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OPERATIONAL NOTE

EFFICACY OF DUET™ DUAL-ACTION ADULTICIDE AGAINST CAGED *AEDES ALBOPICTUS* WITH THE USE OF AN ULTRA-LOW VOLUME COLD AEROSOL SPRAYER

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ABSTRACT. Duet™ was field evaluated against caged *Aedes albopictus*, with the use of a truck-mounted ultra-low volume (ULV) cold aerosol sprayer at the rate of 90.6 ml/ha. Cages were placed in 3 rows stationed 30.5, 61.0, and 91.5 m downwind of the spray vehicle. Initial knockdown was >99% with mortality ranging between 95.8% and 98.0% across the distances. Volume median diameter (VMD) and droplet density were slightly reduced (16.4% and 18.6%, respectively) by distance. Reduction in VMD and droplet density, however, did not reduce mortality. The ULV application of Duet is an effective adulticide against *Ae. albopictus* and may be a useful tool for use in mosquito abatement programs.

KEY WORDS Prallethrin, sumithrin, adulticide, mosquito, *Aedes albopictus*

Ultra-low volume (ULV) application is a proven method against various mosquito genera with several advantages over other application approaches in terms of less insecticide amount, large coverage, rapid dispersion, stage-specific efficacy, and reduced environmental concern for nontarget insects (Mount 1998, Qualls and Xue 2010, Bonds 2012). Adulticide ULV applications against mosquitoes have been adopted in the USA for 4 decades (Mount 1998).

Pyrethroids have high insecticidal activity at low application rates compared to other insecticide classes such as organophosphates, short environmental persistence, no bioaccumulation, and low mammalian toxicity reducing ecological risk (WHO 2006). A recently developed pyrethroid formulation, Duet™ Dual-action Adulticide (Clarke Mosquito Control, Roselle, IL) combines the pyrethroids, prallethrin (1%) and sumithrin (5%), with the synergist piperonyl butoxide (PBO) (5%). Duet has been proposed to have a dual action. First, as an irritant that induces flight in resting mosquitoes, thereby increasing their exposure to insecticide droplets. Second, by quick knockdown of the mosquitoes at low doses. These properties may be useful against *Aedes albopictus* (Skuse), an anthropophilic, day-biting, and peridomestic vector mosquito that oviposits in cryptic larval habitats and has undergone an increasing range expansion and population abundance in the northeastern USA (Hawley 1988, Farajollahi and Nelder 2009).

We evaluated the adulticidal efficacy of Duet against caged *Ae. albopictus* (F1 generation) placed up to a distance of 91.5 m with the use of a truck-mounted Clarke Cougar® (Clarke Mosquito Control, Roselle, IL) ULV cold aerosol sprayer using the maximum label rate of 90.62 ml/ha.

For the study, *Ae. albopictus* adults were collected from Mercer and Monmouth counties, New Jersey, and maintained under standard laboratory conditions at 26 ± 1°C, 70–75% relative humidity (RH), and 16 light:8 dark photoperiod. Ultra-low volume ground applications were conducted over an asphalt surface in a secure area of Trenton-Mercer Airport, Mercer County, on September 11, 2008. A 3 × 3 grid design was used for the experiment. Three rows of cages (14.4-cm diam and 4 cm deep) were placed 30.5 m, 61.0 m, and 91.5 m downwind and perpendicular to the spray path. Stakes (1.5 m height) holding treatment cages (1 cage at each distance; 3 distance points × 3 replicates = 9 cages) and Florida Latham-Bonds rotating impingers on 18-cm horizontal rods were placed within each row (Clayson et al. 2010). Rotating impingers (6-V DC, 590 rpm, 5.6 m/s) were activated immediately before and stopped 10 min after the application to capture aerosolized droplets on 3-mm-wide slides with Teflon® tape. Uvitex® OB fluorescent tracer dye (0.125% w/v; Ciba Specialty Chemicals, Basel, Switzerland) was mixed (1.33 g dye/liter) with the Duet formulation to differentiate ULV adulticide droplets from other airborne particles. To measure volume median diameter (VMD) and droplet density, treated slides were read under a compound microscope using DropVision® FL (Leading Edge Associates, Waynesville, NC).

Up to 30 adult *Ae. albopictus* (7–14 days old) were maintained in a treatment cage before the ULV application and remained inside the cage for a 10-min exposure as the aerosolized fog moved through the application site. Posttreatment adults were transferred to cups with the use of a mouth aspiration tube and kept in 237 ml

Table 1. Susceptibility of caged adult *Aedes albopictus* to Duet™, a dual-action pyrethroid insecticide, with the use of a truck-mounted ultra-low volume cold aerosol sprayer at the maximum label rate of 90.6 ml/ha at different distances ($n = 27$).[1]

	Distance (m)			
	30.5	61.0	91.5	*P*
Droplet volume median diameter (μm)	19.45 ± 0.17 a	17.61 ± 0.62 ab	16.26 ± 0.88 b	0.03
Droplet density	25.81 ± 2.70 a	21.09 ± 1.94 b	21.01 ± 1.94 b	0.04
Knockdown (%)	99.11 ± 0.89 a	99.67 ± 033 a	98.82 ± 0.59 a	0.64
Recovery (%)	1.09 ± 0.76 a	2.50 ± 1.06 a	3.06 ± 0.89 a	0.39
Overall mortality (%)	98.02 ± 1.06 a	96.35 ± 1.16 a	95.76 ± 1.29 a	0.38

[1] All values represented in mean ± SE. Means followed by same letter in a row are not significantly different ($P < 0.05$; 1-way ANOVA). Droplet density was measured as number of droplets per mm^2. Percent recovery represented 24-h posttreatment duration.

cardboard ice cream containers covered with mesh netting lids for 48-h recovery period under laboratory conditions. A 10% sucrose solution was provided during the holding period. Mosquitoes that were immobile and remained on the floor of the cage were counted for knockdown at 1 and 24 h posttreatment. Mosquitoes unresponsive to gentle blowing of air or a mild tap to the holding container were classified as dead at 48 h posttreatment. All treatments were replicated 3 times for all 3 distances by setting up 3 rows of cages and the experiment was repeated 3 times. Control mosquitoes were not exposed to the insecticide; however, they were otherwise handled in the same manner as treatment mosquitoes. Knockdown and mortality of mosquitoes were corrected with controls with the use of Abbott's formula (Abbott 1925) prior to analysis. Data for each cage distance from all 3 repeats of the experiment were pooled. One-way ANOVA was conducted to find significant differences ($P < 0.05$) with the use of least-significant difference (LSD) among different distances.

During the ULV application, a meteorological station (Davis Instruments, Vernon Hills, IL) was used to measure thermal inversion and temperature at 1.5-m and 9.1-m heights. There were 4.8–11.3 km/h wind speed, 51–52% RH, and 20.3°C air temperature, and the ground temperature dropped from 20.2°C to 18.8°C.

Overall VMD and droplet density were 17.8 μm and 22.6 droplets/mm^2, respectively, which were slightly reduced over the distances (Table 1). These findings showed that a 91.5-m ULV swath received droplets of recommended size at the recommended label rate for DUET (http://www.clarke.com/pdf/brochures/22759Duet12pp.pdf).

Knockdown recovery had a minimally negative impact on adulticidal efficacy (Table 1). None of the mosquitoes recovered after 1 h posttreatment. At 24-h posttreatment, only 1–3% mosquitoes had recovered, which was within an acceptable level of efficacy. The combination of prallethrin and sumithrin in the Duet formulation appeared to enhance its effectiveness resulting in less recovery from knockdown. No adults recovered from knockdown during 24–48 h of posttreatment, suggesting a 24-h recovery period for mortality observation would be sufficient for *Ae. albopictus*. In controls, 0.4 ± 0.5% to 1.1 ± 0.9% mortality was recorded. Overall mortality ranged between 98.0% and 95.8%, and there was no reduction in mortality among the distances (df = 2, $f = 1.0$, $P = 0.38$, LSD = 3.43). With the same insecticide, Qualls and Xue (2010) found slightly lower adulticidal efficacy for *Culex quinquefasciatus* Say (90% and 70% mortality at 15.2 and 106.7 m, respectively). These variations were probably due to differences in insecticide susceptibility levels of *Cx. quinquefasciatus* and *Ae. albopictus* with the latter species being more susceptible to Duet (Qualls and Xue 2010). Qualls and Xue (2010) also suggested that the addition of prallethrin to sumithrin increased mosquito mortality.

Aedes albopictus has developed resistance to conventional organochloride and pyrethroid insecticides (Kamgang et al. 2011). These insecticides are based on a single active ingredient, accelerating resistance development. Our results show that Duet may play a role in slowing the evolution of resistance in *Ae. albopictus* because it contains 2 separate pesticides, and it may also overcome existing resistance in some target species because of the presence of PBO. Pyrethroid-resistance-associated esterases are inhibited by PBO (Young et al. 2005).

Efficacy of ULV adulticide application under field conditions may be affected by mosquito host-seeking and resting behavior. Reduction in malathion ULV efficacy against *Aedes aegypti* (L.) was observed because of the endophilic nature of this species (Perich et al. 2000). Unlike *Ae. aegypti*, *Ae. albopictus* is mainly an exophilic and exophagic mosquito (Hawley 1988). Protection of some proportion of an *Ae. albopictus* population resting inside the premises or vegetation may have a negative impact on ULV efficacy compared to the open field study. Prallethrin in Duet may flush out mosquitoes resting in vegetation because of its repellent action (Katsuda et al. 2009), exposing them to more droplets

of sumithrin and PBO. This mechanism may compensate for the potential reduction of Duet adulticidal efficacy in cryptic habitats of *Ae. albopictus*.

In conclusion, Duet appears to be an effective adulticide against *Ae. albopictus*, causing 98% knockdown and 96% mortality up to 91.5 m downwind from a truck-mounted ULV application. The ULV adulticiding may be helpful to interrupt disease transmission.

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