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# EVALUATION OF AN AUTOMATIC-TIMED INSECTICIDE APPLICATION SYSTEM FOR BACKYARD MOSQUITO CONTROL

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ABSTRACT. Several manufacturers and pest management companies have begun to market and install outdoor automatically timed insecticide application systems that claim to provide an envelope of protection against host-seeking mosquitoes within a defined area, e.g., residential backyards. A typical system consists of a multi-gallon reservoir attached to a continuous loop of plastic tubing with multiple single spray head nozzles. Nozzles are usually placed along the perimeter of a backyard in landscaping or other areas suitable for mosquito harborage. This array is then connected to a programmable electric pump set to automatically apply an insecticide at predetermined intervals. An operational field study was conducted to evaluate this technology using previously installed MistAway© systems at 3 residences in northwestern Florida. This system applied a mist-like application of 0.05% AI synergized pyrethrins for 45 sec at dawn and again at dusk in each backyard. Twice-weekly collections from ABC suction light traps, baited with carbon dioxide, were used as the evaluation tool. Female mosquitoes from treatment backyards were compared with trap collections from 3 backyards without automatic misting systems used as controls. We found that weekly mosquito reduction was highly variable and ranged from 98% to 14% during the 35-wk study. Because the primary method of reduction by these application systems was not well understood, a MistAway system was installed in an outdoor simulated residential backyard to determine exposure pathway under controlled conditions with field cage and excised-leaf bioassays. Using laboratory-reared females of *Aedes albopictus* and *Culex quinquefasciatus* in those assays, we found that reduction by the MistAway system was primarily achieved by direct exposure of the mosquitoes to the insecticide application and not from residual deposits on treated vegetation.

**KEY WORDS** Automatic mist systems, synergized pyrethrins, threshold, *Aedes albopictus*, *Culex quinquefasciatus*

## INTRODUCTION

A number of manufacturers and pest management companies have begun to market and install outdoor automatically timed insecticide application systems in order to provide an envelope of protection against host-seeking mosquitoes within a defined area, e.g., residential backyards. The marketing niche for this technology has been fueled by the desire of homeowners to enjoy the outdoors without the annoyance of being exposed to host-seeking mosquitoes, including the possibility of exposure to mosquitoes infected with an arbovirus such as West Nile.

Automated insecticide application systems for flying insect control are not new and have been used in dairy barns, equine stables, poultry houses, and beef cattle loafing areas for decades (McPhee and Hirst 1988, Sheppard et al. 1989, Meyer et al. 1990). A typical automated system for residential mosquito control consists of a multi-gallon reservoir, primarily containing synergized pyrethrins, connected to a continuous loop of plastic tubing and multiple single head spray nozzles. The system is driven by a programmable electric pump that automatically applies the insecticide at predetermined intervals. Generally, the nozzles are placed along the perimeter of the backyard (≈0.9–1.2 m above ground surface) in landscaping or other areas of mosquito harborage. Application is usually performed during periods of peak mosquito movement, i.e., dawn and dusk. In some units, application frequency can be manually increased by the end user via a remote override.

The Florida mosquito control community has questioned the effectiveness of automatically timed insecticide application systems for the control of adult mosquitoes (Rutledge-Connelly 2006). Moreover, no studies are available that sufficiently document their effectiveness (USEPA 2007). Therefore, an operational field study was conducted to evaluate this technology at 3 residences in northwestern Florida. Although it has generally been established that the exposure pathway of a space spray is by direct contact with the flying target, the primary pathway of control is not completely straightforward for these systems. The advertising literature from several manufacturers of automatically timed insecticide application systems state that continued control can be achieved when mosquitoes land on the surrounding treated vegetation after initial application. As a result, we conducted studies to determine whether the primary pathway of control was due to direct contact via inertial impaction of the spray and/or residual tarsal contact from treated vegetation under controlled conditions using a simulated residential backyard.

Fig. 1. Partial view of simulated backyard framed by a 1.2-m-high polyvinyl chloride pipe perimeter "fence" with potted wax myrtle bushes. In the foreground are cylindrical wire mesh cages suspended from wooden stakes used for the wire cage bioassays. Inset shows 1 of the 18 Hago spray nozzles that applied synergized pyrethrins from a Model Gen 1.2 MistAway® automatic-timed misting system.

## MATERIALS AND METHODS

### Simulated backyard study

*Wire cage bioassays:* To determine the exposure pathway of the insecticide application by the automatic-timed insecticide application system, a simulated typical residential backyard (15.2 m deep × 22.9 m wide) was constructed on the grounds of the Mulrennan Public Health Entomology Research and Education Center, Panama City, FL. The backyard was framed by a 1.2-m (height) polyvinyl chloride (PVC) pipe perimeter "fence" arranged in the shape of an open rectangular "U" (Fig. 1). A MistAway® automatic misting system (Model Gen 1.2; MistAway Systems, Inc., Houston, TX) was professionally installed in the backyard by a licensed/certified local pest control company to operational specifications for a residential backyard. The continuous loop system consisted of 0.5-cm-diam plastic tubing connected to 18 non-drip Hago #4023 nozzles (Hago Manufacturing Co. Inc., Mountainside, NJ) spaced 3.1 m (10 ft) apart positioned on the inner top edge of the fence. Nozzles were oriented upwards at ≈45°. A single line of 13.7-liter potted wax myrtle (*Myrica cerifera* L.) plants was placed along the inside perimeter of the PVC fence (total 85 plants) to simulate the vegetative border of a suburban backyard (Fig. 1). Tops of the plants were ≈15.2 cm below the spray nozzles. The application system was attached to a 250-liter drum reservoir that contained 0.05% AI solution of Summerfrost® (MistAway Systems), a water-soluble product that consisted of 3% AI pyrethrins, 6% AI piperonyl butoxide, and 10% AI n-octyl bicycloheptene dicarboximide (MGK 264). According to the manufacturer, system flow rate was 41 ml/min per nozzle at 180 psi.

Mosquito bioassays consisted of 14 × 14 mesh vertical cylindrical copper wire cages that measured 12 cm diam × 13 cm length with solid bottoms that contained a 1.8-cm-diam hole to load mosquitoes (Fig. 1). This configuration was used because it allowed insecticide to drift through the cages from above and sides (Barber et al. 2008). Cages were placed ≈1.5 m from ground surface on wooden stakes arranged in a grid starting 3.1 m away from the nozzles (42 cages total). At least 15 laboratory-reared 5- to 7-day-old female *Aedes albopictus* (Skuse) and *Culex quinquefasciatus* Say were mouth aspirated into each cage. These 2 species were used because of their importance as possible disease vectors. Tests were repeated on 4 different calendar dates, with each species in a separate cage but tested side by side and conducted at dusk. Application consisted of a standard residential application time of 45 sec. Ten minutes after application (to allow enough time for the spray cloud to pass through the backyard) cages were removed from the treatment area. At that time, mosquitoes were removed from the cages by lightly knocking them down with carbon dioxide and transferred to clean 0.6-liter paper containers covered with fine screen cloth. A cotton ball soaked in a 10% aqueous solution of table sugar was placed on the top of each container. Knockdown/mortality was assessed at 24 h. Three untreated cages of each species were used as controls for each test and similarly processed as treatments. Temperature, RH, and wind speed and direction were recorded during each test.

Also, the droplet spectrum in front of Hago nozzles connected directly to a MistAway unit was determined in a wind tunnel using a Malvern laser by Jonathan Hornby (Lee County Mosquito Control District, Fort Myers, FL) using the methods of Hornby et al. (2006). Measurements were replicated 3 times.

*Excised-leaf bioassays:* Potted wax myrtle plants, previously placed along the inner perimeter of the PVC fence-simulated backyard, were used in this portion of the study. Excised-leaf bioassays were performed about 30 min after a 45-sec spray application by removing 2 adjacent leaves from the top canopy of 10 plants in the immediate vicinity of the nozzles. Single leaves were placed in individual screened 250-ml glass beakers. At least 15 female *Ae. albopictus* and *Cx. quinquefasciatus* were mouth aspirated into separate beakers. A cotton ball soaked in a 10% aqueous solution of table sugar was placed on the top of each container. Knockdown/mortality was assessed at 24 h. Tests were repeated on 7 calendar dates and both species were tested at the same time. Mean surface area of leaves used in testing averaged 11.5 ± 2.1 $cm^2$.

Because pyrethrins have been reported to have some repellency, the resting and landing behavior of each mosquito species in the leaf bioassays was observed at 1 h and 24 h. Repellency was considered present if mosquitoes in the treatment beakers avoided continuous contact with the treated leaves.

### Residential operational field study

This study used the MistAway automatic misting system (Model Gen 1.2; MistAway Systems) professionally installed in 3 northwestern Florida backyards (yards averaged ≈17 m deep × 26 m wide) prior to this study by a licensed/certified local pest control operator. Number of nozzles in each backyard ranged from 26 to 43 (placed ≈0.9–1.2 m above ground surface) and were oriented upwards at ≈45°. All systems were programmed to automatically apply a 45-sec spray of 0.05% AI solution of Summerfrost at dawn and another application at dusk. The display panel on the unit could also be accessed to determine if the homeowner had overridden the system for additional sprays. No additional applications were noted at each treatment site during the study.

Each treatment backyard was paired with an untreated (control) yard but separated by at least 30.5 m from one another. Control backyards did not have the automatic misting system installed in them but were similar as much as possible in size and vegetation to treatment backyards. Two of the treatment/control backyard pairs were located in Bay County and the other pair was located in adjacent southern Walton County. Each paired treatment/control site was ≈32 km from one another. Approximately midway through the project (July 16; week 18), one of the treatment yards in Bay County ended their participation, leaving 2 treatment yards and 2 control yards for the remainder of the study.

Female mosquito populations were monitored in each backyard with one ABC suction trap (Clarke Mosquito Products, Roselle, IL), with the light on powered by a 6-V gel battery, per yard. All traps were baited with carbon dioxide dispensed from a 9.1-kg (20-lb) pressurized cylinder at a release rate of 500 ml/min. Traps in treatments and controls were located near the backyard perimeter. Twenty-four-hour collections were obtained twice per week, and trap collections were identified to species with the taxonomic key of Darsie and Morris (2003). The 35-wk study started on March 22 and continued through November 16, 2007. The project ended in mid-November because of the onset of cooler weather.

### Data analyses

Weekly mosquito abundance from ABC traps were pooled separately for controls and treatments. Trap data were transformed using $\log\sqrt{x+1}$ and subjected to ANOVA and Wilcoxon rank-sum test (Ott 1977, SAS Institute 2002). Mean differences were considered significant at $P \leq 0.05$ and $\leq 0.10$. Weekly mean percent reduction was calculated for pooled trap data from treatment yards.

An additional evaluation measure was used for determining effectiveness of the MistAway system in backyards. Weekly mean light-trap data from treatment yards were compared with an established annoyance threshold previously determined by the Florida Department of Agriculture and Consumer Services. This threshold, cited in Florida Statute 5E-13.036, stated that 25 mosquitoes, or more, per night in a light trap justified the application of an adulticide by Florida mosquito control programs (Florida Administrative Code 2006).

Mean knockdown/mortality data from cage bioassays in the simulated backyard study were transformed via $\log\sqrt{x+1}$ and subjected to an ANOVA and the *t*-test to determine differences between species within nozzle distance ($P \leq 0.05$ and $\leq 0.10$) and between distance within species using the Student–Newman–Keuls test ($P \leq 0.05$) (Ott 1977, Sokal and Rohlf 1981, SAS Institute 2002). Mean percent knockdown/mortality in excised-leaf bioassays were calculated after correction for natural mortality using the formula by Abbott (1925). Means of untransformed data are presented in all tables.

## RESULTS

### Simulated backyard study

*Wire cage bioassays:* Generally, efficacy of the insecticide application against caged mosquitoes was influenced by distance from the nozzle, i.e., mosquitoes farther from the nozzle generally exhibited less knockdown/mortality than mosquitoes closer to the nozzle (Table 1). Knockdown/mortality was significantly greater at 3 and 6 m for *Ae. albopictus* but highly variable for *Cx. quinquefasciatus.* Directly comparing the toxicity to both species at each distance revealed that knockdown/mortality of *Ae. albopictus* was significantly greater to the synergized pyrethrins application at 3, 15, and 18 m compared with *Cx. quinquefasciatus*. Wind speed during testing ranged from 3.2 to 6.4 km/h. Mean and associated confidence limits (CL) of the droplet spectrum from the spray directly in front of the nozzles, as determined by the Malvern laser, was as follows: $Dv_{0.1}$ 26.9 μm (24.8–29.0 μm), $Dv_{0.5}$ 50.1 μm (47.3–52.9 μm), and $Dv_{0.9}$ 100.1 μm (92.8–107.4 μm).

*Excised-leaf bioassays:* Mean percent knockdown/mortality of *Ae. albopictus* exposed to treated leaves (22.3 ± 4.5%) was greater than

Table 1. Mean percent (± SE) knockdown/mortality at 24 h of caged female *Aedes albopictus* and *Culex quinquefasciatus* at various distances from treatment nozzles exposed to a 45-sec application of 0.05% synergized pyrethrins from the MistAway® automatic-timed misting system in a simulated backyard.[1]

| Distance from nozzle (m) | *Aedes albopictus* | *Culex quinquefasciatus* |
|---|---|---|
| 3 | 91.2 ± 2.1A | 65.2 ± 11.5A[2] |
| 6 | 89.4 ± 4.8A | 67.6 ± 12.1A |
| 9 | 44.9 ± 9.0B | 42.3 ± 12.2AB |
| 12 | 34.3 ± 10.3B | 33.3 ± 7.8AB |
| 15 | 46.4 ± 9.4B | 7.3 ± 3.38B[2,3] |
| 18 | 36.4 ± 10.0B | 12.8 ± 5.0B[2,3] |
| 21 | 24.3 ± 5.6B | 33.8 ± 8.3AB |

[1] Treatment means in each column significantly different ($P \leq 0.05$), Student–Newman–Keuls test.
[2] Treatment means in each row significantly different ($P \leq 0.05$).
[3] ($P \leq 0.10$); *t*-test.

*Cx. quinquefasciatus* (9.7 ± 3.7%) but far less than the cage bioassays. Repellency was not observed in the leaf bioassays.

### Residential operational field study

During the 35-wk study, 15 and 17 mosquito species were collected from the treatment and control areas, respectively (Table 2). The 3 major pest species, in decreasing abundance, from both areas were *Aedes taeniorhynchus* (Weidemann), *Anopheles crucians* complex, and *Cx. salinarius* Coquillett. During the first 3 wk of the study, mean weekly mosquito abundance in treated yards was significantly lower compared with control yards, with reduction ranging from 98% to 71% (Fig. 2). From week 5, and through most of the summer into September 21 (week 26), mosquito populations remained relatively low due to drought conditions. At that time, populations generally remained below the State of Florida action threshold of 25 mosquitoes per trap-night in treatment and control yards. On weeks 9, 12, and 17, the mean number of mosquitoes in ABC traps were significantly lower in treatments compared with controls ($P \leq 0.10$). Consistent and substantial rainfall started again in late September (week 27), with concomitant increases in mosquito abundance. After week 27, the number of mosquitoes in treatment traps with the misting system was significantly lower for 4 out of the 8 remaining weeks, at which time mosquito reduction ranged from 91% to 48%. Also during that time, mosquito annoyance was at or above the State threshold for 2 of those weeks.

Generally, mean mosquito abundance in treated yards remained below the threshold of 25 mosquitoes per trap-night for 31 wk of the 35-wk study while mean abundance in control yards was below this same threshold for 17 wk (Fig. 2).

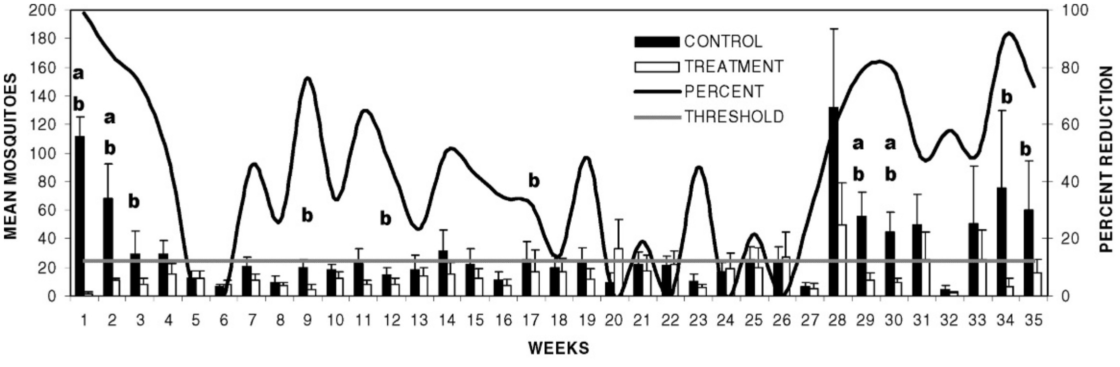
Table 2. List of mosquito species and percent collection from ABC suction light traps collected in residential backyards with and without the automatic-timed mist application system in northwestern Florida, March–November, 2007.

| Species | Percent collection Treatment | Percent collection Control |
|---|---|---|
| *Aedes albopictus* | 0.02 | <0.01 |
| *Ae. atlanticus* | 0.01 | <0.01 |
| *Ae. canadensis canadensis* | 0.07 | 0.11 |
| *Ae. sollicitans* | 0.01 | <0.01 |
| *Ae. taeniorhynchus* | 0.20 | 0.24 |
| *Ae. vexans* | 0.05 | 0.10 |
| *Anopheles crucians* complex | 0.24 | 0.22 |
| *Culex erraticus* | 0.11 | 0.07 |
| *Cx. nigripalpus* | 0.02 | 0.01 |
| *Cx. quinquefasciatus* | <0.01 | <0.01 |
| *Cx. salinarius* | 0.21 | 0.20 |
| *Culiseta inornata* | 0.03 | 0.01 |
| *Coquillettida perturbans* | 0.03 | 0.02 |
| *Psorophora ciliata* | 0 | <0.01 |
| *Ps. columbiae* | 0.20 | 0.03 |
| *Ps. ferox* | <0.01 | <0.01 |
| *Uranotaenia sapphirina* | 0 | <0.01 |
| Total number of specimens | 2,378 | 5,027 |

## DISCUSSION

Primarily, mosquito reduction in backyards with the MistAway system was achieved by the direct exposure of the mosquitoes to the spray application. Control was not consistent from week to week but fluctuated considerably and was probably influenced greatly by droplet size. Indeed, we found that knockdown/mortality in caged bioassays dropped off considerably at 9 m to <50% in our simulated backyard. Although wind speed is an important factor in drift, one cannot discount the influence that droplet size has on movement and impingement on a target, with smaller droplets traveling farther than larger ones. The droplet size range of a spray cloud for most adulticides applied by ground ultra-low volume equipment is much smaller (between 5 and 25 μm) than that from the Hago nozzles used in the MistAway system. This range is considered most efficient for impinging on a mosquito (Haile et al. 1982).

Little residual toxicity (<25%) occurred to mosquitoes exposed to treated leaves of the upper canopy after mist application and was not considered to be the primary means of reduction. Typical median droplet size distribution for an effective residual insecticide application on vegetation is between 100 and 150 μm (J. Barber, personal communication). Because of the smaller droplet size emitted from the Hago nozzles, it is plausible that not enough insecticide had been deposited on the plants to be considered as a useful residual application. Also, residual sprays are commonly applied in considerably greater




[a]Treatment and control means at each date significantly different ($P \leq 0.05$), [b]($P \leq 0.10$), Wilcoxon rank sum test. Wks 1-17 n=3, wks 18-36 n=2.

Fig. 2. Mean mosquito abundance in residential backyards from carbon dioxide-baited ABC suction light traps with and without the MistAway® automatic-timed misting system in northwestern Florida, March 22 through November 16, 2007.

volume than the 41 ml/min per nozzle in our study. Furthermore, after mist application we found no knockdown/mortality of either mosquito species when exposed to excised leaves from mid- and lower plant canopies (J. Cilek, unpublished data). It is obvious that spray volume and droplet size influenced these results.

During the summer and early fall, mosquito abundance generally remained below the State of Florida treatment threshold in ABC traps from control as well as treatment yards. This also coincided with a period of little rainfall. It is conceivable that the insecticide misting systems could have been turned off during that time and achieved similar results. This emphasizes an issue that concerns mosquito control professionals, i.e., application of insecticides on a calendar basis without regard to pest population levels. Such practices are inconsistent with integrated pest management practices. Indeed, the American Mosquito Control Association has issued a position paper on automatically timed mosquito misting systems, echoing this concern (AMCA 2008).

Additional areas of concern to be addressed are 1) the nontarget effects from organisms exposed to daily automated insecticide applications of synergized pyrethrins remain relatively unknown; 2) the effects on human health from inhalation exposure to the active ingredients in the direct spray; 3) the effects of chemical trespass into adjacent untreated areas, especially as these systems become more prevalent in residential areas; and 4) do automatic misting systems contribute to the emergence of insecticide resistance?

Individual misting units in relatively few backyards that are located in large neighborhoods are probably of little concern. But the prevalence of these systems is likely to increase. There are recent instances in which contractors who are building a few of the new housing developments in the South have installed permanent plumbing for individual backyard automatic misting systems as an incentive package for potential homebuyers.

Finally, from an operational standpoint it is unknown whether the label amount of active ingredient per acre per year could be exceeded in a neighborhood when one adds the 2 daily automatic mist applications from one (or several) backyard(s) to those of an organized mosquito control program's periodic applications of the same adulticide for area-wide control.

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