FINAL PROJECT REPORT
WTFRC Project Number: AP-06-603

Project Title: Performance of air induction nozzles under variable wind speeds

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Budget History:

Item	**Year 1:** 2006	**Year 2:**	**Year 3:**
Salaries	0		
Benefits	0		
Wages	1000		
Benefits	0		
Equipment	950		
Supplies	500		
Travel	0		
Miscellaneous	2500		
Total	4950		

Significant Findings

A series of field experiments were undertaken on ‘Pink Lady’/M.7 during 2006 to compare the performance of an axial fan air blast sprayer with either a conventional hollow cone (HC) nozzle configuration or a modified air induction/HC nozzle configuration. Spray drift, spray coverage, and spray efficacy were quantified in order to compare each nozzle configuration. Digital analysis of water-sensitive cards was used to quantify spray drift and spray coverage. The efficacy of a standard post-bloom chemical thinning spray and a “high-risk” cover spray program applied with each nozzle configuration was compared. Spray coverage and chemical thinning efficacy were assessed at three different across-row wind speeds. The major findings were…

- Spray drift was greater from a standard HC nozzle configuration compared to a modified AI/HC nozzle configuration.
- A modified AI/HC nozzle configuration produced very high spray fallout at distances of 20-30 feet from the sprayer. This effect could result in significant carry-over and deposition of spray onto trees two rows over from the sprayer at a between-row spacing of 16-20 feet.
- Spray coverage was greater with a modified AI/HC nozzle configuration compared to a conventional HC nozzle configuration under “high” across-row wind speeds, equivalent to 11.3 mph at a height of 6 feet in the middle of the tree canopy.
- The incidence of fruit with sooty blotch and flyspeck was higher with the AI/HC nozzle configuration under a “high-risk” fungicide program compared to the conventional HC nozzle configuration,
- The effects of each nozzle configuration on efficacy of a post-bloom chemical thinning spray could not be compared because of variability in the fruit set data resulting from a severe fire blight outbreak in the experimental orchard.

Objectives

Most common orchard sprayers are configured with disc/core type hollow cone (HC) spray nozzles producing small droplets that under even moderate wind speeds can result in poor coverage[1] and off-target drift[2]. Spray drift becomes more of an issue as wind speed increases, resulting in greater movement of pesticides away from the intended target. Air induction (AI) nozzles generate large, air-filled droplets that behave in a ballistic way as they travel, quickly falling to the ground once the air support drops below a critical value[3]. Spray droplets generated by AI nozzles are less prone to drift than droplets produced by HC nozzles due to their increased size, and tend to break apart into many smaller droplets once they hit a solid surface. AI nozzles have been shown to considerably reduce airborne drift in field studies in Europe using a cross-flow sprayer producing a planar air jet applied to trees 10-13 feet in height[4]. The performance of AI nozzles has not been evaluated on an axial fan sprayer of the type most frequently used to apply pesticides to the larger tree canopies typical of apple orchards in the US. Output from the upper nozzles on an axial fan sprayer can potentially provide the major contribution to off-target drift under moderate wind speeds. It seems logical to assume that switching the nozzle type in these upper positions from HC to AI may provide the greatest benefits in terms of increased spray deposition and reduced drift under low to moderate wind speeds.

The objectives of the present studies were to compare the performance of an axial fan sprayer equipped with a standard HC nozzle configuration or AI nozzles in various configurations. Sprayer performance included measurements of (i) spray drift, (ii) spray coverage throughout the tree canopy, and (iii) efficacy of thinning and cover sprays. In addition, the effects of each nozzle configuration on spray coverage and thinning efficacy were determined under different across-row wind speeds.

Methods

Sprayer configuration and wind speed control. An axial fan sprayer was configured with either conventional HC nozzles or a modified AI/HC configuration where the upper four nozzles were replaced by AI nozzles as described in Table 1. The sprayer was operated at a pressure of 100 psi and the tractor speed was 2 mph for each configuration. The test trees were mature 'Pink Lady'/M.7 planted in 1998 at the Mountain Horticultural Crops Research and Extension Center in Fletcher, NC at a spacing of 20 feet by 10 feet. These parameters equate to a spray output of 177 and 178 gallons per acre for HC and AI/HC configurations respectively, estimated to be 80% of the calculated full canopy TRV of the orchard. Across-row wind speeds were artificially generated by controlling the fan speed on two additional tractor mounted air blast sprayers parked adjacent to each treatment tree as described in Figure 1. Three levels of across-row wind speed (zero moderate, high) were generated using this approach. Actual wind speed values within the tree canopy were quantified with a digital anemometer at 2 feet intervals in height along the tree trunk.

Table 1. Description of HC and modified AI/HC nozzle configurations.

Nozzle Position	Configuration: Hollow cone size	Hollow cone gal/min@100 psi	Air induction/Hollow cone size	Air induction/Hollow cone gal/min@100 psi
1 Upper	off		off	
2	45/7	1.11	AI1106VS	0.95
3	45/7	1.11	AI1108VS	1.26
4	45/7	1.11	AI1108VS	1.26
5	45/8	1.35	AI1108VS	1.26
6	45/8	1.35	45/8	1.35
7	45/7	1.11	45/7	1.11
8	off		off	
9	off		off	
10 Lower	off		off	
total gal/side/min		7.14		7.19
gal/acre @ 2 mph		177		178

Spray drift and spray coverage. The effects of HC and AI/HC nozzle configurations on spray drift was measured by placing water sensitive cards on the ground at 5 feet intervals along a 70 foot transect perpendicular to the direction of the sprayer in an area of open ground adjacent to the test orchard. The cards were removed after they had dried and drift was quantified by measuring the percent total area covered by droplets in an area representing approx. 5 cm^2 on each card, using the UTHSCSA ImageTool software program (***ftp://maxrad6.uthscsa.edu***). Spray coverage was assessed by analyzing percent spray coverage on water-sensitive cards that had been stapled to the upper surface of a leaf adjacent to the trunk every 2 feet from the soil line using ImageTool software.

Spray efficacy. Two replicated field experiments were undertaken to compare the efficacy of HC and modified AI/HC nozzle configurations. In the first experiment a post-bloom chemical thinning spray (100 ppm MaxCel plus 1 lb/100 gal. Sevin) was applied with each nozzle configuration at the same three across-row wind speeds generated in the *spray coverage* study. Fruit set was calculated from counts of flower cluster and fruit number on representative sample limbs in the lower (two limbs) and upper (three limbs) canopy. The test orchard suffered a severe fire blight outbreak during 2006 with many clusters on the sample limbs becoming infected so that fruit set data were too variable for meaningful statistical analysis. To try to quantify the treatment effects on fruit set the total number and weight of fruit per tree was recorded at harvest. In addition to the nozzle configuration and wind speed treatments there was an unsprayed control treatment. Treatments were applied to fully guarded single trees with four replications arranged in a split-plot design experiment with nozzle configuration as the main plot and wind speed as the sub plot.

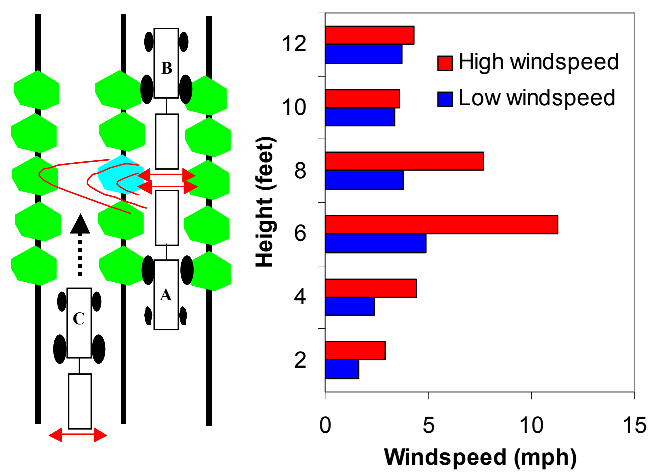
In a second *spray efficacy* experiment the cover sprays were applied with each nozzle configuration in a "high-risk" program where Topsin M was excluded order to increase disease pressure. Each plot was three adjacent rows wide to account for overspray effects and five trees along the row. There were four replications of each nozzle configuration. Two samples of 20 fruit were removed from one tree in the center row of each plot at harvest, representing the upper and lower canopy. The incidence of sooty blotch (a disease complex caused by *Peltaster fructicola*, Johnson, *Geastrumia polystigmatis* Batista and M.L. Farr, *Leptodontium elatius* (G. Mangenot) De Hoog and other fungi) and flyspeck (Zygophiala jamaicensis E. Mason) was measured on each fruit sample.

Data analysis. Data were analyzed using the generalized linear model procedure of the SAS statistical program.

Results and discussion.

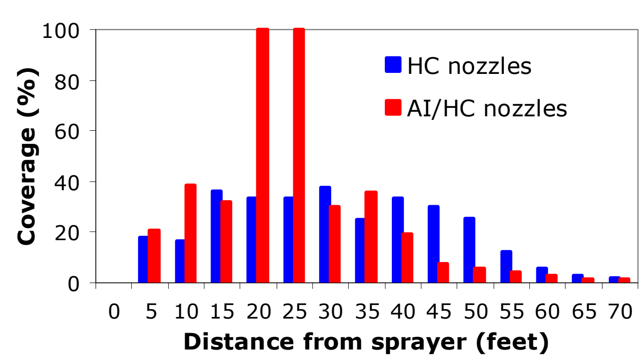
Wind speed control. Preliminary investigations revealed that two sprayers were necessary to achieve a (relatively) constant lateral wind speed across the tree canopy at any given height. However, this type of fan generated considerable variability in wind speeds at different heights within the canopy (Figure 1). Regulating the tractor rpm to generate wind speeds at the fan manifold of either 40 mph or 60 mph resulted in the "low" and "high" wind speed profiles described in Figure 1, respectively. The measured wind speeds reached a maximum at a height of 6 feet above the soil line of 4.9 and 11.3 mph for the "low" and "high" wind speeds respectively. Wind speeds at a height of 2 feet above the soil line were less that one third of the maximum value for each level, whereas at 12 feet they were 76% and 38% of the maximum value for "low" and "high" levels respectively. Although a uniform wind speed could not be generated over the entire canopy using axial fans, the efficacy of HC and AI/HC sprayer configurations was evaluated at three distinctly different levels of across-row wind speed ("zero", "low", and "high") using this approach.

Fig. 1. Schematic of arrangement for establishing variable across-row wind speeds and actual wind speeds obtained at different heights along the trunk of mature 'Pink Lady'/M.7 apple trees.



Spray drift. The two sprayer configurations had different drift profiles under still conditions in an open field, as described in Figure 2. The standard HC nozzle configuration tended to produce more drift than the AI/HC nozzle configuration, with greater spray coverage on water sensitive cards at distances of 40 feet or more from the sprayer. The AI/HC configuration resulted in 100% coverage of water sensitive cards that were placed on the ground at distances of 20 and 25 feet from the sprayer whereas coverage from HC nozzles never exceeded 40%. The dramatic increase in spray fallout from AI/HC nozzle configuration at a distance of 20-25 feet from the sprayer reflects the behavior of droplets formed by the AI nozzles. The larger droplets formed by AI nozzles appeared to exit the air support provided by the sprayer

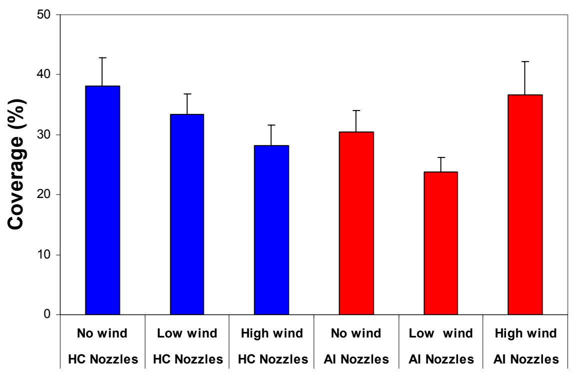
Fig. 2. Effects of sprayer nozzle configuration on drift under still conditions in an open field. Drift assessed as % spray coverage on water-sensitive cards.



fan more quickly as described in earlier studies (3), falling to the ground much sooner than smaller droplets generated by HC nozzles.

The different aerodynamic behaviors of droplets produced by the two nozzle types may have important implications for spray efficacy in an orchard environment quite apart from any effects of droplet size. An orchard sprayer equipped with HC nozzles will produce a relatively constant and diffuse level of drift over a distance of 50 ft from the sprayer that will result in minimal carry-over of a fine spray that is unlikely to penetrate very far into the canopy of trees that are two or more rows over from the row adjacent to the sprayer. AI nozzles on the other hand produce a more intense peak of spray drift that may result in significant overspray of the canopy of trees in the row(s) adjacent to the sprayed row. The extent of this overspray will depend on the row spacing: at 20 feet between rows it will be minimal, but there may be significant overspray when the distance between rows is in the range from 12-16 feet. The extent of this overspray will depend not only on the nozzle type but also on attenuation of spray by the tree canopy in the row immediately adjacent to the sprayer.

Fig. 3. Effects of nozzle configuration and across-row wind speed on spray coverage. Spray coverage was measured on water-sensitive cards stapled to the upper side of leaves at different heights in the canopy.



Spray coverage. There was a significant main effect of above-ground height on spray coverage ($P<0.0001$), with coverage increasing from approx. 15% 2 feet above the soil line to approx. 50% 12 feet above the soil line. The effect of wind speed on spray coverage was not statistically significant ($P=0.15$), but there was a significant interaction between nozzle configuration and wind speed ($P=0.02$). There was a trend for decreasing coverage with increasing across-row wind speeds from HC nozzles, whereas spray coverage from the AI/HC nozzle configuration was greatest at the "high" wind speed level (Figure 3). Spray coverage was poorer with the AI/HC nozzle configuration compared to the HC nozzle configuration when there was no wind, but was better with the AI/HC nozzle configuration under high across-row wind speeds (data not shown).

Spray efficacy. Data from the thinning experiment were not conclusive. Due to severe fire blight infection in the test trees fruit set data could not be analyzed. The incidence of fruit with sooty blotch or flyspeck at harvest was 25% and 40% higher respectively when the cover sprays were applied with the AI/HC nozzle configuration compared to the standard HC configuration, however this difference was only statistically significant for flyspeck ($P=0.02$). An increased incidence of sooty blotch and flyspeck on fruit from trees sprayed with the AI/HC nozzle configuration may reflect the slight decrease in total spray coverage at no and low across-row wind speeds compared to a standard HC nozzle configuration (Figure 3). Alternatively, the reduction in fungicide efficacy may result from differences in droplet size and the pattern of chemical distribution on the fruit surface between the two nozzle configurations.

Literature Cited

[1] Fox et al., 1990. Downwind residue from air spraying of a dwarf apple orchard. Transactions of the ASAE 33(4): 1104-1108.
[2] Fox et al., 1985. A model study of the effect of wind on air sprayer jets. Transaction of the ASAE 28(1): 83-88.
[3] http://www.teejet.com/ms/teejet/newsStory.asp?ID=96
[4] Jaeken et al., 2003. Nozzle choice and its effect on spray deposit and distribution, uptake, drift and biological efficacy in standard apple orchards (Malus sylvestris, cv Jonagold). Pflanzenschutz-Nachrichten Bayer 56(2): 326-353.