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COMPARATIVE ACTIVITY AND EFFICACY OF SUMILARV 0.5G AND ALTOSID XR BRIQUET AGAINST *CULEX QUINQUEFASCIATUS* AND *AEDES AEGYPTI* IN SIMULATED CATCH BASINS

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ABSTRACT. Mosquito control plays a crucial role in the mitigation of mosquito-borne diseases. Larviciding that targets one of the aquatic stages is among the routine practices in mosquito control operations. One of the most extensive and challenging mosquito production sources in urban environments is underground storm drain systems. Along with the research and development of biorational larvicides in recent decades, numerous products based on microbial and insect growth regulators have become available. However, the performance of these products often varies because of product design and challenges associated with urban storm drain systems. This paper validates the comparative bioactivity and semifield efficacy of 2 control release products based on pyriproxyfen and S-methoprene. In laboratory bioassays, pyriproxyfen was significantly more active than S-methoprene against the test species, *Culex quinquefasciatus* Say and *Aedes aegypti* (L.). *Culex quinquefasciatus* was less susceptible than *Ae. aegypti* to both test materials. During a 26-wk-long semifield evaluation using the cast concrete simulated catch basins, the inhibition of emergence pretreatment and posttreatment in untreated control was negligible. The Sumilarv 0.5G applied at 75 g per catch basin provided 100% IE, whereas the Altosid XR briquet applied at 1 per catch basin yielded only partial control fluctuating from 12.7% to 82.7% (average 40.7%) of *Cx. quinquefasciatus* and 8.0% to 78.8% (average 37.4%) of *Ae. aegypti*. The Altosid XR briquet had an average residual weight of 59.9% at the end of semifield evaluation. Results are discussed in relation to field mosquito control operations in urban storm drain systems.

KEY WORDS *Aedes aegypti*, *Culex quinquefasciatus*, pyriproxyfen, S-methoprene, semifield efficacy, simulated catch basin

INTRODUCTION

Upon economic development, climate change, and urbanization, risk and burden of mosquitoes and mosquito-borne diseases have been on the rise, particularly in the tropical and subtropical regions. This scenario has been evidenced by emergence and resurgence of indigenous and exotic vector species and associated diseases (Sutherst 2004, Rocklöv and Dubrow 2020). Mitigation of nuisance and disease vector species heavily relies on environmental management and strategic application of pesticides. Generally, larvicidal operations that target the confined aquatic stage are more practical and effective and have a lower risk of resistance development to insecticides as compared with combating the air-borne adult stage (Su 2022). However, product availability for mosquito larval control is at a historical low because of reasons such as strict regulation, high cost of research and development, low market share and profitability, as well as resistance development in response to repeated applications. Microbials and insect growth regulators (IGRs) are the two major groups of active ingredients (AI) that have been developed for practical uses in mosquito control.

Among the common and diverse mosquito production sites, storm drain systems in urban areas could never be overemphasized (Su et al. 2003, Kwan et al. 2008, Metzger et al. 2008, Harbison et al. 2011, Rydzanicz et al. 2016). Often mosquito production prevention measures are rarely considered proactively when drain systems are designed and implemented in urban development. Mosquito operations therefore inherit the difficulties in mosquito management due to the poor design, unease in access, and neglected maintenance of the massive system that consist of manholes, lateral channels, and catch basins. Various stagnant water *Culex* species, often vectors of West Nile virus, are commonly found in storm drain systems. Recently floodwater species such as the yellow fever mosquito, *Aedes aegypti* (L.), and the Asian tiger mosquito, *Ae. albopictus* (Skuse), have also adapted to the same environment (Paploski et al. 2016, Gao et al. 2018, Wang et al. 2021).

Although innovative design and proper maintenance of the catch basins in urban drain systems are helpful to minimize mosquito production, use of environmentally friendly larvicides is a routine practice by many vector control entities. Because of the irregular flooding, unpredicted water quality, uneasy accessibility for sampling and pesticide application, inconsistent efficacy of control products that are designed for catch basin treatment have been often encountered (Siegel and Novak 1997, 1999; Stockwell et al. 2006; Anderson et al. 2011; Harbison et al. 2015, 2016, 2018; Nasci et al. 2017). Compared with traditional larvicides that kill the larvae directly, juvenile hormone mimic (JHM) pyriproxyfen and juvenile hormone analog (JHA) S-methoprene need more sophisticated evaluation protocols to determine inhibition of emergence (IE) (Knepper et al. 1992; Stockwell et al. 2006;

Fig. 1. The formulations for evaluation in simulated catch basins: Sumilarv 0.5G foil package (A), Sumilarv 0.5G granules (B), and Altosid XR briquet (C).

Bellini et al. 2009; Nasci et al. 2017; Harbison et al. 2018; Mian et al. 2017, 2020; Su and Su 2022a). A new product, Sumilarv 0.5G, that contains 0.5% pyriproxyfen has become available recently for mosquito control in catch basins and other persistent production sites. To optimize product selection, laboratory bioassays were conducted to compare the bioactivity of pyriproxyfen, S-methoprene, and their formulations of Sumilarv 0.5G and Altosid XR briquet, respectively, against *Culex quinquefasciatus* Say and *Aedes aegypti* (L.). Semifield efficacy of Sumilarv 0.5G and Altosid XR briquet was also carried out in simulated cast concrete catch basins against the same species, in consideration of their labeled application patterns for persistent mosquito product sites.

MATERIAL AND METHODS

Test materials

Technical pyriproxyfen: The technical grade (Nylar®) contains 98.8% pyriproxyfen. This sample was provided by MGK (Minneapolis, MN, lot no. 26516 and sample no. 294-16).

Technical S-methoprene: The technical grade contains 98.06% S-methoprene (Environmental Protection Agency [EPA] 73487-1) and was provided by Synergetica International (Marlboro, NJ, lot no. MT08-218).

Sumilarv 0.5G: This product consists of control release fine granules with a relative density of 2.06 g/cm^3 and contains 0.5% pyriproxyfen (Fig. 1). This sample

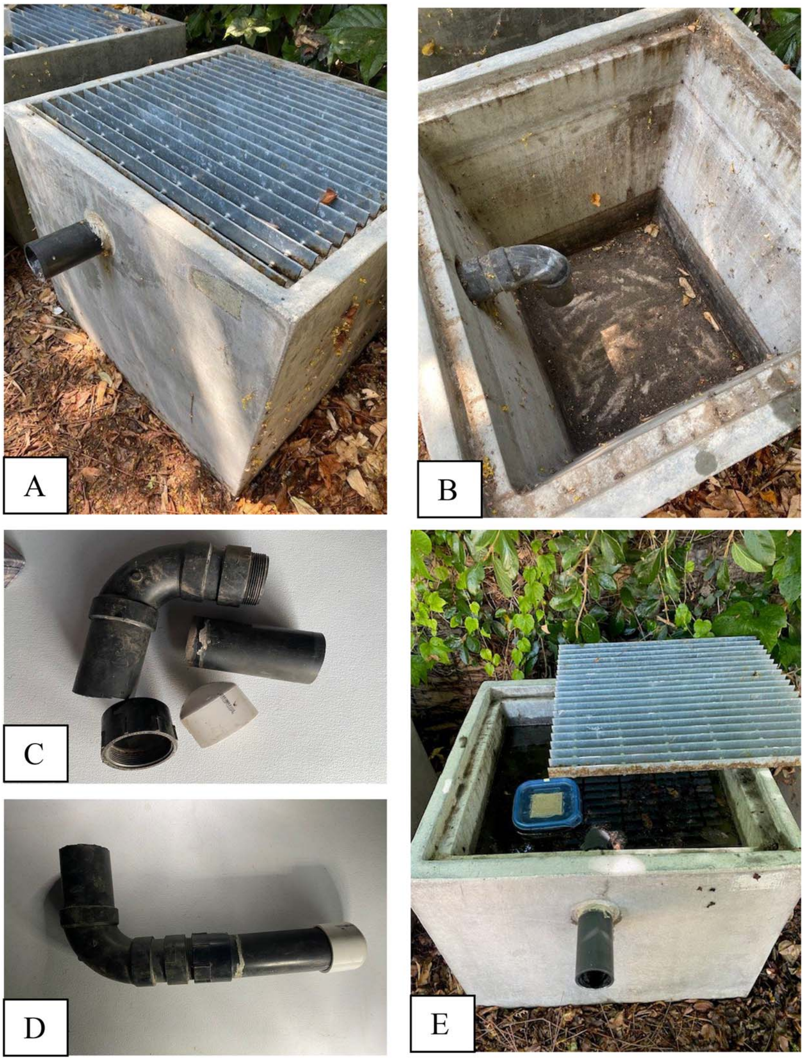

Fig. 2. Cast concrete simulated catch basin: exterior overview (A), interior overview (B), drainpipe components (C), assembled drainpipe (D), and basin in operation (E).

was provided by MGK (lot no. 7015F4, EPA registration no. 1021-2819, and sample no. 221-19).

Altosid XR briquet: This product is an extended release briquet formulation with a relative density of 1.04 g/cm^3 and an average weight of 54.86 g/briquet containing 2.1% S-methoprene (Fig. 1). The samples were provided by MGK (lot no. 1807122465-5, EPA registration no. 2724-421).

Laboratory bioassay

Mosquitoes: The southern house mosquito *Cx. quinquefasciatus* was from natural infestation of the local populations in inland southern California, and the yellow fever mosquito *Ae. aegypti* was provided by the Benzon Research (Carlisle, PA). Considering the susceptible window time for JHM and JHA, which is generally 12–24 h prior to pupation, the late 4th-stage larvae, sometimes called pupating larvae, were used in the bioassay (Su et al. 2021).

Bioassays: A laboratory bioassay was conducted according to the previously published protocols (Su et al. 2021) with slight modifications in sample preparation for the Altosid XR briquet. The technical pyriproxyfen and S-methoprene were dissolved in and serially diluted with ACS pure acetone (Cole Parmer, Vernon Hills, IL). The granules from the Simularv 0.5G were suspended in deionized (DI) water by vortexing for 3 min at 3,400 rpm (Vortex Mixer VX 200; Labnet International, Edison, NJ). The fine particles were sanded off from the Altosid XR briquet with a piece of 800-grade sand cloth and suspended in

DI water by vortexing for 5 min at the same speed as described previously. Serial dilutions were made immediately after vortexing. In the bioassay, 6 concentrations within the range resulting in approximately 5–95% mortality plus untreated control (UTC) were used, with 3 replicates at each concentration and UTC. In each replicate, 25 larvae were placed in 100 ml tap water in a 120-ml disposable Styrofoam cup. A small piece (approximately 100 mg) of rabbit pellet (18% crude protein; Brookhurst Mill, Riverside, California) was added to each bioassay cup to have a slow release of nutrients to support larval growth to pupation. Bioassays were conducted at 27.0–29.0°C and relative humidity (RH) 50–60%. The mortality was recorded when all exposed individuals died at larval or pupal stage, emerged incompletely, or emerged successfully as adults.

Semifield evaluation

Catch basins: The cast concrete catch basin system used in this study was designed structurally and functionally to mimic conditions occurring in typical parking lot catch basins to capture storm surges and trap sediments and oil residues. The air-lock design described by Brooks et al. (1963) in typical drains was achieved with an inverted 90° pipe. To realize a similar design, the cast concrete basin (exterior size: 66.0 × 66.0 × 66.0 cm; interior size: 55.9 × 55.9 × 55.9 cm) was fitted with an inverted 5.1 cm diam ABS overflow pipe at the 7.6 cm below the top. The lid of the basin was galvanized metal grids (2.5 × 10 cm) to simulate a catch basin cover for aeration and rainwater collection (Fig. 2). The water volume in the basin was 150.7 liters. Catch basins were placed in a semishaded area in suburban southern California.

Basin preparation and treatment: Basins were installed with 10-cm-deep topsoil (Miracle-Gro, Scotts Miracle-Gro Company, Marysville, OH) and 100 g rabbit pellets, and then filled with tap water and allowed to season outdoors for 10 days. During fermentation, the basins were covered with window screens, and the drainpipe of each basin was capped to prevent oviposition by mosquitoes from the natural populations. A minimum-maximum thermometer was placed in one of the basins located in the middle of the basin layout to monitor the water temperature during the study period. After fermentation, the screen and drainpipe cap were removed and oviposition by natural *Culex* populations was allowed. During the test period, basins were gently flushed weekly at 2.27 liters/min by adding tap water at 10% (15.1 liters) of the full volume, and allowing it to exit from the overflow pipe, a simulation of dilution by rains. Three replicates were made for each treatment and UTC; in total 9 catch basins were used. Treatment was made on day 6 after screen removal when the 3rd instars prevail in larval numbers. Sumilarv 0.5G in the amount of 75 g was evenly broadcasted over the water surface of the designated treatment basin; this application amount was equivalent to 3 × 25 g water soluble sachets that were registered and became available later. One Altosid XR briquet was dropped in the center of the water surface in the treatment basins.

Efficacy evaluation: Quantitative IE was used to determine the efficacy of pyriproxyfen and S-methoprene formulations. To ensure that the basins used did not have preexiting IE activity, pretreatment sampling was conducted for all basins. During the 1st and the 5th months, basins were sampled weekly to determine expected efficacy increase and decrease respectively, while samples were collected biweekly during the 2nd to 4th months to observe the efficacy persistence. For *Cx. quinquefasciatus*, 75–100 late 4th-stage larvae were collected pretreatment from each basin and allowed to pupate, and observation was made for adult emergence out of 50 pupae. On each sampling day posttreatment, 50 pupae were collected from each replicate in treatments and UTC. Collected pupae were kept in 200 ml of water from the basin where pupae were collected. Pupae were observed for adult emergence in the insectary (26.7–29.4°C) by counting free pupal exuviae (completely detached from adults), dead pupae, and partially emerged adults (still attached to exuviae). For *Ae. aegypti*, 75–100 of late 4th-stage larvae were introduced to a sentinel cage in each basin pretreatment and on each sampling day posttreatment. The sentinel cage was made of a 946.4 ml square plastic tub, a 5.1 × 5.1 cm square window was made in the center of each of 4 sides, and the window was covered by a 0.3 mm screen to allow water to run through freely but to retain the larvae and pupae. The same screened window was also made in the center of the lid to ensure ventilation and to keep debris from falling into the cage. A plastic foam belt was attached underneath the rim of the cage as a floater (Su and Su 2022b). Fifty pupae were collected from each sentinel cage, and the subsequent handling and result reading were carried out in the same manner as in *Cx. quinquefasciatus*. After collection of 50 pupae, the remaining pupae or larvae if any were discarded. After each weekly flushing, 50 g of rabbit pellets were added to each basin to maintain the organic level and oviposition attractancy.

Species composition in natural populations: Approximately 50 3rd- and 4th-stage larvae were collected from randomly selected basins in weeks 1, 13, and 26 posttreatment. Larvae were killed by 95% ethanol, and species was identified morphologically under a dissecting microscope.

Determination of residual weight of Altosid XR briquet: Upon conclusion of the evaluation in week 26, the briquets were carefully retrieved from the treated basins, air dried for 5 days at 26.7–29.4°C, and residual weight was determined and compared with its original weight for each briquet.

Data analysis

Concentration-response data were corrected with the Abbott formula (Abbott 1925) if the mortality in UTC ranged from 5% to 20%, and then analyzed

Table 1. Laboratory bioassays on technical and formulated pyriproxyfen and S-methoprene against the test species.[1]

Products	IE_{10} (ppb) (95% CI)	IE_{50} (ppb) (95% CI)	IE_{90} (ppb) (95% CI)
Culex quinquefasciatus			
Technical pyriproxyfen	**0.042** (0.032–0.056)	**0.123** (0.072–0.216)	**0.400** (0.294–0.590)
Sumilarv 0.5G	**0.036** (0.036–0.059)	**0.127** (0.086–0.243)	**0.388** (0.283–0.602)
Technical S-methoprene	**0.654** (0.435–1.245)	**3.163** (2.49–5.55)	**18.446** (13.79–28.54)
Altosid XG briquet	**0.778** (0.561–1.870)	**3.374** (2.743–5.990)	**19.351** (15.112–29.489)
Aedes aegypti			
Technical pyriproxyfen	**0.010** (0.006–0.019)	**0.039** (0.029–0.053)	**0.162** (0.117–0.243)
Sumilarv 0.5G	**0.008** (0.005–0.012)	**0.044** (0.034–0.077)	**0.192** (0.144–0.288)
Technical S-methoprene	**0.252** (0.166–0.364)	**1.514** (0.949–2.13)	**7.543** (5.154–12.433)
Altosid XG briquet	**0.334** (0.289–0.520)	**1.715** (1.034–2.69)	**8.599** (5.675–14.312)

[1] Mortality data were corrected by factoring the mortality in untreated control (5.8–9.4%), using the Abbott formula (Abbott 1925) before probit analysis. IE_{10}, IE_{50}, and IE_{90}: concentrations causing 10%, 50%, and 90% inhibition of adult emergence, respectively. CI = confidence intervals; ppb = parts per billion.

using POLO (Robertson et al. 1980) to calculate the concentrations causing 10%, 50%, and 90% IE (IE_{10}, IE_{50}, and IE_{90} respectively) and their 95% confidence intervals (95% CIs). The bioassay was repeated if the mortality at UTC reached 20% or greater. The significant differences in IE between test materials and test species were determined with separate 95% CIs (Su and Su 2022a, 2022b, 2023). In the catch basin test, the IE was calculated: IE% = 100 × [1 − (number of successfully emerged adults/total number of pupae collected)]. The significance in IE% among treatments and UTC was analyzed with a chi-square test at $\chi^2 = 3.82$, $P = 0.05$, or $\chi^2 = 6.63$, $P = 0.01$ levels (Social Science Statistics 2022).

RESULTS

Laboratory bioassay

In laboratory bioassays, the typical mode of action by JHM and JHA was observed in all test materials. The mortality presented as some incomplete emergence, primarily dead pupae, and occasionally dead larvae upon concentration increase in the dose-response range. The mortality rate in UTC ranged from 5.8% to 9.4%. The IE_{10}, IE_{50}, and IE_{90} were calculated after data correction with the Abbott formula. As indicated by separate 95% CIs ($P < 0.05$), the activity of pyriproxyfen was significantly higher than S-methoprene in technical and formulated products and in both test species; the susceptibility of *Cx. quinquefasciatus* to both pyriproxyfen and S-methoprene was significantly lower than that of *Ae. aegypti* ($P < 0.05$) across all test materials. The difference in activity between technical grades and formulations was negligible in pyriproxyfen and S-methoprene regardless of test species ($P > 0.05$) (Table 1).

Semifield evaluation

Efficacy against Cx. quinquefasciatus: The designated treatment and UTC basins had a very low and comparable IE prior to treatment, 0–4.0%, averaging 2.4%. The UTC showed very minimum IE after treatment throughout 26 wk of the evaluation period, ranging from 0.7% to 5.3%, averaging 4.0%. At the same time, both Sumilarv 0.5G and Altosid XR briquet treatments resulted in significantly higher IE as compared with that in UTC ($\chi^2 > 6.63$, $P < 0.01$). The Sumilarv 0.5G treatment resulted in 100% control, while the counterpart product Altosid XR briquet yielded only partial control with great fluctuations from 12.7% to 82.7%, with an average of 40.7% (Fig. 3), whereas the former significantly outperformed the latter at every sampling interval posttreatment ($\chi^2 > 6.63$, $P < 0.01$).

In the case of *Ae. aegypti*, a similar trend held true. The designated treatment and UTC showed a very low and comparable IE prior to treatment, 4.7–7.3%, averaging 6.2%. The UTC continued to show very minimum IE throughout the evaluation period, ranging from 0.7% to 8.0%, averaging 4.7%. Meanwhile, both treatments provided significant control as compared with UTC ($\chi^2 > 6.63$, $P < 0.01$). The Sumilarv 0.5G provided 100% IE, and the Altosid XR briquet only yielded partial control fluctuating from 8.0% to 78.8%, with an average of 37.4% (Fig. 3). As in *Cx. quinquefasciatus*, Simularv 0.5G consistently outperformed Altosid XR briquet throughout the evaluation period posttreatment ($\chi^2 > 6.63$, $P < 0.01$).

Water temperature: During the 26-wk evaluation period, the average minimum water temperatures ranged from 9.4°C to 18.9°C with an average of 14.3°C. The maximum measurements fluctuated from 20.6°C to 34.4°C, averaging 26.8°C. The water temperatures underwent a seasonal shift from midsummer to late winter (Fig. 4).

Species composition of natural populations: During the 26-wk evaluation period, *Cx. quinquefasciatus* accounted for 90.0–94.0% of all species that were found in the basins. Other species prevailed at much lower frequency, such as the foul water mosquito, *Cx.*

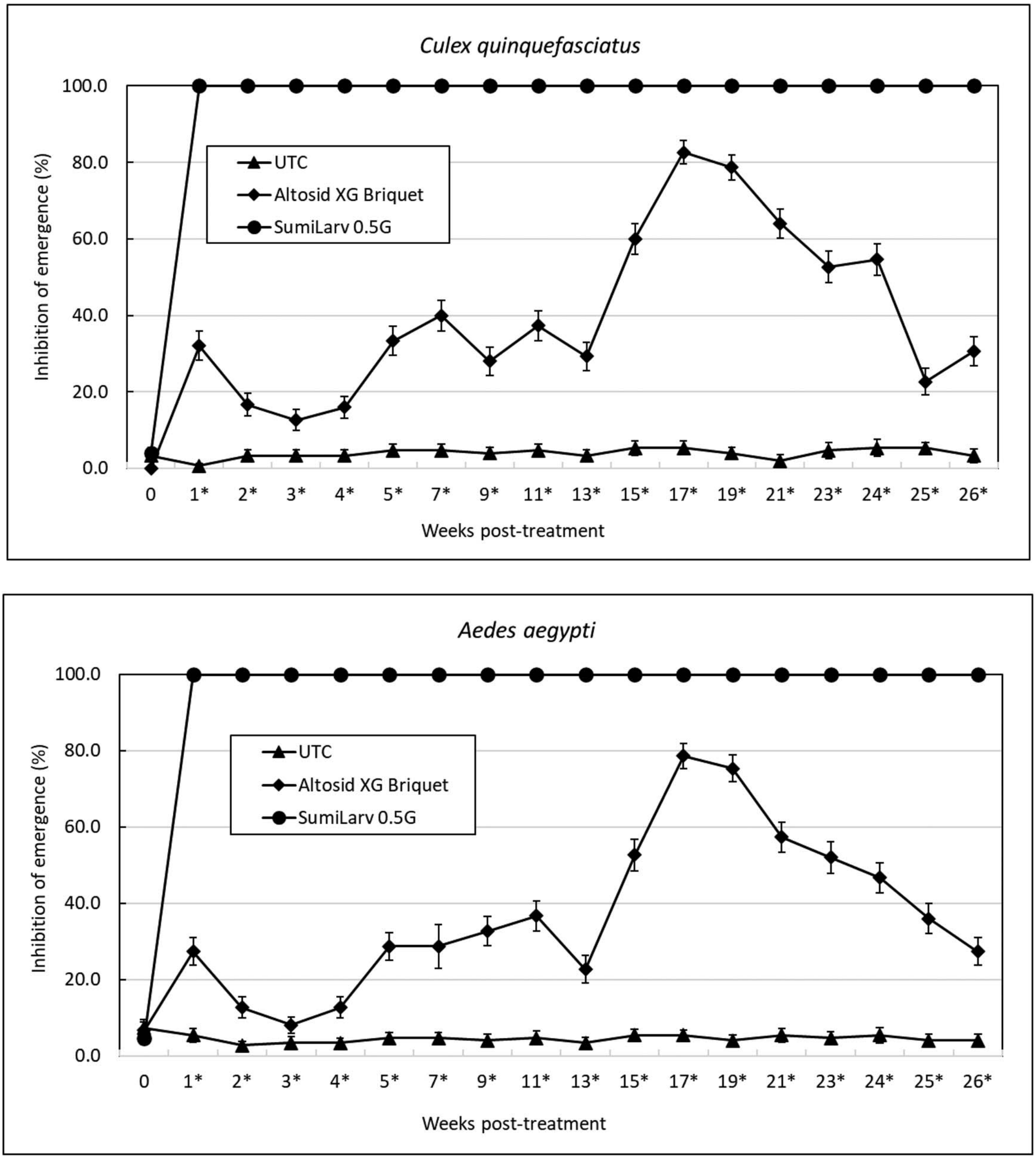

Fig. 3. The inhibition of emergence (IE%) of *Culex quinquefasciatus* (top) and *Aedes aegypti* (bottom) in response to treatments by Sumilarv 0.5G and Altosid XR briquet in simulated catch basins. *Significance in inhibition of emergence among 2 treatments and untreated control were indicated by chi-square test at $\chi^2 > 6.63$, $P < 0.01$.

stigmatosoma Dyar (0–6.0%), and the winter mosquito, *Culiseta incidens* Thompson (2.0–6.0%; Table 2).

The residual weight of Altosid XR briquet: The original average weight ranged from 54.715 g to 54.962 g and averaged 54.862 ± 0.130 g prior to being applied to the basins. At the end of week 26 posttreatment, the remaining average weight fluctuated between 31.443 g and 34.374 g with an average of 32.876 ± 1.467 g. The residual weight upon completion of evaluation was 59.9% of the original weight (Fig. 5).

DISCUSSION

Despite advancements in social, technological, and economic development during the past decades, historical public health burdens by mosquitoes and mosquito-borne diseases persist or resurge, and new vectors and

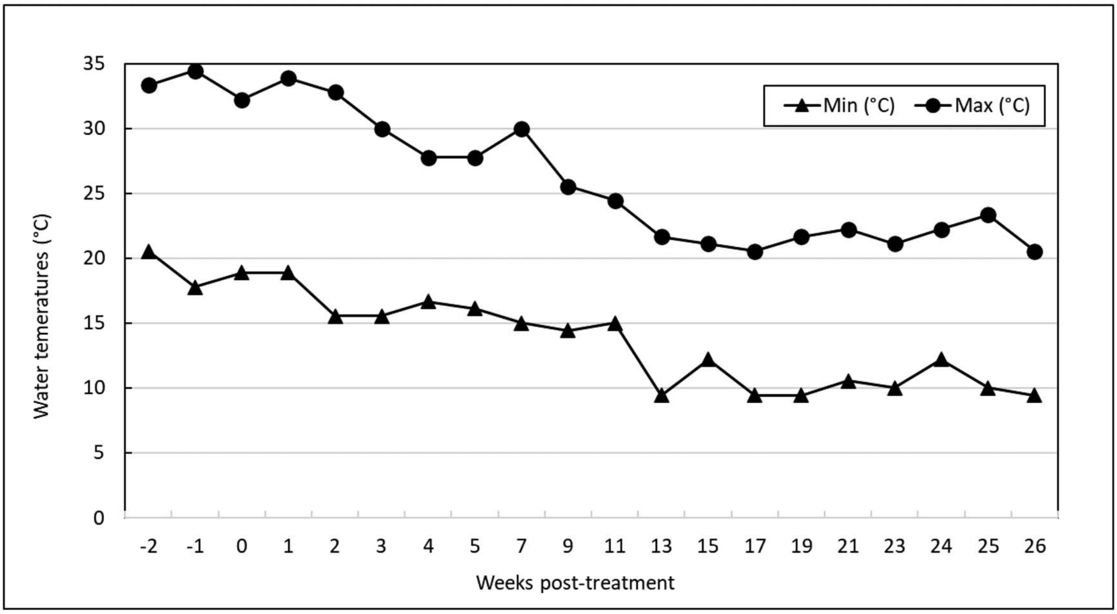

Fig. 4. Minimum and maximum water temperatures during the evaluation period.

diseases emerge. Mosquito control by means of environmental management and strategic application of pesticide products is one of the crucial practices to mitigate the nuisance and public health concerns caused by mosquitoes. Along with urban development, massive storm drain systems have been implemented to facilitate runoff from precipitation and water consumption. Unfortunately, mosquito production is unavoidable when the drain system is improperly designed, installed, and poorly maintained. For numerous reasons, product availability is very limited, and product performance is difficult to validate (Harbison et al. 2015, 2016, 2018). An ideal product for mosquito control in storm drain systems is expected to have the attributes of safety to the environment and nontarget species, high initial and longer residual efficacy, and ease of application, as well as availability and affordability.

Among the limited AIs for mosquito larval control, pyriproxyfen has gained more attention from research and development. This compound, $C_{20}H_{19}NO_3$ (MW = 321.4), chemically known as 4-phenoxyphenyl (R/S)-2-(2-pyridyloxy) propyl ether 2-[1-(4-phenoxyphenoxy) propan-2-yloxy] pyridine by the International Union of Pure and Applied Chemistry (IUPAC), was first developed in the early 1970s by Sumitomo Chemical Co. (SCC) (Tokyo, Japan). Its great potential and safety profile to control a wide variety of arthropod pests have been recognized ever since. The Insecticide Resistance Action Committee (IRAC) recognized pyriproxyfen as Group 7C–JHM. It was introduced and registered in the USA for the first time in the mid-1990s for controlling whiteflies and other greenhouse pests. The United States Environmental Protection Agency (EPA) recognizes pyriproxyfen as a reduced risk pesticide (EPA 2018) due to its identical bioactivity as juvenile hormone in insects. Pyriproxyfen is recommended by the World Health Organization (WHO 2022) for use in drinking water for vector control not to exceed 10 ppb. This compound is the most active ingredient against mosquito larvae as compared with microbial and other IGRs as well as other reduced risk pesticides by the EPA (Su et al. 2021). It also possesses a very low risk of resistance and cross-resistance development and remains effective to control mosquitoes that have developed resistance to other categories of pesticides (Su

Table 2. The species composition of larval populations in weeks 1, 13, and 26 in simulated catch basins.

Week posttreatment	1		13		26	
	No.	%	No.	%	No.	%
Culex quinquefasciatus	46	92.0	47	94.0	45	90.0
Culex stigmatosoma	3	6.0	0	0.0	2	4.0
Culiseta incidens	1	2.0	3	6.0	3	6.0
Total	50	100	50	100	50	100

Fig. 5. Comparison of original (A) with retrieved briquets at the end of week 26 posttreatment (B).

2022). Last, this compound tends to bind itself to the surfaces of plastics, logs, concrete, dirt, sediments, etc., where secondary release can occur to maintain the equilibrium of effective concentrations over long periods of time. This is advantageous for the habitats where residual control is desired. Sumilarv 0.5G was registered with the EPA by SCC (10308-34) in 2010 and by MGK (Minneapolis, MN; 1021-2819) in 2018. Sumilarv 0.5G Sachet was registered with the EPA by SCC (10308-33) in 2010, and by MGK (1021-2818) in 2020. Sumilarv 0.5G by SCC was also listed by WHO Vector Control Product Prequalification in 2017 (WHO 2023). Extensive field trials have been underway along with the development and registration of these products, and persistent efficacy was demonstrated in most previous studies (unpublished review by Su).

As to S-methoprene, the development history started in late 1960s, when racemic S/R-methoprene was synthesized. This compound, named propan-2-yl (2*E*,4*E*)-11-methoxy-3,7,11-trimethyldodeca-2,4-dienoate by IUPAC, has a molecular formula $C_{19}H_{34}O_3$ (MW = 310.5). Initial registration with the EPA as a chemical pesticide was granted in 1975 to Zoëcon (Palo Alto, CA). This registration was revised to biopesticide in 1982 because of the recognition of similar structure and identical function of S-methoprene (true JHA) as compared with natural juvenile hormone III (JH III) in mosquitoes (EPA 2021). The IRAC listed methoprene as category 7A–JHA. Since then, numerous products have been developed to combat arthropod pests of public health, stored products, livestock, and urban environment. To date, high activity and efficacy, environmental and nontarget safety, and low risk of resistance and cross-resistance development have been well documented for S-methoprene (Henrick 2007, Su 2022). The WHO recommended use of S-methoprene for vector control in drinking water not to exceed 1,000 ppm (WHO 2022). The highest product diversity was in mosquito control, where capsule concentrate, granules, pellets, and briquets have been available for decades. Altosid XR briquet is one of the traditional products designed for persistent mosquito production sites including but not limited to catch basins. Although inconsistent performance was observed from time to time (Nasci et al. 2017, Harbison et al. 2018), it has been one of the primary larvicidal tools to combat *Culex* species in catch basins and other persistent production sites, particularly since the arrival of West Nile virus in North America.

In the current study, it was clearly demonstrated that pyriproxyfen was significantly more active than S-methoprene, presumably because of the differences in molecular structures of these compounds. Pyriproxyfen has 2 benzene rings and 1 pyridine ring, which is more stable in the environment than S-methoprene, a long chain ester containing only carbon, hydrogen, and oxygen. The insignificant differences in IE activity between the technical grades and the formulations of both pyriproxyfen and S-methoprene indicated accurate AI levels and proper formulation preparations for bioassay. It remains unknown why *Aedes* spp. are more susceptible than *Culex* spp. to S-methoprene (Su and Su 2022a, 2022b, 2023) and pyriproxyfen. However, this species-dependent difference in susceptibility to the test materials observed in bioassays was not reflected in the subsequent simulated catch basin evaluation. In pyriproxyfen, it could be because of the overwhelmingly high activity, which masked the species-related difference in susceptibility. However, if the concentration of S-methoprene was diagnostic, the expected higher efficacy against *Ae. aegypti* than *Cx. quinquefasciatus* was not seen either, which was at least partially attributable to the short exposure of introduced larvae to the sentinel cage. Nonetheless, it was clearly demonstrated that Sumilarv 0.5G significantly and consistently outperformed Altosid XR briquet by providing 100% control throughout a 26-wk evaluation period.

The intrinsically higher stability, bioactivity, and its tendency to bind on the surface to facilitate the secondary release of pyriproxyfen are believed to be related to the high efficacy of Sumilarv 0.5G. Dose-dependent efficacy was achieved for 0.5% granules of pyriproxyfen in urban catch basins. Inconsistent and low efficacy occurred against *Cx. pipiens* L. and *Ae. albopictus* at 2–30 g of Sumilarv 0.5G per catch basin under field conditions in Italy (Bellini et al. 2009), while short but complete control of *Cx. quinquefasciatus* was observed at 10 or 50 g applied to each field catch basin in southern California (Mian et al. 2017). Recently a 50-wk-long complete control of *Culex* spp. was achieved when each field catch basin was treated with Nylar 0.5G (equivalent to Sumilarv 0.5G) at 75, 125, or 175 g in southern California (Mian et al. 2020). These results are in agreement with the findings in current study where Sumilarv 0.5G was applied at 75 g per catch basin with simulations in structure and function.

Much lower and fluctuating efficacy was encountered with Altosid XR briquet against both test species in current study. The lower stability and bioactivity of S-methoprene and the poor dispersion of Altosid XR briquet were attributable to the low efficacy of the briquet. Low performance was also documented in previous studies. When applied at a rate of one briquet per catch basin in Michigan, a 70% reduction in emergence of *Cx. pipiens* and *Cx. restuans* Theobald adults was observed during a period of 15 wk during summertime (Knepper et al. 1992). In different geographical locations, it was noticed that briquets as a point source of AI are more prone to being buried in organic sediment or completely flushed out of basins (Harbison et al. 2015, 2016, 2018; Nasci et al. 2017). It appears that low water movement would hinder the disperse of the briquet, hence the subsequent release of the AI; the high water turbulence, however, would flush the briquet out. The long label duration such as 150 days for the briquet may not be a reasonable expectation for many basins under field conditions. Indeed, the briquet could perform better if more agitation or water movement prevailed in the basins in the current study. As a matter of fact, the levels of agitation or water movement in a given basin under natural conditions vary tremendously and are unpredictable. Based on the residual weight of the briquet upon the completion of the evaluation, the efficacy would last longer than 26 wk under the sublethal exposure conditions, which, however, is something to be avoided for prevention of resistance development (Su et al. 2021).

In summary, against *Cx. quinquefasciatus* and *Ae. aegypti* that are commonly found in catch basins, pyriproxyfen showed significantly higher activity than S-methoprene, as indicated by significantly lower IE_{10}, IE_{50}, and IE_{90}. The fine granular formulation of Sumilarv 0.5G containing 0.5% pyriproxyfen applied at 75 g per basin significantly and consistently outperformed Altosid XR briquet containing 2.1% S-methoprene applied at 1 briquet per basin against the test species in simulated cast concrete catch basins. Similar activity and efficacy are reasonably expected against other *Culex* and *Aedes* species, namely, *Cx. restuan*s, *Ae. albopictus*, and others that also inhabit storm drain systems. These findings can be used as guidance in strategic product selection for mosquito control operations in urban catch basins.

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