Improving Efficacy of Spray Applications in Almonds

Project No.: **11-WATER3-Giles/Markle**

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Objectives:

1. Determine spray deposition on targeted trees and off-target areas for a typical grower spray application rate at two different ground speeds; and
2. Establish Navel Orangeworm (NOW) control on almond nuts at hull-split for the different spray applications within the lower and upper portions of the canopy.

Interpretive Summary:

Accurate and effective spray application for pest control in almond production is an opportunity for developing methods that increase deposition efficiency, reduce application costs, and provide environmental stewardship. Increasing deposition within the upper sections of the tree canopy during single pass operations can benefit the grower economically through reduced pesticide and energy use. Evaluating spray application practices that are beneficial to the growers, in terms of energy savings and commodity protection, and provide good environmental stewardship in terms of minimizing off-orchard drift and deposition continues to be of interest to all stakeholders.

In the past, spray application studies rarely combine results in terms of in-canopy deposition and off-orchard drift sedimentation with commodity (nut) exposure to insects/pests for establishing pest control efficacy. This project is the continuation of a collaborative study established last year between the USDA's interest in monitoring spray application efficacy for Navel Orangeworm (NOW) control, UC Davis's and Cooperative Extension's focus on increasing efficacy of spray applications using new and existing equipment technologies, and CURES continued work on reducing spray drift and increasing water quality standards.

The present study evaluated two application spray treatments soon after hull-split. The study site was located at the Leslie J. Nickels Soil Laboratory in Colusa County. Target trees were Nonpareils between two alternating rows of pollinator varieties. The spray application rates for both treatments were the same with a target rate of 100 gal/ac (GPA). Ground speeds for the two treatments differed: Treatment 1 was applied at 1.8 mph and Treatment 2 was applied at 2.4 mph. Formulations were similar for each treatment application: DuPont™ Altacor™ (water dispersible granules) was added at 4 oz/ac, R-11® non-ionic surfactant was added at 8 oz/100 gal and micro-nutrient tracers, for deposition recovery measurements, were added at 1.5 pts/ac (Molybdenum) for Treatment 1 and 2 pts/ac (Manganese) for Treatment 2.

Deposition results for this study are presented as percentages of the tank mix application rate. In all cases, deposition within the lower canopy using artificial media (steel mesh cylinders) was higher when compared to biological (leaf samples). Deposition on steel cylinders was 17.1% and 26.4% of the application rate, respectively for Treatment 1 and 2. Leaf punch deposition was 13.3% and 11.4% of the application rate, respectively for Treatment 1 and 2. Whole leaf sample depositions were 9.2% and 9.1% in the lower canopy, and 5.3% and 6.7% within the upper canopy, of the application rate, respectively, for Treatment 1 and 2.

Ground deposition (on steel plates) within the orchard was 1.1% and 10.8% of the application rate, respectively for Treatment 1 and 2. Off-orchard drift measurements found that steel plates did not recover drift deposition for Treatment 1 (the analytical instrument minimum detection level was 5 ppb for each micro-nutrient metal); alpha-cellulose sheets recovered 0.1% of the application rate at the 50 and 75 ft measurement locations. For Treatment 2 steel plates recovered 16.6%, 7.7% and 8.1% of the application rate at 50, 75 and 100 ft while alpha-cellulose sheets recovered 1.1% and 1.0% of the application rate at the 50 and 75 ft locations and less than 1% at the remaining drift measurement locations (100 and 200 ft).

Nuts were collected from the upper and lower sections of the canopy one and fourteen days after the treatments (DAT) and exposed to the NOW eggs. Eggs were either “pinned” to the hull, simulating oviposition, or “tucked” within the open suture of sampled nuts. The overall survival from NOW exposure (combining both canopy heights and exposure positions) for untreated (“control”) nuts was 45.6%.

Survival for Treatment 1 (1.8 mph) found no significant difference between egg placement and canopy height; survival was 1.1% 1DAT. For Treatment 2 (2.4 mph) there was no significant difference in survival between lower and upper canopy nuts 1 DAT, however there was a significant difference between egg placement; tucked eggs were 3.3 times more likely to survive. Pooled survival for Treatment 2 was 1.5%. There was no significant difference between the two treatments 1 DAT; Altacor exposure reduced survival by 97% when compared to the pooled control nuts survival.

Results 14 DAT indicated that there was no difference between egg placement and canopy height for Treatment 1 (1.8 mph) and overall survival was 3.7%. However, using the control nut survival (45.6%), survival was reduced to 91.8%. Also, treated nuts exposed to NOW eggs for Treatment 1 were 3.1 times as likely to survive when compared to results from 1 DAT. For Treatment 2 (2.4 mph) there was no difference between egg placements, however a significant difference was found with canopy height. Eggs placed within the upper canopy nuts (12.9%

survival) were 3 times as likely to survive versus lower canopy nuts (4.3% survival). Population reduction was 90.7% and 71.7% in the low and upper canopy nuts, respectively.

A comparison of the two treatments 14 DAT found that there was no significant difference in survival between the two treatments (i.e., ground speeds) within the low canopy nuts and overall survival was 3.8%. However, there was a significant difference in survival between the two treatments within the upper canopy nuts. Eggs were 3.1 times more likely to survive within the upper canopy versus the low canopy at the faster ground speed. No difference in survival was observed between pinned or tucked egg placements within the upper canopy. Failure of the treatment starts within the upper canopy and is exacerbated by increased ground speed during the spray application. Altacor provided protection at 14 DAT, however, efficacy decreased when compared to the 1 DAT results.

Materials and Methods:

Test Orchard Description

The spray applications for this study occurred within a section of the M-1 Block (planted in 1990) south of Marine Ave (see **Figure 1**) at the Nickels Soil Laboratory. Treatment areas 1 and 2 were approximately 3 acres; the off-orchard drift measurement area south of the test block was approximately 1 ac. Each treatment area consisted of seven rows with 43 trees per row. Tree spacing was 16 ft, row spacing was 22 ft. Three Nonpareil rows within each test block were sprayed for each treatment; Nonpareil trees were separated by two rows of pareil varieties. Nonpareil trees were sprayed with a single pass application, i.e., the spray applications were from one side of the sprayer on each side of the treated row. Treatment 1 occurred between 11 am – 12 pm and Treatment 2 was applied between 1 – 2 pm.

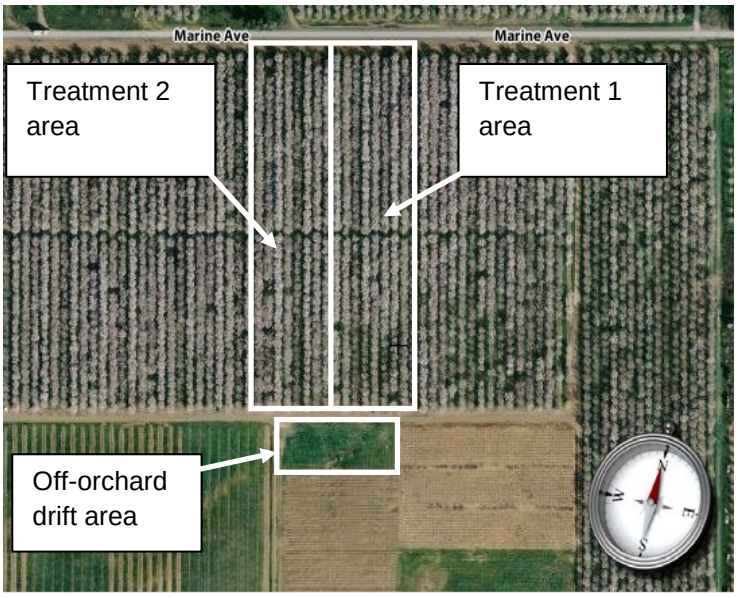


Figure 1. Location for spray application tests at Nickels Soil Laboratory.

Spray drift was measured within a 1 ac block south of the test orchard. Three drift sedimentation transects (four locations/transect) were aligned perpendicular to the respective treatment area. Two transects were aligned along the respective north-south treatment area boundary and an additional transect was aligned perpendicular to the respective treatment area middle. Drift was measured along these transects at 50, 75, 100 and 200 ft south of the orchard foot print. **Figure 2** shows a typical transect layout and a sampling platform, for capturing deposition, equipped with acid-washed cellulose sheet, steel plates and water sensitive paper (WSP).

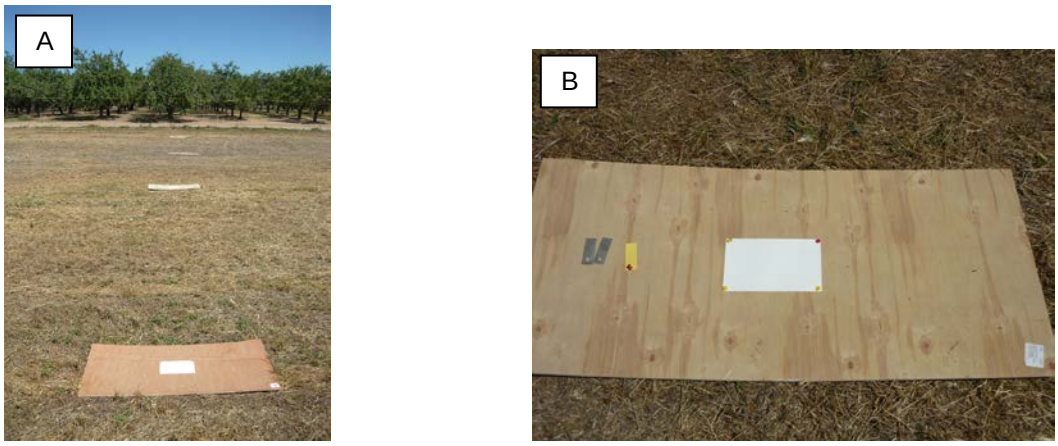


Figure 2. Transect layout (A) showing location (50, 75, 100, 200 ft) alignment south of the treatment area and (B) drift sedimentation platform with alpha-cellulose sheets (9 in. x 6 in.), water sensitive paper (1 in. x 3 in.) and steel plates (1 in. x 3 in.).

Spray Equipment and Formulations

Both spray treatments were made with a tractor (Model 5105ML, 90 hp PTO, 105 hp engine, Deere & Co., Moline, IL) towed Air-O-Fan sprayer (Model No. GB36R, Air-O-Fan Products Corp., Reedley, CA) at full air flow and 540 PTO rpm. Both spray treatments targeted an application rate of 100 GPA. Treatment 1 was sprayed at 1.8 mph; Treatment 2 was applied at 2.4 mph. Each treatment application used 9 nozzles on one manifold on one side of the sprayer; system pressure for each treatment was 150 psi. The sprayer for Treatment 1 was set up to spray two-thirds of the volume from the upper half of the nozzles; Treatment 2 was set up to spray two-thirds of the volume from the top three nozzles. All nozzles for both treatments were configured with slotted nylon strainers and DC-25 cores (Teejet Spraying Systems, Inc., Wheaton, IL). **Figure 3** shows the nozzle disc configurations along the sprayer manifold for each application. Formulations were similar for each treatment application: Dupont™ Altacor™, as water dispersible granules, was added at 4 oz/ac, R-11® non-ionic surfactant was added at 8 oz/100 gal and micro-nutrient tracers, for deposition recovery measurements, were added at 1.5 pts/ac (Molybdenum) for Treatment 1 and 2 pts/ac (Manganese) for Treatment 2.

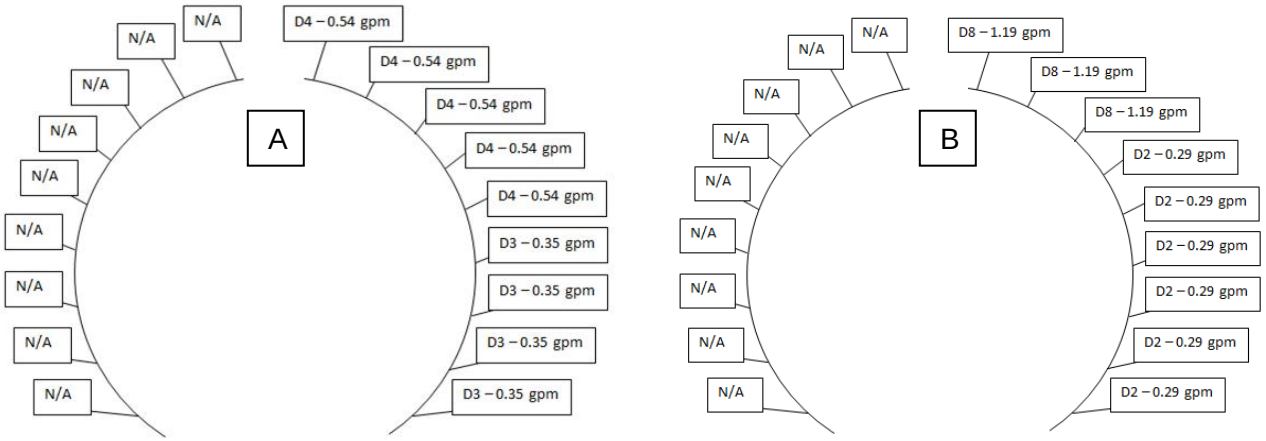


Figure 3. Nozzle configuration along manifold for Treatment 1 (A) and Treatment 2 (B).

Deposition Media

Media used for capturing spray deposition was similar to last year; however, biological (leaf and nut) samples were collected this year for additional comparisons. Deposition within the trees and on the ground surface within the orchard was measured using metallic sample collectors. In tree deposition was measured with stainless steel hollow mesh cylinders (1 in. dia., 3 in. length) suspended from branches within the lower portion of the canopy (four samples per one tree within the middle section of the test block). Ground deposition was measured within the orchard with stainless steel flat plates (1 in. x 3 in.) suspended above the ground surface with stakes. Six plates were set out along the middle row within the respective treatment area; three were located (16 ft apart) in the center of one of the driving rows adjacent to the center row within the treatment area and three were located beneath tree canopies aligned with the driving row samplers. **Figure 4** shows a hollow cylinder located within the lower canopy of one tree adjacent to WSP and a ground deposition sampling plate adjacent to WSP under the tree canopy.

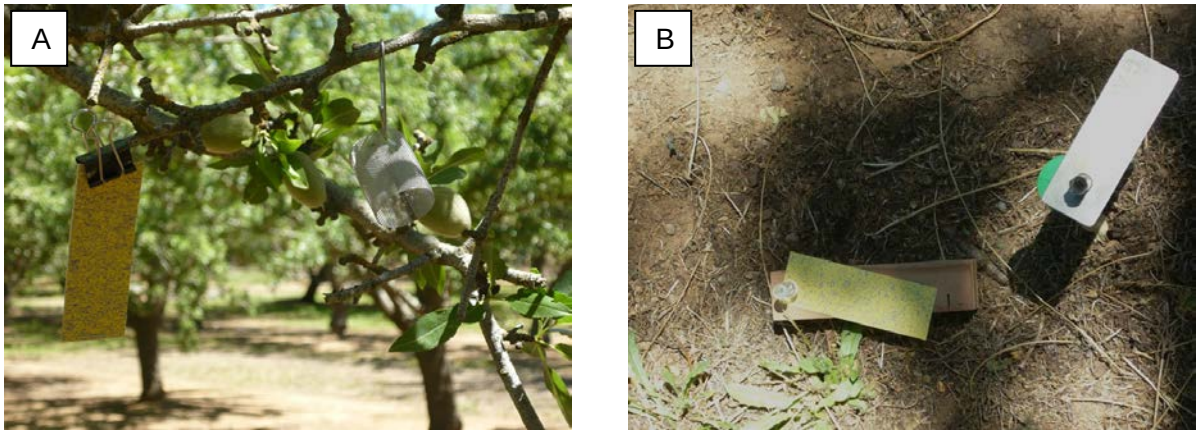


Figure 4. Low canopy WSP placement adjacent to hollow cylinders for measuring in tree deposition (A) and steel plates with adjacent WSP for measuring ground deposition (B).

Two types of leaf samples were collected for both treatments. Forty leaf punches (¼ in. diameter) were collected from four trees aligned along the center row of the respective treatment area. Leaf punches were collected from the lower canopy (approximately 6 ft high); each sample of forty leaf punches encompassed the entire canopy circumference. Whole leaf samples (100 samples per tree) were collected from the same trees prior to and after the treatments from the upper and lower portions of the canopy. These samples also encompassed the entire canopy circumference. Canopy height for whole leaf samples was 6 ft (low canopy) and approximately 20 ft (upper canopy). Ten nuts were collected from the lower canopy of the sampling trees after each treatment and processed for analysis similarly to the method described for leaf punches (see below). All samples were collected and pre-processed (if needed) within one hour of each spray application treatment.

Sample Analysis

There were two separate sampling protocols and subsequent analyses for determinations of spray deposition on biological (and steel media) samples for this study. The first protocol involved whole leaf samples (100 leaves per replicate, four replicates, two canopy heights) that were collected by hand and stored in paper bags at 20º C prior to transporting materials off-site. All leaf samples were dried at 65 ºC and submitted for acid digestible Mo and Mn content: note that background whole leaf samples (samples collected prior to spray applications) were submitted for the same analyses. Samples were quantitatively analyzed for acid digestible Mo and Mn by Inductively Coupled Plasma Mass Spectrometry (ICP-MS) at the University of California-Davis Analytical laboratory (see anlab.ucdavis.edu/analyses/plant/590 for method description). All composite samples (4 locations, 2 heights, 3 treatments) were measured for total surface area, using a leaf area planimeter and mass prior to analysis of Mo and Mn content. The minimum detection limit for Mo was 0.1 mg/kg, for Mn the minimum detection limit was 1.0 mg/kg.

The second protocol involved washing leaf punches (40 leaf punches, each punch was ¼ in. diameter per replicate tree), 10 nuts (from the lower canopy per replicate tree) and artificial media (mesh cylinders, plates and cellulose sheets) in a 1% HNO3 wash solution. Predicated on the sample type, and/or size, different volumes of wash solution were used. For the 10 nut samples and alpha-cellulose sheets, 90 ml of the wash was used; for the leaf punches, steel plates and hollow cylinders, 30 ml of the wash solution was used. All samples with wash solution were shaken for several minutes and allowed to sit prior to decanting the rinsate wash into pre-acid washed sample bottles and stored at 20º C in shipping containers prior to transporting to the laboratory. The rinse solutions were quantitatively analyzed for soluble Mo and Mn by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES) at the University of California-Davis Analytical laboratory (see anlab.ucdavis.edu/analyses/water/835 for method description). The minimum detection limit for both soluble elements in solution was 0.005 mg/L.

Almond Nut Collection for Hull-Split

Hull-split nuts for NOW exposure studies were collected prior to, and 1 and 14 DAT within the respective treatment test blocks. Nut samples (approximately 75 nuts per sample) were collected from four different trees in the lower (6 ft) and upper (20 ft) portions of the canopy within the middle section of the respective treatment sections within the test orchard. All samples (replicate, treatment and height) were preserved on ice and transported to the

Agricultural Research Service Laboratory in Parlier, CA for NOW egg exposure studies under controlled laboratory conditions. There was a small complication this year with the nuts. The upper canopy nuts were predominantly split and the lower canopy nuts were predominantly closed (almost 100%), however were at the suture crack stage. Therefore, these low canopy nuts were sliced open along the suture and gently squeezed, allowing the hull to open. All nut samples were individually infested with a strip of navel orangeworm eggs, 10 eggs per strip. These strips were either tucked into the suture, or pinned onto the hull, simulating oviposition. All nuts were cracked and examined 6 weeks after infestation and all life stages present were recorded and pooled.

Weather Station
On-site ambient conditions (temperature, relative humidity, wind speed and direction) were monitored with a field weather station (Ultimeter 2000, Peet Bros. Co., Inc., St. Cloud, FL). The station was set-up approximately 500 ft south of the southern edge of the orchard. The wind speed and direction sensors were set approximately 6.5 ft above the ground surface; the temperature and relative humidity sensors were approximately 5 ft above the ground surface. Data from the Integrated Pest Management (IPM) weather station, "Nickels_Soils_Lab.P" (available at www.ipm.ucdavis.edu/WEATHER/index.html), for the time periods over which the treatments occurred are given in the Results section with the on-site weather results.

Results and Discussion:

General site conditions
In-orchard, one-sided boom, spraying for hull-split is shown in **Figure 5.** The treatments occurred in late morning and early afternoon (approximately 1 hour apart). **Table 1** gives the ambient on-site weather conditions and, comparatively, the weather conditions measured from the local IPM weather station. Treatment 1 (1.8 mph, 100 GPA) was started at approximately 10:45 am and ended within an hour. Treatment 2 (2.4 mph, 100 GPA) occurred between 1:00 – 1:45 pm the same day. Wind direction on-site was predominantly from the east-northeast during both spray application treatments.

Figure 5. One-sided boom spraying for hull-split.

Table 1. Ambient weather conditions at the test site in addition to weather conditions measured by the local IPM weather station (Nickels_Soils_Lab.P).

Time	Temperature ºF	Relative Humidity %	Wind Speed mph	Wind Direction† compass degrees / dominant direction
On-site weather: Ultimeter 2000				
10:00 am	-	-	-	-
11:00 am	72.7	72.0	2.5	42 / northeast
12:00 pm	76.6	62.0	3.1	40 / northeast
1:00 pm	86.6	56.8	2.7	40 / northeast
2:00 pm	88.0	-	4.3	40 / northeast
IPM weather: Nickels_soils_Lab.P				
10:00 am	70.0	60.0	7	49 / northeast
11:00 am	75.0	53.0	7	30 / northeast
12:00 pm	78.0	49.0	7	55 / northeast
1:00 pm	82.0	44.0	9	101 / east
2:00 pm	84.0	42.0	10	74 / east

† Wind speed and direction sensor height on-site for the Ultimeter 2000 was 6.5 ft high versus the IPM weather station sensor height which was 10 ft above the ground surface. Temperature and Relative Humidity sensors for both stations were the same height above the ground surface.

Hull-Split Exposure Studies

Untreated ("control") nuts when exposed to NOW eggs resulted in a 56.75% survival within the lower canopy nuts; this result was significantly higher when compared to the upper canopy nuts where the survival rate was 34.38% for untreated nuts (χ^2 of 81.6 and $P < 0.0001$). There were no consistent differences between pinned and tucked NOW egg strips in the untreated nuts. The pooled untreated egg survival was 45.56%. It is possible that the hull was moister in the lower canopy nuts (since the majority of these nuts had not split) and this increased NOW egg survival.

Day 1 after Altacor spray applications

Survival for Treatment 1 (1.8 mph) found no significant difference between egg placement and canopy height; pooled survival was 1.12% (19 eggs out of 1,600 survived). For Treatment 2 (2.4 mph) there was no significant difference in survival between lower and upper canopy nuts, however there was a significant difference between egg placement; tucked eggs were 3.25 times more likely to survive (χ^2 of 8.6 with $0.005 > P > 0.001$). Pooled survival for Treatment 2 was 1.49% (34 eggs out of 2,280 survived). There was no significant difference between the two treatments 1 DAT. When the data from these treatments were pooled survival was 1.37% (53 eggs out of 3,880 survived). Altacor exposure reduced survival by 96.99% when compared to the pooled control nuts survival.

Day 14 after Altacor spray applications

Results found that there was no difference between egg placement and canopy height for Treatment 1 (1.8 mph) and overall survival was 3.73% (112 eggs survived out of 3,000). However, using the control survival (45.6%), population survival was reduced to 91.81%. Also, eggs exposed to treated nuts 14 DAT were 3.14 times as likely to survive when compared to results from 1 DAT (χ^2 of 23.5, $P < 0.0001$).

Results from Treatment 2 (2.4 mph) found there was no difference between egg placement, however a significant difference was found with canopy height. Eggs placed within the upper canopy nuts resulted in a 12.88% survival (206 eggs survived out of 1,600) versus 4.25% (68 eggs survived out of 1,600) for the lower canopy nuts. Additionally, eggs within the upper canopy nuts were 3.03 times as likely to survive versus lower canopy nuts (χ^2 of 74.0, $P < 0.0001$). Population reduction was 90.67% and 71.74% in the lower and upper canopy nuts, respectively.

Treatment differences 14 DAT

Results from NOW exposure to low canopy nuts found there was no significant difference in survival between the two speeds (i.e., treatments) and overall survival was 3.80% (114 eggs survived out of 3,000). This resulted in a population reduction of 91.66%; there was no difference in survival between pinned and tucked nuts. Upper canopy nuts, after exposure to NOW, resulted in a significant difference in egg survival at the two speeds. Overall, eggs placed in upper canopy nuts were 3.12 X more likely to survive (χ^2 of 77.6, $P < 0.0001$) versus eggs placed in low canopy nuts. Upper canopy nuts sprayed at 1.8 mph (Treatment 1) resulted in a survival that was 4.13% (66 eggs survived out of 1,600). Survival rose to 12.88% (206 eggs survived out of 1,600) in the upper canopy nuts when sprayed at 2.4 mph. There was no difference between pinned and tucked egg strips in the upper canopy nuts.

The results from these tests indicate that spray application failure starts at the top of the tree (similar results were found by Giles et al., 2011) and is exacerbated by increased ground speed during the application. Altacor provided substantial protection against NOW at 14 DAT, although its efficacy clearly decreased compared to the first day after spray application.

Spray Deposition Results

Deposition results are presented in several formats for the present study in an attempt to develop a standard method of reporting data and for comparative purposes with earlier studies. Deposition on leaf punches, cylinders, steel plates, cellulose sheets and nuts were a function of the wash (rinse) solution volume. Results of tracer material deposited were reported in terms of parts per million (ppm or mg/L). Results from deposition on whole leaf samples were also reported in terms of ppm, however results were on a mass basis (mg/kg). For comparisons of the different media from this study, several equations were developed to present the data in terms of mass of tracer deposited over a specific surface area. Additionally, this required the tank concentration for each spray application to be developed in similar terms, i.e., application rate (100 GPA) reported in terms of tracer mass per area; equations 1 – 5 were developed to present the results in terms of mass deposited per surface area. Specific depositions on the various media were then adjusted in terms of the tank mix and are reported as a percentage deposition of the tank mix application rate for the respective

treatment (e.g., deposition on whole leaves as µg/cm^2 divided by tank mix application rate as µg/cm^2 for the treatment and multiplied by 100).

Deposition area determinations were straight forward for the leaf punches and whole leaves and assumed two-sided deposition. All plates assumed a one-sided deposition. Mesh cylinder surface area was adjusted for the mesh openings and deposition was assumed to be on the external and internal portion of the hollow cylinder. The nut surface area was estimated from the above equations; dimensions for the major (3.68 cm) and minor axes (2.69 cm) were determined from a sample of 50 nuts and averaged to represent a typical nut size.

Deposition results within the orchard and from off-orchard drift are given in **Tables 2 – 5**. The data show that in all cases Treatment 2 resulted in a larger amount of tracer material deposited on all surfaces. However, the magnitude of tracer mass for Treatment 1 within the tank mix was 65% of that for Treatment 2. **Table 2** gives quantitative results of deposition within the orchard in terms of mass deposited per surface area. **Table 3** data show the same results in terms of deposition as a percent of the tank mix application rate. From **Table 3**, deposition from material collected within the lower canopy (leaf punches, whole leaves and nuts) resulted in similar magnitudes of deposition for both treatments; approximately 10% of the tank mix application rate was deposited on these surfaces. **Figure 6** shows qualitative results from the treatments on WSP within the lower canopy. Upper canopy whole leaves resulted in depositions of 5.3% and 6.7% for Treatment 1 and 2, respectively. The upper canopy deposition results indicate there may be a lower limit on deposition rates that provide reasonable efficacy for NOW control.

The data show that artificial media (steel hollow cylinders and steel plates) result in increased depositions and this increase may also be confounded by specific metal tracers. Averaging the deposition across the low canopy nuts, lower canopy whole leaves and leaf punches, from **Table 2**, and comparing this to the deposition results on steel cylinders reported in **Table 2** indicates that the steel cylinder deposition was 1.7 and 2.5 times that of the biological media samples for treatments 1 and 2 respectively. The spray treatments should result in similar levels of deposition, as a percentage of the tank mix application rate, within the lower canopy for these two treatments, regardless of media used. The biological media show this to be the case; however, non-biological media results in increased depositions recovered. A similar response is seen with the steel plates used for in-orchard ground and off-orchard drift depositions. From **Table 2**, Treatment 2 ground deposition within the orchard was at least 13 times that of Treatment 1. Considering ground deposition on WSP in **Figure 7** this result appears to be artificially elevated. Also, as a percentage of tank mix application rate, Treatment 2 was an order of magnitude greater than Treatment 1. Although this may be an accurate result, considering the results in **Table 4 and 5** (off-orchard drift) indicates that the metal tracer used for Treatment 2 (manganese), in combination with the metal plate media resulted in artificially elevated results. The metal plates used in this study have been field deployed for a number of years and surface micro-pitting from the strong acid rinse used to remove deposition could be releasing manganese into the rinse solutions. Additionally as with zinc, manganese as an analytical tracer can be problematic due to the prevalence of the material in the natural environment. Future spray studies may need to avoid use of the manganese micro-nutrient as a metal tracer for spray deposition recovery studies if metal media are used spray recovery during field studies.

Table 5 gives the data from off-orchard drift on alpha-cellulose sheets from both treatments. The results indicate that Treatment 1 drift sedimentation was approximately 0.1% of the tank mix application rate within 75 ft of the orchard edge; no drift sedimentation was measured at the 100 or 200 ft locations. Treatment 2 resulted in approximately 1% of the tank mix concentration application rate within 75 ft of the orchard edge, and less than 1% was measured at the 100 and 200 ft locations. **Figure 8** shows WSP off-orchard deposition for the two treatments for the different locations along transects south of the orchard. Noting that the limit of detection was 5 ppb for each tracer, **Figure 8** indicates that although WSP may show deposition qualitatively, analytically, the deposition on media may result in undetectable levels.

Table 2. Metal tracer deposition recovered within the orchard after the spray treatments (standard deviations in parentheses).

Sample location	Treatment 1	Treatment 2
	----- Deposition, µg/cm^2 -----	
Tree – cylinders	0.191 (0.083)	0.458 (0.126)
Tree – leaf punches	0.149 (0.024)	0.198 (0.063)
Tree – leaf lower canopy	0.103 (0.010)	0.157 (0.172)
Tree – leaf upper canopy	0.060 (0.016)	0.117 (0.110)
Tree – low canopy nuts	0.091 (0.025)	0.204 (0.051)
Ground - drive	0.010 (0.009)	0.186 (0.065)
Ground – tree-line	0.014 (0.012)	0.187 (0.013)

Table 3. Deposition on specific surfaces within the orchard as a percentage of the tank mix application rate.

Sample location	Treatment 1	Treatment 2
	-- Deposition, % of Tank Mix --	
Tree – cylinders	17.1	26.4
Tree – leaf punches	13.3	11.4
Tree – leaf lower canopy	9.2	9.1
Tree – leaf upper canopy	5.3	6.7
Tree – low canopy nuts	8.1	11.8
Ground†	1.1	10.8

† Ground surface results (driving row and tree line) were combined.

Table 4. Metal tracer drift deposition south of the orchard after the spray treatments (each respective location over all three transects were averaged, standard deviations are given in parentheses).

Treatment Number	-------- Transect location, ft ---------			
	50	75	100	200
	--------- Deposition, µg/cm^2 ---------			
Steel plates				
Treatment 1, 1.8 mph	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	- -
Treatment 2, 2.4 mph	0.287 (0.08)	0.134 (0.015)	0.139 (0.018)	- -
Alpha-cellulose sheets				
Treatment 1, 1.8 mph	0.001 (0.001)	0.001 (0.001)	0.000 (0.000)	0.000 (0.000)
Treatment 2, 2.4 mph	0.019 (0.011)	0.017 (0.008)	0.011 (0.003)	0.011 (0.004)

Table 5. Drift deposition south of the orchard (each respective location over all three transects were averaged, standard deviations are given in parentheses) as a percentage of the tank mix application rate.

Treatment Number	-------- Transect location, ft ---------			
	50	75	100	200
	---- Deposition, % of Tank Mix -----			
Steel plates				
Treatment 1, 1.8 mph	0.0	0.0	0.0	-
Treatment 2, 2.4 mph	16.6	7.7	8.1	-
Alpha-cellulose sheets				
Treatment 1, 1.8 mph	0.1	0.1	0.0	0.0
Treatment 2, 2.4 mph	1.1	1.0	0.6	0.6

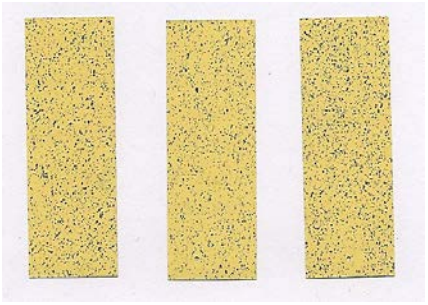
A – Driving Row

Treatment 1

Treatment 2

B – Tree line

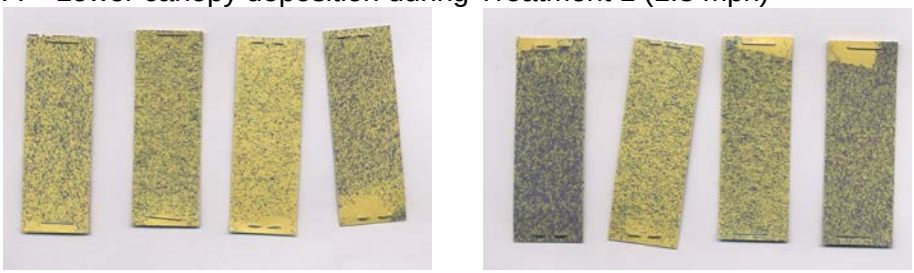
Treatment 1



Treatment 2

Figure 6. Ground deposition along the driving row (A) and tree line (B) for Treatment 1 (1.8 mph) and Treatment 2 (2.4 mph).

A – Lower canopy deposition during Treatment 1 (1.8 mph)



B – Lower canopy deposition during Treatment 2 (2.4 mph)

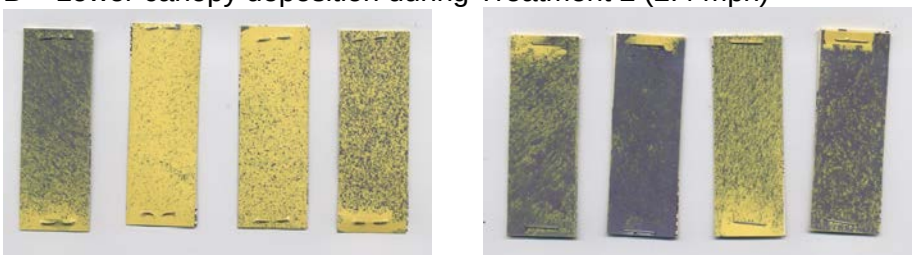


Figure 7. In tree (lower canopy) deposition for (A) Treatment 1 (1.8 mph) and (B) Treatment 2 (2.4 mph).

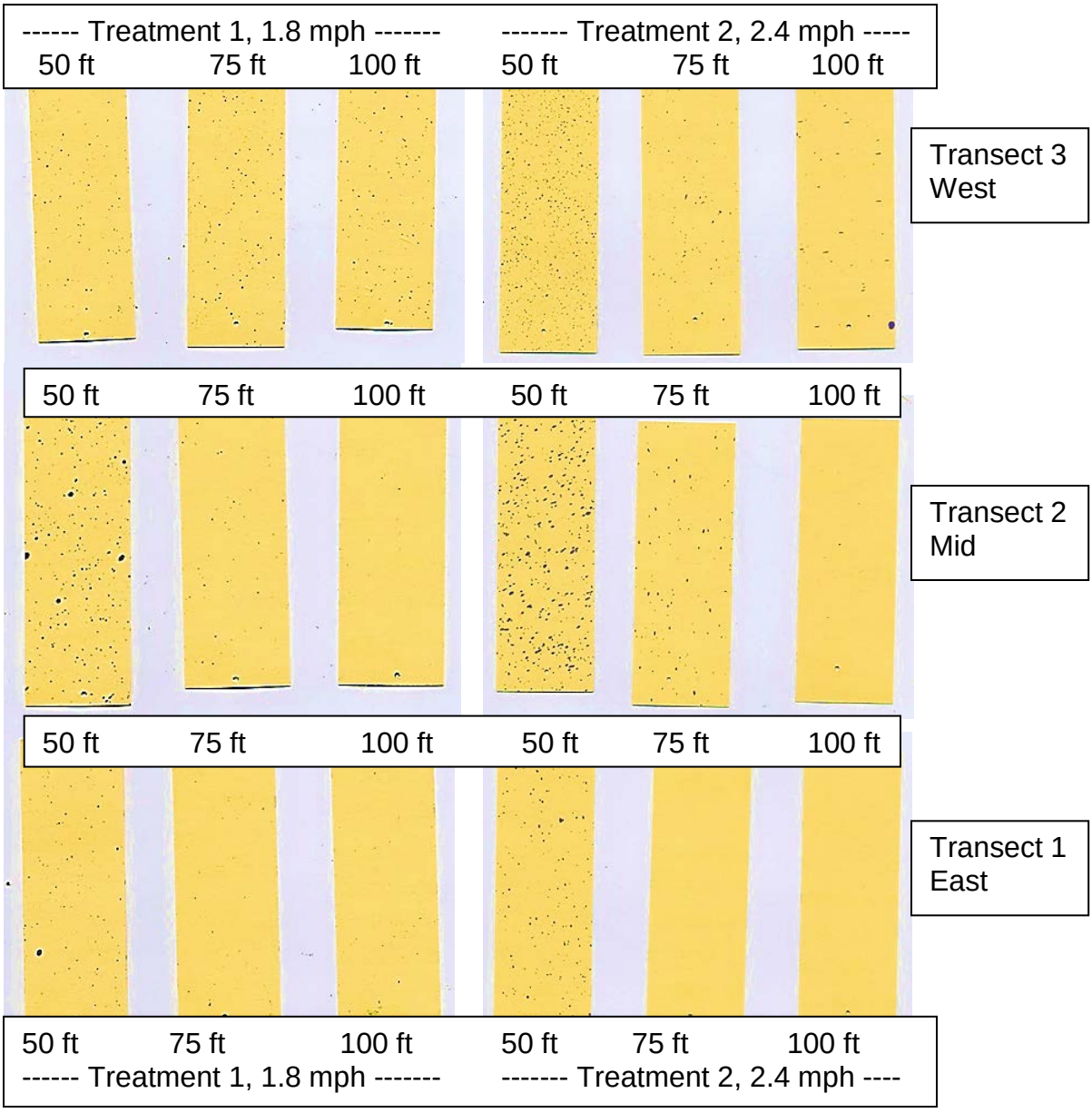


Figure 8. Water sensitive paper showing deposition from spray drift for three distances and three transects aligned perpendicular to orchard foot-print.

Comparisons with previous studies
In light of these results, and with consideration of last year's work (Giles et al., 2011), a comparison of the data results for the two studies are presented. Additionally, an early season independent spray study (soon after fruit set) using micro-nutrient metal sprays for assessing metals as an analytical tracer for determining deposition was developed; these unpublished results are also presented.

Last season's spray study (Giles et al., 2011) evaluated the differences between a conventional and reduced rate spray application (100 GPA versus 50 GPA) during hull-split at similar ground speeds (2 mph) using a medium droplet size range for both applications. The tracer used for this study was a relatively photo-stable dye (brilliant sulfaflavine, BSF); use and recovery for this material was described earlier (Klassen et al., 2007). This season's independent study for evaluating spray applications using metal tracers to determine deposition (soon after fruit set) compared two applications (using fine versus medium/coarse droplets) sprayed at 100 GPA and applied at ground speeds of 2.5 mph. Treatment 1 from this study used molybdenum (Mo) and Treatment 2 used manganese (Mn) as the tracer. The present study evaluated hull-split sprays, using metal tracers, at 100 GPA and two ground speeds (1.8 and 2.4 mph). Spray droplets were in the medium droplet size range. As with the early season spray, Treatment 1 used molybdenum and Treatment 2 used manganese as the tracer.

Comparisons of the tests described above are given in **Tables 6 - 8.** The data show that in all cases, steel cylinders result in greater magnitudes of deposition recovery regardless of tracer type. Also, for the two studies from this year (early season and hull-split), lower whole leaves, leaf punches and lower nuts result in similar magnitudes of deposition recovery, noting that whole leaves are analyzed for acid digestible metals versus acid soluble analyses for the rinse solutions from leaf punches and nuts. This result can be helpful for future studies with regards to sampling time frames within the field and man-power requirements for field studies.

The data for upper canopy whole leaves, in relation to the results from the NOW exposure studies on upper canopy nuts, indicates there is a deposition level required (especially when compared to low canopy deposition recovery) for increased pest control efficacy from spray applications within the upper canopy.

Analysis of the results for ground deposition within the orchard indicates that steel plates likely over-represent deposition when using manganese as an analytical tracer. This is evident from the two studies over this past year and includes results from the drift sedimentation results. In all cases, manganese recovery from steel plates was equivalent to or greater than molybdenum recovery. Although this is generally not the case for recovery of the metal tracers from alpha-cellulose sheets, there appears to be an elevated trend of increased recovery when using manganese. Future studies, if using manganese as a tracer, should probably use alpha-cellulose sheets for all ground deposition recovery analyses.

Table 6. Comparison of several spray application studies in terms of deposition as a percentage of the tank mix application rate within the orchard.

Application rate GPA-tracer	Ground Speed mph	Number of nozzles	System pressure psi	Droplet size Category	---- Deposition, % of tank mix application rate ---- Leaf Low†	Leaf Upper	Nut Low	Leaf Punch	Steel Cylinder	Steel Plate
2010 Hull-split††										
50-BSF	2.0	22	110	Medium	---	---	---	---	22.9	6.4
100-BSF	2.0	22	110	Medium	---	---	---	---	17.8	7.6
2011 Early Season										
100-Mo	2.5	36	150	Fine	9.3	4.5	---	11.6	42.3	3.3
100-Mn	2.5	36	140	Medium/Coarse	9.1	7.4	---	17.6	25.5	21.3
2011 Hull-split										
100-Mo	1.8	9	150	Medium	9.2	5.3	8.1	13.3	17.1	1.1
100-Mn	2.4	9	150	Medium	9.1	6.7	11.8	11.4	26.4	10.8

† "Low" indicates low canopy (approximately 6 ft above ground) and "Upper" indicates samples from approximately 20 ft above ground. Additionally, Low leaf and Upper leaf tracer recovery was based on acid digestible analyses of bulk samples while Nut Low, Leaf Punch, Steel Cylinder and Steel Plate results were based on soluble metal or dye measurements in solution as described earlier.
†† 2010 Hull split applications were with a Turbomist sprayer; 2011 applications were with an Air-O-Fan sprayer. Note that BSF, Mo and Mn tagged to the application rate indicates the tracer used at the specified application rate for that specific test.

Table 7. Comparison of several spray application studies in terms of deposition as a percentage of the tank mix application rate due to drift sedimentation onto steel plates.

Application rate GPA-tracer	Ground Speed mph	Number of nozzles	System pressure psi	Droplet size Category	---- Deposition, % of tank mix application rate ---- ---------- Distance from orchard edge ---------- 15 ft	30 ft	45 ft	50 ft	75 ft	100 ft	200 ft
2010 Hull-split†											
50-BSF	2.0	22	110	Medium	---	1.2	---	0.6	0.4	---	---
100-BSF	2.0	22	110	Medium	---	2.8	---	0.7	0.6	---	---
2011 Early Season											
100-Mo	2.5	36	150	Fine	2.4	2.3	1.5	---	---	---	---
100-Mn	2.5	36	140	Medium/Coarse	4.8	2.3	3.1	---	---	---	---
2011 Hull-split											
100-Mo	1.8	9	150	Medium	---	---	---	0.0	0.0	0.0	---
100-Mn	2.4	9	150	Medium	---	---	---	16.6	7.7	8.1	---

† 2010 Hull split applications were with a Turbomist sprayer; 2011 applications were with an Air-O-Fan sprayer. All samples results were based on measurements of soluble metal or dye measurements in solution as described earlier.

Table 8. Comparison of several spray application studies in terms of deposition as a percentage of the tank mix application rate due to drift sedimentation onto steel plates versus alpha-cellulose sheets.

Application rate GPA-tracer	Ground Speed mph	Number of nozzles	System pressure psi	Droplet size Category	---- Deposition, % of tank mix application rate ---- ---------- Distance from orchard edge ---------- 15 ft	30 ft	45 ft	50 ft	75 ft	100 ft	200 ft
2011 Early Season – Steel Plates†											
100-Mo	2.5	36	150	Fine	2.4	2.3	1.5	---	---	---	---
100-Mn	2.5	36	140	Medium/Coarse	4.8	2.3	3.1	---	---	---	---
2011 Early Season – Alpha-cellulose sheets†											
100-Mo	2.5	36	150	Fine	1.5	1.1	0.8	---	---	---	---
100-Mn	2.5	36	140	Medium/Coarse	2.0	0.4	0.2	---	---	---	---
2011 Hull-split – Steel Plates											
100-Mo	1.8	9	150	Medium	---	---	---	0.0	0.0	0.0	---
100-Mn	2.4	9	150	Medium	---	---	---	16.6	7.7	8.1	---
2011 Hull-split – Alpha-cellulose sheets											
100-Mo	1.8	9	150	Medium	---	---	---	0.1	0.1	0.0	0.0
100-Mn	2.4	9	150	Medium	---	---	---	1.1	1.0	0.6	0.6

† All sample results were based on measurements of soluble metal in solution as described earlier.

Research Effort Recent Publications (also cited within this report):

None

References Cited:

Giles, D.K., Downey, D., Niederholzer, F.J., Markle, J.C. and J.P. Siegel. 2011. Mitigation of environmental effects from Spray applications in orchard crops. Final Project Report (Report # 10-WATER3-Giles/Mark) submitted to the Almond Board of California, Modesto, CA. 11 pp.

Klassen, P., Downey, D., Giles, D.K. 2007. Methods To Measure and Optimize Spray Deposition In Orchards. Final Project Report (PRISM Grant #04-051-555-0) submitted to the California Regional Water Quality Control Board, Central Valley Region, Rancho Cordova, CA. 33 pp.