Evaluation of Barrier Sprays Containing a Pyrethroid and an Insect Growth Regulator to Control *Aedes albopictus* in a Suburban Environment in North Carolina

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Abstract
Barrier sprays are a common method for controlling a variety of diurnal and crepuscular mosquito species, especially for residential backyard applications. Little is known, however, about the extent to which barrier sprays containing insect growth regulators (IGR) such as pyriproxyfen affect immature mosquito development and life table characteristics. To learn more, we carried out a field study in a suburban Eastern North Carolina neighborhood from May 16–November 2, 2017. We evaluated the effect of Demand CS (pyrethroid adulticide with active ingredient lambda-cyhalothrin) and Archer (IGR with active ingredient pyriproxyfen) exposure with respect to reproduction (measured by fecundity, fertility, and adult emergence) and abundance of host-seeking mosquitoes *Aedes albopictus* (Diptera: Culicidae). These mosquitoes were collected using BG-Sentinel 2 traps; oviposition intensity was monitored using ovitraps for each property involved in the study. Eggs from ovitraps were reared in the laboratory to assess life table characteristics. Significantly more *Ae. albopictus* eggs ($p < .05$) were detected in ovitraps located in control lots, whereas no significant differences were observed in host-seeking adult abundance of *Ae. albopictus* between treatments. Potential reasons for this finding are discussed with respect to oviposition and host-seeking behavior of *Ae. albopictus*. Pyriproxyfen could be a useful control method for some populations of *Ae. albopictus*, especially where resistance to other active ingredients or cryptic oviposition sources are present.

Introduction

Aedes albopictus (Skuse) is an invasive mosquito species and a competent vector of several arboviruses (e.g., dengue, chikungunya, Zika). In the absence of effective vaccines, vector control is the primary means of controlling the spread of these arboviruses (Chandel et al., 2016). Larval oviposition sites for *Ae. albopictus* are diverse, ranging from natural sites (e.g., tree holes, bromeliads) to artificial containers (e.g., discarded tires, plant pot receptacles, birdbaths) (Hawley, 1988). Reducing routine sources of water-holding containers can help reduce populations of container-ovipositing mosquitoes. Furthermore, larvicides can be applied to mosquito oviposition sites to control mosquitoes before they emerge as adults. It can be difficult for larvicides, however, to reach cryptic oviposition sources and therefore larval control has proved to be difficult over large urban areas (Chandel et al., 2016; Fonseca et al., 2013).

Pyriproxyfen is an insect growth regulator (IGR) that mimics natural juvenile hormones to stop young insects (such as mosquitoes) from maturing into adults (Cross et al., 2015). The efficacy of pyriproxyfen autodissemination stations was assessed for *Ae. albopictus* and showed that *Ae. albopictus* carrying pyriproxyfen (from autodissemination stations) on body parts effectively contaminated cryptic cups (59–85%) and resulted in >29% pupal mortality (Chandel et al., 2016). A study with pyriproxyfen applied as a barrier spray in conjunction with the adulticide lambda-cyhalothrin showed efficacy at controlling *Ae. albopictus* for up to 4 weeks and suggested that increased scale (number of properties treated), frequency/timing of application during peak *Ae. albopictus* activity periods, and technique for application of barrier sprays are important for maximizing control (Unlu et al., 2018). Other studies have shown that sublethal doses of pyriproxyfen can have negative effects on life

Aerial View of the Study Area
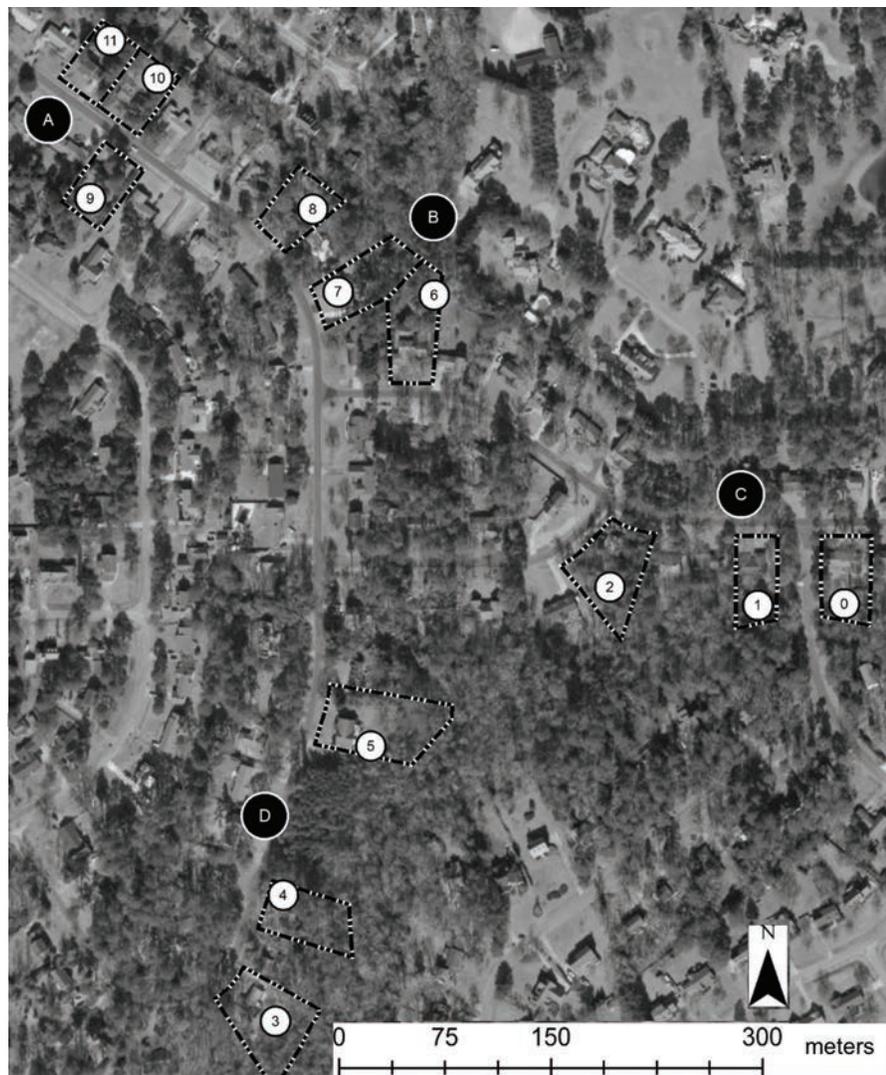
Dotted outlines represent lots included in the study for: A. Demand CS 0.03% + Archer 0.005% (every 30 days, code DA30); B. Demand CS 0.06% + Archer 0.010% (every 60 days, code DA60); C. Demand CS 0.03% (every 30 days, code D30); and D. control. White circles indicate BG-Sentinel 2 and oviposition traps. Numbers indicate de-identified codes for house addresses.

table characteristics of adult *Aedes aegypti* (Linnaeus). After exposure of *Ae. aegypti* larvae to pyriproxyfen, fecundity and fertility were measured in blood-fed adult females (Harburguer et al., 2014). In larval groups of *Ae. aegypti* exposed to a dose of pyriproxyfen (0.2 g/kg pyriproxyfen fumes for 8 min), adult emergence was reduced by 40% and fecundity and fertility were significantly reduced (Harburguer et al., 2014).

Lambda-cyhalothrin is a type II pyrethroid that is used in barrier sprays for adult mosquito control. Muzari et al. (2014) used leaves treated with lambda-cyhalothrin in a laboratory bioassay against *Ae. aegypti* and demonstrated high (>94%) knockdown after 1 hr of exposure to lambda-cyhalothrin and 100% mortality after mosquitoes were held for 24 hr in a clean container. Demand, with active ingredient lambda-cyhalothrin, 25 g/L,

was applied as a barrier spray in Australia and caused a significant decrease in mosquito populations, primarily *Verallina lineata* (Taylor) as measured using sweep net collections between treated and control sites (Muzari et al., 2014). A study in China evaluated Demand CS, with active ingredient lambda-cyhalothrin, 20 mg/m^2, used as a barrier spray against *Ae. albopictus*. In this study, human landing counts were used to assess differences in abundance of mosquitoes between treatment and control properties and a reduction of 83–98% of *Ae. albopictus* was observed in treatment compared with control sites (Li et al., 2010).

Many mosquito control programs do not possess the personnel and/or financial resources to consistently suppress *Ae. albopictus* effectively through source reduction and public education campaigns in peridomestic environments (Del Rosario et al., 2014; Faraji & Unlu, 2016). In many cases, the public turns to private pest management companies for assistance with mosquito control (e.g., barrier sprays) on their properties. Therefore, it is vital that the efficacy of different barrier spray products be evaluated.

We evaluated the extent to which different application rates and frequencies of a barrier spray containing Demand CS with Archer (active ingredient: pyriproxyfen) affects life table characteristics (fecundity, fertility, adult emergence rates) of *Ae. albopictus* in a suburban environment. We hypothesized that pyriproxyfen would negatively affect life table characteristics in *Ae. albopictus* because the mosquito would contact the IGR on foliage and potentially transfer it to multiple containers within the environment, as this mosquito is known to exhibit skip-oviposition behavior. We used a combination of field and laboratory methods to evaluate impacts on mosquito abundance and life table characteristics.

Methods

Recruitment of Participants

Our study was conducted in Pitt County in Eastern North Carolina in the Cherry Oaks neighborhood historically known for abundant *Ae. albopictus* populations (data not shown). Homeowners were invited to participate in the study via door-to-door invitation. If homeowners were home at the time

of the investigators' inquiry, we provided a verbal description with details of the study. For homeowners who were not home, we left a handout at their front door with contact information for investigators. Investigators conducted two to three follow-up visits until the homeowner was contacted and invited to participate in the study.

In total, 12 residences (grouped by three nearby residences for each treatment type) were targeted for recruitment in our study. Control properties were recruited and were at least 100 m from treatment properties. Participants were instructed not to carry out any insecticide treatments in their yards for the duration of the study. Barrier sprays were provided to homeowners free of charge for the duration of the study to encourage participation. The institutional review board (IRB) at East Carolina University was consulted and determined that the study did not meet the federal definitions of research involving human participants, hence full IRB review was not required.

Treatments

Certified pest control operators from Clegg's Pest Control (private company with a franchise location in Greenville, North Carolina) carried out barrier sprays for the project. Properties were treated via barrier sprays (Stihl SR 200 backpack blower mister) by a Clegg's Pest Control operator as follows (Figure 1):

1) Demand CS 0.06% + Archer 0.010% (every 60 days; treatment dates of June 13, August 15, and October 17) (code DA60).
2) Demand CS 0.03% + Archer 0.005% (every 30 days; treatment dates of June 13, July 13, August 15, September 15, and October 17) (code DA30).
3) Demand CS 0.03% (every 30 days; treatment dates of June 13, July 13, August 15, September 15, and October 17) (code D30).
4) Control (not treated).

The label recommends Demand CS be applied at the 0.06% rate for residual control of mosquitoes. In our study, we used this rate at an interval of 60 days and a lower rate (0.03%) at a more frequent interval of 30 days to evaluate efficacy. Similarly, the label recommends Archer be applied at the 0.010% rate for residual control of mosquitoes and in our study, we used this rate at an interval of 60 days and a lower rate (0.005%) at a more frequent interval of 30 days to evaluate effi-

TABLE 1

Total Adult Mosquitoes Collected From BG-Sentinel 2 Traps

Mosquito Species	Treatment			
	Control	Demand CS 0.03% (Every 30 Days)	Demand CS 0.03% + Archer 0.005% (Every 30 Days)	Demand CS 0.06% + Archer 0.010% (Every 60 Days)
Aedes albopictus	371	193	396	392
Ae. atlanticus	311	199	22	21
Ae. canadensis	3	4	0	0
Ae. japonicus	1	1	2	1
Ae. tormentor	60	29	2	11
Ae. triseriatus	3	7	1	0
Ae. vexans	26	9	10	36
Anopheles crucians complex	4	4	3	1
An. punctipennis	118	88	70	112
An. quadrimaculatus	5	4	7	7
Culex erraticus	44	51	17	26
Cx. pipiens/ quinquefasciatus	23	16	8	9
Cx. restuans	1	0	0	0
Cx. salinarius	0	0	0	1
Orthopodomyia signifera	3	1	0	0
Psorophora ciliata	5	1	6	2
Ps. columbiae	25	29	76	60
Ps. ferox	51	106	16	103
Ps. howardii	0	0	0	1
Toxorhynchites rutilus	1	0	0	0

cacy. Operators, following label instructions, applied 2–5 gallons of the finished solution per 305 m² in circular patterns to vegetation until runoff. Treatments were not conducted in high winds or misty/rainy conditions. We coordinated with the Pitt County Vector Control manager and the City of Greenville Public Works mosquito control operators to let them know of the ongoing study and requested that no insecticides be sprayed in the study area for the duration of the project.

Host-Seeking Mosquitoes

Host-seeking mosquitoes were sampled weekly May 16–October 31, 2017, using BG-Sentinel 2 traps (BioQuip) baited with human scent lure, octanol, and carbon dioxide. Carbon dioxide tanks containing regulators set

to release gas at 200 ml/min (BioQuip) were affixed upright to a shepherd's hook pole and a clear vinyl tube (1/4-in. outside diameter; 1/8-in. inside diameter) was clipped to the opening of the BG-Sentinel 2 trap. Each week, a BG-Sentinel 2 trap was set at each study residence (N = 12 traps) for a 24-hr period starting at approximately 9 a.m.

BG-Sentinel 2 traps were placed in a shaded area in the approximate center of properties within the barrier zone. When traps were retrieved the next morning at approximately 9 a.m., adult mosquitoes were transported to the laboratory on ice, identified to species using a dichotomous key (Harrison et al., 2016), and counted using a dissecting microscope. Data for each trap were tracked in Excel according to property address and date.

Mean Numbers (± *SE*) of Adult Female *Aedes albopictus* per BG-Sentinel 2 Trap in Different Treatment Areas After Treatment Commenced
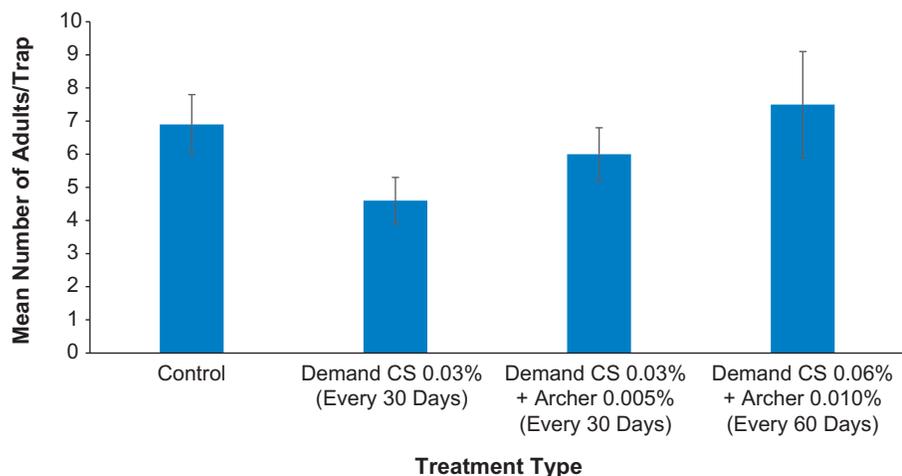
Note. No significant differences were observed between treatment areas.

Assessment of Oviposition Intensity

Egg-laying intensity of container-ovipositing mosquitoes was monitored to determine whether treatments affected this measure of fecundity. We expected eggs laid in ovitraps to originate from gravid mosquitoes residing in the same yards, as well as from mosquitoes immigrating into the yards from other yards in the vicinity. Eggs were collected weekly at all 12 sites (treatment and control) by using a standard oviposition trap (i.e., black plastic 500-ml cup half filled with tap water containing an oviposition substrate of seed germination paper (2.5 x 7 cm) placed inside around the circumference and drainage holes drilled 4 cm from the lip. The cup was zip tied to the same shepherd's hook pole to which the carbon dioxide tank (for the BG-Sentinel 2 trap) was affixed.

At each property, one ovitrap was placed continuously on the ground. The oviposition substrate was replaced weekly (when BG-Sentinel 2 traps were retrieved) for the duration of the study. Each week, the oviposition substrate was transported back to the laboratory and eggs were identified to mosquito species (Bova et al., 2016), counted, and added to data sheets coded for each property. The water in the cups was poured into Whirl-Pak bags each week, because larvae sometimes hatched on the strips; we tracked this information, also. After emptying each cup, fresh tap water was poured into the ovitraps.

Assessment of Life Table Characteristics

After eggs on oviposition substrates were counted, egg strips were dried (to stimulate hatching) and then submerged in 450–750 ml of tap water in emergence cages (Bio-Quip). For the purposes of this study, fecundity equals the number of eggs laid per trap, although we did not track how many mosquitoes laid eggs in each trap. We kept emergence cages in an incubator at 28 °C and fed larvae liver powder ad libitum. Approximately 5 days post-hatching, the number of larvae were counted to calculate fertility (fertility equals the number of larvae per trap divided by number of eggs on ovistrips per trap) and allowed to reach adulthood. Larvae that had hatched prior to the egg strip being retrieved (i.e., collected in Whirl-Pak bags) were also counted in the life table characteristics measures. Adults (females and males) from each brood, separated by date and address, were identified to species, counted, and sacrificed.

Weather Monitoring

Weekly averages for temperature and precipitation were retrieved and tabulated from Weather Underground, an online source of historical weather data. Time lags of 1, 2, 3, and 4 weeks were computed and used in statistical analyses of weather variables in relation to mosquito abundance.

Data Analyses

Statistical analyses were carried out using SAS and comparisons with $p < .05$ were considered significant. Kolmogorov–Smirnov tests were used to determine if the numbers of adult mosquitoes collected in different treatments and weeks were normally distributed. A nonnormal distribution was detected, hence data were log transformed ($\log [x + 1]$) prior to statistical analyses to improve normality. A mixed model using repeated measures (traps; control properties were used as a reference) determined the extent to which these variables differed between treatments and weeks: host-seeking adult *Ae. albopictus*, *Ae. albopictus* eggs (fecundity), all species of larvae (fertility), and all species of adults (including *Ae. albopictus*) that had emerged in the laboratory. We list all species collected in BG-Sentinel 2 traps (Table 1). Our analyses, however, focused primarily on *Ae. albopictus* because this species is targeted by BG-Sentinel 2 traps. Analyses of treatment effects were conducted after treatments had commenced (i.e., after week 24 in mid-June). The life span of mosquitoes is variable; therefore, time lags (1, 2, 3, and 4 weeks) were introduced into a regression model for weekly total rainfall amounts in relation to abundance of both *Ae. albopictus* eggs and host-seeking adults.

Results

Host-Seeking Mosquitoes

We collected a total of 3,220 adult female mosquitoes from 6 genera and 20 species in BG-Sentinel 2 traps over 24 weeks from May 16, 2017, to October 31, 2017 (Table 1). Of these, 1,352 were *Ae. albopictus* adults (42% of total adults collected). The mean numbers of adults per trap week for each treatment are shown in Figure 2.

Week 24 (before treatments had started; traps set and retrieved June 12 and 13, 2017) and week 27 (before second treatment for lots treated every 30 days; July 6 and 7, 2017)

FIGURE **3**

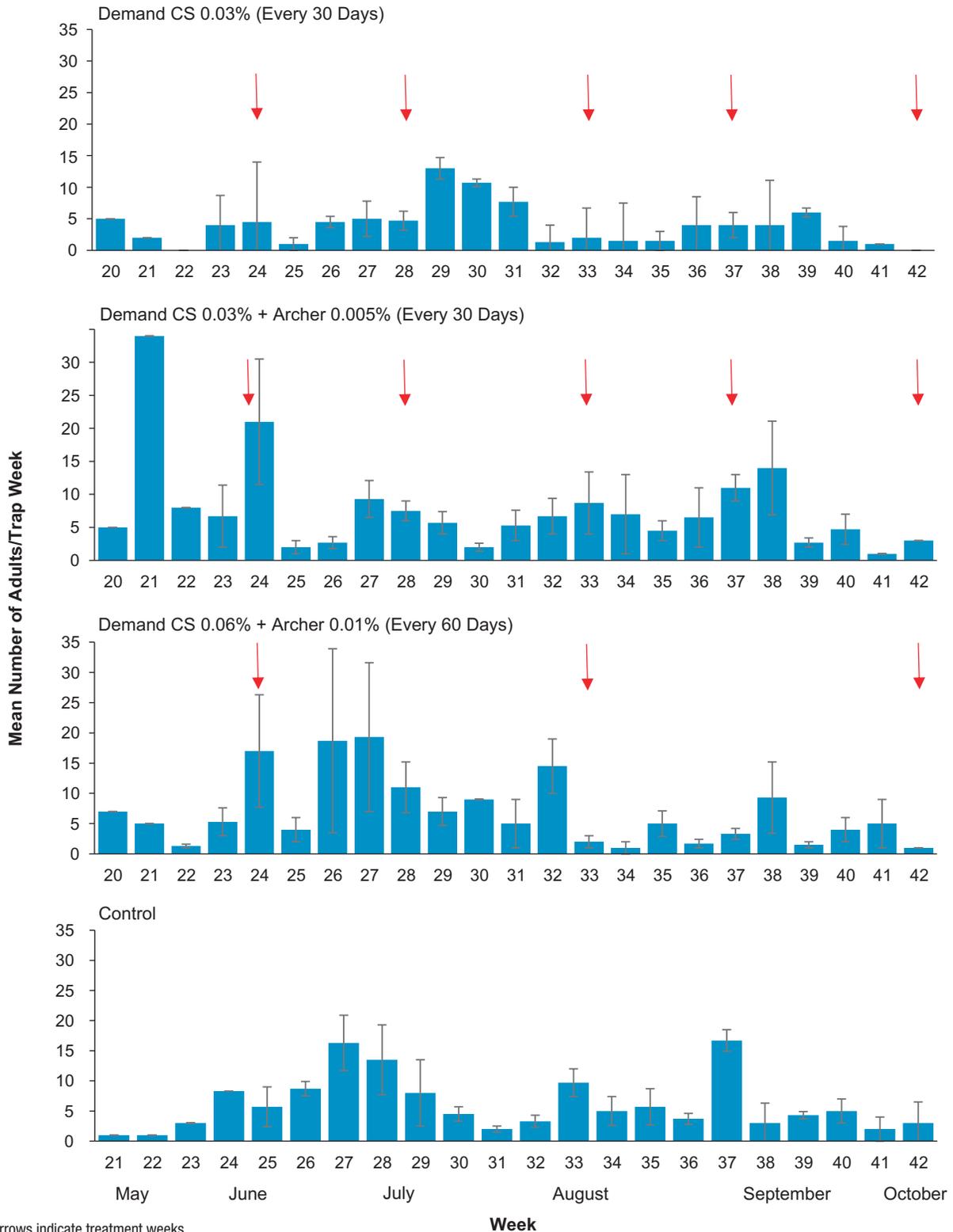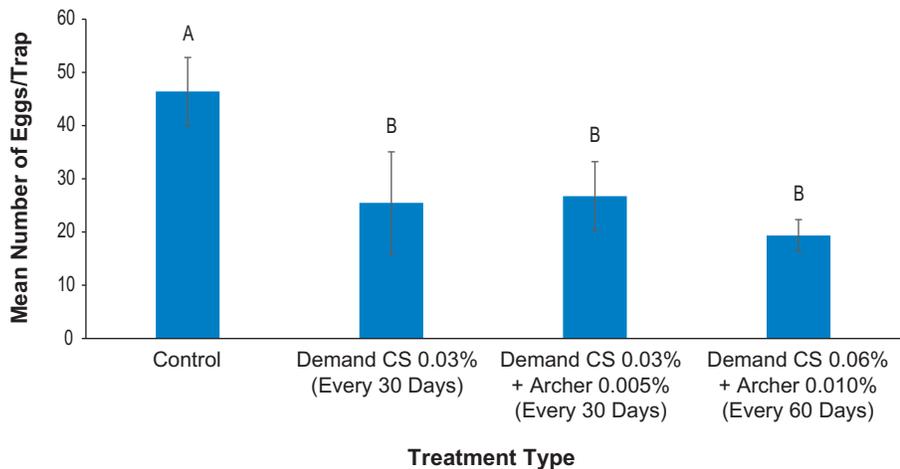**Weekly Means (± *SE*) of *Aedes albopictus* Adults Collected in BG-Sentinel 2 Traps**

Note. Red arrows indicate treatment weeks.

Mean Numbers (± *SE*) of *Aedes albopictus* Eggs per Ovitrap in Different Treatment Areas

Note. Means with different letters indicate significant differences (*p* < .05).

showed a significantly higher mean number of *Ae. albopictus* per BG-Sentinel 2 trap than the other weeks of the study (*df* = 22; *F* = 2.65; *p* = .002); however, no differences between treatments were observed (*df* = 3; *F* = 1.06; *p* = .417; Figure 3).

After week 24 (when treatments had commenced), no significant differences were observed in the abundance of host-seeking female *Ae. albopictus* between treatments (*df* = 3; *F* = 0.99; *p* = .444). We did observe, however, differences in abundance of *Ae. albopictus* adults between weeks when all treatments were considered in the analyses (*df* = 17; *F* = 2.41; *p* = .003). When analyses were performed for each treatment type individually, analyses after week 24 indicated no significant differences in mean numbers of host-seeking *Ae. albopictus* between weeks in traps placed at DA60 lots (*df* = 17; *F* = 1.36; *p* = .243) or DA30 lots (*df* = 17; *F* = 1.31; *p* = .259). Significant differences, however, were observed in mean numbers of host-seeking *Ae. albopictus* per trap between weeks in D30 lots with the highest in week 29 (July 19 and 20) (*df* = 16; *F* = 2.58; *p* = .022) and also in control lots, with the highest in week 27 (July 6 and 7) and week 37 (September 14 and 15) (*df* = 22; *F* = 2.45; *p* = .009). Figure 3 presents this information.

The numbers of host-seeking *Ae. albopictus* collected in control lots (*df* = 17; *F* = 2.66; *p* = .002), D30 lots (*df* = 16; *F* = 2.78; *p* = .015), and DA60 lots (*df* = 17; *F* = 2.86; *p* = .012) could be predicted by average temperatures during the week of collection, but not for DA30 lots (*df* = 17; *F* = 1.31; *p* = .259). Likewise, rainfall during the week of collection was a positive predictor of host-seeking *Ae. albopictus* collected in traps in the D30 lots (*df* = 17; *F* = 3.92; *p* = .05).

Aedes albopictus Eggs
We collected a total of 4,423 *Ae. albopictus* eggs in ovitraps during the study from May 16, 2017, to November 2, 2017. The mean numbers of *Ae. albopictus* eggs per trap for each treatment are shown in Figure 4. Significant differences were observed in the abundance of *Ae. albopictus* eggs between treatments (*df* = 3; *F* = 4.62; *p* = .037), with the control lots having higher abundance compared with treatment lots. Conversely, we did not observe statistically significant differences in abundance of *Ae. albopictus* eggs between weeks (*df* = 19; *F* = 1.05; *p* = .412; Figure 5).

Data for ovistrips collected from the field and mosquitoes reared in the laboratory are shown in Figures 5 and 6. Significant differ-

ences were observed in the mean numbers of larvae hatched per ovitrap (fertility) between treatment groups (*df* = 3; *F* = 4.32; *p* = .043). Significantly more larvae of all species hatched from eggs on strips collected from control lots compared with other groups. We observed a similar pattern in the mean numbers of *Ae. albopictus* adults (females and males that were reared in the laboratory from ovistrips collected in the field; *df* = 3; *F* = 2.82; *p* = .041) and total adults of all species (*df* = 3; *F* = 4.04; *p* = .050) among treatment groups. Furthermore, significantly more adult *Ae. albopictus*—and adults of all species—emerged in the control group compared with other groups.

The number of *Ae. albopictus* eggs collected could be predicted by average rainfall 4 weeks before collections in control lots (*p* = .013) and DA30 lots (*p* = .014), as well as by temperatures 3 weeks before collections in DA60 lots (*p* = .026). No other significant relationships were observed between weather variables and *Ae. albopictus* abundance.

Discussion
Week 24 was one of the weeks with a significantly high abundance of host-seeking *Ae. albopictus* in BG-Sentinel 2 traps. The trapping for week 24 occurred the day prior to the first barrier spray treatments of the study and provided a baseline of early-season mosquito populations in a North Carolina suburban neighborhood. After treatments had commenced, no significant differences in host-seeking *Ae. albopictus* abundance were observed for DA60 or DA30 lots between weeks. Hence, these two treatment regimens might have interrupted *Ae. albopictus* occurrence and abundance within the study lots. Of note, however, we observed significantly higher host-seeking *Ae. albopictus* adults in D30 lots in mid-July compared with the other weeks of the study; this finding suggests a lack of interruption in these lots during this time of year. As bimodal peaks (early July and mid-September) of *Ae. albopictus* adults were detected in control lots, the DA60 lot and DA30 lot treatments might have interrupted host-seeking *Ae. albopictus* occurrence during these periods.

As others have reported, the movement of *Ae. albopictus* from untreated properties into treated properties can confound the interpretation of adult trap counts (VanDusen et al.,

FIGURE **5**

Weekly Means (± *SE*) of *Aedes albopictus* Eggs Collected in Ovitraps
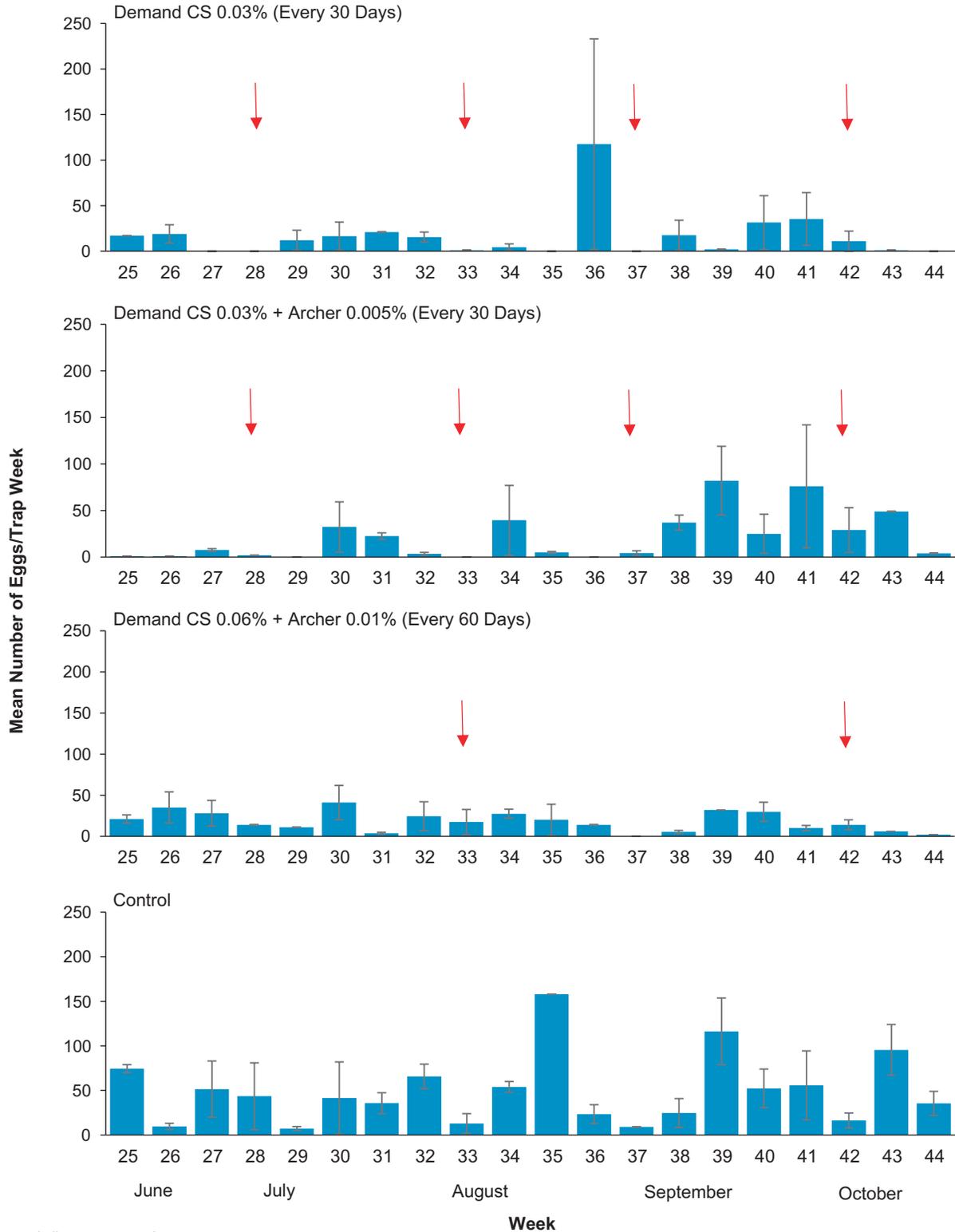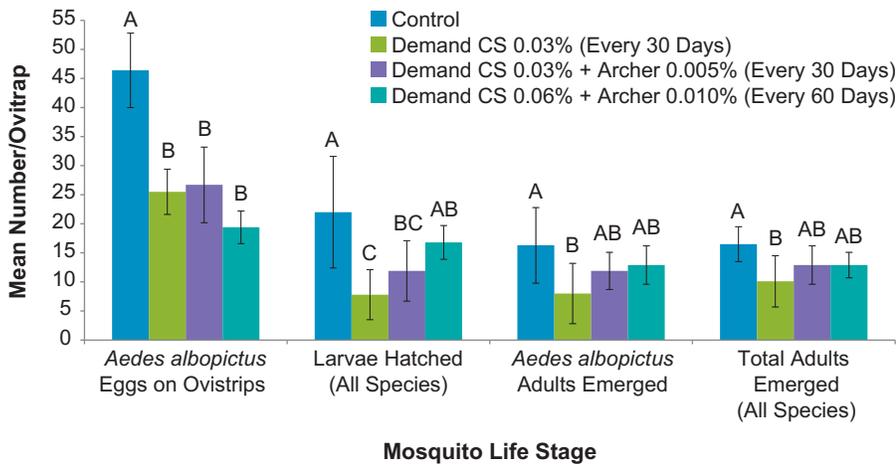

Note. Red arrows indicate treatment dates.

Mean Numbers of Mosquitoes at Different Life Stages Collected in Ovitraps and Reared in the Laboratory

Note. Means with different letters indicate significant differences within variables ($p < .05$).

2016), especially when single properties are treated but are surrounded by untreated properties. A greater distribution of BG-Sentinel 2 traps within the neighborhood could improve the estimation of adult mosquitoes (VanDusen et al., 2016); however, the skip oviposition behavior of *Ae. albopictus* increases the likelihood that these mosquitoes will oviposit in containers from neighboring yards within its flight range of <200 m. It is likely that application technique; frequency of application; scale (i.e., number of adjacent properties treated); number, size, and organic content of water-holding containers present; and other unknown factors impact efficacy (Unlu et al, 2018). This type of barrier spray treatment using a mixture of adulticide and IGR shows promise and should be evaluated further.

Truck-mounted ultralow volume application of pyriproxyfen has also been shown effective for control of *Ae. albopictus* (Doud et al., 2014; Unlu et al., 2017) and should be investigated further as a control method for *Ae. albopictus* and other container-ovipositing mosquitoes. We noted that foliage and brush was cut away at one of the properties within the DA30 lot during weeks 38–39 (late September, approximately 2 weeks after a treatment), which might have affected trap counts during this period. Furthermore, the

same property within the DA30 lot was only partially treated during the mid-September monthly treatment due to a pet left outdoors. This variable might have affected the results for the traps set at this residence during the latter part of September.

Significantly more *Ae. albopictus* eggs were observed in control lots; therefore, treatments might have negatively affected mosquito egglaying. As expected, these effects varied across weeks. These findings are similar to another study that used a different delivery method via pyriproxyfen autodissemination stations and showed significantly lower numbers of eggs collected from treatment compared with control ovitraps (Unlu et al., 2017). Pyriproxyfen has a delayed effect on *Ae. albopictus* populations because the adults that contact the IGR then deliver the active ingredient to containers in their environment during oviposition—hence these dynamics should be considered when interpreting results.

The greater numbers of hatched larvae per ovitrap and *Ae. albopictus* adults emerging from ovistrips collected in control lots makes sense, as these lots were not treated with any insecticides. We expected, however, the lowest numbers of larvae and emerged adults in the lots where high-frequency treatments occurred every 30 days with the pyrethroid

and IGR (DA30). This group was equivalent to larvae collected from DA60 lots that had a lower insecticide application frequency, but higher insecticide concentration, of the IGR. It might be possible, therefore, to treat with a higher-labeled concentration of Demand CS with Archer less frequently depending on labor, weather, and other constraints of mosquito control applicators.

While we did not detect any differences in overall host-seeking mosquito abundance between treatments, we did detect week-to-week variation in abundance based on weather variables, treatment dates, and other unknown factors. In field studies, year-to-year variation in mosquito populations is likely and should be considered and analyzed. There might even be differences in levels of insecticide susceptibility and resistance in mosquito populations within the same season; we did not address these questions in our study. One possibility is that a greater number of adjacent properties should be treated in order to increase the potential effects of barrier treatments. This increased scale potentially could minimize the number of mosquitoes immigrating into treated properties—and potentially into CO_2-baited traps or to lay eggs in ovitraps—from untreated properties.

We expected mosquito abundance to vary over time and under different biological and environmental conditions. In our study, there was no predictive relationship between time-lagged rainfall or temperature with host-seeking *Ae. albopictus* abundance. We found it interesting that temperature the same week of trapping was a significant predictor of host-seeking *Ae. albopictus* in properties within control, D30, and DA60 lots, which indicates that temperature likely plays a role in host-seeking activity. Rainfall 4 weeks prior (properties within control and DA30 lots) and temperatures 3 weeks prior (DA60) to trapping were predictive of numbers of *Ae. albopictus* eggs. This finding strengthens the assumption that rainfall and temperature are factors that, in part, drive mosquito abundance and could influence the efficacy of barrier treatments due to degradation of active ingredients with environmental pressure. It makes sense, though, that these trends were not consistent across all groups, as there likely was variation in abundance of water-holding containers, influence of neighboring

properties, and other unknown factors that we did not assess.

Interestingly, the lowest number of hatched larvae and *Ae. albopictus* adults that emerged came from the D30 group, which could illustrate some degree of natural variation in *Ae. albopictus* abundance between lots and/or that the adulticides affected egg laying and/or hatch rates. The reason for assessing life table characteristics (i.e., fecundity, fertility) for eggs laid in the field in the different control and treatment properties was to determine if the IGR and/or adulticide affected egg laying or hatching. While it would be difficult to ascertain the degree to which mosquitoes from adjacent untreated properties laid eggs in our ovitraps, we see this study as a starting point for evaluating this specific IGR-adulticide mixture used in barrier spray applications. Laboratory studies are ongoing and we will further analyze the relationship between IGR exposure in adult mosquitoes and subsequent measures of fecundity and fertility.

As *Ae. albopictus* continues to expand its geographic range, additional research into alternative approaches, such as barrier treatments with mixtures of IGRs and adulticides, are needed to improve mosquito management programs. To maximize *Ae. albopictus* control, mosquito control personnel should remove or empty water-holding containers, treat containers with larvicide during each visit to the property, and inform homeowners how to eliminate mosquito oviposition sites. Individual homeowners and/or homeowner's associations should consider implementing neighborhood education campaigns to inform homeowners about preventable mosquito issues. These education and source-reduction practices, along with barrier treatments, can be used together as part of an integrated mosquito management approach to prevent and reduce nuisance mosquitoes to protect public health.

Conclusion

Pyriproxyfen might be a useful control method for some populations of *Ae. albopictus*, especially where resistance to other active ingredients or cryptic oviposition sources are present. Comparisons could be done to evaluate the efficacy of autodissemination stations, barrier sprays, and/or other methods of application for this IGR, as well as this IGR/adulticide mixture. In addition, the size, level of organic content, and occurrence and abundance of water-holding containers in the landscape could be assessed throughout the mosquito season to test the efficacy of pyriproxyfen at controlling mosquitoes in a variety of container types. The results from this field study have led us to conduct a controlled laboratory study to further evaluate the impacts of pyriproxyfen on life table characteristics in *Ae. albopictus* (Rhyne & Richards, 2020). Taken together, the data gained from these studies will inform mosquito control personnel about the efficacy of barrier sprays against *Ae. albopictus*.

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