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SCIENTIFIC NOTE

EVALUATION OF THREE COMMERCIAL BACKPACK SPRAYERS WITH AQUALUER® 20–20 AGAINST CAGED ADULT *AEDES AEGYPTI*

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ABSTRACT. Three commercially available backpack sprayers were evaluated with Aqualuer® 20–20 (20.6% permethrin, active ingredient; 20.6% piperonyl butoxide, technical) against caged adult *Aedes aegypti* in semifield trials in northeastern Florida. Two battery-powered sprayers, Birchmeier and Hudson, were compared with the standard hand-pump SOLO 425 sprayer, which is currently used in pest management operations. Physical characteristics, droplet analysis, and overall ease of use were documented. Multiple dilutions of the insecticide were also evaluated. The results indicated that the Birchmeier sprayer was the preferable machine in terms of its physical characteristics and operator use. There was no significant difference in percent mortality of the test mosquitoes between the sprayers. Multiple dilutions ranging from 1:9 to 1:1050 of the insecticide resulted in greater than 80% mean mortality.

KEY WORDS *Aedes aegypti,* backpack sprayer, Aqualuer®, permethrin

Aedes aegypti (L.) is a major container-breeding species that vectors diseases of growing concern, such as chikungunya and dengue fever (Womack 1993). Streamlining mosquito management to address threats like *Ae. aegypti* involves efforts to optimize permethrin and its application equipment (Xue et al. 2012). Backpack sprayers have been designed, manufactured, and marketed to mosquito control districts and the public over the years as convenient means for application of liquid products (Kardatzke 1981, Hoffman et al. 2008). Manual pump spraying units, such as the SOLO 425® (Solo Inc., Newport News, VA), are widely used in insecticide distribution (Brown et al. 1997). Manually powered backpack sprayers use a piston or diaphragm design that requires continuous pumping throughout use. Battery-powered backpack sprayers, such as the Hudson® (13854 NeverPump® Bak-Pak®, H.D. Hudson Manufacturing Co., Chicago, IL) and Birchmeier (REC 15, Birchmeier Sprühtechnik AG, Stetten, Switzerland) are electrically pressurized and do not require manual pumping. Battery-powered backpack sprayers promote efficiency of dispensing chemicals and simplicity of use. When testing new technology, it is important to consider safety, simplicity, economy, and efficiency. Durability in particular has been a key criterion in past studies (Brown et al. 1997) and is a logistical concern for both safety and efficient handling.

The purpose of this study was to determine the effectiveness of 2 battery-powered backpack sprayers with a permethrin product against caged adult *Ae. aegypti.* The effectiveness of insecticide dilutions has been known to be influenced by droplet size (Brown and Xue 2011), so a droplet analysis was done on all 3 sprayers. In an effort to continue streamlining mosquito management, a semifield evaluation was conducted to compare the standard SOLO with 2 battery-operated competitors, the Birchmeier and Hudson. Safety, simplicity, economy, and efficiency were the parameters for evaluation.

The study site was located at the Anastasia Mosquito Control District of St. Johns County (AMCD) on East Pope Road, St. Augustine Beach City, FL (29.859515, 81.279366). All sprayer models had basic physical features calibrated to meet label specifications for use with Aqualuer 20–20® (AllPro Vector Group, Bloomington, MN), and included features such as output and spray distance. The batteries for the Hudson and Birchmeier sprayers were fully charged the day before use. The plastic Hudson nonadjustable nozzle did not create droplets in the barrier treatment size range or produce a similar output as the other machines, so an adjustable nozzle from an extra plastic Solo sprayer was used to replace the Hudson nozzle. All nozzles were calibrated to spray droplets in the barrier treatment size range; therefore, the nozzles themselves were not under evaluation. The Birchmeier nozzle had brass parts and was able to spray in the barrier treatment size range from the onset of the experiment. The Solo sprayer has been used in multiple barrier treatment studies previously (Amoo et al. 2008). The Hudson nozzle was replaced with the Solo nozzle because they both have plastic nozzle parts and the Solo nozzle on the Hudson

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is the most comparable with the Birchmeier. To calibrate all the machines, water was sprayed from each sprayer into a 19-liter container for 60 sec to quantify spray volume. The Solo was pumped every 3 sec to maintain constant pressure during calibration. The nozzles were taped to ensure that outputs for all models were standardized to within 660–700 ml/min (Hudson: 692.31 ml/min, Solo: 660.37 ml/min, Birchmeier: 697.93 ml/min). Under windless conditions, spraying toward a wall and measuring the distance between where the mist made contact with the wall and the nozzle documented the spray distance. All 3 sprayers produced a spray distance between 1.5 and 1.8 m. Equipment handler's walking speeds were standardized at 6.4 km/h. All mosquitoes were acquired from the USDA Center for Medical, Agriculture, and Veterinary Entomology in Gainesville, FL. Mosquitoes were maintained in AMCD's insectary (26.6°C, 85 ± 5% relative humidity [RH]), 14 h light:10 h dark) on a 10% sucrose solution (Gerberg 1994). Six–eight-day-old non-blood-fed female mosquitoes were used for the tests. A mouth aspirator transferred 10 female mosquitoes into cylindrical cages (15 cm diam, 5 cm high) that had both ends secured with white mesh. For each test, 12 cages (9 treatments, 3 controls) were utilized. The control cages were placed a minimum of 26 m upwind and outside of the spray path to prevent insecticide drift from the treatments. The cages were attached to vertical PVC pipes by double-sided tape at a height of 1.2 m. The pipes were placed 3 m apart in a row. While walking 6.4 km/h and 1.5 m perpendicular to the cage row, the applicator sprayed the treatment cages in an undulating motion. The same number of cages was used when evaluating each sprayer on each test day (36 cages for each sprayer, 3 sprayers). In total, 6 dilutions of Aqualuer 20–20 were tested: 1:18, 1:27, 1:36, 1:45, 1:64, and 1:1050. In addition, reverse osmosis (RO) water was tested in each machine to ensure the velocity of the spray did not cause mortality. Sprayed cages sat for 15 min after exposure before a knockdown (KD) count was taken. Each set of treatment and control cages were handled with nitrile gloves, which were changed after each test set to prevent cross contamination. Postexposure cages were brought back into the AMCD laboratory and maintained on a 10% sucrose solution. Mortality of mosquitoes was evaluated 24 h after exposure. Weather readings were taken by a WatchDog 2550 weather station (Spectrum Technologies Inc., Plainfield, IL). Temperature, wind speed, wind direction, and RH were documented every 15 min throughout each test. A posttreatment droplet analysis with the use of a 2D Phase-Doppler particle analyzer system (TSI Inc., Shorenes, MN) was done on the 3 backpack sprayers at Navy Entomology Center of Excellence (NECE). Six readings were taken from each sprayer at distances of 0.3 and 1.5 m. The mist from the sprayers were projected across the laser and measured for mean droplet size and velocity (Table 1).

All 3 sprayers produced a relatively high mean mortality of 94% with all Aqualuer 20–20 dilutions (Table 1). The droplet analysis revealed that the Birchmeier produced the smallest droplet size of the 3 backpack sprayers at 100.1 μ. The operating pressure for the Birchmeier can be adjusted, but the Hudson pressure cannot. The smaller droplets are likely due to the increased pressure. Both the Hudson and the Birchmeier used hydraulic nozzles and the flow rate and the droplet size characteristics changed with the change in pressure.

The standard Solo weighed 4.8 kg and appeared to be a reliable sprayer, as its mechanical parts are relatively simple and easy to repair. The Hudson weighed 7.4 kg and was powered by a12v10ah lead-acid battery. The design of the machine made it awkward to wear and all of the electronic parts were mounted to the bottom of the sprayer, which limited access for repair. The Birchmeier weighed 4.4 kg and was powered by a detachable Li-ion battery. The Birchmeier design was very wearable and the mechanics were accessible and adjustable. The nozzles and wands of the Solo and Hudson were made of plastic, whereas the Birchmeier's wand and nozzle were made of brass. The brass parts allowed finer adjustments of the spray, as observed during calibration, and nozzle type is associated with droplet quality (Brown et al. 1997). Brass is a more durable option for insecticide sprayers.

The RO water was tested as a control to observe possible mortality from water droplet collision. The RO water mean mortality results for the Birchmeier, Hudson, and Solo were 4%, 7%, and 0%, respectively. The label rates for an ultra-low-volume application are 1:5 dilution of Aqualuer 20–20 with water, whereas barrier spray application calls for a 1:1015 dilution with water. Testing the 1:1015 dilution with the Birchmeier produced 99% mortality with a wind speed average of 1 mph (1.6 km/h). This high mortality at such a low concentration showed the lower dilutions to be overapplications of the insecticides. The Birchmeier, Hudson, and Solo machines all had similar 15-min KD at a mean mortality of 96% when all dilutions were averaged. All the machines are adequate for barrier treatments; however, the Hudson nozzle will require changing for that application type.

Solo backpack sprayers require both hands to operate and constant pumping to maintain pressure. The Hudson and Birchmeier battery-powered sprayers provide a constant pressure and swath of

Table 1. Mean velocity and mean droplet size for the 3 sprayers as well as mean mortality of caged *Aedes aegypti* exposed all dilutions of Aqualuer® 20–20.

Sprayer	Distance (m)	Mean velocity (m/s)	DV50 (μm)	Mortality (%)
Birchmeier	0.3	1.4	100.1	
	1.5	0.9	105.1	96
Hudson	0.3	1.3	140.2	
	1.5	1.0	145.9	98
Solo	0.3	1.8	130.8	
	1.5	1.2	159.4	92

spray with 1-handed application. More tests on the Hudson should investigate how long it takes to reach the operating pressure and how long it takes to return to maximum pressure when the spray ends. The Birchmeier had the smallest mean droplet size, but all 3 produced droplets within the range of a barrier spray application. Usually smaller droplets linger longer in the air, drift more effectively through air and vegetation, and cover more surface area with insecticides (Harburguer 2012). More tests should be done on the Birchmeier to analyze the flow rate for different nozzles at different pressures and operating time for the fully charged battery at different pressures.

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