Journal of the American Mosquito Control Association, 39(4):288–290, 2023

OPERATIONAL NOTE

FIELD EVALUATION OF FYFANON EW AGAINST *AEDES AEGYPTI:* A LOW ODOR ULTRA-LOW VOLUME FORMULATION OF MALATHION

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ABSTRACT. A low odor formulation of ultra-low volume (ULV) malathion (Fyfanon EW®) mosquito adulticide was evaluated in the field for its efficacy using caged female *Aedes aegypti*. Cages were placed in three rows, 30 m apart at 30, 60, and 90 m from the spray line. The product was applied at the manufacturer's suggested operational rate of 0.28 liter/min (9.5 fl oz/min) and at the maximum label rate of 0.37 liter/min (12.6 fl oz/min) with a Guardian 190ES truck mounted ULV sprayer. At 1 h post-treatment for the manufacturer's suggested operational rate, adult mortality ranged from 85% at 30 m to 46% at 90 m (overall average 65.5%). At 24 h post-treatment, mortality was significantly greater at each distance with complete control of caged mosquitoes at 30 m and >95% at 90 m. Overall, 24-h average mortality at this rate was 96.8%. At the maximum label rate, mosquito mortality at 1 h was considerably greater at all distances and ranged from about 89% to 75% with an overall average of 84.3%. At 24 h post-treatment, complete mortality was recorded at all transect distances at this higher rate. In conclusion, our results showed that at 24 h, Fyfanon EW® was considered very effective when applied by ULV truck mounted ground equipment for area-wide control of mosquitoes.

KEY WORDS Adulticide, control, Culicidae, organophosphate insecticide, resistance management, ULV

In the closing decades of the 20th century, pyrethroid insecticides emerged into prominence for area-wide adult mosquito control in the USA. In addition to the quick knock down action and decreased environmental toxicity of this insecticide class, there was no highly objectionable odor compared with organophosphates as experienced with technical grade malathion, currently marketed as Fyfanon® in the USA. These facts resulted in higher public acceptance of pyrethroids by operational mosquito control in addition to relatively low application rates and cost (Suderland and Bloomquist 1990) that lead to a subsequent dramatic decrease in the use of organophosphates as adulticides. Furthermore, public health pest management professionals generally embraced pyrethroids (especially aqueous formulations) partly due to elimination of possible automotive paint damage caused by the ULV technical grade malathion formulation if ≥3% of the total spray droplets were ≥32 μm during application (Tietze et al. 1992). Unfortunately, continued reliance upon pyrethroid insecticides to control adult mosquitoes has resulted in several geographic areas with high levels of resistance to the active ingredients in several products (e.g., Scott et al. 2014, Kupferschmidt 2016, Estep et al. 2018, Schluep and Buckner 2021). Often pyrethroid products are rotated with more toxic ones of the same chemical class in order to retain operational control of adult mosquitoes instead of switching to another class such as an organophosphate (e.g., malathion). The end result most often produces a subsequent greater increase in overall pyrethroid resistance. To mitigate the issues of automotive paint damage and offensive odor, a 40.6% aqueous oil in water emulsion ULV formulation of malathion (Fyfanon EW®, FMC Corporation, Philadelphia, PA) is now commercially available for adulticide application. We report here on field efficacy trials of Fyfanon EW conducted in northeastern Florida against caged female *Aedes aegypti* (L.) to characterize its suitability for military and civilian use as an option to allow rotation of insecticide classes for adult mosquito integrated pest management, especially against pyrethroid-resistant populations.

The study was conducted on the grounds of the Anastasia Mosquito Control District in a mowed, open grass field (29.901158, -81.413401). Applications were performed with a Guardian 190ES truck mounted ULV sprayer (Adapco, LLC, Sanford, FL). The vehicle was operated at 16 kph (10 mph) and the product applied undiluted at manufacturer's suggested operational rate of 50.4 g/ha and at maximum label rate of 67.2 g/ha active ingredient (AI) (0.045 and 0.06 lbs/acre, respectively). The AI application rates corresponded to 0.12 and 0.15 liter/ha (1.6 and 2.1 fl oz/acre, respectively) of formulated product and were achieved with flow rates of 0.28 liter/min (9.5 fl oz/min, operational rate), and 0.37 liter/min (12.6 fl oz/min, maximum label rate), respectively. Application nozzle orientation was horizontal (0°). Previous work by Farooq et al. (2017) showed that a horizontal nozzle orientation provided better mixing of spray into the air column when applied by truck mounted ULV compared with 45° angle. Flow rate was calibrated on the day prior to application. Air temperature, relative humidity (RH), and wind speed during testing was obtained from an onsite weather station (AcuRite®, Model 01512, Chaney Instrument Co,

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Table 1. Corrected mean±SE percent mortality of caged female *Aedes aegypti* (insecticide susceptible Orlando strain) after 1 and 24 h post exposure to Fyfanon EW ground applied aerosol from a Guardian 190ES truck mounted ULV sprayer, Anastasia Mosquito Control District, St. Augustine, FL 2020.

Application distance (m)	n	% Mean mortality 1 h		% Mean mortality 24 h	
		Operational rate[1]	Maximum rate[1]	Operational rate	Maximum rate
30	222	85.3 ± 7.4a	88.8 ± 3.7a	100a	100a
60	219	65.2 ± 9.9ab	88.8 ± 4.1a	93.6 ± 3.4ab	100a
90	214	46.4 ± 9.1b	75.3 ± 10.0a	96.8 ± 2.4b	100a

[1] Operational rate 0.28-liter/min (9.5 fl oz/min, manufacturer suggested rate) and maximum label rate 0.37-liter/min (12.6 fl oz/min). Column means with different letters are significantly different, Tukey HSD pair-wise comparison test, $P \leq 0.05$.

Lake Geneva, WI) located in the application area. Ground temperature was measured using a hand-held infrared temperature sensor (Cooper Model 425, Cooper-Atkins Corp., Middlefield, CT). Applications were conducted between 1800 and 2000 h from August 26 through October 15, 2020, and were repeated three times on separate dates. One replication of both application rates was evaluated on each date.

Laboratory-reared, insecticide-susceptible 3–5-day-old non-blood fed *Ae. aegypti* (Orlando strain) were obtained from the Navy Entomology Center of Excellence insectary and used in all evaluations. On the day of treatment, three transect rows of screened cardboard (9 cm diam) cages containing 25 females each, were arranged 15 m (50 ft) apart for evaluation. In each row, three cages were placed at 30, 60, and 90 m from the spray line (total 9 cages per treatment). Cages were positioned in the field at a height of 1.5 m and suspended on staked poles. The vehicle's path was perpendicular to wind. Application started 30 m before the first row of cages then continued 30 m past the last row. Nine rotary droplet collection spinners (Leading Edge Associates, Inc., New Smyrna, FL), with Teflon coated 3 mm rods were stationed approximately 1 m away from each cage to collect spray for determination of droplet size characteristics of the spray cloud. Three control cages were placed approximately 250 m from the spray area.

Fifteen minutes after application, cages were retrieved from the field and transferred into the laboratory where mosquitoes were lightly knocked down using CO_2 from a pressurized gas cylinder. Mosquitoes were then immediately transferred to clean holding cages and provided with 10% sugar water-soaked cotton balls placed on top of each cage. Mortality was recorded at 1 h and 24 h post-treatment. Mosquitoes were considered dead when they were unable to remain upright or fly. Mean percent mortality in treatments was corrected for those in controls using Abbott's formula (Abbott 1925) and percent mortality was transformed by arcsine $\sqrt{x+1}$ prior to statistical analysis to normalize data distribution. Droplet volume median diam (Dv_{50}) on the Teflon rods were determined within 24 h post-application using DropVision® (Leading Edge Associates, Inc., New Smyrna, FL).

Generally, *Ae. aegypti* mortality decreased with increasing distance from application source at both application rates (Table 1). At 1 h, mortality at the operational rate ranged from about 85% at 30 m then decreased to 46% at 90 m (overall average 65.5%). At this rate, 24-h post-treatment, mortality was considerably greater at each distance (100% at 30 m and >95% at 90 m) with overall average mortality at 24h of 96.8%. At the maximum label rate, mosquito mortality at 1 h was slightly greater at 30 m (89%) but considerably higher at 90 m (75%) compared with the operational rate. At this higher rate, 24-h mortality was complete (100%) in all cages at all transect distances. Droplet volume (Dv_{50}) at the operational rate was 13.8 ± 1.1 μ and at maximum label rate was 14.9 ± 0.5 μ. Relative humidity averaged 80.4 ± 2.6% while air and ground temperatures averaged 28.0 ± 0.8°C and 26.7 ± 0.5°C, respectively. Wind speed averaged 5.1 ± 1.0 kph during application. Mortality in controls during operational rate trials did not exceed 1% and 3% at maximum label rate trials.

Our results were similar to a Fyfanon EW study reported by Bonds and Latham (2012) where an application rate of 67 g AI/ha resulted in an average 24 h mortality of >80% for insecticide-susceptible *Ae. albopictus* (Skuse) and ≥96% mortality for susceptible *Anopheles quadrimaculatus* Say and *Culex quinquefasciatus* Say, using an ULV Grizzly cold fogger in southwestern Florida. The average overall mortality levels observed at 24 h for the EW malathion formulation in our study generally met or exceeded that of the technical formulation of ULV Fyfanon found in other studies. For example, Britch et al. (2010) previously reported that an average of up to 88% mortality at 24 h was achieved against caged insecticide-susceptible *Ae. taeniorhychus* (Wied.) as well as *Cx. quinquefasciatus* when ULV Fyfanon was applied using a London Fog 18-20 sprayer at an application AI rate of 0.17-liter/ha.

As previously mentioned, paint damage can occur with the 91% AI ULV malathion formulation if ≥3% of the total spray droplets were ≥32 μm (Tietze et al. 1992). According to the manufacturer, with the new aqueous formulation of Fyfanon EW this issue has virtually been eliminated. We observed that only 1.5% and 1.1% of droplets (as determined by our

DropVision data) exceeded this threshold at the operational and maximum label rate applications, respectively. In conclusion, our results showed that at 24-h post exposure, Fyfanon EW was considered just as effective as ULV Fyfanon and would provide a viable low odor option for malathion applications, using truck mounted ULV ground equipment for area-wide control of mosquitoes while reducing odor and damage to automotive paint.

The authors thank the staff of the Anastasia Mosquito Control District for their assistance during this study. The views expressed in this article are those of the authors and do not reflect the official policy or position of the Navy and Marine Corps Force Health Protection Command, Navy Bureau of Medicine and Surgery, Department of Defense, the US Government, or Anastasia Mosquito Control District. This is a research report only. The name of the commercial products mentioned in this publication does not constitute nor imply endorsement by the US Government or Anastasia Mosquito Control District. The authors include employees of the US Government. This work was prepared as part of their official duties. Title 17, U.S.C., §105 provides that copyright protection under this title is not available for any work of the US Government. Title 17, U.S.C., §101 defines a US Government work as a work prepared by a military Service member or employee of the US Government as part of that person's official duties.

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