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OPERATIONAL NOTE

EFFECT OF TRAVEL SPEED ON DISPERSION OF AQUALUER 20-20 SPRAYED BY A TRUCK-MOUNTED ULTRA-LOW–VOLUME SPRAYER AGAINST CAGED *AEDES AEGYPTI*[1]

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ABSTRACT. The effect of travel speed of a truck-mounted ultra-low–volume (ULV) sprayer on its application efficacy was studied at St. Johns County Fairground, Elkton, FL, during summer 2015. The efficacy was assessed by spray deposition, droplet size spectrum, and 24-h mortality of caged adult *Aedes aegypti*, using 2 rows of sampling locations, 15 m apart and spread up to 122 m from the spray. Each location had a bioassay cage and an impinger droplet sampler, 1 m apart from each other, at 1.5 m off the ground. Aqualuer® 20-20 (20.6% permethrin AI and 20% piperonyl butoxide) was applied at the maximum label rate, travelling at 8, 16, and 32 km/h. Three replications were completed on 3 days at least a week apart, with 1 replication of each travel speed per day. On each application day the travel speeds were rotated. Overall, a travel speed of 32 km/h achieved the highest efficacy of Aqualuer® 20-20, followed by 16 km/h, and then 8 km/h, in an open field. In general, droplet size, deposition, and mosquito mortality increased with increasing travel speed. The increased travel speed will also enhance the work rate of a sprayer and operator, thus reducing the cost of ULV applications.

KEY WORDS Efficacy, mortality, nozzle angle, parameters, permethrin, ultra-low–volume

Despite short-lived control, ultra-low–volume (ULV) space sprays of adulticides are today's tools of choice for quick and effective knockdown of mosquito populations and are the best management practice during arboviral epidemics (Perich et al. 2000). However, there are mixed reports on the efficacy of this technology with some studies indicating adequate control while others showing a lack of acceptable control. Mount et al. (1968, 1978), Stains et al. (1969), Taylor and Schoof (1971), and Rathburn and Boike (1972) all reported ≥90% mortality at ≥91 m from the spray line. McNeill and Ludwig (1970), Mount et al. (1970), Rathburn and Boike (1975), Turner (1977), and Bunner et al. (1987) reported good control at one time or place but poor at other times and places, even with similar applications. Reddy at al. (2006) and Xue et al. (2013) reported poor control. These inconsistencies in efficacy of ULV ground applications may be due to the interaction(s) of application technique, weather conditions, and selected sprayer parameters. Husted et al. (1975) reported increased distance of >90% mortality of *Culex pipiens* (L.) with higher wind speeds and smaller droplets. Farooq et al. (2017) found that the ULV nozzle angle with respect to the ground influenced adulticide efficacy while a horizontal nozzle provided the greatest control of caged *Aedes aegypti* (L.) with Aqualuer® 20-20.

Most adulticide labels allow travel speeds of truck-mounted ULV sprayers from 8 to 32 km/h. Any increase in travel speed will need to increase the flow rate of the ULV machines, which increases their droplet size (Hoffmann et al. 2012), a disadvantage when smaller droplets are desired. On the other hand, increased travel speed helps better mixing of spray droplets into the air due to enhanced wake effect, certainly an advantage. However, the extent of the impact of travel speed on the efficacy of ULV applications has not been studied. The objective of this study was to evaluate the effect of travel speed of a truck-mounted ULV sprayer on spray dispersion and mortality of caged *Ae. aegypti*.

The study was conducted at St. Johns County Fairgrounds in Elkton, FL, on a 378 × 378–m unpaved parking lot surrounded by trees. Aqualuer 20-20 (20.6 % permethrin AI, 20% piperonyl butoxide AI, AllPro Vector Group, Northville, MI) mixed with oil-soluble Yellow 131SC® fluorescent tracer dye (Rohm and Haas Co., Philadelphia, PA) at 12,500 ppm was applied at the maximum label rate (37 ml/ha) with a truck-mounted Cougar® ULV sprayer (Clarke Mosquito Control, Roselle, IL) with nozzle pointed 45° upward. Travel speeds of 8, 16, and 32 km/h were evaluated with flow rates of 46, 92, and 182 ml/min, respectively. Caged (3–5-day-old)

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Table 1. Weather conditions during applications for each replication of treatments.

Replication	Date	Travel speed (km/h)	Temperature (°C)	Relative humidity (%)	Wind speed (km/h)	Wind direction
1	June 24, 2015	8	23.9	91	3.2	SW
		16	26.1	93	3.2	WSW
		32	27.8	87	5.0	SW
2	July 8, 2015	8	27.2	72	3.2	SW
		16	28.3	69	4.8	SE
		32	26.1	78	3.2	S
3	July 15, 2015	8	27.8	84	9.9	S
		16	25.6	91	6.4	SSW
		32	26.7	88	9.6	SSW

insecticide-susceptible, laboratory-reared female *Ae. aegypti* were used for bioassays. Effectiveness of the application was assessed by spray deposition, droplet size spectrum, and 24-h mortality.

The experimental setup consisted of 2 rows, at least 15 m apart, of 6 measurement locations extending up to 122 m perpendicular to the spray line. In each row, 6 bioassay cages with 25 female *Ae. aegypti* and 6 spinners were positioned at 0, 15, 30, 61, 91, and 122 m from the spray line. Details of the layout are provided in Farooq et al. (2017). Cages and spinners were 1.5 m above the ground. Only 1 application of each travel speed was performed on the same day and replicated on 3 subsequent days at least 1 wk apart. Temperature, relative humidity, wind speed, and wind direction were recorded at 3.0 m aboveground using a HOBO® weather station (Onset Computer Corporation, Bourne, MA) (Table 1).

Control cages were held in the environment well out of the spray zone for 15 min and were collected before spray started. Spray cages and rods were placed in the field when ready for each spray. Fifteen minutes postspray, cages were removed and rods were collected from all locations. Control and spray cages were placed in separate vehicles and supplied with 10% sugar solution. Teflon®-coated rods were preserved for measurement of droplets and the others were stored in prelabelled, resealable bags for deposition measurement. After collection, rods were stored in a cool and dark environment. All bioassay cages were maintained in the Anastasia Mosquito Control District laboratory until 24-h mortality count was recorded. All rods were stored in the refrigerator at the Navy Entomology Center of Excellence for droplet size and deposition measurements.

Droplets were measured using the DropVision system (Leading Edge Associates Inc., Fletcher, NC) and droplet distribution parameters were determined. Droplet diameters were measured in micrometers, and their distribution paramenters, where 10%, 50%, and 90% of the spray volume is contained in droplets smaller than these diameters, were represented as $D_{V0.1}$, $D_{V0.5}$, and $D_{V0.9}$ (ASTM 2004). Deposition was measured using analysis described by Farooq et al. (2009). Rods were washed inside the plastic bag using 20 ml of hexane; fluorescence readings of the solution were determined using a spectrofluorophotometer (Shimadzu, Model RF5000U, Kyoto, Japan) and converted to spray volume on rod using calibrations developed from a set of standard concentrations. The spray volumes for each sample were then converted to active ingredient (AI) deposition (ng/cm^2) using sampling area of 63 cm^2 and the ratio of dye and AI in the spray tank.

Statistical analysis was conducted with Intel® Visual Fortran Composer XE 2013 with $\alpha = 0.05$. Initial Kolmogorov–Smirnov tests (Smirnov 1939) performed on all data sets revealed that the data were nonnormally distributed while the Bartlett test (Bartlett 1937) showed nonhomogeneity of variances. Thus a 1-way nonparametric Kruskal–Wallis analysis ($\alpha = 0.05$) (Kruskal and Wallis 1952) was conducted to study the overall effect as well as effect at each distance of travel speed on deposition, $D_{V0.5}$, and 24-h mortality. Subsequent Tukey multiple-comparisons tests were conducted to identify effects of those speeds that were significantly different from each other.

The vehicle travel speed had a significant effect on mean deposition ($\chi^2 = 6.95$, $df_1 = 2$, $df_2 = 107$, $P = 0.0016$) and travel speeds of 8, 16, and 32 km/h resulted in overall mean depositions of 0.54, 0.73, and 1.37 ng/cm^2, respectively. The mean depositions at all travel speeds were significantly different from each other. Also at 15- and 30-m distances, there were differences in deposition from travel speeds (Fig. 1).

The overall effect of vehicle travel speed on mean volume median diameter ($D_{v0.5}$) of droplets was significant ($\chi^2 = 6.45$, $df_1 = 2$, $df_2 = 107$, $P = 0.0023$) and travel speeds of 8, 16, and 32 km/h resulted in overall mean $D_{v0.5}$ of 9.3, 9.5, and 11.0 µm, respectively. These means at all travel speeds were significantly different from each other. As shown in Fig. 1, at each distance, the $D_{v0.5}$ from 32 km/h was generally higher, but not significantly different from other speeds. As flow rate has to be increased with an increase in travel speed, the increase in $D_{v0.5}$ is a result of the increase in flow rate as shown by Hoffmann et al. (2012) and Farooq et al. (2016).

Travel speed significantly affected mean 24-h *Ae. aegypti* mortality ($\chi^2 = 4.15$, $df_1 = 2$, $df_2 = 107$, $P = 0.0199$) and the speeds of 8, 16, and 32 km/h resulted

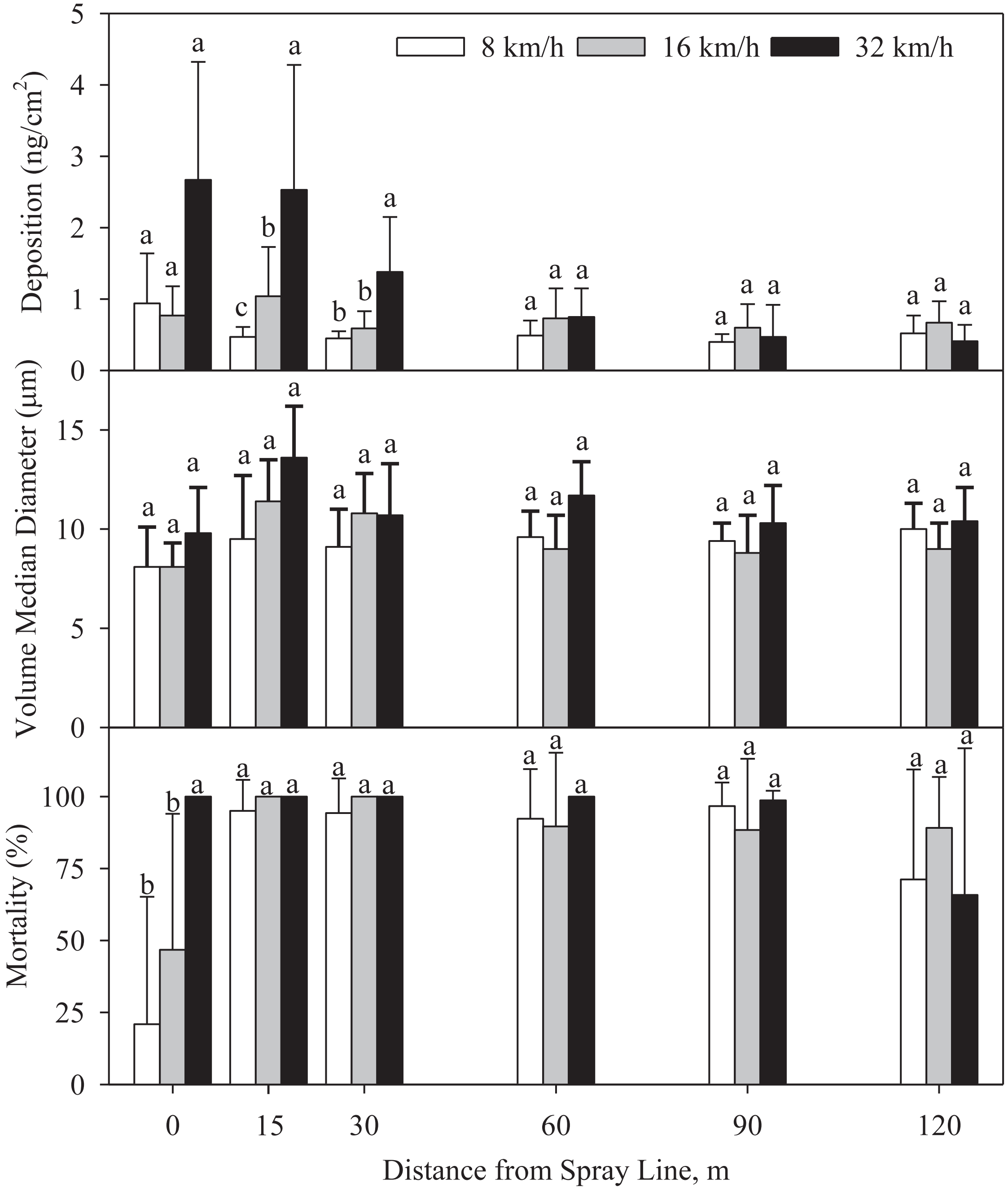

Fig. 1. Comparison of spray deposition (top), volume medium diameter (VMD) (middle), and 24-h mosquito mortality (bottom) for individual travel speeds of the spray vehicle at different distances from the spray line. Different letters indicate significant difference ($\alpha = 0.05$) between means of VMD, deposition, or mortality.

in mean mortalities of 79.7%, 85.6%, and 94.1%, respectively, all significantly different from each other. As illustrated in Fig. 1, mortality from 32-km/h travel speed was 100% up to 90 m, but low at 120 m. At distance 0, mortality from 32 km/h was significantly higher than mortality from other speeds.

Greater effectiveness of a ULV spray can be achieved when it is thoroughly mixed within the air in the target area (Farooq et al. 2017). The results of this study showed that spray droplet size, deposition (flux), and caged mosquito mortality increased with increasing travel speed, and spray performance was best at the highest speed. Mount (1998) commented based on Mount et al. (1970) that when an effective insecticide dose and appropriate atomization are maintained for a designated swath, travel speed does not affect efficacy; however, no details of how this conclusion was drawn are reported.

Improvement in application efficacy with increasing travel speed, as seen in this study, can be attributed to 2 physical phenomena observed during the spray. First, speed of the induced air due to and in a direction opposite to sprayer travel increases with the increase in travel speed. The induced air deflects the spray plume, released at 45° upward, toward the ground and suppresses upward spray movement resulting in better efficacy as evidenced by Farooq et al. (2017). Second, movement of a vehicle creates an air vortex behind it, which strengthens with increasing travel speed. This vortex helps better mix the spray with air, resulting in higher probability of droplets contacting flying insects.

Although this study demonstrates that an increase in travel speed during ULV application results in improved deposition and mosquito mortality, the improvement may have been curtailed to some extent by the increase in droplet size with increasing travel speed. An increase in engine and blower/fan speed, or an increase in rotary atomizer rotational speed decreases droplet size (Farooq et al. 2016). A new feature in future equipment, to link engine, blower/fan or rotary atomizer speed with travel speed, is recommended to maintain droplet size. Another difficulty in using and maintaining higher speeds may arise from the practical limits on travel speeds due to ground surface and shorter runs in urban settings. Use of available control systems to vary flow rate with change in travel speed can help overcome this difficulty.

In addition to effectiveness, use of increased travel speed will increase work rate, enhance timeliness, and reduce the operational cost of ULV applications.

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