Improving Efficacy of Spray Applications in Almond

Project No.: **10-WATER3-Giles/Markle**

Project Leader: Ken Giles
Biological & Agricultural Engineering Department
UC Davis
One Shields Ave.
Davis, CA 95616
(530) 752-0687
dkgiles@ucdavis.edu.

Project Cooperators and Personnel:
D. Downey, Biological and Agricultural Engineering Department, UC Davis, Davis, CA
F. J. Niederholzer, UCCE - Yuba City
J.C. Markle, Coalition for Urban/Rural Environmental Stewardship, Dinuba, CA
J. Siegel, U.S. Department of Agriculture - Agricultural Research Service, Parlier, CA

Objectives:

1. Develop a collaborative study with industry on spray application research that will establish field test protocols that can be used in future studies for evaluating spray efficacy under different field conditions and application scenarios;
2. Measure and evaluate spray deposition within the orchard (trees and ground surface) and from off-orchard drift for conventional and reduced volume hull-split applications; and
3. Determine pest control efficacy on nut samples due to the different spray applications.

Interpretive Summary:

Effective orchard crop protection is vital for pest- and disease-free healthy trees and economically sustainable production levels. Ensuring adequate spray coverage to maintain product quality is a primary focus for growers and orchard managers.

A collaborative study was developed to determine spray efficacy for conventional and reduced spray volume applications. The fundamental goal of spray application and testing is pest control efficacy; however it is often not reported or measured during drift or deposition efficiency studies. A coordinated research and outreach project was the goal of this project using the combined resources of the Agricultural Research Service (ARS) for pest control efficacy on hull split nuts, Coalition for Urban/Rural Environmental Stewardship (CURES) focus on spray drift concerns and grower education and the UC (Ag Experiment Station and Cooperative Extension's) interest in equipment and spray performance defined by deposition, drift and economics of operation. This initial project developed field test protocols that can be used in future projects addressing the almond industry needs for spray application research.

The spray application tests described in this work occurred in Sutter County, CA after initiation of hull split within the test orchard. **Figure 1** shows an example of the typical extent of hull split on the nuts within the test orchard prior to the tests. Variety mix within the study orchard was Nonpareil (50%), Carmel (25%) and Butte (25%). Spray tests included a conventional spray treatment at 100 gal/ac (gpa) and reduced application volume treatment (50 gpa) both applied at 2 mph ground speeds. Brigade (bifenthrin) and Kanemite (acequinocyl) were applied at the same rates for both treatments – 1.5 pound/acre and 31 oz/acre, respectively.

Figure 1. Hull split observed in test orchard.

Deposition within trees for the 50 gpa treatment was 35.7% lower versus the 100 gpa application (using artificial deposition media to determine recovery). Ground deposition was reduced by 50% for the 50 gpa treatment versus the 100 gpa spray treatment (also using artificial media to capture spray droplet fall-out within the orchard). Off-orchard drift measurements resulted in a 79% reduction in deposition 25 ft from the orchard footprint for the 50 gpa treatment compared with the 100 gpa treatment. Deposition was not detected at positions of 50 and 75 ft from the orchard footprint for the 50 gpa treatment, however it was less than 0.1 $\mu l/cm^2$ for the 100 gpa application at those locations.

Nut samples were collected one and 14 days after each spray treatment (DAT) for multiple Nonpareil trees within the low (6 ft) and upper portions (25 ft) of the canopy. These samples were then exposed to Navel Orange Worm (NOW) eggs in a controlled laboratory environment. Nuts exposed to NOW eggs one DAT found that both treatments provided excellent control of NOW within the lower portion of the canopy. Survival of NOW from nuts in the upper portion of the canopy was less than 1% for both treatments one DAT. For nuts collected 14 DAT, NOW survival within the lower portions of the canopy were less than 1% for both treatments; the upper canopy nuts exhibited a higher survival rate (5-11% depending on treatment).

Under the conditions of this study, the reduced spray application volume (50 gpa) effectively protected almonds from NOW up to 14 DAT when compared with the conventional application volume (100 gpa). Significant application cost savings for growers may be found if these results can be shown to be repeatable under other conditions. However, the increased survival of NOW within the upper portion of the canopy 14 DAT for this study implies that further research is needed to determine how efficacy can be increased.

Materials and Methods:

Test Orchard Description

The 17.4 ac orchard for efficacy and deposition tests was configured with 31 tree rows running in an east-west direction (**Figure 2**). Tree rows alternated between Nonpareil (50%), Carmel (25%) and Butte (25%) varieties. Five rows on the northernmost section of the orchard were left as an untreated control. Twelve rows were treated with the reduced application (adjacent to the untreated control section) while 8 rows were treated with the conventional application. Areas were calculated to allow a single tank of the sprayer to cover the entire test area for the respective treatment.

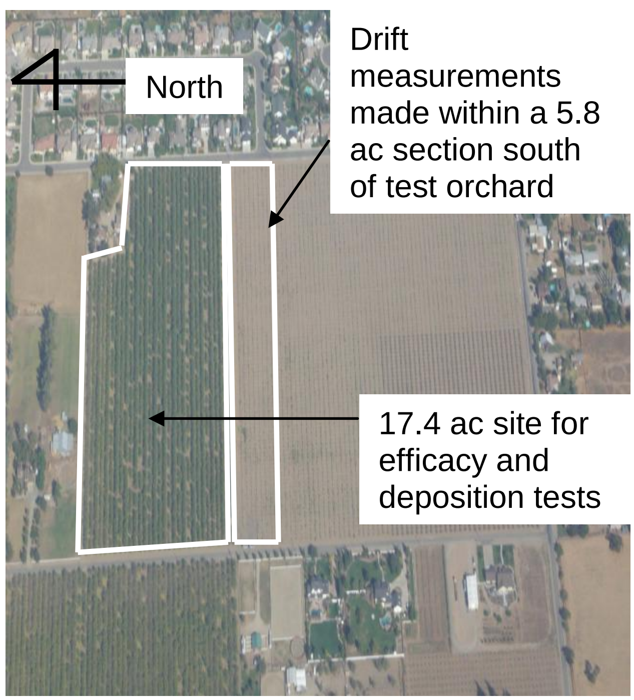

Figure 2. Test site located in Sutter County southeast of Sutter Buttes.

Due to anticipated prevailing north winds, the southernmost section of the orchard (six rows) was used for off-orchard drift tests and was split along a north-south centerline; the eastern section was used for the reduced application drift tests, the western section for conventional spray application drift tests. Each orchard section for the spray drift tests was equivalent in area. Three equally spaced transects (separated by 150 ft) were used to measure drift sedimentation at distances of 25, 50, 75 ft perpendicular to the orchard row direction and south of the orchard. **Figure 3** shows a representative transect for off-orchard drift sedimentation measurements.

Figure 3. Drift sedimentation transect south of the test orchard (perpendicular to the primary spray direction).

Spray Equipment and Formulations

Spray applications were made with a tractor (Model 5105ML, 90 hp PTO, 105 hp engine, Deere & Co., Moline, IL) towed TurboMist sprayer (Model 30P, 30 in. fan, 600 gal tank, Slimline Mfr, Penticton, B.C., CAN) in high fan gear setting, 540 PTO rpm, and 2 mph ground speed for the conventional and reduced volume spray treatments. The sprayer was calibrated off-site prior to the tests. Each application used 22 nozzles with nylon slotted strainers (TeeJet Technologies, Wheaton, IL); the bottom two nozzles on each side of the sprayer were turned off for each treatment. Spray pressure for both treatments was 110 psi. Nozzles (with hollow cone spray patterns) for the 50 gpa treatment were D1.5/DC25 disc cores; the 100 gpa treatment used D4/DC25 disc cores. Both treatments produced medium droplet classifications with Dv0.5 (volume median diameter) ranging between 177 – 218 µm (Teejet Technologies, Wheaton, IL). The application rates of materials were constant for the 50 and 100 gpa treatments. Spray mixes for both treatments were Brigade® WSB insecticide/miticide at 1.5 lbs/ac, Kanemite™15 SC miticide at 31 fl. oz/ac, a nonionic surfactant R-11 at 8 oz/ac, and a fluorescent tracer at 20 ppm finished volume.

Deposition Media

Spray deposition within trees and on the ground surface 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 tree in three separate tree rows adjacent to three separate driving rows). Ground deposition was measured within the orchard with stainless steel flat plates (1 in. x 3 in.) suspended above the ground surface with stakes. Nine plates were set out along three rows, three in the center of the driving row, three beneath tree canopies and three between tree gaps. Additionally, off-orchard drift sedimentation was measured with acid washed alpha-cellulose sheets (8 in. x 12 in.) and stainless steel flat plates. **Figure 4** shows the mesh cylinders within the canopy, stainless steel plates and alpha-cellulose sheets within the field.

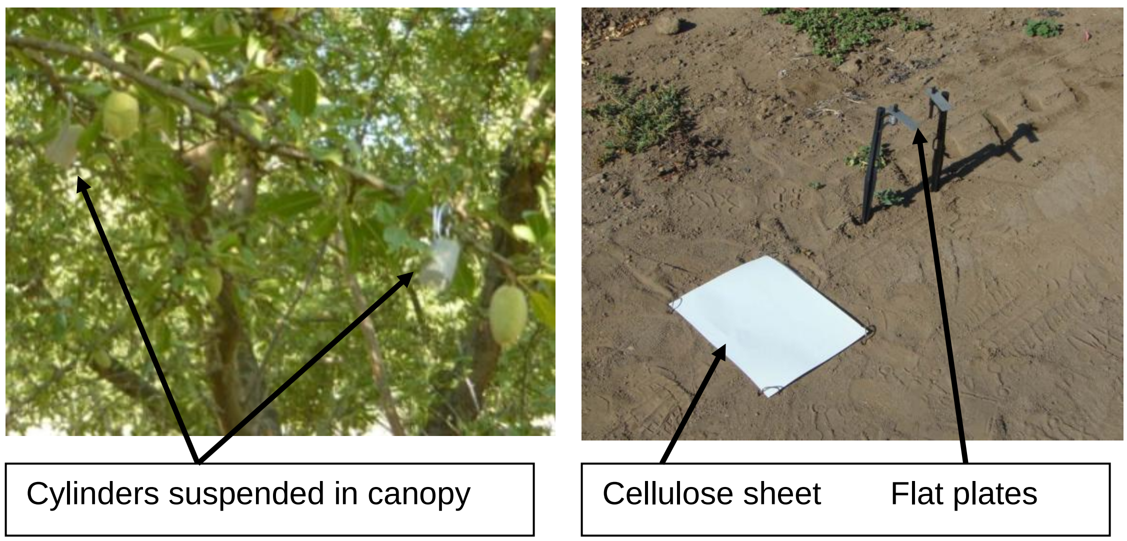

Figure 4. Artificial media used for recovery of spray deposition within trees, on orchard floor and from off-orchard drift sedimentation.

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 (**Figure 5**) was set-up approximately 300 ft south of the southern-most row of the orchard test section centered between the eastern and western spray drift test section. 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. Additional weather stations (available from www.cimis.water.ca.gov and mesowest.utah.edu) were used for reporting on-site weather conditions for the afternoon spray treatment test.

Almond Nut Collection

Hull split nuts for NOW exposure studies were collected one and 14 DAT. Nut samples were collected from four different trees in the lower (6 ft height) and upper (25 ft height) portions of the canopy within the middle section of the treated and untreated sections of the test orchard. Four replicates of approximately 50 nuts were collected on the respective days after the spray treatments for each test section, preserved on dry ice and transported to the Agricultural

Research Service Laboratory in Parlier, CA for exposure studies under controlled laboratory conditions.

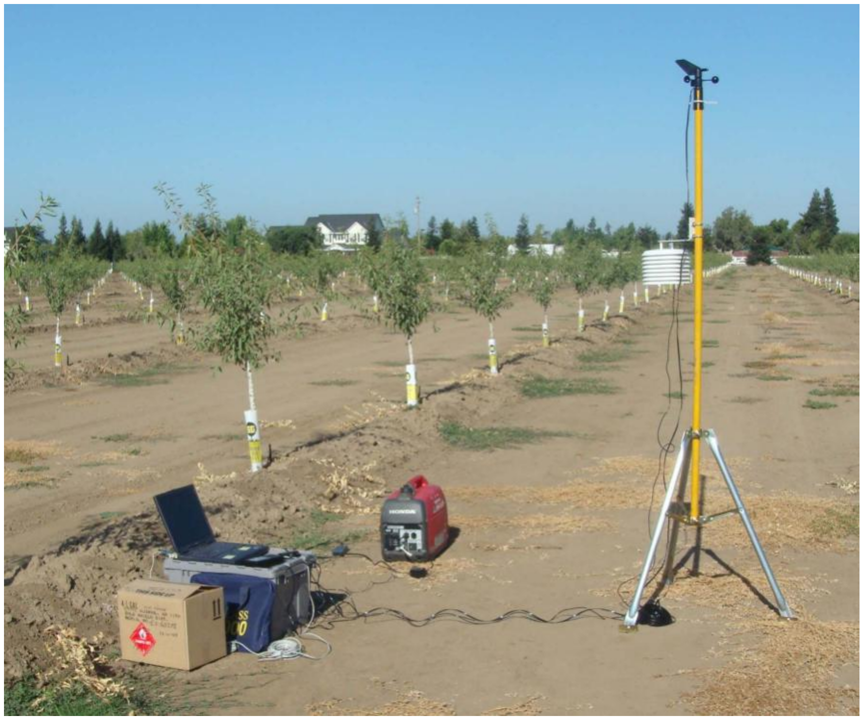

Figure 5. On-site weather station, located approximately 300 ft south of the test orchard, for monitoring ambient conditions during spray tests.

Results and Discussion:

Spray Deposition Results

In-orchard spraying, spray drift through the canopy, and off-orchard drift when spraying within rows at the southern edge of the orchard are shown in **Figures 6-8**. Ambient weather conditions are given in **Table 1**. The reduced volume treatment (50 gpa) was applied in the morning between 9:00 – 10:30 am; the conventional treatment was applied in the afternoon between 2:00 – 3:30 pm. There was a lack of sustained north wind during both tests: this minimized the off-orchard drift sedimentation recovery results presented in the study.

Spray deposition recovery of fluorescent dye tracer for both tests used techniques developed in an earlier study (Klassen et al., 2007). Calibration solutions were formulated and used to determine spray tank concentration and resultant deposition on the various media. All (media) samples were collected in the field within ½ hour after each test and preserved within polyethylene containers for recovery analysis in the lab. Three replicates were sampled for each test application section within the orchard. As mentioned previously, each replicate consisted of four samplers within the lower portion of trees, one ground deposition sampler beneath trees, one ground deposition sampler between trees and one ground deposition sampler along the treatment (driving) row. Additionally, one sample was collected for off-orchard drift sedimentation per transect location (described previously). Samples were averaged according to location (tree, ground and transect location).

Figure 6. Conventional spraying for hull split in 2010.

Figure 7. End of row application showing off-canopy and through-canopy drift.

Figure 8. Off-orchard drift leaving the southwestern edge of the orchard footprint.

Table 1. Ambient weather conditions at the test site: note that the morning data were measured with the on-site weather station, afternoon data were averages of data obtained from CIMIS (Station 32†) and MesoWest (Station KMYV†) websites.

Time	Temperature ºF	Relative Humidity %	Wind Speed mph	Wind Direction
8:00 am	68.5	73.7	0	-
9:00	69.6	71.2	0	-
10:00	73.8	67.2	0	-
11:00	76.8	66.0	0	-
1:00 pm†	87.9	41.0	4.3	East/Southwest
2:00	90.5	39.5	5.0	East/Southwest
3:00	91.6	37.5	5.6	East/Southwest
4:00	93.4	33.5	5.6	East/Southwest

† Station 32 was located near Colusa, CA approximately 17 miles west of test site; Station KMYV was located several miles south of Yuba City and approximately 15 miles east southeast of test site. There was no sustained wind observed on-site during afternoon tests, likely due to the location of the test site (several miles south of the Sutter Buttes). Entries for wind direction for the afternoon tests are reported from "CIMIS"/"MesoWest" weather stations.

Deposition results from the reduced volume and conventional spray application are given in **Table 2**. Deposition within trees for the reduced application treatment versus the conventional application resulted in a 35.7% reduction in spray deposit on the mesh cylinders suspended within the lower portion of the canopy. Ground deposition within the orchard was reduced by 50% for the reduced application treatment versus the conventional spray treatment. Off-orchard drift measurements of spray fall-out resulted in a 79% reduction in deposition 25 ft from the orchard footprint for the reduced application treatment. Deposition was not detected at positions of 50 and 75 ft from the orchard foot-print for the reduced application treatment, however it was less than 0.1 µl/cm^2 for the conventional application at those locations. The large standard deviations associated with drift samples were likely due to the lack of the anticipated north wind during testing conditions.

Table 2. Tracer deposition recovery from artificial media after conventional and reduced spray applications (standard deviations in parentheses).

Sample location	50 gpa	100 gpa
	----- Deposition, µliters/cm2 -----	
Tree	2.7 (1.0)	4.2 (1.7)
Ground	0.9 (0.2)	1.8 (0.6)
Drift 25 ft	0.13 (0.09)	0.62 (0.56)
Drift 50 ft	0.00 (0.00)	0.09 (0.14)
Drift 75 ft	0.00 (0.00)	0.06 (0.12)

Hull Split Exposure Studies

Establishment of the NOW in the control (untreated) almonds was low for the summer of 2010 and may have been indicative of a shift in the lab colony. Colony establishment may have also been a response from unknown nut factors. Results, given in **Table 3**, found that untreated control nuts collected 14 DAT supported NOW development to a greater degree than those collected one DAT (20.3% living versus 6.5% living): this may reflect some kind of maturation process/change in the ratio of fatty acids. Additionally for the control nuts, the difference between NOW eggs placed inside the suture and on the hulls was analyzed; pooled data results indicated that survival was significantly greater when the eggs were placed inside the suture (18.3% versus 10.6%).

Results from NOW exposed to treated nuts (larvae placed on hulls) showed that both spray treatments provided a high level of control for nuts in the lower portion of the trees one DAT (**Table 4**). Survival was greater for nuts in the higher location of trees; however was also less than 1% for both spray treatments.

Fourteen DAT survival of NOW exposed to treated nuts found survival within lower canopy nuts less than 1% while survival in high canopy nuts was 5.3% for the reduced application and 10.7% for the conventional application. A further study on initial location of larvae on treated hull split nuts exposed 14 DAT found a significant increase in survival based on larvae

Table 3. Untreated "control" hull split nuts response to NOW egg placement.

Days after treatment when control nuts were collected, d	Nut location in tree	Location of egg placement	Survival rate %
1	Low+High	Hulls	6.5
14	Low+High	Hulls	20.3
14	Low	Hulls	1.0
14	Low	Suture	5.0
14	High	Hulls	20.3
14	High	Suture	31.5

Table 4. Results from exposure to NOW egg placement on hulls of hull split nuts 1 and 14 days after the reduced and conventional spray applications.

Nut location in tree	Days after spray application, d	Application rate gpa	Survival rate %
Low	1	50	0.0
Low	1	100	0.0
High	1	50	0.5
High	1	100	0.1
Low	14	50	0.2
Low	14	100	0.0
High	14	50	5.3
High	14	100	10.7

placement in the sutures versus on hulls (**Table 5**). These nuts had split open further and approximately 50% of their surface area had not received pesticide deposit. These results supported the need for a second post hull split spray application in areas affected by NOW under the field conditions reported in this study.

Spray tracer deposition on artificial media (stainless steel mesh screen cylinders) in the lower portion of the canopy was greater at 100 gpa vs 50 gpa (**Table 2**). Under the conditions of this study, the reduced spray application volume (50 gpa) effectively protected almonds from NOW up to 14 DAT and was comparable to the conventional spray treatment (100 gpa). Significant application cost savings for growers may be found if these results can be shown to be repeatable under other conditions. Smaller droplet sizes used in lower volume spraying may risk reduced deposition when spraying in warm, dry conditions – conditions not seen in this study (**Table 1**).

Table 5. Results from exposure of hull split nuts to NOW 14 days after spray application based on initial placement of eggs.

Nut location in tree	Larvae placement location	Application rate gpa	Survival rate %
Low	In suture	50	9.2
Low	In suture	100	9.3
High	In suture	50	28.3
High	In suture	100	31.0
Low	Hulls	50	0.2
Low	Hulls	100	0.0
High	Hulls	50	5.5
High	Hulls	100	0.0

The results presented in this report were based on a successful coordinated and collaborative effort for establishing pest control efficacy after spray application treatments during hull split within almonds. Deposition rates within the canopy and orchard floor were determined in addition to off-orchard drift sedimentation. Additionally, pest control efficacy for a reduced application spray treatment versus a conventional spray treatment was determined. This initial project developed field test protocols that can be used in future projects to address industry needs for spray application research.

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

None

References Cited:

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.