Almond Culture and Orchard Management

Project No.: **12-HORT3-Holtz**

Project Leader:
Brent A. Holtz, PhD
UCCE – San Joaquin County
2101 E. Earhart Ave., Suite 200
Stockton, CA 95206
209.953.6124
baholtz@ucdavis.edu

Project Cooperators and Personnel:
David Doll, Farm Advisor, Merced County
Roger Duncan, Farm Advisor, Stanislaus County
Elizabeth Fichtner, Farm Advisor, Tulare County
Franz Niederholzer, Farm Advisor, Sutter and Yuba Counties

Problem and its Significance:

Farm advisors conduct numerous projects addressing local issues in their counties. Many of these issues are addressed with small projects that may not require major support to conduct and complete the work. This project is designed to provide local support for county farm advisors general extension research programs related to almond production. Each advisor participating in this project highlights research results in their county from local projects they feel address an important question worthy of reporting to growers at the annual Almond Industry Conference.

Farm Advisor Projects:

1) <u>Do Honey Bees Increase Set and Yield of Self-Fertile Almond Varieties?</u>

Project Leader: Roger Duncan, Farm Advisor, UCCE - Stanislaus County

Objective:

- Determine if the addition of honeybees increases nut set and yield of a self-fruitful almond variety.

Background:
Pollen of self-fertile almond varieties can fertilize the ovule of the same blossom, eliminating the need for a pollinizer variety to set a commercially acceptable crop. However, questions remain about whether the addition of honeybees might increase the transfer of pollen from the anthers to the stigmas, improve fertilization, and increase yield.

Methods:
The trial was conducted in a commercial, 3rd leaf orchard consisting of only the 'Independence' self-fertile almond variety. Prior to bloom, ten shoots on each of twelve, consecutive trees were tagged and the number of flower buds on each tagged shoot was counted. Screened structures were then erected around six of the trees individually in a

randomized complete block design. Two hives of honeybees were placed outside of the structures in an adjacent row. Structures remained in place until petal fall was nearly complete. Due to wind gusts exceeding 40 MPH on March 6, 2013, three of the six structures blew over and were destroyed when the trees were at about 50% petal fall. Percent nut set was determined on screened and unscreened trees by counting flower buds on tagged limbs prior to bloom and later comparing those data to the number of nuts formed on the same limbs. After the trees were shaken at harvest, nuts were collected from each tree and weighed. Samples were taken to determine kernel quality and final yield.

Results and Conclusions:

Trees enclosed by screen structures from pre-bloom through petal fall had 63% lower nut set and 51% lower yield than unscreened trees. Trees enclosed only until 40-50% petal fall had 35% less nut set and 10% lower yield than unscreened trees (**Table 1**). Although these data suggest that honeybees increased set and yield, it is unclear if the screen structures created "unnatural" conditions that might have reduced nut set even if pollination was similar to unscreened trees. Minimum/maximum thermometers placed within tree canopies showed that maximum temperatures were reduced by 1.0 – 1.7 degrees F within screened structures and minimum temperatures were 0.5 - 2.7 degrees warmer. Air movement and ambient light was clearly reduced within screened structures. In summary, these conclusions should be tested using another method to validate the assumption that honeybees increase nut set and yield of self-fertile almond varieties.

Table 1. Nut set and yield comparison of self-fruitful almond trees within and outside of screened structures.

	Yield (lb / acre)	Reduction in Yield (%)	Nut Set (%)	Reduction in Set (%)
Within screened structures	364	51	10.5	63
Screened until 50% petal fall	672	10	18.3	35
Unscreened Control	743	--	28.1	--

2) Fertilizing One Year Old Almond Trees: How Much Nitrogen?

Project Leader: David Doll, Farm Advisor, UCCE - Merced County

Project Cooperators and Personnel:
Andrew Ray, Research Assistant, UCCE - Merced County
Kris Randall, Research Assistant, UCCE - Merced County

Objectives:
- Determine the most effective rate of nitrogen for young almond trees.
- Compare effectiveness of controlled release fertilizers with conventional fertilizers.

Background:
Growers have realized the benefits of increased fertilizer rates and applications to first leaf trees. These include increased vegetative growth, shorter time to first harvest, and larger crop loads on young trees. With this increased use of fertilizers for non-bearing trees, there are questions in regards to what source and rate of nitrogen will provide the strongest growth response.

In 2011, two trials in Merced County tested which nitrogen source was most effective for fertilizing first leaf almond trees. The results of these studies suggested a slight benefit of using non-nitrate, NPK blend based fertilizers for young tree development. This supports the current University of California recommendation of using an NPK urea based blend for fertilizing young trees. This project will focus on what rate of urea based fertilizer is most effective.

With the application of granular based fertilizers, there is also an interest in controlled release fertilizers for young trees. Since the root system is small and has a limited ability for nutrient uptake, slow release fertilizers may maintain nutrients within the establish rootzone of the tree longer than regular fertilizers. This may increase tree growth or diminish the need for applied fertilizer due to an increase in nutrient use efficiency. These fertilizers are more expensive, and it is unknown if they are economical for young trees.

Methods:

In 2012 a trial was set up in Winton, CA to test different nitrogen rates. Trees in the orchard were randomly assigned one of the following treatments:

a) Control - no fertilizer was applied
b) Conventional fertilizer at 7.5 lbs/acre
c) Conventional fertilizer at 15 lbs/acre
d) Conventional fertilizer at 30 lbs/acre
e) Conventional fertilizer at 45 lbs/acre
f) 120-day control release fertilizer at 15 lbs/acre
g) 120-day control release fertilizer at 30 lbs/acre
h) 120-day control release fertilizer at 45 lbs/acre
i) 180-day control release fertilizer at 15 lbs/acre
j) 180-day control release fertilizer at 30 lbs/acre
k) 180-day control release fertilizer at 45 lbs/acre

The conventional, 120-day controlled release and 180-day controlled release had a fertilizer analysis of 21%-7%-14%. Applications per treatment ranged between 7.5 and 45 lbs total nitrogen applied per acre. The experiment was established as a randomized complete block design with five blocks and four replicate trees. The conventional fertilizer applications were made at six different times (about once a month) from early April to September, while the controlled release fertilizer treatments were applied once in early April. Seasonal growth of each tree was measured by taking the difference of pre-leaf out and end of year dormant caliper measurement. Leaf samples were taken mid-May, mid-July, and mid-September, and then were sent to a UC Davis lab so that nitrogen content could be determined.

Results:

The 120-day controlled release fertilizers applied at 15 lbs/acre and 30 lbs/acre were the only treatments that outperformed the control in total season growth (**Table 1**). All of the treatments applying 45 lbs of N per acre had a higher leaf nitrogen percentage than the control treatment (**Table 1**). Within the regression, both the conventional and 120 day controlled release fertilizers showed linear and polynomial relationship between nitrogen rate and seasonal growth (**Table 2**). The polynomial regression had a better fit, and indicated that maximal growth could be achieved between 20 and 30 lbs/acre (**Figure 1**). The 180 day controlled release did not show a rate response.

Discussion:

The results suggest that applying between 20-30 lbs/acre might be the best rate of nitrogen for first leaf almond trees. While the 45 lbs/acre treatments resulted in higher nitrogen leaf tissue concentrations, those trees did not have significantly higher seasonal growth changes. Since the 15 and 30 lbs/acre applications of the 120-day controlled release were the only treatments to outperform the control in seasonal growth, this may suggest that these two treatments provided maximum uptake by the trees. Also, a single application of the 120-day controlled fertilizers performed as well as six applications of conventional fertilizer at all rate indicating that controlled release fertilizers could be economically competitive based on their labor savings. The success of the 120-day controlled release fertilizer may also provide some clues for the right timing of fertilizer. The spoon feeding nature of the controlled release fertilizer may have been more effective than the all at once monthly applications of conventional fertilizer. Providing young tree nitrogen in small doses may allow for a higher percentage uptake than larger, less frequent applications.

Table 1. Growth and leaf nitrogen percentage of the eleven treatments. Treatments not connected by the same letter indicate a statistical difference at $p > 0.05$.

Treatment	Growth	Leaf Nitrogen %
30 lbs/acre 120 day	40.86 A	3.84 AB
15 lbs/acre 120 day	39.39 A	3.76 AB
30 lbs/acre conv	38.15 AB	3.76 AB
15 lbs/acre conv	37.83 AB	3.88 AB
15 lbs/acre 180 day	37.69 AB	3.77 AB
45 lbs/acre 120 day	37.09 AB	3.90 A
7.5 lbs/acre conv	36.69 AB	3.67 AB
30 lbs/acre 180 day	35.61 AB	3.78 AB
45 lbs/acre 180 day	34.91 AB	3.91 A
45 lbs/acre conv	34.64 AB	3.90 A
control	32.76 B	3.62 B

Table 2. Probability of error and squared residuals of the linear and polynomial regression for the three fertilizer types.

Fertilizer Type	Term	Prob<(t)	Squared Residuals
Conventional	Applied Nitrogen	0.029	0.081
	(Applied Nitrogen)^2	0.002	0.132
120 Day Controlled Release	Applied Nitrogen	0.05	0.071
	(Applied Nitrogen)^2	0.003	0.178
180 Day Controlled Release	Applied Nitrogen	0.56	NS
	(Applied Nitrogen)^2	0.102	NS

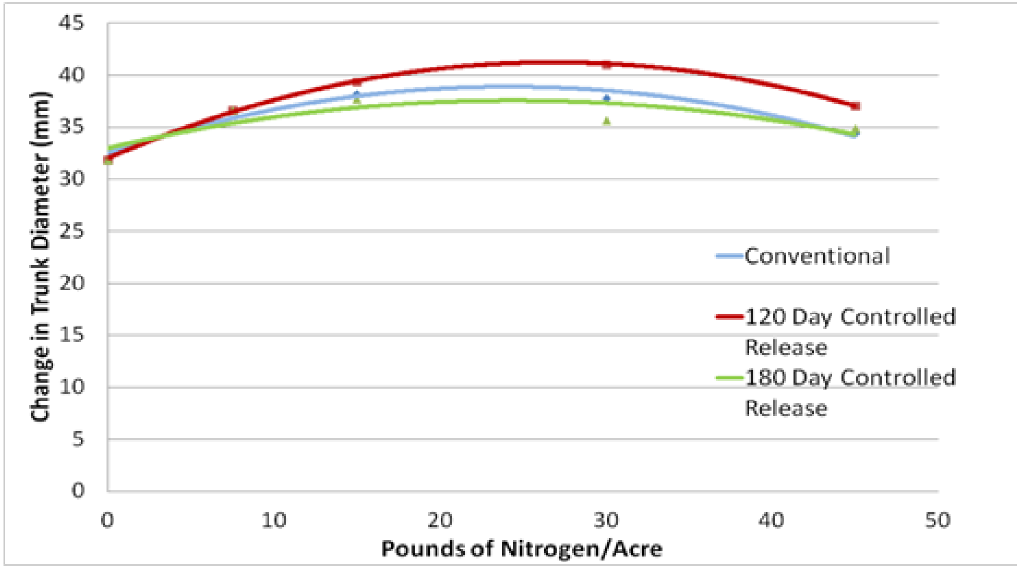

Figure 1. Polynomial regressions of the relationship between change in trunk diameter and nitrogen rate.

3) Factors Affecting Prevalence and Activity of Tenlined June Beetle in Tulare County Orchards

Project Leader: Elizabeth Fichtner**,** Farm Advisor, UCCE - Tulare County

Project Cooperators and Personnel:

A. Molinar and G. Ritokova, Staff Research Associates, UC Riverside
K. Wilson, Staff Research Associate, UCCE-Tulare County
M. Johnson, Extension Specialist, UC Riverside

Objectives:

- Determine whether TLJB larval activity is inversely related to soil water potential.
- Determine whether infection with *A. tumefaciens* enhances larval populations on roots.

Background:

Root predation by the larvae of Tenlined june beetle (TLJB) (*Polyphylla sobrina*) may cause extensive tree damage, either directly by loss of root mass and function, or indirectly by predisposing trees to collapse in heavy wind or rendering roots more susceptible to infection by soilborne pathogens. Although TLJB is an inhabitant in many orchards, it only causes damage in a fraction of infested blocks. TLJB damage is sporadic within orchards and is often associated with sand streaks, particularly during drought years.

In Tulare County orchards, TLJB appears more prevalent in well drained soils, with the majority of larval activity observed in sandy soils, often in riparian areas or in sand streaks from historic drainage channels. The association between heightened TLJB populations and well-drained agro-ecosystems suggests a relationship between soil water potential and TLJB activity. Additionally, larvae appear to embed in gall tissue associated with *Agrobacterium* *tumefaciens* infection on walnut, suggesting a potential association between TLJB larvae and crown gall. The influence of soil water potential on TLJB activity and the propensity for larval colonization of gall tissue versus roots has not been determined.

Methods:

A titration procedure used to measure CO_2 evolution from soil as a measure of total soil microbial activity was amended for assessment of 1st instar larval activity in a sand:soil mixture. Larval respiration rate (mg CO_2/g larvae/day) was determined in a 4:1 (v/v) mixture of sand and soil equilibrated at the following soil matric potentials: 0, -25, -50, -100 and -200 ψ_m. The gravitational soil moisture content (g water/g dry soil) was determined for each matric potential treatment. CO_2 evolution was assessed on one 1st instar larvae in each of five replicates over 24 hours.

Due to the high prevalence of crown gall in Tulare County walnut orchards, walnut was used as a model system to preliminarily assess prevalence of larval populations on *A. tumefaciens* infected trees. In 2010, 2011, and 2012, 10 sets of paired asymptomatic (no gall) and symptomatic trees (gall) were surveyed for TLJB populations. In 2010 and 2012, soil was excavated around trees to a depth of 30 cm, to a distance of 30 cm from the trunk. The number of TLJB larvae from the bulk of excavated soil was enumerated and recorded. In 2011, TLJB populations were assessed on declining trees as they were excavated from the orchard. Trees were noted as either symptomatic or asymptomatic for crown gall. Larval populations were compared between symptomatic and asymptomatic trees.

Results and Discussion:

CO_2 evolution (ie. larval respiration) was measured as an indirect assessment of larval activity. Larval activity decreased with increasing soil matric potential (i.e., wetter conditions). Gravimetric soil moisture remained at approximately 4% at -50 through -200 mbar ψ_m, but increased to 8% and 14% at -25 mbar and 0 mbar $\psi_{m,}$ respectively.

TLJB larvae were more over four times more abundant on trees symptomatic of *A. tumefaciens* infection than on asymptomatic trees. Larvae were often observed embedded in gall tissue.

The results of this study indicate that increasing soil water potential (i.e., moister conditions) is suppressive to TLJB activity. The observed relationship between larval activity and water potential is commensurate with anecdotal evidence that sandy orchards and sand streaks are conducive to root predation and consequent tree decline. Future research addressing the potential value of soil amendments (i.e., compost) to mitigate low soil water potential conditions may be of benefit to the industry.

The combination of TLJB predation and crown gall infection may either additively or synergistically contribute to tree decline. The prevalence of larvae on gall tissues suggests that the larvae may preferentially feed on this tissue over healthy root tissue. Alternatively, larval feeding may exacerbate disease incidence by creating wounds to serve as infection courts. Larvae may also mechanically transport the pathogen from symptomatic tissues to asymptomatic tissues, either spreading disease along the root zone of a single tree, or to neighboring trees. The potential relationship between larval predation and crown gall could be the subject of future research studies.

4) Increasing Almond Tree Boron Levels in Sutter County – How Long Can it Last?

Project Leader: Franz Niederholzer**,** Farm Advisor, UCCE – Colusa/Sutter/Yuba Counties

Project Cooperators and Personnel:

Andrew "Bobby" Johnson, UC/ABC Farm Advisor Intern
Jed Walton, PCA, Big Valley Ag Services, Gridley, CA
Sam Kamilos, grower

Objectives:

- Conduct a field study to determine if a single application of a high rate of boron fertilizer (20-50 lbs/acre of a 14-20% B fertilizer material; 4-8 lb boron/acre) can increase hull boron levels to 100-125 ppm B? If this application can increase almond tree B to those levels, how long can this "boost" last?
- Determine if a fall application of soil-applied boron fertilizer can increase flower B levels the following season (February-March).

Interpretive Summary:

Fall applied boron fertilizer (4-8 lbs actual B deliver to the soil) did not increase flower B levels the following spring. Soil applied B fertilizer did increase hull B over 100 ppm, but the effect only lasted 1 (spring applied soil B) or 2 (fall applied soil B) seasons. Boron can be leached below the root zone with irrigation or rainfall amounts that exceed the water holding capacity of the root zone soil. In areas with high rainfall, soil applied B fertilization may be less efficient than adequate rates of foliar B fertilizer.

Materials and Methods:

A study site in a commercial orchard in Sutter County was identified. The soil is an Olashes sandy loam, and irrigation water is delivered by hose-pull impact sprinklers. The unfertilized soil has very low boron levels (≤0.05 ppm B) by saturated paste extract method. The grower applies a liquid B equivalent to 0.6 pounds of B/acre (= 3 pounds of Solubor®/acre) as a foliar spray each November.

Nonpareil/Lovell almond trees with low B status (<50 ppm hull B at harvest, 2007) were treated with 20 or 40 lbs/acre Solubor® (20.5% B) in October 2008 or late May 2009. Granubor® (14% B) was applied at 50 lb/acre in late May 2009. Material was applied evenly to half the distance across rows on each side of the study trees using a weed sprayer (20 gpa or hand applied with belly grinder. Flower samples were taken at full bloom in 2009, 2010, 2011, and 2012. Hull samples were taken at harvest in those same years. Sample processing and analysis was conducted by the UC Davis Plant Sciences Analytical Lab.

Results and Discussion:

Soil applied boron as 20 or 40 pounds/acre Solubor® in October 2008 did not significantly increase flower B levels at bloom in 2009 (see **Table 1**). Similar results with bloom B levels were obtained in 2008 following application of 10 or 20 pounds/acre of Solubor® in October 2007 (data not presented).

Soil applied boron, as Solubor® (20 or 40 lb/acre in fall 2008) or Granubor® (50 lb/acre in spring 2009) increased hull and leaf B levels in summer 2009 (**Table 2**). The higher rates of boron fertilizer (40 lbs/acre Solubor® or 50 lbs/acre Granubor®) significantly increased hull boron levels in all three years (2010-2012) following the year of application (2009) compared to control hull levels. Lower rates of boron fertilizer (20 lbs/acre Solubor®) did not consistently increase hull boron levels in the same time period. (**Table 2**).

High rates of soil applied boron, as Solubor® (40 lb/acre in spring 2009) or Granubor® (50 lb/acre in spring 2009) increased flower B levels in 2010 (**Table 1**). A lower rate of Solubor (20 lb/acre), applied at the same time, did not significantly increase flower B in 2010. Flower B concentrations were significantly increased over control levels by the high rates of boron fertilizers in the three years after the year of application (**Table 1**).

Compared with 2009 and 2008, high levels of B were found in all flower samples in 2010 (**Table 1**).. Decreases in fruit set and crop yield have been measured in Butte trees fertilized (in the fall) with foliar B where flower B levels > 60 ppm B. It was not possible to test if high rates of soil applied B fertilizer increased or decreased yield in 2010, due to poor Nonpareil set across the study orchard in treated and untreated trees. In 2011 and 2012, flower B levels dropped below 60 ppm B (**Table 1**).

Soil applied boron fertilizer increased hull boron levels above the target of 100 ppm B in the year following application of 40lb/acre Solubor® (October 2008), 40lb/acre Solubor® (May 2009), and 50lb/acre Granubor® (May 2009), but the effect did not last beyond that year (**Table 2**). The potential for the high levels of flower boron produced by high soil boron fertilizer rates (40-50 lbs/acre Solubor® or Granubor®; 7-8 lbs actual boron/acre) to influence almond flower set could be a topic for future research.

Table 1. Nonpareil almond flower boron concentrations (average of eight trees for each treatment) in 2009 - 2012 following soil applied boron fertilizer in fall 2008 or spring 2009. There is a 95% chance that data in the same column are significantly different if they do not share a letter, based on Tukey's HSD test.

Treatment	Flower Boron (ppm B) 2009	Flower Boron (ppm B) 2010	Flower Boron (ppm B) 2011	Flower Boron (ppm B) 2012
Untreated	30 a	47 a	28 a	25 a
20 lb/acre Solubor® October 2008	36 a	52 a	39 ab	34 bc
40 lb/acre Solubor® October 2008	38 a	69 b	48 bc	39 cd
20 lb/acre Solubor® May 2009		60 ab	46 bc	29 ab
40 lb/acre Solubor® May 2009		86 c	59 c	37 c
50 lb/acre Granubor® May 2009		90 c	56 c	43 d

Solubor® is 20.5% B; Granubor® is 14.3% B

Table 2. Nonpareil almond hull boron concentrations (low, high, and average measurements) sampled at harvest in 2009-2012 following soil applied boron fertilizer in fall 2008 or spring 2009. Data are from two individual trees in each of four separate replicates for a total of eight trees per treatment. Lowest reading per treatment appears on the left of each column, the highest reading is on the right of each column. The average value appears in the middle in bold print. There is a 95% chance that data in the same column are significantly different if they do not share a letter, based on Tukey's HSD test. Data from 2009 did not conform to requirements for analysis, and so no statistical analysis results are presented.

Treatment	Hull Boron (ppm) 2009	Hull Boron (ppm) 2010	Hull Boron (ppm) 2011	Hull Boron (ppm) 2012
Untreated	35 **41** 44	39 **50** 60 a	30 **37** 40 a	31 **37** 44 a
20 lb/acre Solubor® October 2008	40 **65** 84	41 **59** 76 a	37 **46** 56 a	44 **52** 56 bc
40 lb/acre Solubor® October 2008	72 **104** 153	63 **108** 150 bc	46 **66** 79 b	48 **59** 77 bc
20 lb/acre Solubor® May 2009	47 **54** 61	55 **80** 100 ab	43 **48** 50 a	41 **47** 60 ab
40 lb/acre Solubor® May 2009	45 **59** 78	84 **114** 126 cd	53 **65** 69 b	53 **55** 69 bc
50 lb/acre Granubor® May 2009	60 **77** 94	120 **138** 166 d	68 **78** 92 c	47 **63** 83 c

Solubor® is 20.5% B; Granubor® is 14.3% B

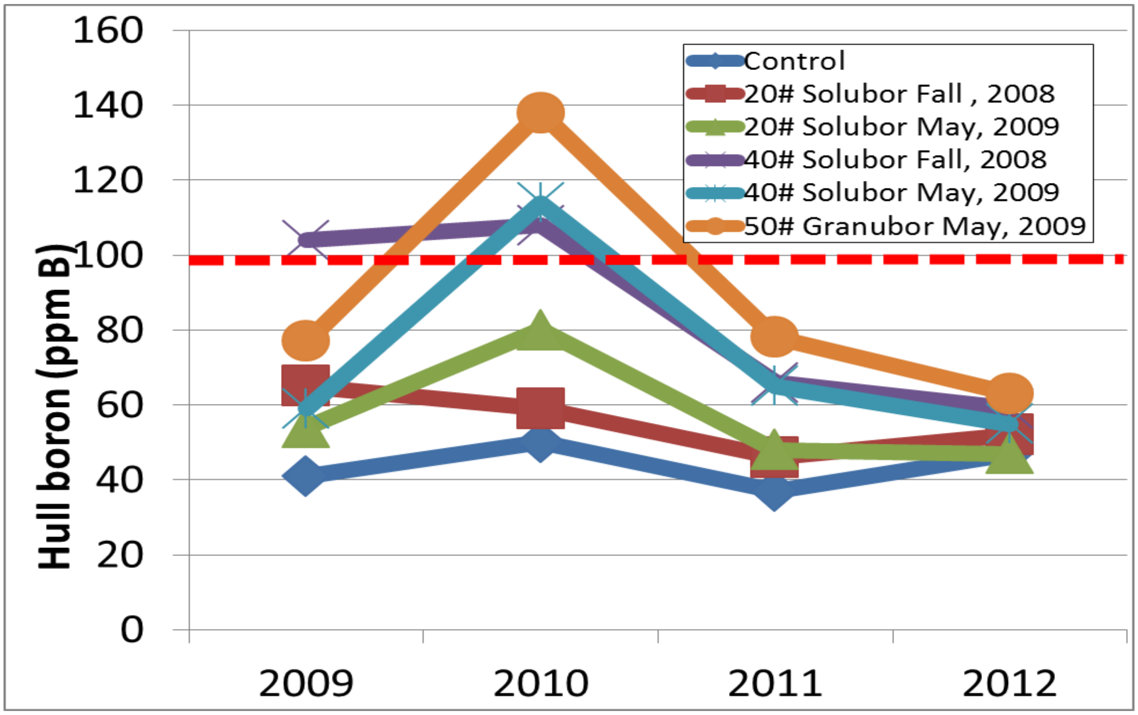

Figure 1. Nonpareil almond harvest hull boron concentrations (ppm B) over four years following soil applied boron fertilizer in fall 2008 or spring 2009. Dotted line represents project target hull boron at harvest (100 ppm B).

5) Efficacy Trials of Registered and Developmental Insecticides for Navel Orangeworm

Project Leader: Brent A. Holtz, Farm Advisor, UCCE - San Joaquin County

Project Cooperators and Personnel:
Walt Bentley, UC IPM, Stephen Colbert, DuPont USA

Problem and its significance:
Navel orangeworm continues to be a major pest of harvestable almond nut meats throughout the San Joaquin and Sacramento Valleys of California. In some cases multiple insecticide sprays are applied in addition to sanitation programs to remove overwintering inoculum sources. During the past few years there have been several new insecticides that target worms that have become registered for almonds in California, with more on the way. One group of products includes newer generation pyrethroids such as Brigade, Battalion, Baythroid, Danitol, Renounce and Warrior. Additionally there are a wide range of new reduced-risk insecticides that offer a variety of existing and new modes of action such as Altacor, Belt, Delegate, Intrepid, Asana, Proclaim, Brigade, Athena, and Hero. Currently there is a large gap in our understanding of the efficacy of these products. Many of these products have undergone substantial testing and have been proven effective against codling moth in apples, pears and walnuts; however, to date there is very little information on how they perform on navel orangeworm on almonds. Considering the economic scale of the significance of navel orangeworm as a pest of almonds in California, including both the effects on percentage offgrades and aflatoxins, it is essential that we learn more about how each of these new insecticides works and might contribute to improved control in the field.

Materials and Methods:

An insecticide efficacy screening trial was conducted in 2012 at the Kearney Research and Extension Center. Products tested and rates applied were determined through consultations with members of the almond industry, chemical company product development representatives, and other colleagues within the University of California. The trial was organized as a completely randomized block design with five replications of single-tree plots; exact specifications made after field sites were approved and located. Plots were sprayed at hull split with portable hand gun sprayers or back pack sprayers. Water volume was dependent on the size and density of the tree canopy. The trial was performed on the Nonpareil variety. At harvest, trees were shaken and a nut sample of at least 200 nuts per tree was collected. Nuts were cracked and evaluated for navel orangeworm damage to the kernel. Data was analyzed by ANOVA with means separated by Fisher's Protected LSD.

Table 1. Efficacy Trial for Navel Orangeworm in Nonpariel Variety. All the materials tested significantly reduced Navel Orangeworm (NOW) populations when compared to the control.

Treatment		Application Rate	% NOW[a]	
5	Cyazypyr (HGW86)	13.5 fl oz	0.0	a
3	Altacor®+Asana® XL	3.0 oz+ 9.6 fl oz	0.1	ab
6	Proclaim + Dyne-Amic	4.5 oz + 0.25%v/v	0.2	abc
11	Belt	4 fl oz	0.3	abcd
7	Intrepid+ Delegate	12.8 fl oz + 3.2 oz	0.4	abcd
4	Altacor® + Bifenthrin	3.0 oz +16.0 oz	0.5	abcd
12	Asana	12.8 fl oz	0.6	abcd
1	Altacor® (Rynaxypyr)	3.5 oz/ac	0.9	abcd
9	Athena	19.2 fl oz	0.9	bcd
10	Hero EW	11.2 fl oz	1.0	bcd
8	Brigade WSB	18 oz	1.0	cd
2	Altacor®	4.0 oz	1.1	d
13	Untreated		3.3	e

[a]200 nuts were cracked out of each replication, 5 replications, 1000 nuts per treatment. Percent worm damage was determined per 1000 nuts. Data was transformed for analysis.

Results and Discussion:

All treatments at hull-split significantly controlled Navel Orangeworm when compared to untreated control: Cyazypyr (HGW86), Altacor (Rynaxypyr), Altacor + Asana (Esfenvalerate), Asana, Altacor + Brigade (Bifenthrin), Brigade, Proclaim (Emamectin benzoate), Belt (Flubendiamide), Intrepid (Methoxyfenozide) + Delegate (Spinetoram), Athena (Bifenthrin + Abamectin), and Hero (Bifenthrin+Zeta-cypermethrin)