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Research Article

Comparative performance of mobi and thermal fogger during field operations directed for control of adult mosquito population

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ABSTRACT

In Pakistan, vector-borne illnesses are becoming more prevalent. Numerous illnesses, including malaria, dengue hemorrhagic fever (DHF), chikungunya, filariasis, Japanese encephalitis, and dengue shock syndrome (DSS), are spread by mosquitoes. The current vector control program is getting harder every day with fewer and fewer control interventions. Therefore, in practice, Integrated Vector Management (IVM)-based systems rely heavily on environmental management and the prudent use of chemicals. The field trials for this study were conducted at the University of Agriculture Faisalabad, which is situated in Pakistan's Punjab province. Mosquito breeding grounds were chosen in the area around the university. Adults of Culex species and A. aegypti were used in the trials. A variety of foggers were positioned in front of the cages. The suggested dosage for mosquitoes, which was 33–66 milliliters per five liters of diesel, was followed while mixing this chemical with diesel. Diesel alone, without any chemicals, was used to treat the control. As an emulsifiable concentration and ultra-low-volume formulation, deltamethrin 1.5%EC is used. After fogging for five minutes, data was gathered. When the mortality and knockdown of these foggers were examined, the results indicated that traditional thermal foggers had a higher mosquito mortality rate at 10 feet as opposed to 5 feet, 15 feet, and 20 feet, respectively. Mosquitoes showed higher mortality at a 5 ft. distance when exposed to mobi-foggers, which had a low throw than conventional foggers in contrast, a typical thermal fogger demonstrated a high rate of mosquito knockdown at a distance of 15 feet as opposed to 5 feet, 10 feet, and 20 feet, respectively. In the case of a mobi-fogger, mosquitoes showed higher knockdown at a distance of 20 feet than others because mobi-foggers have a lower throw than conventional foggers. The conclusion is that thermal foggers are recommended because of their higher fog throw compared to mobi-foggers; nonetheless, both conventional thermal foggers and mobi-foggers have the same high throw for mortality and knockdown.

Keywords: Deltamethrin; *Aedes aegypti*; mobi-fogger; thermal fogger; insecticides; mosquito; knockdown

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INTRODUCTION

More than 100 nations around the world are prone to mosquito-borne diseases, which annually affect millions of people worldwide. Mosquitoes belongs to the family Culicidae comprising of over 3500 different species of mosquitoes worldwide (Karthika et al., 2018; Zheng, 2020). *Aedes aegypti* is regarded as the most dangerous Arbovirus vector in the tropics, wreaking havoc with a variety of diseases like Yellow fever, Dengue, Zika, and Chikungunya (Qasim et al., 2020; Nebbak et al., 2022; Kumawat et al., 2023). Dengue fever can present itself in two ways: either as a classic form of dengue fever with additional symptoms such as fever, headache,

muscle or bone pain, rash, pain behind the eyes, and petechial bleeding under the terms dengue hemorrhagic fever (DHF) and dengue shock syndrome (DSS) (Bhatt et al., 2021; Dowd et al., 2023; Pourzangiabadi et al., 2024). According to the world health organization (WHO), one-sixth of the global population is affected by vector-transmitted diseases, and among them, dengue fever is the world's fastest-growing disease, with a 30-fold increase in incidence over the last 50 years. (Imran et al., 2022). Dengue fever (DF) is caused by dengue virus with 4 serotypes (DENV-1, DENV-2, DENV-3, and DENV-4) (Soo et al., 2016; Niu et al., 2020).

Due to behavior and reproductive biology of *A. aegypti* controlling populations of vector mosquito species in urban environments is a major challenge. *Aedes aegypti* is well adapted to and will successfully exploit many artificial and natural habitats present in u0 0 rban environments, presenting a major challenge for the development of control strategies (Wilke et al., 2019). Reactive control strategies based on the use of larvicide and adulticide are widely ineffective due to the inherent difficulty in reaching cryptic breeding habitats and escalating resistance issues (Stoddard and P. K, 2018) Moreover, *Ae. aegypti* populations have high levels of insecticide resistance which will further impair the effectiveness of reactive mosquito control strategies in urban environments (Estep et al., 2018; Mundis et al., 2020). Local management tactics for *Ae. aegypti* include indoor residual sprays (IRS) with either pyrethroids (e.g., deltamethrin) or organophosphates (e.g., malathion) and ULV with organophosphate insecticides (e.g., chlorpyrifos and malathion) (Vazquez et al., 2017; Dunbar et al., 2019). To overcome the time-consuming aspects of IRS and account for *Ae. aegypti*-specific behaviors, several modifications to the 'classic' IRS strategy intended to control vectors of dengue (i.e., full house spraying, movement of furniture and treatment of all walls and ceiling) have been proposed (Vazquez et al., 2017).

Alternative vector control strategies such as the release of genetically modified mosquitoes are still years away from being used in real-world operations and their effectiveness in controlling not only mosquito populations but also in decreasing the incidence of arbovirus transmission is yet to be proven (Achee et al., 2019; Wilke et al., 2018). Controlling populations of vector mosquitoes in urban areas is a difficult task and control strategies based on the Integrated Vector Management (IVM) framework are complex relying on many actions that rationally build on each other. However, the IVM key components such as mosquito surveillance, source reduction (i.e., aquatic habitat removal), community engagement, and improved policies can achieve great success (Trewin et al., 2017). The Integrated Vector Management (IVM) based system thus in practice is largely dependent on environment management and judicial use of chemicals. Fogging as one of its key components is a heavily dependent strategy for the adult mosquito control program (Usuga et al., 2019). Keeping in few the economic burden incurred because of control program a strategy to reduce the cost of fogging. Mobi-Fogger is a locally designed fast and economical system of fogging potential mosquito breeding sites, system that is attached with the motor bike. The system is likely to improve overall cost in terms of time and labor. Cold fogger is a device used for fighting against pest problems, insect elimination like mosquitoes and to avoid molds and foul odors. This device is known as "cold", because it works following opposite principle to the thermal fogger. In thermal fogger heat is used for vaporizing liquid which is expelled as smoke, while in cold fogger tiny droplets or particles are sprayed out with the help of high air pressure. In this way cold spraying is done. ULV fogger is most common type of this fogger and usually they are considered as cold foggers (Beier et al., 2008; Boubidi et al., 2016).

Deltamethrin 2.5% EC (Emulsifiable Concentrate) is a synthetic pyrethroid broad-spectrum and non-systemic insecticides which is used to control different insect pests. It is used as insecticide in animal and used to overcome and control the numerous insect pests such as mosquitoes, flies, cockroaches, and other insect pests at very low dose as residual spray (Trostanetsky et al., 2023).

MATERIALS AND METHODS

Study Area

Trials in the field were managed in University of Agriculture Faisalabad, located in the province of Punjab, Pakistan. Breeding places of mosquito were selected within the vicinity of the university. Trials were conducted on adults of *A. aegypti* and *Culex* spp.

Insect Culture

The field-collected adult mosquito species were reared in Dengue Vector Research Laboratory, Department of Entomology, University of Agriculture, Faisalabad. Immature were collected from mosquito breeding sources and kept in plastic jars covered with a white muslin cloth. Temperature 27±2C and relative humidity 65±5% was maintained in

the laboratory. Male mosquitoes were fed on 10% sugar syrup by cotton wicks dipped in small bottles while females were fed on the blood of humans and white rats.

Foggers

Three foggers were used i.e. Thermal and Mobi-Fogger that is attached with the motorbike to improve overall cost in terms of time and labor. Its comparative efficacy was measured. The overall duration of fogging per unit area was estimated. Thermal fogger is known as high efficiency machine in the industry. This fogger machine can be carried over the shoulder of the user. These foggers pick up the porous material and deodorant droplets and convert into smoke odors and during a fire what occurs are closely duplicating.

Fogging Methods

Different foggers were placed before the cages in which adults of mosquitoes were released and each cage contained about 10 adults. The distance between the foggers and cages was 5 ft., 10 ft., 15 ft. and 20 ft., respectively. The distance was increased on daily basis from the cages to check the fog effect and efficacy. Total time exposure of fog which was given to adults was 3 minutes and after 3 minutes 10% sugar solution was given to knockdown adults for 5 minutes. The mortality was counted thereafter. There were three replications and a simple water as a control was used with mosquito adults. In case of Mobi-Fogger was started after the engine become hot and thus caused the liquid to immediately convert into fog via silencer of a motorbike. Combustion, consumption and swath width of fog applied by Mobi-fogger based on speed was measured. Percentage mortality of adult population was recorded in the cages after 5 minutes.

Trials in Cages

Adult mosquitoes were placed in cages to check the effects of Deltamethrin applied by different foggers. Each cage contained 10 adults of mosquitoes. The distance between the foggers and cages was 5 ft., 10 ft., 15 ft. and 20 ft., respectively. Total time exposure of fog which was given to adults was 3 minutes and after 3 minutes 10% sugar solution was given to knockdown adults for 5 minutes. Each experiment was repeated two times to reduce the errors in Trials.

Insecticide

In these foggers Deltamethrin 2.5% EC (Emulsifiable Concentrate) is a synthetic parathyroid broad-spectrum and non-systemic insecticides which are used to control different insect pests. This chemical was mixed with diesel according to their recommended dose (33 ml to 66 ml per 5 liters of diesel) for mosquitoes. The control was treated with only diesel without chemical.

Data Analysis

The collected data was analyzed by using statistical software (8.1) of randomized complete block design (RCBD) and means were compared by LSD test in field conditions.

RESULTS AND DISCUSSION

In this research comparative efficiency of thermal and mobi –fogger was evaluated against the mosquito species. The mobi-fogger was self-manufactured while thermal foggers were commercially available. The aim was to investigate the comparative efficiency of thermal and mobi –fogger against mosquitoes. The comparison of efficiency has been depicted in table 1.

Probability values for the mortality effect by the use of thermal and mobi fogger is shown in table no.1 at 5,10,15 and 20 feet which shows that the thermal fogger was highly effective showing high mortality and high efficacy in the field as mobi fogger have low through rate due to the engine capacity and their flow output. The overall p-values show that the field trials have highly significant values in both the thermal and mobi-fogger.

Table 1. Showing the probability value of mobi and thermal fogger against mortality of different mosquitoes at various distances.

	Distance from the Mosquito cages			
	5 feet	10 feet	15 feet	20 feet
Thermal fogger	0.0008	0.0000	0.0004	0.0002
Mobi-fogger	0.0008	0.0002	0.0001	0.0001

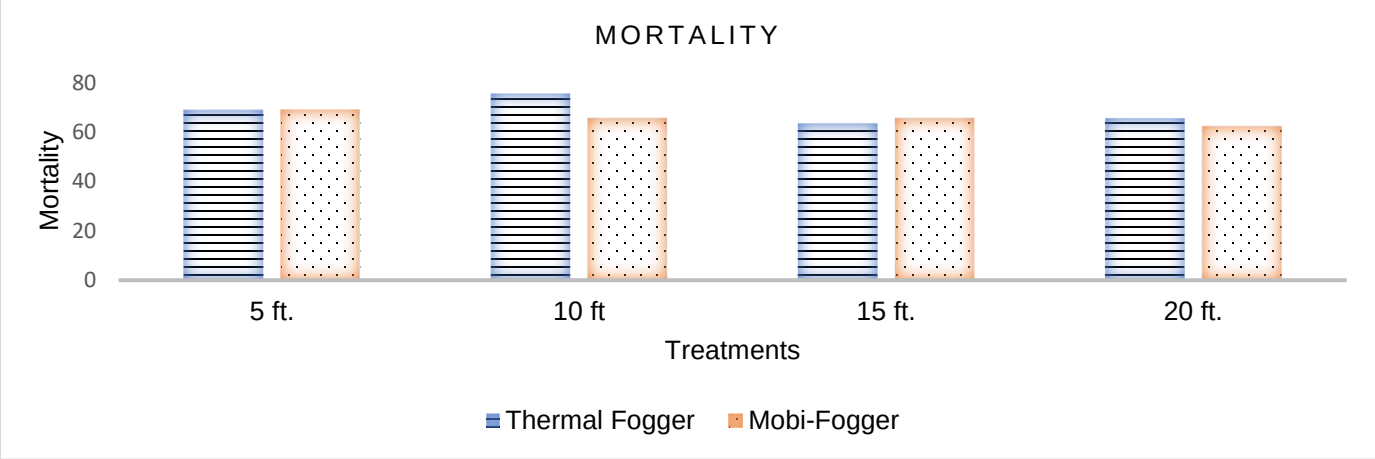

Figure 1. Comparison between mobi and thermal fogger (mortality).

The figure (1) shows that conventional thermal fogger showed high mortality of mosquitoes on 10 ft. distance as compared to 5 ft., 15 ft. and 20 ft., respectively. While in case of Mobi-fogger, mosquitoes showed high mortality 5 ft. distance as compared to others due to mobi-fogger have low throw as compared to conventional foggers. This data was taken after five minutes treated with Deltamethrin 2.5% EC (Emulsifiable Concentrate) by using Mobi-fogger at 20 feet distance between fogger and mosquito cages. The distance between the cages was also 5 feet. The mean percent mortality was calculated using three different volumes of insecticide (3 ml, 6 ml, and 13 ml) dissolved in one liter of diesel.

Table 2. Showing the probability value of mobi and thermal fogger against knockdown of different mosquitoes at various distances.

	Distance from the Mosquito cages			
	5 feet	10 feet	15 feet	20 feet
Thermal fogger	0.0421	0.0057	0.0064	0.0054
Mobi-fogger	0.0421	0.0054	0.0023	0.0010

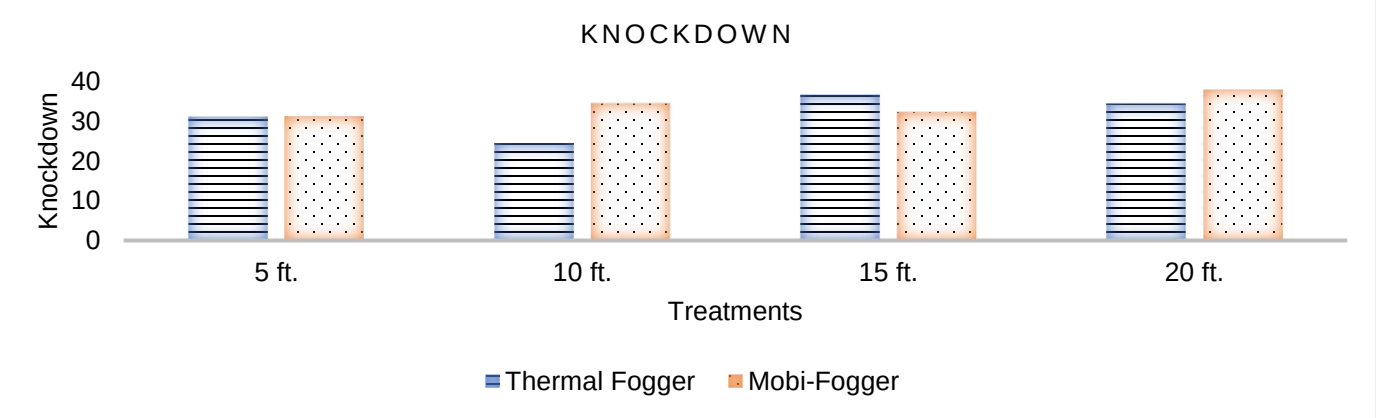

Figure 2. Comparison between mobi and thermal fogger (Knockdown).

Probability values for the knockdown effect by the use of thermal and mobi fogger is shown in table 1 at 5,10,15 and 20 feet which showed that the thermal fogger is highly effective showing high mortality and high efficacy in the field as mobi fogger have low through rate due to the engine capacity and their flow output. The overall p-values showed that the field trials have highly significant values in both the thermal and mobi-fogger.

The figure 2 shows that conventional thermal fogger shows high knockdown of mosquitoes at 15 ft. distance as compared to 5 ft., 10 ft. and 20 ft., respectively. While in case of Mobi-fogger, mosquitoes show high knockdown at 20 ft. distance as compared to others due to mobi-fogger have low throw as compared to conventional foggers. This data was taken after five minutes treated with Deltamethrin 2.5% EC (Emulsifiable Concentrate) by using Mobi-fogger at 20 feet distance between fogger and mosquito cages. The distance between the cages was also 5 feet. The mean percent mortality was calculated by using 3 ml, 6ml and 13 ml of insecticide in one liter of diesel.Fogging, as one of its primary

components, is an extremely reliant approach for adult mosquito control. Different public health pesticides are used to control different types of mosquitoes in their adult phase using foggers since they are safe for humans and the environment. Deltamethrin 2.5%EC is used as an ultra-low-volume formulation and emulsifiable concentration to combat pests of animal husbandry and agricultural crops. (Henriet et al., 2009).

The field trials for this study were conducted at the University of Agriculture Faisalabad, which is situated in Pakistan's Punjab province. Mosquito breeding grounds were chosen in the area around the university. Adults of Culex species and *A. aegypti* were used in the trials. The Dengue Vector Research Laboratory, Department of Entomology, University of Agriculture, Faisalabad, was used to raise the adult mosquito species that were collected from the field. Immature mosquitoes were gathered from breeding grounds and reared in plastic containers covered with white muslin cloth. The laboratory was maintained at 27±2C and 65±5% relative humidity. Female mosquitoes were fed human and white rat blood, while males were fed 10% sugar syrup on cotton wicks dipped in tiny bottles. Previously, various foggers were positioned. Different foggers were placed before the cages into which adult mosquitos were released, with each cage containing approximately ten adults. The distance between the fogger and the cage was 5, 10, 15, and 20 feet, respectively. The distance between the cages was increased on a daily basis to assess the fog effect and efficacy.

Adults were exposed to fog for a total of three minutes before being knocked out for five minutes with a 10% sugar solution. After distributing the solution, the mortality rate was determined. There were three replications, and a control was used with mosquito adults, whereas mobi-Fogger was started until their engine was very hot because liquid immediately converted into fog via a motorbike's silencer. The combustion, consumption, and swath width of fog applied by a mobi-fogger based on speed were measured. Deltamethrin 1.5% EC (Emulsifiable Concentrate) is a synthetic parathyroid broad-spectrum, non-systemic insecticide that is used to control insect pests. This chemical was mixed with diesel according to the recommended dose for mosquitoes, which was 33 ml to 66 ml per 5 liters of diesel. The control was treated with only diesel without chemical.

In the present study, T1, T2, and T3 contain 3 ml, 6 ml, and 13 ml, respectively, of insecticide solution. In the first trial of the conventional thermal fogger, the percentage mortality and knockdown of adult mosquitoes at a 5-foot distance were about 70% and 30%, respectively. The distance between the fogger and the cage was also 5 feet, and the distance between the cages was 5 feet. The trough of fog was high due to the conventional fogger. The environmental temperature was about 21 degrees centigrade, while wind speed was recorded according to WHO as 5 km/hour in time of trials.

These results are convergent from Hoffmann et al. (2009) due to environmental factors and spray machines used in many numbers for the applications of pesticides to control mosquitoes, house flies, cockroaches, and many other vectors that cause different diseases in humans as well as other organisms. The droplet size was maintained in nine different ultra-low volume foggers by oil-based spray and water solutions, and it showed very significant results as compared to two thermal foggers in which water and diesel were used as a solution.

In this study, T1, T2, and T3 contain 3 ml, 6 ml, and 13 ml, respectively, of insecticide solution. In the second trial of the conventional thermal fogger, the percentage mortality and knockdown of adult mosquitoes at a 10-foot distance were about 83% and 26%, respectively. The distance between the fogger and the cage was also 10 feet, while the distance between cages was 5 feet. The trough of fog was high due to the conventional fogger. The environmental temperature was about 18 degrees centigrade, while wind speed was recorded according to WHO as 5 km/hour in time of trials. These results are not similar to Amoo et al. (2008), who studied the applications of d-phenothrin, resmethrin, and permethrin by using a backpack sprayer for plants and vegetation to evaluate the duration and efficacy against adult mosquitoes. About 100% mortality (24 h) of mosquitoes was determined in test cages placed within the vegetation. Insecticide treatments showed a 70–100% reduction of adult mosquitoes that were collected by traps baited with 1-octen-3-ol after 48 hours and one week of post-treatment.

In the third trial of the conventional thermal fogger, the percentage mortality and knockdown of adult mosquitoes at a 15-foot distance were about 70% and 30%, respectively. The distance between the fogger and the cage was also 15 feet, while the distance between cages was 5 feet. The trough of fog was high due to the conventional fogger. The environmental temperature was about 20 degrees centigrade, while wind speed was recorded according to WHO as 5-6 km/hour at the time of trials. These results are not similar to Zairi and Lee (2005). According to the regional and global scenario field and laboratory evaluation of insecticides related to public health against vector house flies and mosquitoes, household insecticide products are classified into three phases. The actual efficacy of the insecticides was recorded in Phase I in laboratory conditions. For adult flying insects, Peet-Grady Chamber and Glass Chamber (0.7 x 0.7 m) are more suitable for testing these methods. After one week of post applications, permethrin showed 90%

mortality, while resmethrin and d-phenothrin showed the level of mortality in 48 hours of post-application, and significant results were measured.

In the fourth trial of the conventional thermal fogger, the percentage mortality and knockdown of adult mosquitoes at a 20-foot distance were about 70% and 30%, respectively. The distance between the fogger and cage was also 20 feet, while the distance between cages was 5 feet. The trough of fog was high due to the conventional fogger. The environmental temperature was about 19 degrees centigrade, while wind speed was recorded according to WHO as 5-6.5 km/hour at the time of trials. These results are convergent with Lee *et al.* (2005) in field trials, the effect of *Bacillus thuringiensis* ssp. *israelensis* (B.l.i.) against the larvae of mosquitoes dispersed by ULV spraying. There were three indicators used to check the effectiveness of these species on larval stages: droplet analysis, larval mortality, and colony-forming unit enumeration. They concluded that a dosage of 0.5 liter/min can be used when high residual activity is desired, and it was given an output of 0.3 liter/min, which is effective for controlling *A. aegypti*. Both dosages were effective for control of C. *quinquefasciatus* in low residual activity. For control of *Anopheles maculatus*, the discharge rate of 0.5 liters/min was effective with low residual activity. It covered a large area, and its penetration was very deep in the body of mosquito larvae.

In the first trial of the Mobi-Fogger, the percentage mortality and knockdown of adult mosquitoes at a 5-foot distance were about 70% and 30%, respectively. The distance between the fogger and the cage was also 5 feet, and the distance between the cages was 5 feet. The fog was not high due to the model of the motorbike. The environmental temperature was about 19 degrees centigrade, while wind speed was recorded according to WHO as 5-7 km/hour at the time of trials. While in the second trial of the Mobi-Fogger, the percentage mortality and knockdown of adult mosquitoes at a 10-foot distance were about 70% and 30%, respectively. The distance between the fogger and the cage was also 10 feet, while the distance between cages was 5 feet. The fog was not high due to the model of the motorbike. The environmental temperature was about 21 degrees centigrade, while wind speed was recorded according to WHO as 5-6 km/hour at the time of trials. These results are not similar to Fulcher *et al.* (2016), who compared the physical characteristics as well as efficacy with multiple insecticides for BonideH Fog Rx Insect Fogger, Black Flag H Propane Insect Fogger, and BurgessH Outdoor Propane Insect Fogger. Evaluations were conducted with 7 machine chemical combinations, 3 depths of spray, and 3 species of laboratory-reared mosquitoes: *Anopheles quadrimaculatus*, *Culex quinquefasciatus,* and *Aedes aegypti*. Combinations of these factors were analyzed in conjunction with environmental parameters. Data showed statistical significance between all machines. The Bonide machine maintained integrity and durability for the longest period of time compared with the other 2 machines. When evaluating the 3 machines with DUETTM, mortality was highest with the Bonide and lowest with the Burgess machine.

In the third and fourth trials of the Mobi-Fogger at 15- and 20-foot distances between the fogger and cages. About 10 adults were released in cages, and the distance between cages was 5 feet. The percentage mortality and knockdown of adult mosquitoes at 15- and 20-feet distances were about 65-70% and 30-40%, respectively. The fog was not high due to the model of the motorbike. The environmental temperature was about 21 degrees centigrade, while wind speed was recorded according to WHO as 5-7 km/hour at the time of trials. These results are not the same with Ponlawat *et al.* (2017) compared the thermal fogger and ULV by using two insecticides, such as pyrethrin and permethrin, and an insect growth regulator, i.e., pyriproxyfen, was used to control the *A. aegypti* adult population. The effect of indoor and outdoor space spray was monitored by using these sprayers. There was a significant reduction of *A. aegypti* by using 3% pyrethrin and 10% pyriproxyfen as a space spray up to 20 days post-spray as compared to control. The thermal fogger showed fewer good results as compared to ULV because adult emergence is very high from larval populations due to the larger size of droplets when bioassays were completed.

In case of mortality, the conventional thermal fogger showed high mortality of mosquitoes at a 10 ft. distance as compared to 5 ft., 15 ft., and 20 ft., respectively. While in the case of Mobi-fogger, mosquitoes show high mortality at a 5 ft. distance as compared to others due to Mobi-foggers having a low throw as compared to conventional foggers. This data was taken after five minutes treated with Deltamethrin 1.5% EC (Emulsifiable Concentrate) by using a mobi-fogger at a 20-foot distance between the fogger and mosquito cages. The distance between the cages was also 5 feet. The mean of percent mortality by using 3 ml, 6 ml, and 13 ml of insecticide in one liter of diesel.

In case of knockdown, the conventional thermal fogger showed a high knockdown of mosquitoes at a 15 ft. distance as compared to 5 ft., 10 ft., and 20 ft., respectively. While in the case of the Mobi-Fogger, mosquitoes show a high knockdown at a 20 ft. distance as compared to others due to the Mobi-Fogger having a low throw as compared to conventional foggers. This data was taken after five minutes treated with Deltamethrin 1.5% EC (Emulsifiable Concentrate) by using a mobi-fogger at a 20-foot distance between the fogger and mosquito cages. The distance

between the cages was also 5 feet. The mean of percent mortality by using 3 ml, 6 ml, and 13 ml of insecticide in one liter of diesel. It is concluded that thermal fogger recommended due to its high throw of fog as compared to mobi fogger but in case of results mortality and knockdown are same due to high through of conventional thermal fogger and mobi-fogger.

CONCLUSION

While both thermal and mobi-foggers demonstrate comparable high rates of mosquito mortality and knockdown, traditional thermal foggers are recommended for field operations due to their superior fog throw, which likely enhances insecticide dispersal over a greater distance. Mobi-foggers, with their lower throw, exhibit higher mortality at closer ranges. Therefore, the choice of fogger should consider the specific operational context and target area size for effective adult mosquito control.

AUTHOR'S CONTRIBUTION

Muhammad Umar Farooq conducted experiment; Syed Aoun Taqi Bukhari worked as research collaborator in the experiment; Waseem Akram designed the experiment; Ahmad Hassan Tahir analyzed the data; Shah Alam provided technical assistance during experimentation; Muhammad Munam Atta and Hafiz Zill-e-Rehman revised the manuscript.

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AVAILABILITY OF DATA AND MATERIAL

Data will be provided upon request.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTERESTS

Authors declare no conflict of interest.

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