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Efficacy of ultra-low volume and thermal fogging as space spray for control of adult *Aedes aegypti* Linnaeus (Diptera: Culicidae) in Holy Makkah (Mecca) city, KSA

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Abstract
Makkah (western Saudi Arabia) is one of the endemic areas of dengue fever. The efficacy of outdoor Ultra-low Volume (UL) with cyfluthrin 5% EW, and indoor thermal fogging (TF) with deltamethrin 2% EW as space spraying (SS), at the recommended and higher dose for controlling of *Aedes aegypti* were evaluated in Alsharayie area of the city, following WHO standard protocols. Bioassay tests for females were carried out for sugar- fed adults upon emergence (1-5) days. The efficacy of UL at different distances from the spray path (5, 15, 25, 40 and 50 m), and TF at 5 locations inside the house (center, corner, dark, window and hall) was also investigated. The data showed that the SS efficacy was significantly affected by the dose applied of pyrethroid. Tested distances from the spray path did not affect UL efficacy. Similarly, the locations of the cages indoor showed no difference on the performance of TF. However, it was observed that the TF efficiency was affected by the volume/size of the sprayed area, i.e. ≤20 m^2 inside the rooms (73.8 to 96.6 %), compared with ≥30 m^2 hall (57.7 to 79.7%). Regarding KdT, adults were rapidly knocked-down with UL (cyfluthrin) 29 min, when compared to TF (deltamethrin) 40 min. The results revealed that the LC_{50} and LC_{90} values for cyfluthrin against *Ae. aegypti* were 0.026 mg/L and 0.05 mg/L, respectively. While the respective values for deltamethrin were 0.008 mg/L and 0.015 mg/L. It can be concluded that the two pyrethroids are not effective at currently recommended doses SS against adult. Doses 300mg/L of cyfluthrin, and 160mg/L of deltamethrin proved to be more effective and recommended for the control of this vector.

Keywords: *Aedes aegypti*, dengue fever, susceptibility to insecticides, bioassay, space spraying, cyfluthrin, deltamethrin, Mecca city, KSA

1. Introduction

Mosquito (Diptera: Culicidae) species that were reported in KSA [1, 2]. Mosquitoes are notoriously undesirable arthropods and are well–known disease vectors for dengue (DF), filaria, malaria and Rift Valley fever (RVF). In KSA, the most common mosquito-borne disease (MBD) is DF [3]. DF is an emerging arboviral disease with many complications. Human is the primary vertebrate host of all four DF serotypes [4]. The dengue virus belong to the genus Flavivirus, family Flaviviridae [5]. It is mainly transmitted by mosquitoes of the genus *Aedes*. The principal vector of DF is *Ae. aegypti* Linnaeus, is highly adapted to human habitation. *Ae. albopictus* (Asian tiger mosquito or forest mosquito), however, in the past few decades, has spread to many countries [6]. Both mosquito species show breeding preferences for domestic water containers. DF emerged in the 1940s and rapidly spread across the tropics and subtropics [7].

The dengue virus was detected only in female *Ae. aegypti* mosquitoes. It is the main vector of dengue in KSA [8], and has recently been incriminated in dengue epidemics in some areas, including Mecca [9]. According to Aziz *et al*. [10], 4411 cases of DF were reported in KSA, in the yr 2013, and outbreak was also reported in the neighboring Yemen [11]. The geographical location of KSA puts the kingdom near the hot spots of dengue [10]. Many factors are associated with the transmission of this disease; including climate- change, population growth, urbanization, travel, and poor vector control (VC). DF is endemic in Mecca, since all of these factors are present. Furthermore, there was an outbreak in 2009 [12].

It is believed that *Ae. aegypti* originated from Central Africa, where it is found in greatest abundance [13], and has been distributed to all parts of the world [4]. The vector it is highly anthropophilic and thrives in close proximity to humans [14], preferring to live indoors [6]. Common in urban areas, and the most densely populated districts [15].

Current efforts to control MBD rely heavily on insecticides, including KSA. The application of larvicides, and the spraying of adulticides deltamethrin, cyfluthrin and *lambda*-cyhalothrin are the primary strategies [16]. Mecca city DF control program relies on anti-larval measures. The entomological surveys revealed the presence of 3,248 mosquitoes breeding sites during the yr 2016 [17]. House-to-house indoor and outdoor of deltamethrin 2% and cyfluthrin 5% application are commonly practiced during mosquito's seasons, or when adult mosquito densities increase. Around >418,181 houses and outdoor resting shelters are subjected to spraying/yr to control vector-borne diseases (VBDs) [18], and conflicting results have been obtained for several reasons.

Controlling the vector of DF using space spraying (SS) is one of the most common interventions. Two approaches are used; *viz*. thermal fogging (TF) and, ultra-low volume (UL). Indoor thermal fogs (ITF) and UL applications in Malaysia, was successful against *Culex quinquefasciatus* and *Ae. Aegypti* [19]. Many epidemics of VBDs can be stopped or drastically curtailed, if the infected vector population is reduced or eliminated [20, 21]. Trials were carried out against *Ae. aegypti* [22]. using several different OP concentrates; the TF of malathion, fenthion and chlorpyrifos gave effective kills of *Ae. aegypti* in bioassay cages.

Four types of resistance mechanisms against the insecticides have been described: metabolic, target site, penetration, and behavioral resistance [23]. The main defense against resistance is close surveillance of the susceptibility of vector populations [24]. Pyrethroids are intensively used in Mecca area. Therefore, evaluating their efficacy for DF vector under the operational conditions is needed.

The objectives of the current study was to assess the efficacy of UL with cyfluthrin 5% EW, and TF with deltamethrin 2% EW space spraying for control of DF vector in Holy Mecca City, calculate the KdT_{50} and KdT_{90} of the adults exposed to tested concentrations of these two pyrethroids and to determine theirLC_{50s} and LC_{90s}.

2. Materials and Methods

2.1 Study Design and Study Area

The study was conducted as an experimental study. Al-sharayie area is a semi- urban residential area, northeast of the Holy Mecca City, Holy Mecca Municipality, the western region of KSA, and the capital of Mecca Province. The area is located in a narrow valley, 277m above the sea level, 65 km from the Red Sea. Total population of 2 million [25]. The rain-fall is scarce and volatile; early fall (Sep.-Oct.), and late-winter (Jan.-Feb.); average 100 mm/yr. Maximum temp. 48°C (July) and the minimum 18°C (Jan.); the average R.H. 32-57%, maximum in Jan., and minimum in July [26]. Most houses 1-3 story's (300-400m²) and made of cement bricks, red bricks and cements, or pure cements. Chosen for trials for three reasons: a semi-urban suitable for vehicle –mounted spraying, *Ae. aegypti* density and the accessibility and acceptance of house owner to conduct the trials (TF).

Fig 1: Map of Saudi Arabia showing Mecca City, the capital of Al-sharayie area.

2.2 Methods

2.2.1 Laboratory work

The immature stages were collected from the breeding habitats and reared up to adulthood in the Public Health Laboratory of the municipality, during which they were fed with grinded rice. The resulting females (1-5 days- old) were used for the bioassays test [27].

2.2.1.1 The CDC bottle bioassay

The susceptibility status of the adults *Ae. aegypti* to the tested insecticides (deltamethrin 2% and cyfluthrin 5%) was investigated following the CDC bottle bioassay procedures [28]

2.2.2 Field work

Applications of SS were conducted at 6-9 p.m., during June, 2017 to May, 2018. The mean temp. was 30±1.9°C, and the R.H was 45±10 %, wind speed was 7.9±4.4 km/h. The female mosquitoes were transported from the lab to the various study sites (distance 3-6 km, within 2-8 min), using conditioned vehicle, in a large rearing cages covered with a clean damp cloth with automatic vaporizer device to control the R.H. at 70 ± 10% inside the vehicle. The females were placed in the test cages, which were distributed at the experimental sites, depending on the type of SS technique. All the cages and spray equipment were cleaned between applications using ethanol or acetone.

3.2.2.1 Insecticides and Equipment
Two currently used pyrethroids by the municipality *viz.* cyfluthrin 5% (Solfac® EW 050) and deltamethrin 2% (Aqua K-othrine® EW) were used. "Dyna-fogs®" (max-pro 2p vehicle-mounted machine) was used for outdoor UL spray with two nozzles, with ≥90% of the droplets under 20µm. Adjustable device was used to deliver a spray volume of 0.5 L/min. For indoor TF spray, portable machine (Plusfog®" K-10 SP), was used, with 0.8mm nozzle size and 100% of droplets below 25 µm dia. The discharge rate of the machine was calibrated at 100ml/min. The experimental matrix design of sentinel cages for TF purpose was constructed of fine mesh polyester netting cylinder (10 cm in dia. and 15cm in height) [29]. For UL, rectangular cage (0.09m^2) was used. Hand- held digital thermometer and digital thermo hydrometer were used. Personal protective equipment (PPE) and safety procedures followed WHO recommendations [27].

2.2.2.2 Bioassay Method
2.2.2.2.1 UL Method
Efficacy of UL application was assessed outdoor in an open field by checking the mortality. That was studied by placing a total of 140 susceptible females in each experiment, distributed into 7 cages, 20 females /cage. Five cages were then hung at 1.5m above the ground level as replicates, at 5, 15, 25, 40, and 50 m away from the spray path and downwind of the spray vehicle, perpendicular to line of application. Two cages were held outdoor at 200 m away from the spraying area upwind (control), the distance between these cages was within <50m.

2.2.2.2.2 ITF Method
SS indoors (ITF) was assessed by selecting several households (HHs) at the ground floor in the study area, 3-4 similar rooms (≤20m^2), with or without kitchen, were selected for treatment in each experiment. The trials were conducted by placing 5 cages at 1.5 heights (reps). One cage outdoor ≤ (30m^2), and 4 cages were placed indoor, close the assumed resting sites as follows: in the 1st and 2nd rooms from the entrance, 2 cages near the center (as standard), and the corner, respectively, and in the other rooms, the cages were placed near to dark places, such as closets, and the last cage close to the window wall. Each with 20 females. One room was serving as control with two replicate cages /trial, placed at 1.5 heights, upwind at >50m away from the spraying area.

2.2.2.2.4 Dosages
Two dosages (recommended and higher dose) of each insecticide were tested, 3 reps/dosage. Fresh dilution were made for each test. Cyfluthrin was tested at the recommended dose by the manufacturer 1:166 insecticide: water (300 mg/L), other tested dose, according to (WHO, 2009a), as a higher dosage 1:100 (500 mg/L). Likewise, deltamethrin were diluted based on diesel oil at 1:199- (100 mg/L) as recommended dosage and, 1:125 (160 mg/L) as higher dosage.

2.2.2.2.3 Spraying procedure
No spraying was conducted in the area one wk before the tests. "Dyna-fogs" vehicle-mounted machine was spraying downwind; the UL sprays were applied for a period of 1hr, at car speed of 9±1.0 km/hr. Prior to insecticide treatment, the external doors, windows, and the eaves of selected HHs were closed. Fogging continued for a period of 15 sec from the front door without having to enter room of the HH. The farthest room from the entrance was sprayed first and progressively the other rooms moving towards the entrance, this was to make sure that the insecticide spray is directed to all parts of each room, and then the rooms and kitchen were left closed.
Exposure for 1hr (UL) and 10 min (TF). The knocked- down (kd) was recorded up to 1hr after exposure. The cages were removed and the mosquitoes were transferred to separately mark clean holding cups. These were provided with 10% sugar solution soaked cotton wool, placed on the top of the cups, and placed in a protective holder for transport to the lab to hold in especial room maintained at 27±2 °C, and 60–70% RH.

2.4 Mortality Calculation and Data Analysis
The assessment of mortality rate (acute toxicity), *i.e.* a count of the number of dead mosquitoes in both the exposed and the control cages, is made 24 hr post-exposure. A mosquito is classified as dead or alive according to WHO [30]. Abbott's formula of [31]. was used when the % mortality is between 5-20 %. Data was analyzed using SPSS and BioStat computer software programs. Mean ± SE and The slope of LCs were calculated.

3. Results
3.1 Laboratory Work
The adults selected randomly (250) for all lab and field tests (1680) proved to be *Ae. aegypti* according to different morphological keys [1, 32, 33]. Table (1) showed that the tested populations are susceptible to deltamethrin and cyfluthrin (98% mortality), according to the updated CDC guidelines [28]. After 15 min of exposure to cyfluthrin, 77% of the adults died, whereas 82% died during the same period when exposed to deltamethrin. In both treatments 98% mortality was reached after 30 min the 100% mortality was registered at 120 min for cyfluthrin and 105 min for deltamethrin.

Table 1: The exposure time *vs.* % mortality in the CDC bottle test for cyfluthrin5% and deltamethrin 2% in Al-sharayie area, Holy Makkah City, KSA (May 2017)

Exposure time (min)	Cyfluthrin (%)	Deltamethrin (%)
0	0	0
15	77	82
30	98	98
35	98	98
40	98	98
45	98	99
60	99	99
75	99	99
90	99	99
105	99	100
120	100	100

3.2 Field Work
3.2.1 Bioassays
Assessment for 1hr exposure period for KdT_{50} and KdT_{90} after 24hr was determined for the applied dose (Table 2). The populations proved to be more susceptible to deltamethrin than to cyfluthrin; the LC50 fot the former was 0.008 mg/L

and for the latter was 0.026 mg/L. However, the LC90s were 0.015 and 0.05 mg/L, following the same order. The results of 24 hr %mortality for the recommended and the higher tested doses, ITF and UL outdoor space spraying are presented in fig. (1).

Table 2: LC_{50} and LC_{90} (mg/L; ppm) for cyfluthrin and deltamethrin on female *Ae. aegypti* within 24hrs under the field conditions, Al-Sharayie area, Holy Mecca City, KSA.

Insecticide	LC_{50} (95% CL)	LC_{90} (95% CL)	* Slope ±SE
Cyfluthrin	0.026 (0.0226 -0.028)	0.050 (0.045 -0.056)	4.43±0.55
Deltamethrin	0.008 (0.0007 -0.0087)	0.015 (.0137 - 0.0167)	4.42±0.07

Cyfluthrin: x^2=6.41; df= 4; p = 0.17[a]; CL = confidence limits;
Deltamethrin: x^2 = 2.74; df = 4; p = 0.61[a;] *Slope = calculated

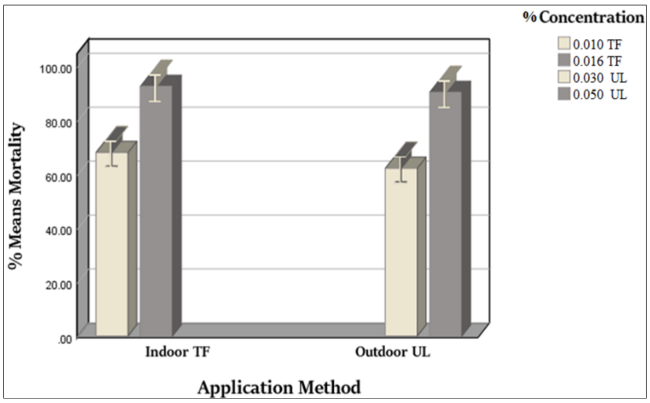

Fig 1: Adult of *Ae. aegypti* %mortality (mean) at 24hr of exposure to UL and TF space spraying application with cyfluthrin 5% and deltamethrin 2%, in Al-sharayie area, Holy Makkah City, KSA.

3.2.1.1 Effect of outdoor UL

A significant differences in mortalities of caged adults *Ae. aegypti* exposed to UL (cyfluthrin) outdoor was observed between the recommended and the higher dose in the Study area (p= 0.0). The 500 mg/L (higher dose) caused a much higher mortalities 78.8 to 98.0% at the specified distances, when compared with the recommended dose (300mg/L), which gave 50.7 to 75.3 % (Table 3). The efficacy of UL and doses tested for controlling *Ae. aegypti* not affected by distance from the spray path (p= 0.19). However, data in table (3) shows a gradual insignificant decrease in the mortality with the distance from the UL spray release path for cyfluthrin.

Table 2: % mortality of adult females *Ae. aegypti* exposed to space spraying (SS) with cyfluthrin (UL) and deltamethrin (TF).

Space Spraying (insecticide)	Dosage (% & mg/L)	% Mortality (within 24hr) (Mean ± S.E.)
UL (Cyfluthrin 5%)	Rec. (0.03% = 300 mg/L)	62.1 ± 2.91
	Higher (0.05%= 500 mg/L)	90.3 ± 1.99
TF (Deltamethrin 2%)	Rec. (0.01%= 100mg/L)	67.9 ± 2.6
	Higher (0.016% = 160mg/L)	92.5 ± 2.1

Rec. = Recommended dose; Total no. /treatment = 140;
No. treatment /dose =3x; No. of insects /rep =20;
Treatment reps = 5; Control reps =2.

Table 3: Mean adult *Ae. aegypti* % mortality after UL application with the recommended (300 mg/L) and the higher dose (500 mg/L) of cyfluthrin 5% at different distances from the spraying point.

Distance		% Mortality	
(m)	*n*	Rec. (300 mg/L)	High (500 mg/L)
5	6	75.3 ± 5.1[a]	98.0 ± 1.9[a]
15	6	69.9 ± 4.4[a]	94.4 ± 3.4[a]
25	6	60.2 ± 2.1[a]	92.7 ± 2.3[a]
40	6	54.4 ± 4.4[a]	87.4 ± 2.5[a]
50	6	50.7 ± 3.9[a]	78.8 ± 1.6[a]

Means followed by the same letter within the column are not significantly different
n = number of cages (reps)

3.2.1.2 Effect of ITF

Efficacy of ITF with two dosages of deltamethrin (100 and 160 mg/L) was affected significantly by the dosage (p= 0.0, Table 4). However, the locations/position of the cages indoor showed no effect on the performance of ITF (p= 0.35).Thus, there is a relationship between the cages locations (in/out the rooms) and ITF effects. The decrease of the mortality observed was significant at out of the rooms location, compared with the cages inside the rooms. Moreover, it was observed that the ITF efficacy was affected by the volume of the spraying area ≤20m^2 inside the rooms (73.8 to 96.6%), compared with ≥30m^2 at the hall, outside the rooms (57.7 to 79.7%). Deltamethrin dosages tested by ITF against adults scored high adult mortalities with the higher dose, i.e. 160mg/L 79.7 to 96.6% at specific locations, when compared with the recommended (currently used) dosage (100mg/L) which caused 57.7 to 73.8%.

Table 4: Mean adult *Ae. aegypti* % mortality after ITF application with two dosages of deltamethrin 2% (100 and 160 mg/L) at indoor locations in Al-sharayie area, Holy Mecca City, KSA.

Location		% Mortality	
(indoor)	n	Rec.(100 mg/L)	High (160 mg/L)
Center	6	71.7 ± 6.9[a]	96.6 ± 1.7[a]
Corner	6	65.2 ± 5.3[a]	95.0 ± 2.9[a]
Dark	6	73.8 ± 3.3[a]	94.7 ± 5.3[a]
Window	6	71.7 ± 5.2[a]	96.4 ± 3.5[a]
Outdoor	6	57.7 ± 5.9[ab]	79.7 ± 2.7[ab]

Means followed by the same letter within the column are not significantly different
n = number of cages (reps)

3.2.2 Toxicity of the pyrethroids tested

The 1st laboratory reared batch of adults was found to be resistant to the recommended dosages of pyrethroids when space –sprayed. As a result shows (Table 5), a recommended dose 300 mg/L (0.03%) of cyfluthrin tested by UL gave 62.1% mortality. Similarly, 67.9% mortality was obtained with TF deltamethrin at 100 mg/L. Nevertheless, the same strain exposed to the higher dosages of pyrethroid found to be tolerance, 90.3% and 92.5% mortality obtained for 500 mg/L of cyfluthrin and, 160 mg/L of deltamethrin, respectively. This suggests that, there was a significant difference in the mortality rates between the pyrethroid dosages.

The results revealed that the LC_{50} and LC_{90} values for cyfluthrin against *Ae. aegypti* were 0.026% (0.026 mg/L) and 0.05% (500 mg/L), respectively. While the respective values for deltamethrin were 0.008% (80 mg/L) and 0.015% (150 mg/L).

3.2.3 The Knock-down time (KdT)

The time required for knocking down 50% (KdT_{50}) and 90% (KdT_{90}) of the exposed adults to the tested pyrethroids with SS were calculated (Table 5). The average of KdT_{50} and KdT_{90} values for cyfluthrin 5% were 29 and 512 min, respectively. The respective values for deltamethrin were 40 and 266 min..

Table 5: KdT50 and KdT90 of adult female *Ae. aegypti* exposed to UL with cyfluthrin 5% and TF with deltamethrin 2% under the operational conditions.

Insecticide	KdT50 (min) (95% CL)	KdT90 (min) (95% CL)
Cyfluthrin 5%	29 (22.9 – 36.5)	518 (307 – 1,158)
Deltamethrin 2%	40 (34.6 – 47.7)	266 (171.6 – 569.9)

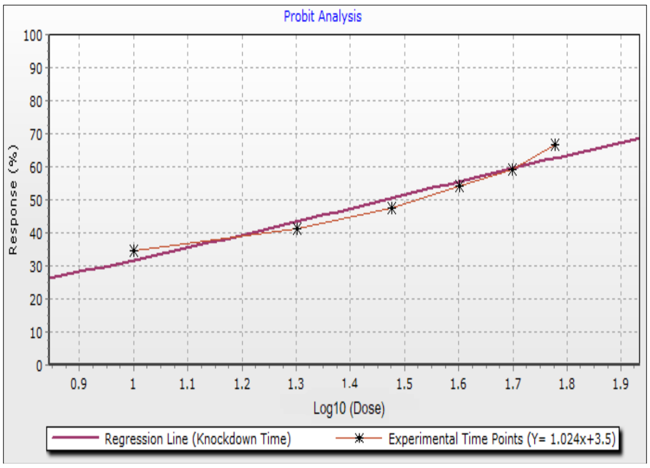

Fig 2: Log- time (min) *vs*. the response of cyfluthrin to females *Ae. aegypti* populations of Al-sharayie area, Holy Makkah City, KSA.

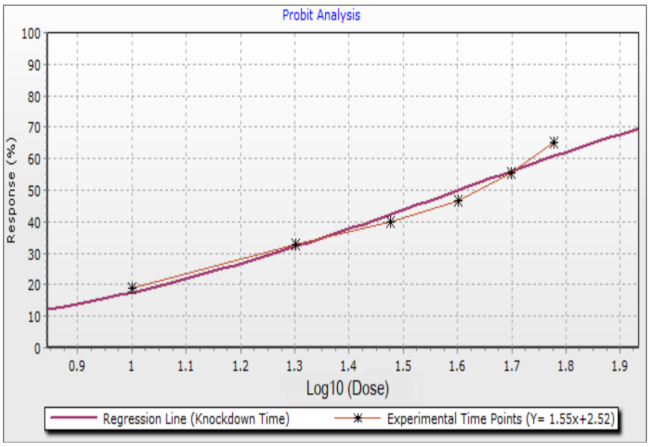

Fig 3: Log- time (min) *vs*. the response for deltamethrin to females *Ae. aegypti* populations of Al-sharayie area, Holy Makkah City, KSA.

4. Discussion

Through a series of laboratory and field experiments, the present study evaluated adulticides space spray efficacy that is currently used in the DF vector control program of the Holy Mecca municipality. Generally, and despite the importance of the application method on the control of adult mosquitoes, the results of the present work revealed that the intensive, carefully planned and performed space spraying with close supervision (TF - UL) can reduce the number of female *Ae. aegypti* in houses and outdoor. These results are in line with several studies [19, 21, 34, 35, 36, 37, 38].

Portable TF was effective in eliminating 67 -92.5% of females in the experimental cages inside the treated houses. This finding agrees with another study has been shown that indoor TF using adulticides has a strong effect against *Ae. aegypti* [37]. TF of lambda-cyhalothrin, or mixture of deltamethrin and cyphenothrin (Pesguard®-FG 161) was effective against vector mosquitoes in other studies [19, 36].

On the other hand, this study evaluated the efficacy of UL mounted truck to adult *Ae. aegypti* under operational conditions, and resulted in 62 - 90% mortality in adult cages, which were placed at a distance up to 50 m away from the spraying path/point. This finding is in line with results of a study that showed combination of Pesguard®-PS 102 and Vectobac®-AS 12 (Bti) applied by vehicle mounted UL machine against *Ae. aegypti* in Malaysia resulted in >90% mortality in adults, which were placed at a distance of 100m away from the spraying machine [35]. Further, 90% mortality of caged mosquitoes in an open field was also reported [21]. The control of *Ae. aegypti* in Venezuela showed that mortality was >90% in caged mosquitoes set in the open fields [38].

The result that obtained during the UL efficacy outdoor is in line with [34]; who observed 95.5% mortality in caged *Ae. aegypti* suspended in the open *vs*. 49% in more sheltered locations. In the present study, the efficacy of UL was not affected by distance from the spray path ($p = 0.19$). These results disagree with those of Al-Sarar *et al*. [39]. They found that CF application of three pyrethroids against mosquitoes was significantly affected by distance from the spray machine. This difference could be attributed to the application equipment and technology.

In the present work, TF effected high mortality rates 67.9 to 92.5%, when compared with UL which caused 62.1 to 90.3%. This result agrees with those conducted by Britch *et al*. [40], who evaluated the efficiency of truck mounted UL and TF and found that there is 100-fold greater chance that a droplet will come in contact with a mosquito in the sentinel cage in a TF application *vs*. a UL application.

The bioassay results revealed that, *Ae. aegypti* females populations tested under the current operational conditions and specifically the current adopted dose proved to be resistant to the recommended dosages of cyfluthrin 5% (300mg/L), and deltamethrin 2% (100mg/L) with 62.1% and 67.9% mortality, respectively, in the study area. However, the two insecticides gave higher mortalities 90.3% and 92.5%, when tested at higher doses (500 and 160mg/L, following the same order), according to the WHO criteria for characterizing insecticide susceptibility, i.e. indicating some level of tolerance (possibility of resistance). In the KSA, the tolerance of *Ae. aegypti* to deltamethrin has been reported from the different parts of Jazan [41]. Moreover, a study from Thailand documented that the resistance to deltamethrin was developed in *Ae. aegypti* in most of the collection areas [42]. Tolerance to deltamethrin was also reported from Rosairs and Damazin, the Sudan [43]. In India, *Ae. aegypti* showed moderate level of resistance to pyrethroids (deltamethrin: 64.4–74.3%; permethrin: 66.8–82.3% mortalities) in all sites tested in India [44]. In Central Africa, resistance to deltamethrin was also suspected in *Ae. albopictus* from Yaounde, Cameroun (83% mortality [45]. Increasing *Ae. aegypti* resistance to cyfluthrin was reported in many locations in Bangkok [46]. The use of cyfluthrin has just started in some places, but it has precipitated tolerance in *Ae. aegypti* in some areas of Thailand

[47]. However, no previous baseline data is available in the study area.

Based on a municipality report of the city of Mecca, in 2007, the estimated amount of undiluted mosquito adulticides used were 17,975 L [48]. However, pyrethroids are currently used largely as space spray for adult control all over the KSA [49], because of their quick Kd effects, high insecticidal activity and relatively low mammalian hazard at operational doses [50]). In fact, the extensive successive use of these insecticides in the city and the Province to control MBDs by the Ministries of Health, Municipalities and Agriculture, this might have resulted in rapid development and spread of resistance in mosquito, which might have implications on the sustainability for any VC program [51]. Quality control of spraying efforts and insecticide resistance testing must be an integrated component of municipalities and ministries program, although these are not new messages [5, 27].

The KdT values are usually considered as indicators for imminent development of resistance to insecticides and can be considered as base- line data for future observations on the development of resistance by the vector to the insecticide used in VC. It was observed that log-time line slope in cyfluthrin (1.02) was smaller than that of deltamethrin (1.55) in the study area. Therefore, the result showed that *Ae. aegypti* population proved to be more homogeneous towards deltamethrin in its response than cyfluthrin. However, it is high time to alternate insecticides for controlling the adult to avoid homogeneity (resistance development) to the very limited number of available mosquito insecticides.

This study add new data to the local VC methods and, to manage the development of resistance in mosquitoes, the decision- makers must consider The mosquito studies and, thus help develop a policy and strategy to apply space spraying as public health response to dengue VC.

5. Conclusion and Recommendation

5.1 Conclusion

1. The two pyrethroids are not effective, when using the currently recommended dose of SS for adult *Ae. aegypti* in Mecca City. Higher tested doses (500 mg/L of cyfluthrin, and 160 mg/L of deltamethrin) proved to be more effective.
2. Space spray application of these pyrethroids is effective in reducing the abundance of *Ae. aegypti* indoor and outdoor of semi-urban environment, under the required conditions.

5.2 Recommendations

1. Close supervision should be done during applications of the space spraying.
2. Awareness-raising messages should be delivered to the household owners to respond and open their house for the DF control team.
3. Further studies are required to test the efficacy of different TF and UL equipment with different types of nozzles and other adulticides.
4. Adopting the concept of rotation of insecticides as part of the IVM strategy.
5. Insecticide resistance monitoring program must be established to cover the other parts of the city, the province, and the kingdom to provide dependable data necessary for the planning, implementation and intervention.

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