

EFFECT OF NOZZLE ORIENTATION ON DISPERSION OF TRUCK MOUNTED ULTRA LOW VOLUME SPRAY AT DIFFERENT HEIGHTS AND DISTANCES⁴

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Subject Editor: Alden Estep

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ABSTRACT

A field evaluation study was conducted to understand the dispersion of spray from a truck-mounted ultra-low-volume (ULV) sprayer when released with the nozzle oriented at the conventional angle of 45° in addition to 22° and 0° with respect to ground surface. The study was conducted in an open grassy field at the Anastasia Mosquito Control District by applying Aqualuer™ 20-20 at the highest label application rate. Mortality of caged female *Aedes aegypti* was tested at 1.5, 3.0, 6.0, and 8.5 m heights at 0, 30, 60, and 90 m from the spray line. Spray trials were conducted during early morning hours and all test groups were replicated three times over different days. During these evaluations higher mortality was recorded from the 22° and 0° nozzle orientations up to 30 m from the spray line and at heights up to 3 m. The conventional nozzle orientation of 45° provided the greatest mortality 30 m from application source at heights of 6.0 and 8.5 m.

Key Words: *Aedes aegypti*, nozzle angle, adulticide, droplet dynamics

INTRODUCTION

Ultra-low volume (ULV) space sprays of mosquito adulticides, in spite of their spatially short-lived duration of effectiveness, have no equal alternative when it is required to quickly and effectively suppress insect populations during public health emergencies. Perich et al. (2000) has described ULV as the best management practice against adult mosquito vectors during epidemics. The factors that cause environmental dilution (e.g., wind) of ULV application for area-wide control ultimately limit the temporal and spatial duration of toxicity against mosquito populations that result in not enough residual insecticide left behind. Consequently, inconsistent performance has been reported from a vast majority of studies evaluating ground ULV application of mosquito adulticides. These

inconsistencies in control have been reported by some researchers as dismal performance (Reddy et al. 2006; Lesser and Latham, 2013; Xue et al. 2013), others showing excellent control (Mount et al. 1968; Stains et al. 1969; Taylor and Schoof 1971; Mount et al. 1978) while some others showing sporadic results (McNeill and Ludwig 1970; Mount et al. 1970; Rathburn and Boike 1975; Turner 1977; Bunner et al. 1987; Britch et al. 2011).

The effectiveness of mosquito adulticide applications in residential areas can be confounded by tree lines and other landscape features such as shrubbery, as well as physical structures that act as barriers to spray movement. Based on the density of these barriers, spray may pass through these barriers or may deflect over and around them. Realizing the complexities of the areas to be treated and inconsistencies in effectiveness of

truck mounted ultra-low volume space sprays, a series of studies were conducted to investigate the causes of these inconsistencies. These studies were also aimed at optimization of spray applications and were conducted between 2014 and 2017. One study compared conventional 45° upward nozzle orientation with horizontal (0°) and 30° downward nozzle orientations in open field trials. Results revealed that horizontal nozzle orientation was most effective against caged female *Ae. aegypti* (L.) (Farooq et al. 2017). Another study (Farooq et al. 2018) assessed the effect of travel speed on spray effectiveness, also in open field settings and revealed that increased travel speed improved spray dispersion and effectiveness against caged female *Ae. aegypti*. Similar comparison in urban environments of Gainesville, FL indicated that horizontal nozzle orientation was a better alternative to the standard 45° upward nozzle orientation against caged female *Ae. aegypti* and *Ae. albopictus* (Skuse) (Jiang and Farooq 2016; Jiang et al. 2020). During these studies, effectiveness of spray was checked at 1.5 m above the ground. Effectiveness of sprays in all of the above-mentioned studies indicated that when spray nozzles were orientated horizontally, the spray plume remained centered around 1.5 m above ground surface. The pattern of spray movement during other orientations, e.g., 45° upward, was not evaluated. However, it remains unclear how spray plumes interact with residential vegetative barriers that can alter its effectiveness. To help resolve concerns about vertical drift of the spray plume, and along longitudinal distance, our objective was to evaluate spray dispersion at different

heights and distances from the spray path when applied using three different nozzle orientations of a truck mounted ULV sprayer.

MATERIALS AND METHODS

Experiments were conducted at an adulticide evaluation field at the Anastasia Mosquito Control District (AMCD), St. Augustine, FL (N29.901119, W-81.413381). The application area measuring 122 m x 122 m is an open area grassy field bordered with slash pine trees (*Pinus elliotii*) and small shrubs along three sides and buildings on one side (Figure 1). During this study, Aqualuer 20-20 (AI: permethrin 20.6%, piperonyl butoxide 20.6%, Value Garden Supply, St. Joseph, MO) was applied using a truck mounted ULV sprayer (Guardian 190 ES, ADAPCO, Sanford, FL) at the maximum label rate. Nozzle orientations consisted of upward 45°, 22°, and horizontal (0°) positions in relation to ground surface. Each nozzle orientation was replicated three times.

Caged mosquitoes and droplet impinges (Leading Edge, Fletcher NC) were mounted at four different heights (1.5, 3.0, 6.0 and 8.5 m) on 8.5 m on telescopic poles at 0, 30, 61, and 91 m from the spray line (Figure 2A). At each height on the pole, cages and droplet impinges were on the opposite sides and 0.6 m away from the pole. Each cage held 25, 5-7 day old, laboratory reared insecticide susceptible (Orlando strain) females *Ae. aegypti*, that was attached to the rope at each location and height (Figure 2B). Similarly, spinning impinges were hung upside down



Figure 1: Experimental field shown on the map with trees visible on all three sides.

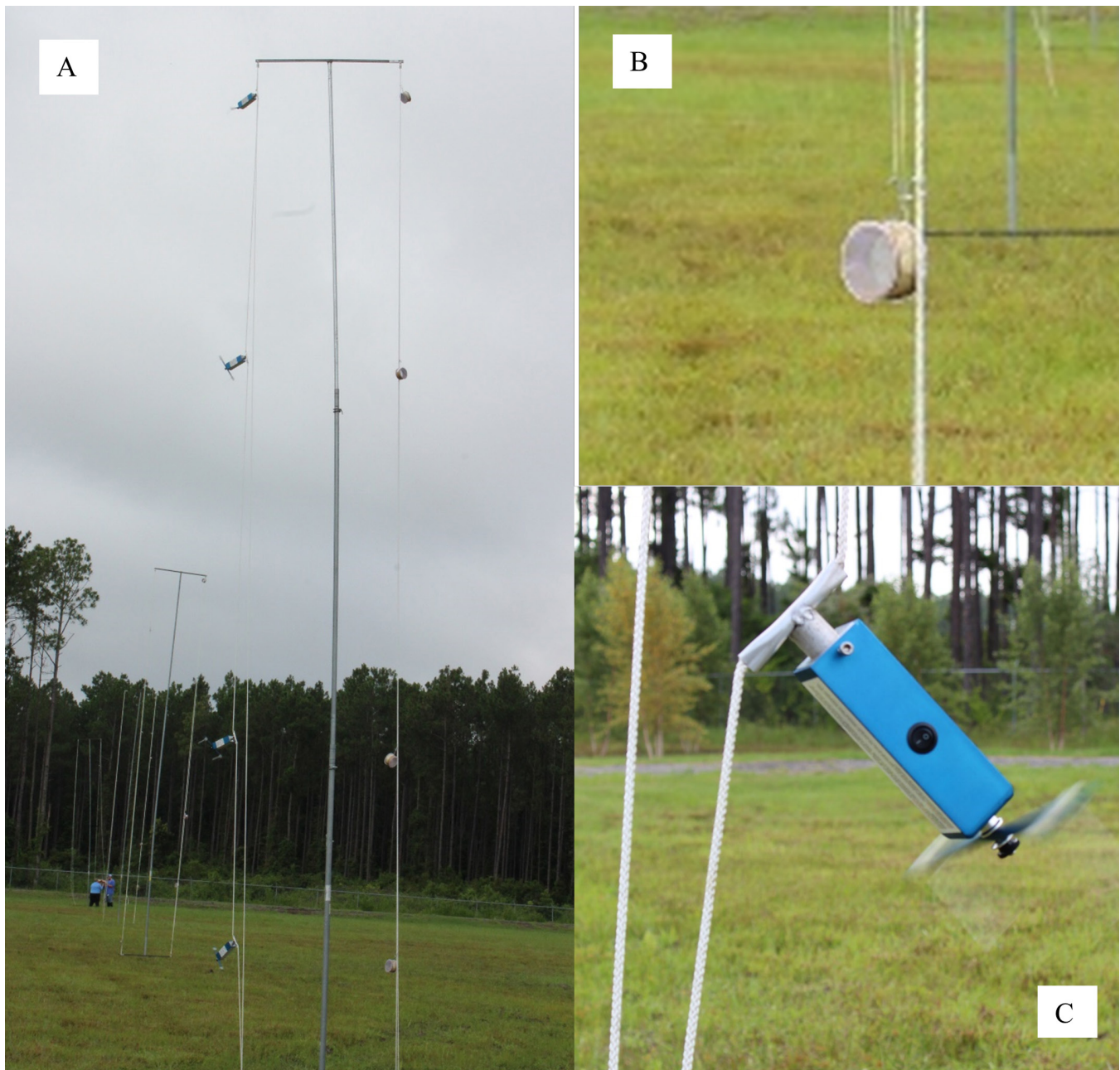


Figure 2: Field Layout. 2A) Overall view of the sampling locations showing relative position of cages and spinners; 2B) cages attached to the rope; 2C) spinner attached to the rope.

tied with a rope passing through a pulley at the end of the extension pipe (Figure 2C). Cage and impinger assemblies were raised before spray and lowered 15 min after the application. Each spinner had one Teflon[®] coated 3 mm rod for droplet size measurement (Leading Edge, Fletcher NC) and one plain rod to balance the spinner. After securing the slides and turning the spinner on, the cages and spinners were raised by pulling the rope. Fifteen minutes after the spray, the spinners and cages were lowered by releasing the rope and cages/slides were collected.

Three control cages were placed in the same outdoor environment for 15 minutes and removed before start of the spray. Applications were made with the drive path perpendicular to the sampling line when the wind direction would carry drift towards the cages. For each treatment pass, spray was initiated 30 m before reaching the sampling line and continued about 30 m past the line. One replication of each nozzle orientation was completed in one day and the experiment spanned over three weeks. Applications were made between 0800 and 1100 under slightly convective and neutral conditions. It has been

Table 1: Ranges of weather conditions during all the spray applications

Treatment	Wind Speed km/h	Wind Direction, Angle (°) w. r. t. Sampling Line	Temperature °C	Relative Humidity %
Horizontal Nozzle	4.8 – 9.7	30.0	25.6 – 32.2	59.5 – 69.0
Nozzle 22° Upward	6.4 – 8.0	30.0 – 60.0	28.9 – 33.4	50.7 – 67.7
Nozzle 45° Upward	1.6 – 9.7	0.0 – 60.0	30.6 – 31.9	61.7 – 67.4
Control	1.6 – 9.7	30.0 – 60.0	25.2 – 28.8	60.0 – 73.7

demonstrated in a previous study that when wind speed is > 5 mph, inversion is not required for a ULV application (Miller et al. 2012). Wind speed, wind direction, temperature and relative humidity were recorded at 1.5 m above ground with WatchDog 2550 weather station (Spectrum Technologies Inc., Plainfield, IL). The weather data is summarized in Table 1.

Fifteen minutes after application, cages were removed and taken to the laboratory, provided with 10% sugar solution, and stored under ambient laboratory conditions. Mortality was observed at 1 and 24 h after treatment. Rods from spinners were removed at the same time. Teflon® coated rods were stored in pre-labeled boxes for droplet measurements which were completed within 24 h after spray application.

The control mortality in all cages was from 0-4 % with an average of 1.5% and the mortality was not adjusted for control mortality. An analysis of variance was performed on 1 and 24 h mortality using JMP Version 14 (SAS Institute Inc, Cary, NC). Mean mortality between heights and distance separately were compared with Tukey's multiple comparison test and were considered significant at $p < 0.05$. As there were considerable number of rods which did not have enough droplets to measure, the available data for droplets was not meaningful and is not reported.

RESULTS

Ae. aegypti mortality was recorded at both 1-h and 24-h post-treatment. However, because mortality at 1-h and 24-h post-treatment was consistent, only 24-h post-treatment data is presented. Analysis of variance indicated that *Ae. aegypti* mortality at 24-h post-treatment was not significantly affected by nozzle angle ($F = 0.11$, $df = 2$, $p = 0.89$) and height ($F = 0.79$, $df = 3$, $p = 0.5$). However, the mortality was significantly affected by distance from the spray line ($F = 5.47$, $df = 3$, $p = 0.0013$). The interaction of spray distance, height, and nozzle orientation did not have

a significant effect on 24 h mortality. The 24 h mortality, was greater at distance 0, at height of 1.5 and 3.0 m above ground, from 0° and 22° nozzle orientations compared with 45° orientation (Fig 3). At 6.0 and 8.5 m heights, 45° nozzle orientation resulted in greater mortality than the other two orientations. These trends indicated that spray using nozzles at 0° and 22° orientations remained close to the ground while spray using nozzle at 45° orientation moved to the upper heights. At 30 m distance from application path, the 0° and 22° orientations had high mortality compared to 45° orientation. At other distances, the 0° resulted in lower mortality compared with 22° and 45° orientations.

DISCUSSION

In this study, we found that spray from the horizontal (0°) nozzle orientation showed greater mortality near the spray line, but resulted in less mortality at farther distances when compared to the 22° and 45° orientations. This result generally contradicts to what has been observed in prior studies (Farooq et al. 2017 and Jiang et al 2020) which showed higher mortality from horizontal nozzle at all distances. A key difference in our study was that the application site (while in an open field) was surrounded by forest on three sides (Figure 1). When the wind crosses over the tree line, it creates a downdraft with eddies near the trees as shown in Figure 4 (Iowa State University). This downward movement of wind pushes the spray plume towards the ground. This movement could be substantive even in low wind speeds as the ULV droplets are too small to resist air movement. The results of our study show that this downdraft phenomenon was a factor to depress the expected upward range of ULV drift. We believe that the spray was pushed down by the air current coming from top of the trees that negatively affected the 0° spray application where droplets were pushed below the level of mosquito cages in the field showing lower

mortality. The downdraft phenomena also corrected the trajectory of the 45° sprays, resulting in greater-than-expected mosquito mortality. This phenomenon may affect the spray more in the morning (when this study was conducted) when strong inversion conditions developed overnight still existed. In the evening, the inversion is just in its inception and its effect is reduced. Therefore, it is important that the time in which an application is

performed can considerably affect the effectiveness of a treatment. In an experiment to study the potential of ULV spray to penetrate dwellings to control dengue vectors harboring indoors, it was found that horizontal nozzle orientation resulted in considerable concurrent mortality of *Ae. aegypti* inside and outside of the dwelling (Farooq et. al 2020). The horizontal nozzle orientation by keeping spray close to the ground also provides an opportunity

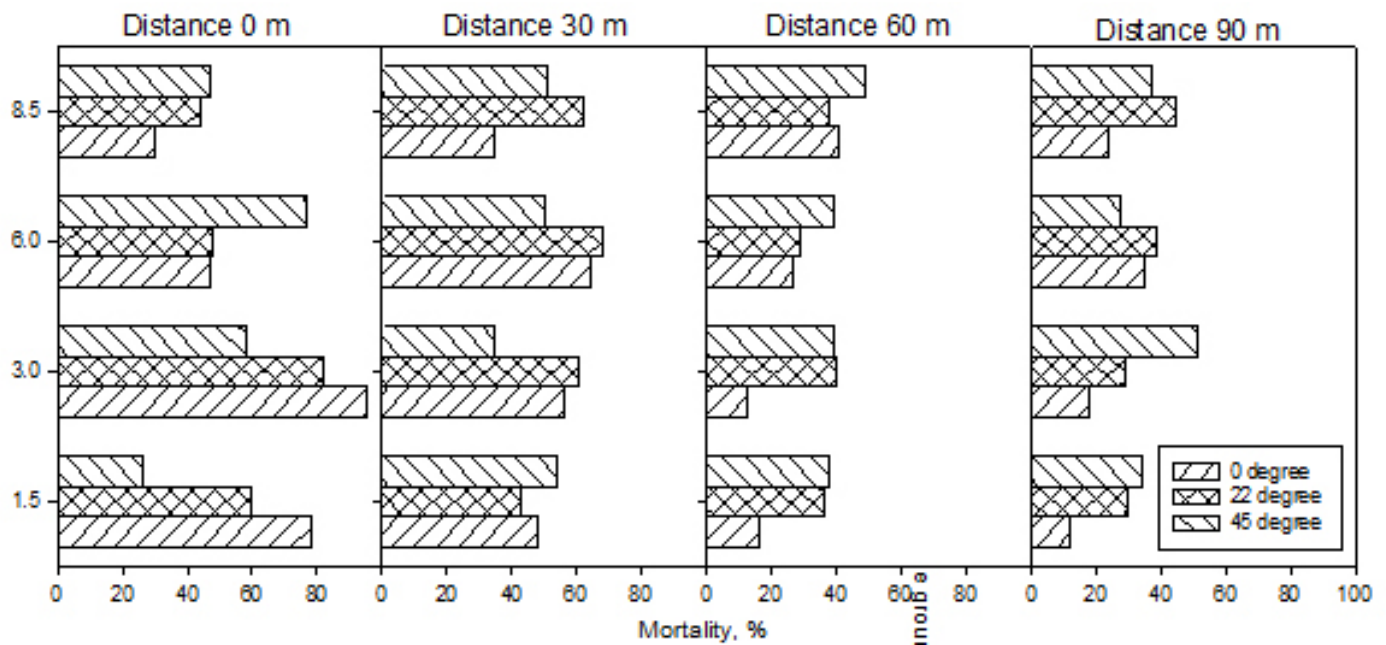


Figure 3: Mosquito mortality from spray delivered with nozzle at different orientations to different distances and heights

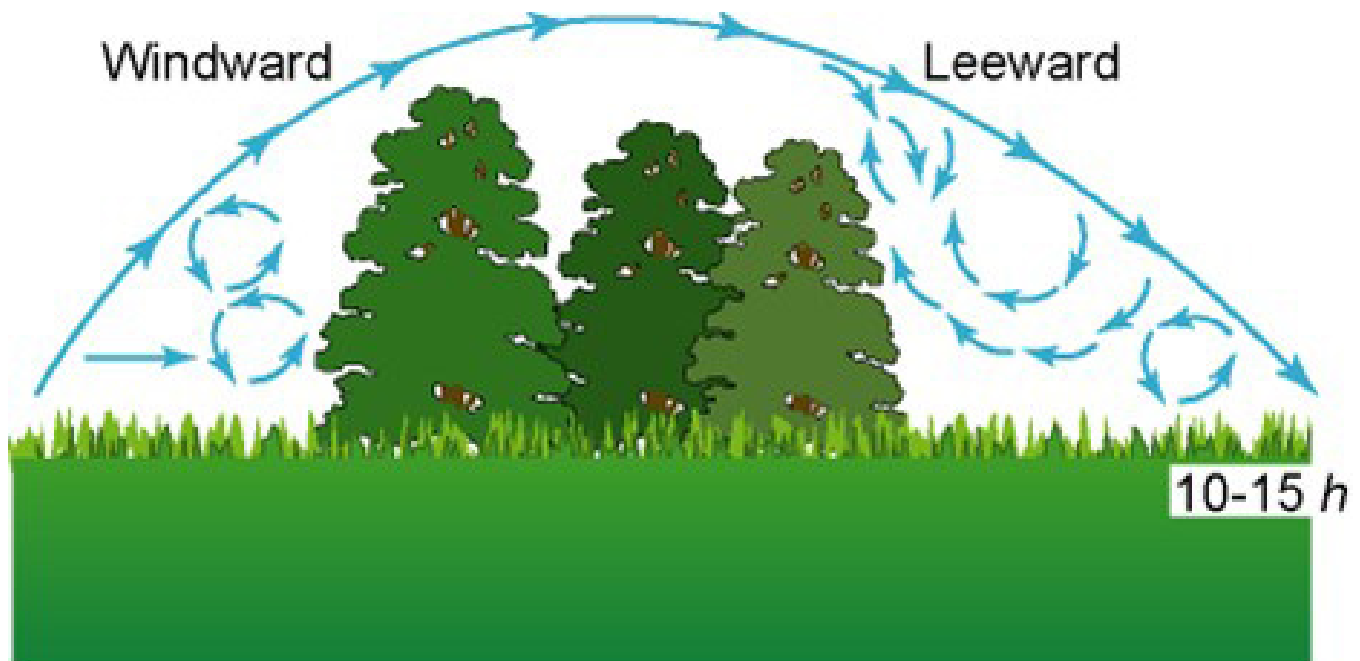


Figure 4: Wind Profile over trees (Courtesy: Iowa State University)

to target mosquitoes hiding under vegetation and raised buildings but it needs to be further investigated. Results of this and other studies on this topic indicate the need to adjust the nozzle orientation to suite the habitation being treated.

ACKNOWLEDGEMENT

The authors like to thank K. Gaines, M. Duet, and J. Wynn for help to design and set up the poles, and to apply the pesticides and other AMCD and NECE staff for helping to carry out this study that involved tremendous labor. This is a research report only and the mention of commercial products does not imply endorsement by AMCD.

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Submitted date: June 30, 2022, Accepted date: December 20, 2022, Published date: June 30, 2023.