sonora (10%) pollinizers -- all on Lovell rootstock-- planted in 1997 in Colusa County. Tree spacing is 16' X 22' = 124 trees/acre. Irrigation is by micro-sprinker. Nonpareil yield ranges from 2500-3000 kernel pounds/acre and Aldrich yield from 2500-2900 kernel pounds/acre in the last several years. See (**Table 1**) for yield, fertilizer rates, and July leaf levels for 2013-2017.

Table 1. Yield (Nonpareil or Aldrich), orchard fertilizer N rates, and July leaf levels (Non-pareil, only) for the study orchard for years 2013-2017.

Year (leaf)	Preharvest (March-June) N fertilizer rate (lbs. N/acre)	July leaf %N (Non-pareil)	Non-pareil yield (kernel lbs./acre)	Aldrich yield (kernel lbs./acre)
2013 (17th leaf)	225	2.93	3,194	2,584
2014 (18th leaf)	195	2.72	2,940	2,496
2015 (19th leaf)	195	2.72	2,950	2,899
2016 (20th leaf)	190	2.63	2,520	2,780
2017 (21st leaf)	190	2.71	2,808	1,608

For this study, six rows of 44 trees per row (4 rows of Non-pareil, 2 rows of Aldrich) were used, with each row divided into quarters (11 trees). A randomized complete block design experiment was set up to test the hypothesis that post-harvest nitrogen fertilization improves almond yield the following year. In this experimental design, each treatment is replicated equally within separate areas of the experimental site. Those separate areas show different levels of a factor, a source of variability, influencing the dependent variable (yield). In this case, that "Blocking" factor was yield history.

On Oct 20, 2016, UN32 at the rate of 0, 30 or 60 lbs. N/acre as UN32 and ammonium sulfate was applied to the orchard floor under micro-sprinklers. Eleven tree sections of four separate rows of Nonpareil trees (5 reps per treatment) and to 6 sections of two separate rows of Aldrich trees (3 reps per treatment) were treated in the same orchard. The Non-pareil trees treated in 2015 received the same N rates in 2016. These N rates represent 12% or 24% of an annual N budget of 242 lbs. N/acre for the orchard (based on a yield of 2500 lbs./acre, 70%

nitrogen use efficiency, and 68 lbs. N removed per 1000 lbs. kernel yield/acre). Trees received 190 lbs. N (as UN32 or mixture of UN32+potassium chloride) in 2016 in five applications between April and mid-June.

Each 11-tree section was harvested separately in August (Non pareil) or September (Aldrich), 2017, and kernel weight per 11 trees determined from field weight and the kernel weight of a 4 lbs. subsample of the field weight. Kernel weight per acre was scaled up from the total yield/11 trees.

Results and Discussion:

The Non-pariel crop was up roughly 300 kernel pounds per acre in 2017 compared to 2016 in the study block, while the Aldrich crop was off almost 1000 kernel pounds/acre (**Table 1**). The decrease in Aldrich yield may have been related to the heavy rain during Aldrich bloom in 2017 compared with dry early bloom weather in 2016.

The average Non-pareil yield (kernel pounds per acre) was not statistically greater (p=0.82) for fall N treated compared to control treatment trees for either 30 lbs. N or 60 lbs. N treatment (**Table 2**). The blocking effect, based on yield history had a much higher p value (p=0.29), although still not statistically significant, indicating that location in the orchard affected yield more strongly than fall N fertilization. The differences between 2015 and 2016 yields for each of the fifteen sections of the orchard were not significantly different (p=0.90) across the treatments (**Table 2**).

Aldrich yield (kernel pounds per acre) was also not significantly influenced by fall N application (p=0.58). The drop in Aldrich yield from 2016 to 2017 was not influenced by fall, 2016 N fertilization (p=0.41). All Aldrich data in (**Table 2)**.

Table 2. Kernel yield (lbs./acre) for three (on Non-pareil) or two (on Aldrich) N treatments applied on Oct 20, 2016 to a mature almond orchard in Colusa County. Data in a column, followed by the same letter are not significantly different from each other at the 5% level based on Tukey's HSD test.

Treatment	2017 Non-pareil yield (kernel lbs./acre)	Non-pareil yield difference from 2016 to 2017 (kernel lbs./acre)	2017 Aldrich yield (kernel lbs./acre)	Aldrich yield difference from 2016 to 2017 (kernel lbs./acre)
0 lbs. N	2,952 a	+ 384 a	1,522 a	-1,318 a
30 lbs. N	2,895 a	+ 429 a	1,608 a	-1,172 a
60 lbs. N	3,161 a	+ 591 a		

In this, the second year of this study, Non-pareil almond yield (kernel lbs./acre) was not significantly improved by fall (October) nitrogen application the previous year. Factors other than fall N application were responsible for the jump in Non-pareil yield/acre in 2017 compared with 2016. In addition, Aldrich yield was not affected by fall N application.

Project Title: **Post-plant Solarization or Pre-plant Soil Fumigation for Control of Verticillium Wilt in Young West Side Orchards**

Project Leader: Roger Duncan
UC Cooperative Extension
Stanislaus County

Cooperators: Jerry Goubert, TriCal, Inc. fumigation company

Objectives:

- Determine if pre-plant soil fumigation or post-plant soil solarization can reduce symptoms of Verticillium wilt in young trees when planting orchards in disease-prone areas.
- Measure effects of pre-plant fumigation or post-plant solarization on young tree performance.

Interpretive Summary:

Trees in all treatments have grown very well and there was no measurable effect on tree growth (trunk circumference) from the pre-plant fumigation or post-plant solarization treatments after the first year. No pathogenic nematodes were detected in the field before treatments nor one year after treatments. Signs of verticillium wilt disease generally do not present until 2nd or 3rd leaf. Therefore, treatment effects on verticillium disease could not be determined during the scope of this report. The trial will continue to be monitored for verticillium symptoms and eventually yield differences.

Materials and Methods:

The trial was implemented in a Capay clay soil in Westley, CA in a field that has had a very long history of tomatoes and melons. Local orchards planted under these conditions frequently suffer from mild to severe symptoms of Verticillium wilt disease. Preplant soil fumigation treatments, including Telone II (340 lb./acre), C100 (chloropicrin, 200 lb. / acre), C60 (340 lb. / acre) and Dominus® (allyl isothiocyanate, 340 lb. / acre), were applied with and without tarps on September 17, 2016. Fumigants were applied to 11.5’ wide strips in plots that were 304’ (19 trees) long with a standard deep Telone injection rig at a depth of 18 inches. Tarps were removed ten days after treatment. Soil was sampled from each treatment replication before fumigant treatment and again after treatment to determine fumigant effects on parasitic nematodes. In late October, potted ‘Shasta’ self-fertile almond trees grafted onto Cornerstone peach / almond hybrid rootstock were planted in treated and untreated plots at a spacing of 16’ x 22’. In early March of 2017, post -plant solarization treatments were applied by installing a solid, six-foot wide strip of black, embossed polyethylene film down the tree rows. The film was applied by sliding the trees through a small slit in the center of the plastic and burying the edges to make an “air-tight” seal. Film was sealed around each tree with tape to improve soil heating. Trees in the trial were irrigated with double-line drip irrigation to meet estimated ET. At the end of the first growing season (December 2017), tree growth was estimated by measuring trunk circumference at a height of 12 inches. During the spring of 2018, trees were examined for signs of verticillium wilt disease.

Results and Discussion:

The Westside of the North San Joaquin Valley has long been an area planted to row crops, including processing tomatoes, watermelons, cantaloupes, honeydews and many other melon species. However, due to the more profitable nature of nut crops, almond orchards are rapidly being planted in this traditional row crop area.   Tomatoes and melons are excellent hosts for the soil borne fungal pathogen, *Verticillium dahlia*, which can survive in the soil for many years after a favorable host has been removed. Thus, most new almond orchards planted in these soils following many years of tomatoes and melons show typical Verticillium wilt symptoms during the first few seasons. Symptoms can range from minor shoot tip die-back to death of whole scaffolds. Verticillium wilt symptoms are more severe in many peach x almond hybrid rootstocks which are commonly planted in the alkaline soils of this area. In badly affected orchards, economic losses can be significant. While obvious wilt symptoms are generally limited to young trees, it is unknown if there are long-lasting yield consequences. Many Westside growers fumigate with Telone II prior to planting almond orchards. It is unlikely that Telone substantially reduces Verticillium inoculum and there are generally few, if any almond parasitic nematodes present. Therefore, fumigants may be applied needlessly.

Despite application of high label rates of fumigant, there were no noticeable effects on tree performance among any treatments (**Table 1**). Because there were no parasitic nematodes detected prior to planting, it is not surprising that we did not see a benefit from Telone II which is primarily a nematicide. In addition, we saw no growth benefit from the use of Dominus, chloropicrin alone or chloropicrin in combination with Telone II. Because this is a first-generation orchard, we would not expect to see tree growth retardation from replant disease, although there have been cases where a growth response has been observed after chloropicrin even without the presence of primary pathogens. It is still possible that fumigation treatments will reduce expression of verticillium wilt in 2019 and therefore affect tree performance and income.

Table 1. Trunk Circumference of Almond Trees One Year After Planting in Fumigated and Nonfumigated Soil

	Trunk Circumference (cm)*
Untreated	21.7
Untreated + tarp	21.3
Telone II	20.8
Telone II tarped	20.3
C 100 @ 200 lb.	21.7
C 100 @ 340 lb.	21.0
C 100 @ 340 lb. + C60	21.8
C 100 @ 340 lb. + tarp + C60	20.8
Dominus	21.1
Dominus + tarp	21.6
Post plant solarization	21.3

*Means were not significantly different at the 95% confidence level.

Project Title: **Investigation of Hull Rot Causal Agents, and Environmental Conditions Conducive to Disease Development in Kern County**

Project Leader: Mohammad Yaghmour
UC Cooperative Extension
Kern County

Objectives:

The objective of this project is to investigate the causal agents of hull rot and associated fungi in Kern County and understanding orchard factors and environmental condition playing role in disease development. Is *Aspergillus niger* an important factor in disease development in Kern County? What are plant and environmental factors that affect disease development.

Interpretive Summary:

Hull rot is considered one of the important diseases that can cause significant losses in almond orchards if it is not well managed. Beside *Rhizopus stolonifer* as one of the causal agents of hull rot in the San Joaquin valley, this work was focused on *A. niger* causing hull rot in Kern County. *A. niger* has been associated with hull rot in Kern County and was isolated from the cankers from samples sent to Dr. Michailides' lab. In preliminary pathogenicity tests, *A. niger* reproduced hull rot symptoms in field inoculations. Association of *A. niger* with hull rot was also observed in Fresno, and San Joaquin Counties during the 2017 season, and one-year results from this project have also shown the association of *A. niger* with natural hull rot infections in test plots in Kern County. Previous research had shown that nitrogen and plant water status plays role in hull rot development caused by *R. stolonifer*. However, in 2017, there was not significant difference in Leaf nitrogen content between the two plots in Kern County to explain the difference in hull infection by *A. niger* and *R. stolonifer*. The difference in stem water potential may explain in part the higher percentage of *R. stolonifer* infection compared to *A. niger*. However, it is still not well understood if tree water status or other environmental factors such as temperature and relative humidity has any effect on hull rot development caused by *A. niger*.

Materials and Methods:

This work was performed in two major plots in an orchard planted in 2011 with 50% Nonpareil, 25% Sonora, and 25% Monterey. Trees are planted at 22’×20’ spacing and irrigated with microsprinklers. Five replicates in each main plot established on the NP rows. The southern plot had a sandier soil compared to the northern plot. Pathogenicity test was conducted by spraying two branches on each tree with *A. niger* with a spore suspension of 10^5 until run off. One control branch on each tree was sprayed with sterile water. Four different trees were used for pathogenicity test.

Trees were also monitored during hull split for stem water potential as well as leaf nitrogen content. Before Harvest, trees were evaluated for natural incidence of hull rot, and Fruits associated with hull rot symptoms was collected from affected spurs and evaluated for *A. niger* and *R. stolonifer* infections. Yields per acre was calculated based on average yield of two trees per replicate.

Results and Discussion:

Disease symptoms were reproduced in inoculated fruits and 34 ± 16.2 percent of inoculated spurs showed hull rot symptoms, and 10.1 ± 6.6 percent of spurs sprayed with sterile water in the field were symptomatic (**Figure 1**). Hull rot natural incidence in the northern plot was higher with an average of 92.2 ± 10.1 stikes per tree compared to the southern plot with an average of 26.9 ± 5.4 (**Figure 2A**). However, fruits collected from symptomatic spurs in the Southern plot had more fruits infected with *R. stolonifer* while fruits collected from the northern plot had more fruits infected with *A. niger* than fruits infected with *R. stolonifer* (**Figures 2B**). This maybe explained in part by the stem water potential status of the trees since the tree nitrogen content was in the normal range and was not significantly different between the plots (**Figure 3**).

Trees in the Northern plot were under more water stress during hull split compared to the trees in the Southern plot (**Figure 4**). This may explain the higher percentage of fruits infected with *R. stolonifer* in the southern plot. However, more investigation is needed to understand the increase in hull rot in the northern plot caused by *A. niger*. Is it due to higher inoculum or due to changes in the tree water status or other environmental factors such as temperature? The warmer temperature in the southern San Joaquin valley may play a role as this fungus thrive in warmer regions compared to cooler ones. Purcell et al. have shown higher incidence of *A. niger* on almond kernels and hulls in warmer almond producing orchards in Kern County compared to other cooler regions. They also showed that incidence of *A. niger* was higher than the incidence of *Rhizopus* spp.

Yield in the northern plot is significantly higher than the southern plot (**Figure 5**). For this study, this yield will be used as a baseline to see the effect of hull rot on tree production in both plots for the coming years.

References Cited:

Purcell, S. L., Phillips, D., and Mackey, B. E. 1980. Distribution of *Aspergillus flavus* and other fungi in several almond growing areas of California. Phytopathology 70:926-929

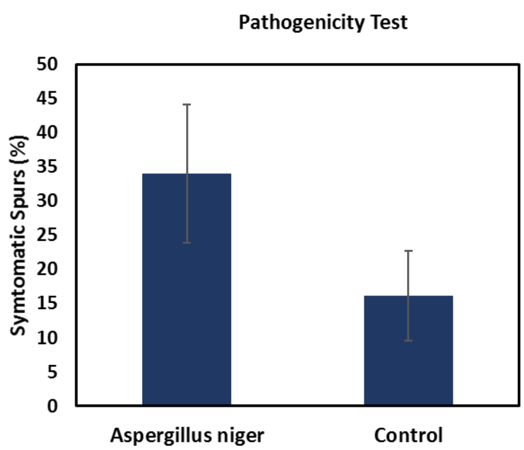

Figure1. Percentage of Symptomatic spurs inoculated with *Aspergillus niger*

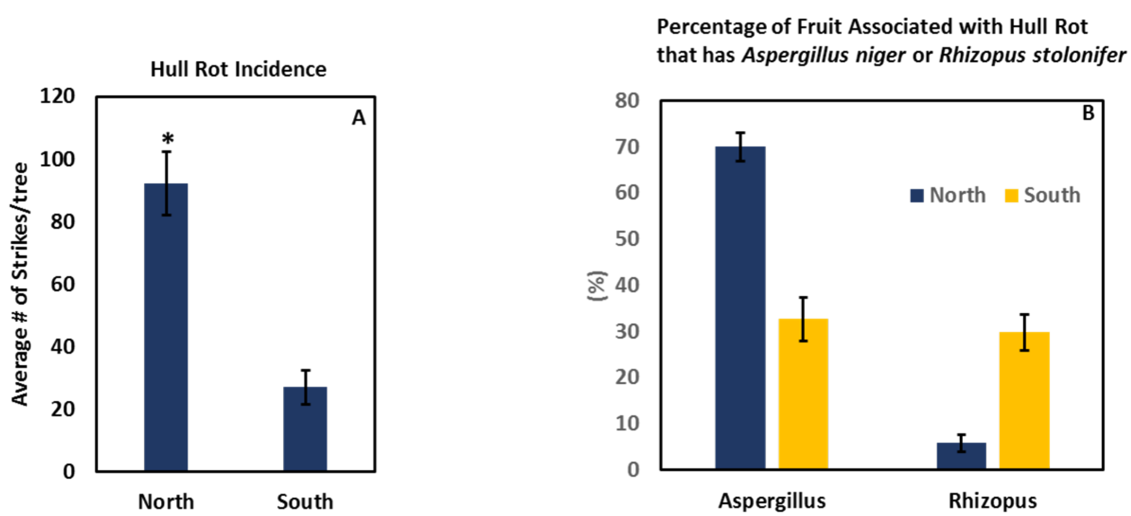

Figure 2. Natural incidence of hull rot in two plots in an orchard in Kern County (A) and percentage of fruit infected with *A. niger* and *R. stolonifer* associated with natural infection from the same plots (B)

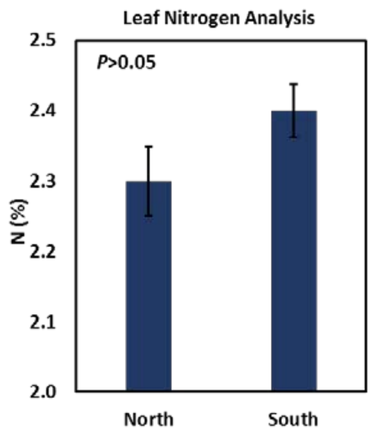

Figure 3. Leaf tissue Nitrogen content.

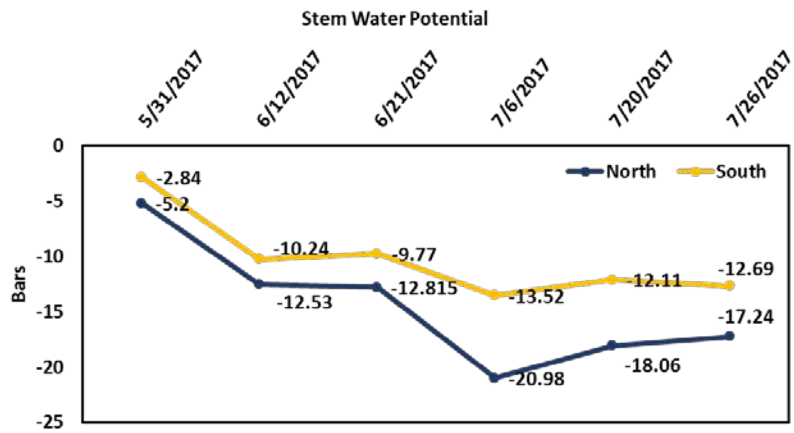

Figure 4. Tree midday stem water potential

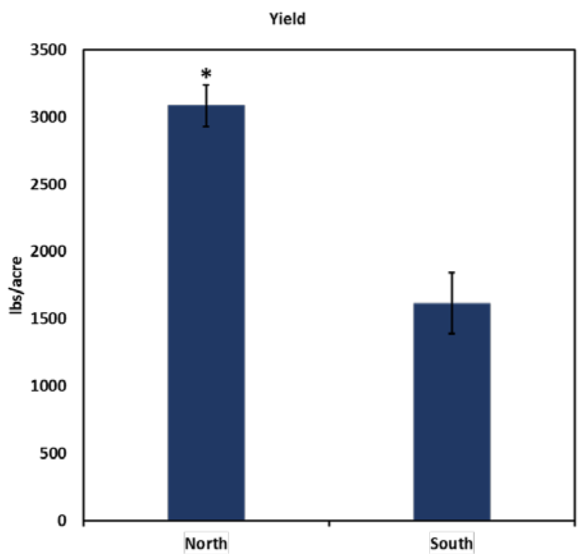

Figure 5. Average almond yield (lbs./acre) for test plots based on yields of 2 trees per replicate