Title: **Can air-induction nozzles reduce spray drift without sacrificing pesticide coverage in California almond orchards?**

Project Number: 03-FN-01 Correct Project Number: 03-FN-00

Project Leader: Franz Niederholzer, UCCE Farm Advisor, Sutter and Yuba Counties.

Cooperating Personnel: Ken Giles, Biological and Ag Engineering Department, UC Davis.

Conclusions: Under the local conditions and equipment used in these tests:

1. Spray coverage can be extremely variable within trees and from tree to tree.
2. In all three tests, spray card coverage was much less on the far side of the tree from the sprayer, than on the "sprayer side" of the tree.
3. Separate, one-time-only comparisons of spray card coverage by Air Induction (AI) nozzles or electro statically charged spray droplets with conventional sprayers showed little difference in spray deposit. After these limited tests, both of these technologies show potential to benefit almond growers and should be studied further.
4. Differences in both spray drop size and volume per acre made it difficult to compare drift between different sprayer types.

Objectives: Evaluate spray coverage and drift from conventional orchard air blast sprayers using 1) hollow cone tips with swirl plates or 2) TurboDrop® venturi body and standard pattern-shaping tips. Also compare leaf coverage and drift from charged and uncharged particles deliver from the same sprayer.

Materials and Methods:

Three tests were conducted in July and August, 2003. Surround® WP (25 lbs/100 gallons of water)—a white kaolin clay particle registered for use in tree crops -- was added to spray water. Tree spray coverage was measured as percent coverage using Tee-Jet® Water and Oil Sensitive Paper (Spraying Systems Co, Wheaton, IL). [Contrast of Surround deposits on dark paper cards was also used to assess coverage, but with poor results to date. Those results are not presented.] Drift was measured as percent coverage of orchard floor by spray material using either water sensitive paper and/or Surround deposition on 6" x 6" black ceramic tiles placed directly on the orchard floor.

Percent coverage of spray cards was determined by scanning cards on a flatbed scanner, and then analyzing the scanned images using DropletScan™ (WRK of Arkansas, Lonoke, AR) or Scion Image (Scion Corporation, Fredricksburg, MD) software. Statistical analyses of these data were conducted via one-way analysis of variance (Statgraphics 5 Plus, Manugistics, Inc. Rockville, MD).

Weather data (temperature, relative humidity, and wind speed) were measured every two seconds at 6 feet (temperature and RH) and 10 feet (wind speed) at the study site before, during, and after spray application.

Test 1: July 11, 2003

Location: Sutter, CA
Orchard: 10th leaf Non-Pareil, Butte, and Carmel on 'Lovell' peach rootstock.
Sprayed trees: Carmel. Maximum height = 16 feet.
Tractor: Ford 90 HP 7610
Sprayer: Spectrum 2050 PTO Sprayer (Progressive Ag Inc., Modesto, CA)
Ground Speed: 3.5 mph
Spray Tip Configuration: Air-shear droplet formation with or without electrostatic charging.

Treatments:

1. 40 gpa with electrostatic charging (+E)
2. 40 gpa without electrostatic charging (-E)
3. 100 gpa without electrostatic charging (100gpa)

Weather Conditions at Time of Application:

Treatment	Spray Timing	Temp(^oF)	RH	Wind spd
1. +E	8:40 AM	72.46	51.50%	0-3.4mph
2. -E	9:45AM	75.25	51.00%	0-3.4mph
3. 100gpa	10:45 AM	79.76	48.75%	0-5.9mph

Water sensitive paper (WSP) was clipped to the top and bottom of leaves at four locations in each of three trees. The same locations were used in all three treatments. These sampling sites were located at a height of 10 or 14 feet (appear as "mid" or "high" locations in this report) above the orchard floor and 5' out perpendicularly from the base of the tree into the tractor aisle in opposite directions. Thus, there were two measurement sites on the sprayer side of the tree – these are identified as "near" in the figures-- and two on the side of the tree away from the sprayer -- identified as "far" in the figures.

WSP was removed from leaves after spray water had dried, and placed in ziplock bags for later analysis.

Tiles used for drift measurement were allowed to dry and then placed in ziplock bags for late analysis.

Test 2: July 29, 2003

Location: Orland, CA
Orchard: Mature Non-Pareil, Butte, and Carmel on ‘Lovell’ peach rootstock.
Sprayed trees: Non-Pareil. Maximum height = 22 feet
Tractor: Ford 90 HP
Sprayer: TurboMist Model 30P (Slimline Manufacturing Ltd., Okanogan, Canada).
Ground Speed: 2.7 mph
Treatments: all at 50 gpa with same number of nozzles and alignment.

1. Ceramic TeeJet® D3 and D4 hollow cone tips with DC25 cores. (Con 150psi)
2. TurboDrop® UIC015 hollow cone at 150 psi (AI 150psi)
3. TurboDrop® UIC015 hollow cone at 200 psi (AI 200psi)

On recommendation of AI nozzle manufacturer, 200psi pressure application was compared as well as 150 psi.

Weather Conditions at Time of Application:

Treatment	Time of Spray	Temp(^{o}F)	RH	Wind spd
• Con 150psi	7:45 AM	82.95	48.25%	0-2.5mph
• AI 150psi	9:15 AM	90.96	37.35%	0-2.5mph
• AI 200psi	11:35 AM	101.79	26.75%	0-2.5mph

Water sensitive cards were stapled together to produce a two-sided measurement surface, and then attached to PVC pipe at 12’ (mid) or 18’ (high) height in almond tree canopy, and a distance of 5’ out from the trunk and perpendicular to the tree row in opposite directions. Thus, there were two measurement sites on the sprayer side of the tree (“near” sites), and two on the side of the tree away from the sprayer (“far” sites).

WSP was removed from leaves after spray water had dried, and placed in ziplock bags for later analysis.

Ground coverage was measured by tiles and attached water sensitive paper one row on either side of the sprayer path. Trees in the row to the west were young replants, while trees on the east side row were mature study trees. Tiles with attached water sensitive paper used for drift measurement were allowed to dry and then placed in ziplock bags for late analysis.

Test 3: August 5, 2003

Location: Sutter, CA
Orchard Conditions: same as July 11. Same trees and sampling locations were used.
Tractor: Ford 90 HP
Sprayer: Durand-Wayland AF505CPS PTO Sprayer (Durand-Wayland Manufacturing Inc, La Grange, GA). Gearbox set on “high”.
Ground Speed: 2.0 mph

Treatments: all at 150 gpa with identical number of nozzles and alignment.

4. Ceramic TeeJet® D7 and D5 hollow cones with DC25 cores. (Con 160psi)
5. TurboDrop® UIC05 flat fan at 160 psi (AI 160psi)

Weather Conditions at Time of Application:

Treatment	Time of Spray	Temp(^{o}F)	RH	Wind spd
• Con160psi	3:30 PM	82.95	36.50%	0-11mph
• AI160psi	6:10 PM	82.95	36.75%	0-11mph

Same measurement methods were used as on July 11.

<u>Results:</u>

Test 1:

Winds were light, and temperature and relative humidity fairly constant despite the 2 hours that separated first and last application.

Regardless of treatment, very little to no spray card coverage occurred on the far side of the tree from the sprayer (Figure 1). No coverage was recorded for any treatment on the bottom sides of leaves on the far side of the tree and high in the canopy (Figure 2).

There was no significant difference (at 5% level) between treatments of charged water at 40 gpa and uncharged water at 100 gpa when measuring card coverage (average of top and bottom coverage) at four different locations in the tree (Figure 1).

Coverage by charged droplets at 40 gpa and uncharged drops at 100 gpa was not significantly different (at 5% level) when "leaf" tops or bottoms were considered separately (Figure 2), except for significantly more coverage of "leaf" bottoms at 14 feet on the sprayer side of the tree by the uncharged drops (Figure 2).

Uncharged spray at 40 gpa provided consistently less coverage of cards in both measurement locations on the sprayer side of the tree compared with the other two treatments (Figure 1).

Spray drift was evaluated for 40 gpa applications, only. No spray deposits were observed on the tiles, which were placed upwind of the sprayer.

Test 2:

Winds were light, but temperature rose 20^{o}F and relative humidity dropped more than 20% between the first and last applications. Consequently, % coverage and drift deposition should have decreased from Treatment 1 to 3.

Coverage was variable, and no treatments, at any level of evaluation (tree location, or tree location x leaf side), were significantly different at the 10 % level – despite numeric differences in treatment averages (Figures 3 and 4). Coverage was greatest on the sprayer side of the tree at 12', and % coverage dropped off by 2/3 at 18' on the sprayer side. At best, far side coverage was 10x less than that of near side cards.

Spray card coverage on the orchard floor was less than 5% in all treatments, and less than 1% for all but one treatment – the conventional treatment on the downwind side of the sprayer (Figure 5). Tree cover and climatic conditions probably affected drift measurement, although it is difficult to separate the degree of influence from each.

Test 3:

Temperature and relative humidity were essentially constant between sprays, but wind fluctuated rapidly between 0 and 11 mph, often every 2 seconds. These wind gusts may have added to the variability of our results.

The conventional combination of D7 hollow cone tips and D25 cores showed a consistent trend towards higher coverage compared to the AI flat fan configuration for total coverage in different sites within trees (Figure 6). However, this trend was never statistically significant at the 5% level for any location.

When leaf top or bottom coverage by each treatment was compared (Figure 7), there were, generally, no statistical differences between the nozzles. The exception is leaf bottom coverage on the far side of the tree at 10', where the conventional nozzles provided significantly (at 5% level) more coverage than the AI nozzles.

As in the other treatments in this study, there was virtually no spray coverage of leaf bottoms high in the canopy on the far side of the tree from the sprayer. However, there was substantial (average of 15-35%) coverage on leaf tops at that location in the canopy.

Regarding orchard floor coverage by spray material, there was very little deposition 40' away from the sprayer path. However, there was significant coverage of the tiles in the next row over from the sprayer path in either direction. The deposits were higher on the downwind side, and wind may explain the skew to the north in deposition from AI application.

Discussion:

Few definite conclusions can be drawn from this study after one year. However, if the results in these studies are consistently repeated in further work, both use of AI nozzles and charged droplets may have a place in almond orchard pest management – for different reasons.

AI nozzles, while providing slightly less coverage than conventional hollow cone and core spray nozzles in this study, are proven to reduce aerial spray drift from air-blast sprayers. These nozzles may offer a compromise solution for spraying in areas where finer spray patterns produced by conventional nozzles risk environmental or crop damage (along roads, near streams, near sensitive crops, etc.). In addition, AI nozzles may allow effective pesticide application under higher wind speeds (up to a point) in non-sensitive locations compared to conventional nozzles. More work with these nozzles at different times of the growing season is needed.

Electrostatic sprayers may offer growers savings in labor, fuel, and equipment costs if coverage results are repeated. In addition, if electrostatic sprayers can improve spray efficiency, i.e. units of pesticide deposited on the crop per unit of pesticide applied to the orchard, as the results here suggest, then net off target movement of pesticides and foliar fertilizers may be reduced compared to higher volume, uncharged applications. An assessment of aerial drift from electrostatic sprayers should be considered, as small droplets generated by electrostatic (air-shear) sprayers are easily moved by wind and air currents.

An additional point that stood out in this research was the consistently poor to non-existent spray coverage, regardless of sprayer configuration, on the far side of the tree from the sprayer. While this research did not relate spray card coverage to pest control, the measured large differences in % coverage on the near and far sides of the tree from the sprayer raise questions about insect control following hull split sprays applied to every-other tree row.

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- ✓ Rick Cordero, Durand-Wayland, Inc.
- ✓ Mitchell King, Engelhard Corp.
- ✓ PBM Supply, Chico

Figure 1. Percent of leaf coverage (average of top and bottom coverage) of spray cards at four measurement sites. Sutter, CA July 11, 2003. Same letters indicate no significant difference at the 5% level (LSD) between treatments for each site.

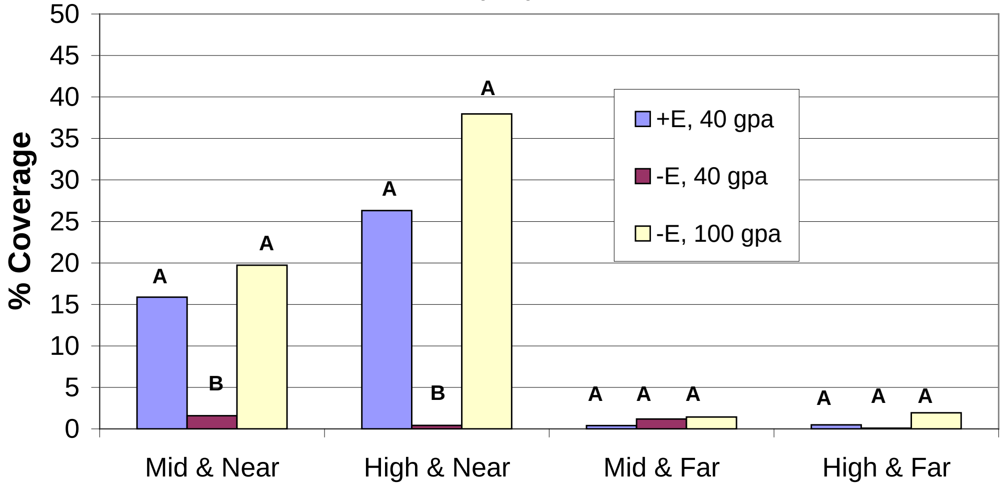


Figure 2. Percent of leaf top or bottom coverage at four measurement sites in Test 1. Sutter, CA. July 11, 2003. Same letters indicate no significant difference between treatments at the 5% level (LSD) for each measurment site.

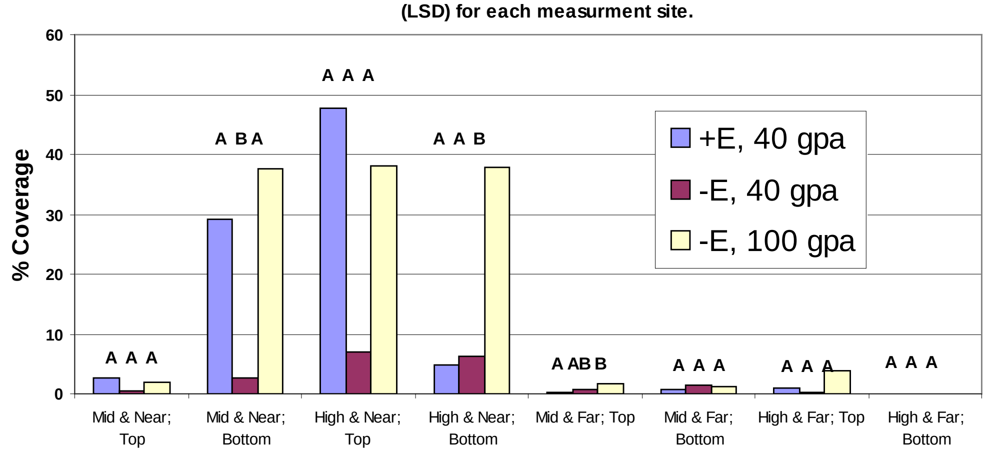


Figure 3. Percent of spray card coverage (average of top and bottom) of spray cards at four measurement sites. Orland, CA July 29, 2003. No significant differences existed at the 10% level between treatments at each site.

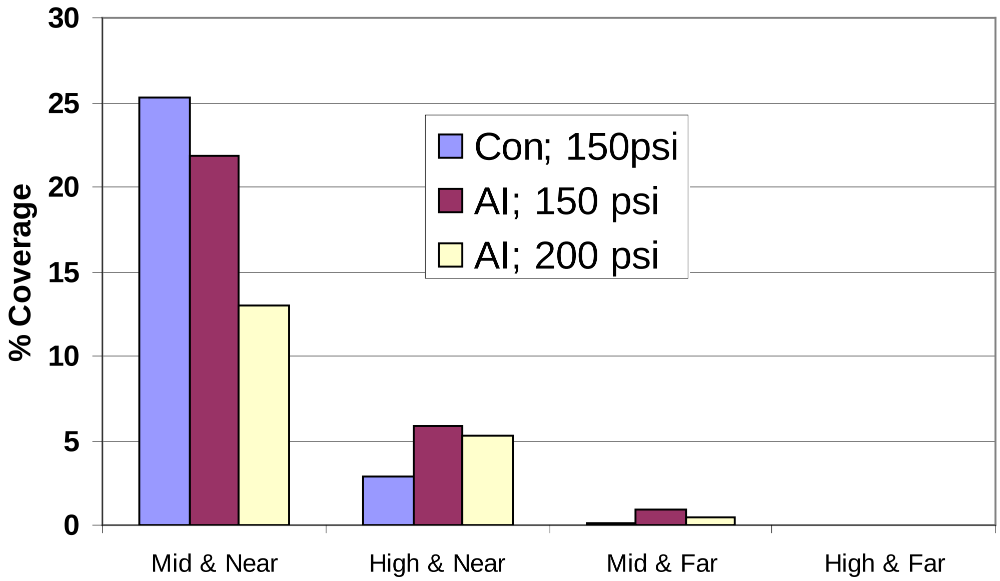


Figure 4. Percent of spray card top or bottom coverage at four measurement sites in Test 2. Orland, CA. July 29, 2003. No significant difference existed between treatments at the 10% level for each measurment site.

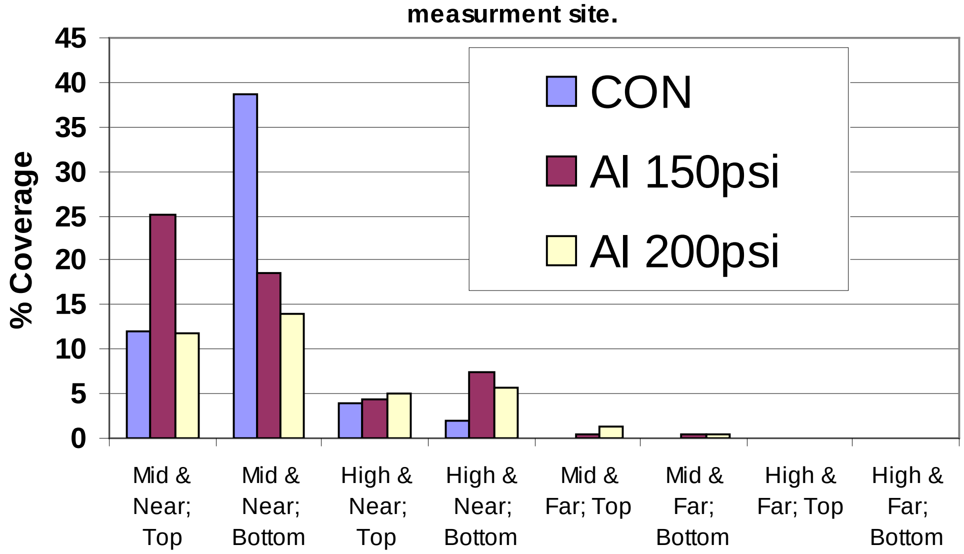


Figure 5. Comparison of orchard floor spray card coverage in one row east and west of sprayer pass. Orland, CA. July 29, 2003. No statistical difference between treatments at the 5% level.

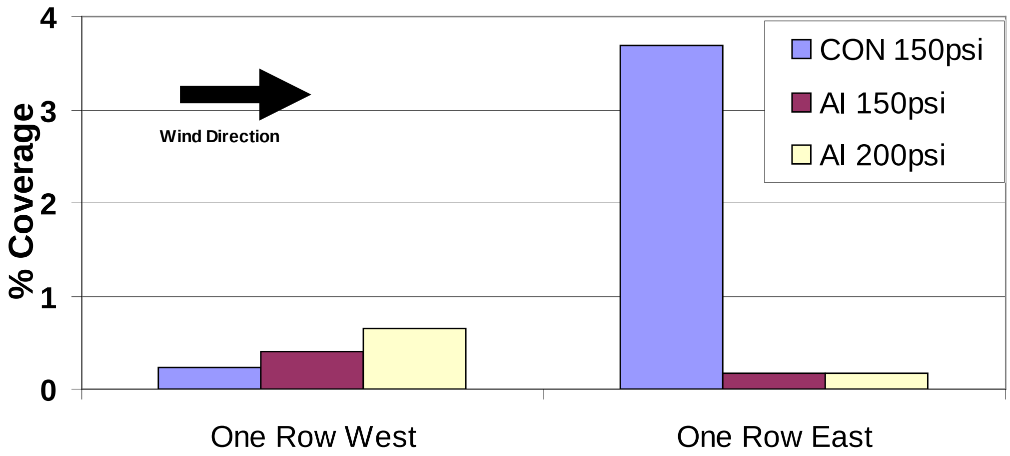


Figure 6. Comparison of total spray coverage at four locations within almond tree canopies for conventional (hollow cone) vs Air Induction (flat fan) nozzles. August 5, 2003. Sutter, CA. No statistical differences between treatments existed at 5% level.

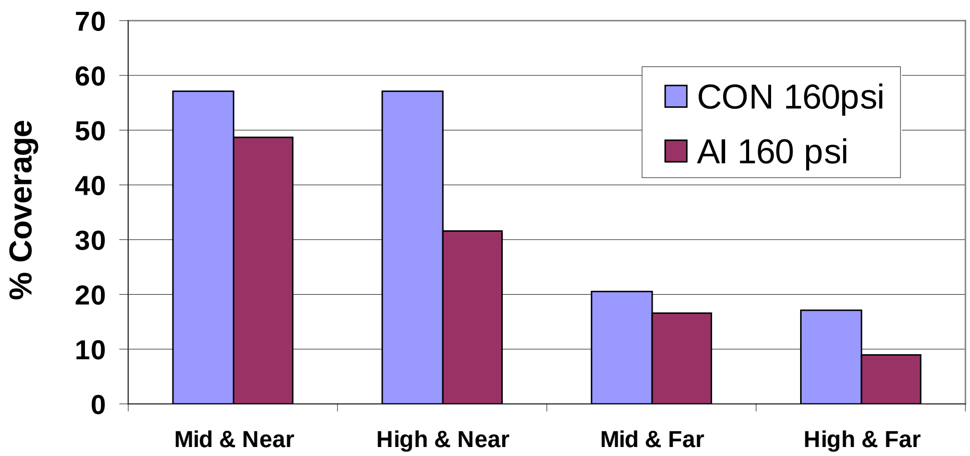


Figure 7. Comparison of spray card top or bottom coverage at four locations in almond tree canopies. Sutter, CA August 5, 2003. Significant differences between treatments (at the 5% level) are identified by different letters only where they exist.

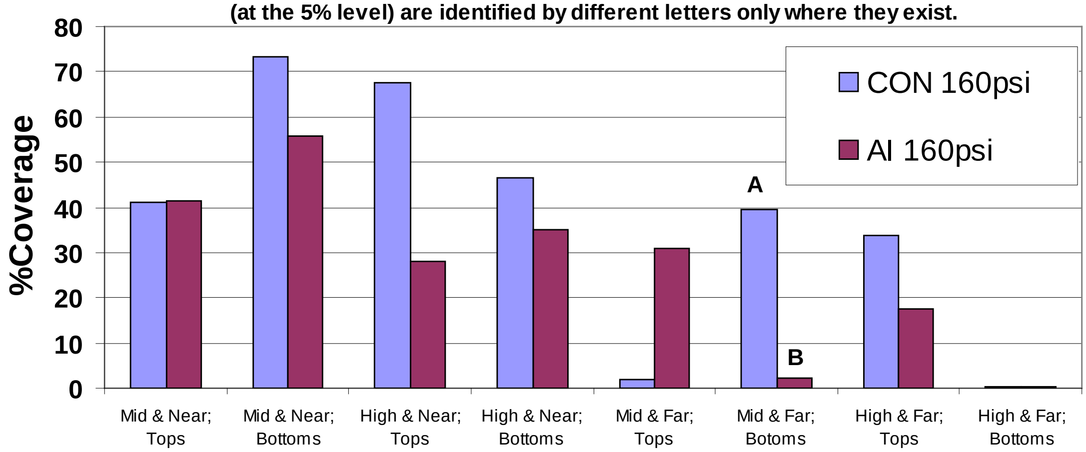
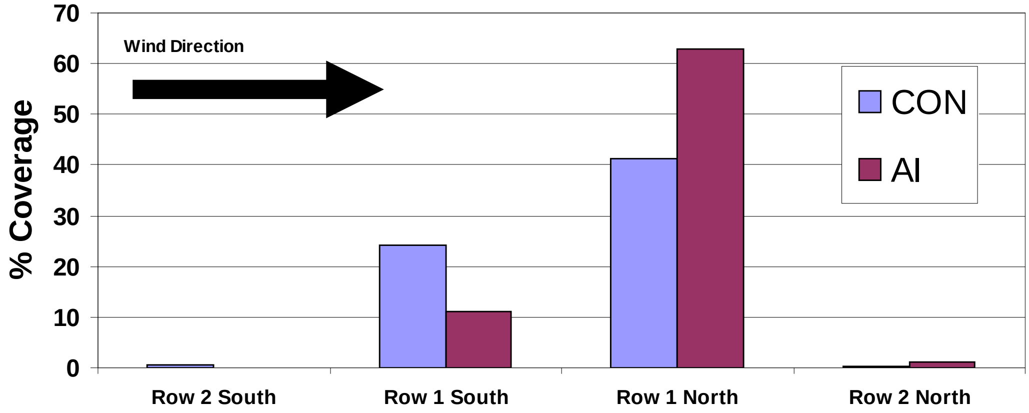


Figure 8. Percent ground coverage of spray after application at 150 gpa by either Air Induction (AI) or conventional (CON) hollow cone/core nozzles. Trial 3. Sutter, CA. August 5, 2003. No significant difference existed at 5% level.



Title: **Can air-induction nozzles reduce spray drift without sacrificing pesticide coverage in California almond orchards?**

Project Number: 03-FN-01 (additional report from work in 2004)

Project Leader: Franz Niederholzer, UCCE, Sutter and Yuba Counties, Yuba City, CA.

Cooperating Personnel: Ken Giles, Biological and Ag Engineering Department, UC Davis.

Conclusion: Under the local conditions and equipment used in these tests:

1. Low drift, venturi nozzles with flat fan or hollow cone exit nozzles provide similar coverage compared with standard hollow cone nozzles.

Objectives: Evaluate spray coverage and drift from conventional orchard air blast sprayer using 1) standard hollow cone nozzles or 2) venturi body with hollow cone or flat fan exit nozzles.

Materials and Methods:

A final experiment was conducted on July 14, 2004. This work incorporated lessons learned in the work in 2003: a) more replicates were needed for more accurate data analysis and b) at hull-split in almond orchards, rigid targets placed in the trees and raised and lowered from the ground are a better way of assessing coverage by different sprayer or nozzle treatments compared to attaching the cards to leaves and climbing into the trees to change the cards.

This test was done to evaluate differences in spray card coverage between two low drift spray nozzles and conventional hollow cone nozzles. Tree spray coverage was measured as percent spray coverage using Tee-Jet Water and Oil Sensitive Paper (Spraying Systems Co, Wheaton, IL). Spray cards were attached to a square card holder that held four cards, each facing a different direction. The spray card holders were held in the upper 25% of the tree canopy by a PVC pole. The pole was placed midway between tree trunks directly in the tree row, which ran east-west. Two cards were held horizontally, with one facing up and the other down. The card holder held another two cards vertically, one facing one drive row (north) and the other faced the other drive row (south). Four passes were made for each measurement (nozzle set up), one pass per drive row for the two drive rows on either side of the tree row where the spray cards were located (see Figure 1 for map of layout).

Weather data (temperature, relative humidity, and wind speed) were measured every two seconds at 6 feet (temperature and RH) and 10 feet (wind speed) at the study site during spray application.

The following are the details of the application:

Location: Sutter, CA
Orchard: 11th leaf Non-Pareil, Butte, and Carmel on 'Lovell' peach rootstock. 13' x 20'
Sprayed trees: Non-pareil. Maximum height = 20 feet
Tractor: Ford 7610
Sprayer: Durand-Wayland AF505CPS PTO sprayer
Ground Speed: 1.9 mph
Sprayer pressure: 125 psi
Treatments: all at 60 gpa:

1. Ceramic hollow cone nozzles (Lechler* TR 80-01, 80-015, 80-02)
2. Ceramic hollow cone nozzles with venture (Lechler* ITR 80-01, I80-015, I80-02)
3. Ceramic flat fan nozzles (Lechler* ID 110-01, ID 110-015, ID 110-02)
   *Lechler USA, St. Charles, IL.

Weather Conditions at Time of Application:

Treatment	Spray Timing	Temp(^{o}F)	RH	Wind spd
1. HC	2:50 PM	89	38%	0-11mph
2. Venturi, HC	4:10 PM	91	21%	0-11mph
3. Venturi FF	5:30 PM	91	25%	0-11mph

WSP was removed from leaves after spray water had dried, and placed in ziplock bags for later analysis. Spray card coverage and spray droplet volume mean diameter (VMD) were measured using DropletScan™ (WRK of Oklahoma, Stillwater, OK).

Results and Discussion:

There was no difference in spray card coverage, averaged for each spray card holder (4 cards) between the three nozzles (Figure 2). Spray card orientation affected coverage, with significantly more coverage on the downward facing cards compared with cards facing upwards or to the each side. This difference was due to significantly more coverage on the downward facing cards sprayed with the hollow cone nozzles, especially the non-venturi model (Figure 3). The flat fan venturi combination delivered more uniform coverage relative to the non-venturi and venturi hollow cone (Figure 3). The addition of a venturi port to the hollow cone exit nozzle increased VMD, averaged per card holder, from 182-209 µm to 326-353 µm (data presented = 95% confidence interval). Spray quality (VMD) on a per tree basis was not significantly different between venturi nozzles using flat fan or hollow cone exit tips.

These data, plus those from 2003, indicate that venturi nozzles can deliver acceptable spray coverage compared to hollow cone nozzles without venturi ports, while decreasing the amount of spray delivered as small droplets. If further research indicates that pesticide efficacy in almonds is not significantly reduce when using venturi nozzles compared to grower standard (usually hollow cone without venture), then California almond growers will have a viable tool to deliver effective pest control while reducing potential pesticide drift. In addition, venturi nozzles may also improve pesticide efficacy when spraying in breezy conditions (that do not exceed the 10 mph wind speed recommended by the University of California) compared to non-venturi hollow cones.

Figure 1. Spray card locations relative to sprayer travel in the study orchard for each nozzle treatment. Spray cards were actually directly in line with the tree trunks, not off-center to the left as appear in this diagram.

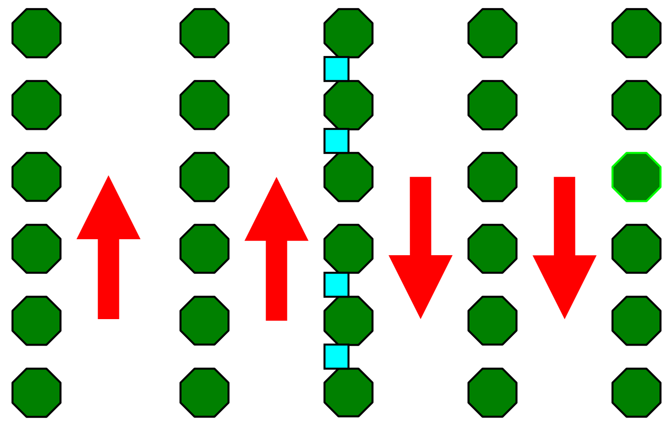


Figure 2. Average %coverage per card holder, for water senstive cards place in the upper canopy of mature 'Non-pareil' almond trees and sprayed with water using three different nozzles. HC = hollow cone. Bars indicate 95% confidence interval.

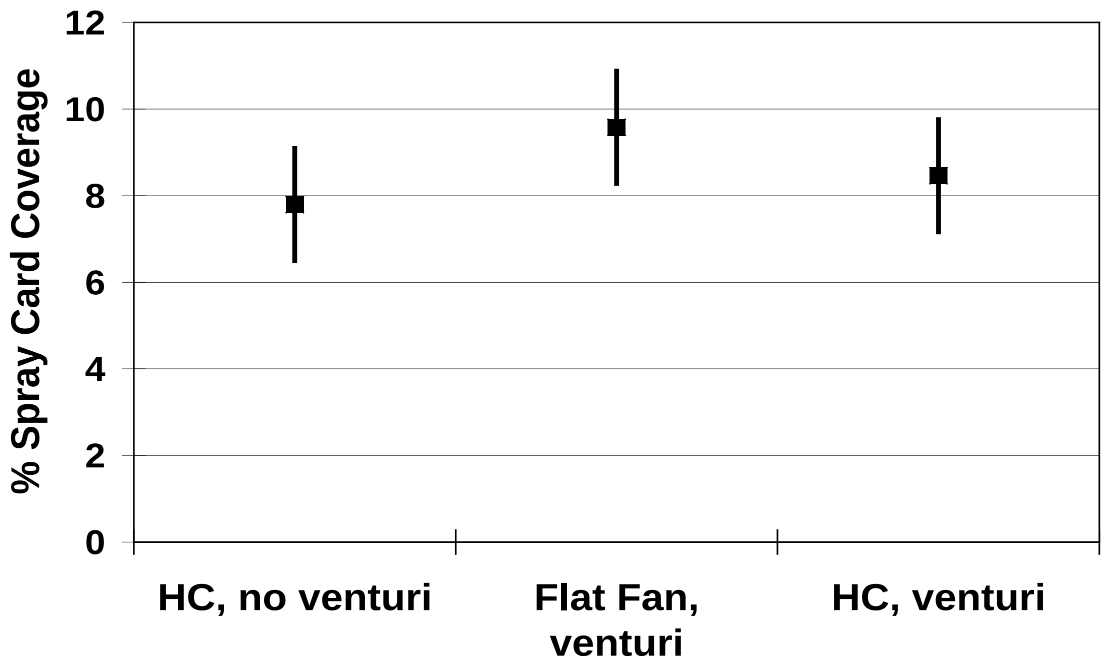
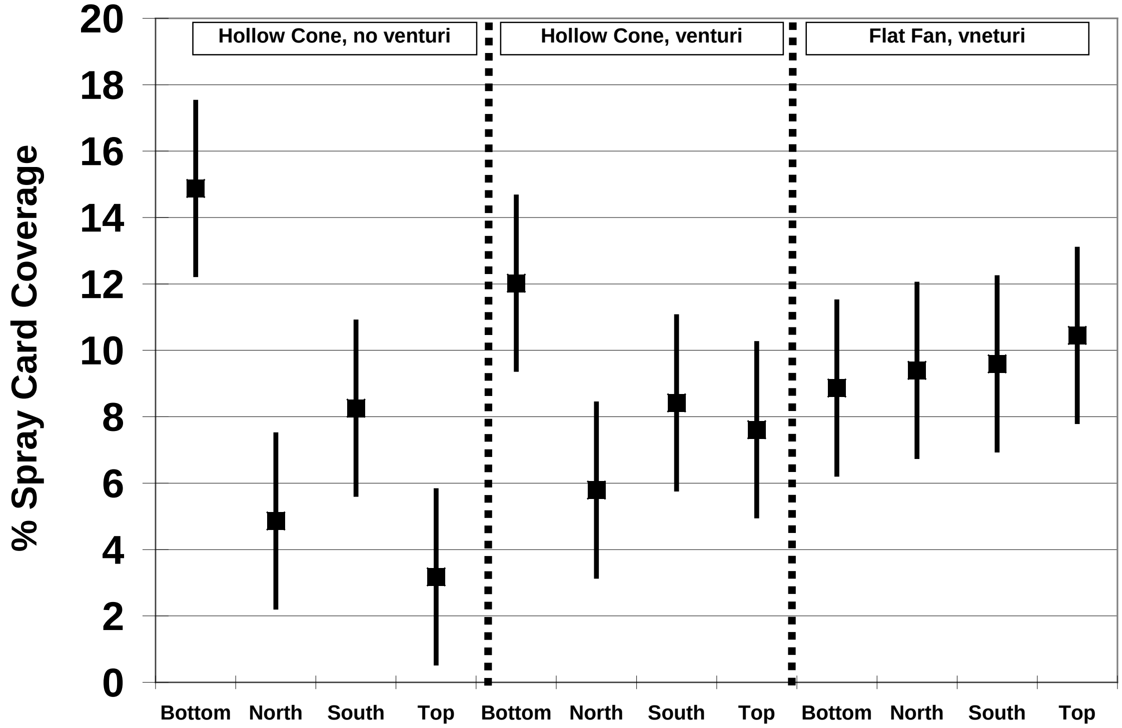


Figure 3. Affect of nozzle type on % coverage of water sensitive spray cards oriented in four, opposite directions in upper quarter of the canopy of of mature almond trees (n=8). Bars indicate the 95% confidence interval.



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- Lechler USA, St. Charles, IL.