Acta Entomologica Serbica, 2022, 27(1): 81-90

UDC: 616.98:578.833.1(549.3)
616-008.97:595.771.1(549.3)
DOI: 10.5281/zenodo.6334658

LARVICIDAL EFFECT OF SELECTED SALTS AGAINST THE DENGUE VECTOR MOSQUITO *AEDES AEGYPTI* (DIPTERA: CULICIDAE) IN BANGLADESH

MOHAMMAD ZAGLUL HAIDER IQBAL[1*], KABIRUL BASHAR[2] and ABDUL JABBER HAWLADER[2]

1 Department of Zoology, Govt. Shahid Asad College, Narsingdi, Bangladesh
*E-mail: zaglul_iqbal@yahoo.com
2 Department of Zoology, Jahangirnagar University, Dhaka, Bangladesh
E-mails: bkabirul@juniv.edu; jabberjuniv@gmail.com

Abstract

The container breeding mosquito *Aedes aegypti* (Linnaeus) is the major universal vector of dengue viruses that cause dengue fever (DF), dengue hemorrhagic fever (DHF) and dengue shock syndrome (DSS). Vector control has an important role in reducing human cases of DHF/DSS. The purpose of this work was to evaluate the larvicidal effect of salt solutions against the larvae of *Ae. aegypti*. Freshly collected larvae were transferred to the laboratory and reared using rainwater as the rearing medium, with yeast granules as larval food. Five salts, $AgNO_3$, $HgCl_2$, $CdCl_2$, $CuSO_4$, and $CuCl_2$, were tested to assess the larvicidal effect on both the 1st and 3rd instar larvae of *Ae. aegypti*. Serial concentrations (0, 1, 3, 5, 7 and 10 ppm) of each salt were prepared using distilled water as the solvent. Silver nitrate ($AgNO_3$) was noted as the most effective larvicide, followed by $HgCl_2$, $CdCl_2$, $CuSO_4$, and $CuCl_2$. The LC_{50} values of $AgNO_3$ against 1st and 3rd instar larvae were 0.12 and 1.66 ppm, and the LC_{90} values were 2 and 3.35 ppm, respectively. The LT_{50} values of $AgNO_3$ (1 ppm) against 1st and 3rd instar larvae were 0.58 and 30.42 h, and the LT_{90} values were 6.00 and 67.49 h, respectively. All 1st instar larvae died, failing to pupate in every salt concentration (1-10 ppm) within 7 days. Third instar larvae were also unable to pupate entirely in $AgNO_3$ and $HgCl_2$ solutions but a very few (5.00-36.66%) pupations were found at 7 ppm, with higher concentrations of $CdCl_2$, $CuSo_4$ and $CuCl_2$ salts. In addition, $CdCl_2$, $CuSo_4$ and $CuCl_2$ prevented 66.66%, 57.14% and 50% of adult emergences from pupae at 5 ppm concentration, respectively. The order of decrease of toxicity for larval mortality was $AgNO_3$>$HgCl_2$>$CdCl_2$>$CuSO_4$>$CuCl_2$, and in preventing pupation and adult emergence it was $AgNO_3$≥$HgCl_2$>$CdCl_2$>$CuSO_4$>$CuCl_2$. $AgNO_3$ was found to have very good potential in the killing of *Aedes aegypti* larvae, prevention of pupae formation and adult emergence. Therefore, the results obtained could be considered a contribution to the search for eco-friendly larvicides of natural origin. Further studies are needed to understand the residual aquatic toxicity of this salt in the field.

KEY WORDS: Vector, larvicidal effect, dengue, organic salts

Introduction

Aedes aegypti (L.) is the predominant vector of dengue virus, a mosquito-borne arbovirus belonging to the family Flaviviridae (Gubler & Kuno, 1997). It is also a recognized vector of the Zika, Chikungunya and yellow fever viruses. Like *Plasmodium* species, the causative agents of malaria, dengue virus has become a global threat (Pinheiro & Corber, 1997; Gubler, 1998). Dengue fever (DF) is an acute and painful disease that is often not lethal, but dengue hemorrhagic fever (DHF) may lead to dengue shock syndrome (DSS), i.e., circulatory failure that is often lethal within 12 to 24 h. Dengue virus is transmitted almost always from man to mosquito and *vice versa* (Rudnick & Lim, 1986). Dengue virus spreads rapidly and can develop into pandemic proportions (Jelinek, 2000). A recent study estimated that there were more people at risk of dengue infection, calculating up to 3.97 billion living in 128 countries (Brady *et al*., 2013). Both species of *Aedes* (*Ae. aegypti* and *Ae. albopictus*) mosquitoes frequently breed in artificial containers such as water-storage vessels, flower vases, water accumulations, discarded tins, automobile tires and blocked gutters. These provide excellent larval habitats and adult resting sites (Curtis, 1991). Though DF has been reported as an urban disease (Gubler, 2004), recently dengue infection and the vector mosquitoes have been detected in rural areas of Thailand and India (Tewari *et al*., 2004; Mammen *et al*., 2008). Unplanned urbanization in cities and technological advancements in villages might have played a significant role in dengue transmission (Samuel *et al*., 2007; Pongsumpun *et al*., 2008).

The World Health Organization described mosquitoes as public enemy no. 1 (WHO, 1996). Mosquito control is a worldwide problem due to the vector nature and revival of various infectious diseases. The control of dengue transmission can be achieved by different strategies against the immature stages of *Ae. aegypti.* Application of control measures during these stages would increase the mortality of this vector before it reaches the adult stage (Bhat & Krishnamoorthy, 2017). The best way to manage dengue vectors is level control because breeding habitats are confined to limited stagnant water bodies. The most frequently used method of mosquito control worldwide is the use of synthetic insecticides (Burdick *et al*., 1964). Several insecticides have been indiscriminately used against mosquito larvae and as a result they have developed, over the time, resistance to a wide variety of insecticides. *Ae. aegypti* has developed resistance to malathion, temephos, permethrin, propoxur (Brown, 1986; Lee & Lime, 1989) and fenitrothion (Wattanachai *et al*., 1994). Although conventional insecticides have rapid effects, their adverse effects on humans and the environment are well known. Burdick *et al*. (1964) observed that residual toxicity may be magnified biologically in the food chain. On the other hand, salts are generally safer and more environmentally friendly than chemical pesticides. Therefore, the present study was conducted to determine the effects of salt solutions on the larvae of *Ae. aegypti*.

Materials and Methods

Mosquito rearing

The period from July to September has been reported as the peak dengue season in Bangladesh. *Ae. aegypti* larvae were collected from breeding sources at Amin Bazar Bus stops in Dhaka, Bangladesh. Freshly collected *Ae. aegypti* larvae were brought to the laboratory and kept for a short time in distilled water to remove dirty water from the breeding sites. The larvae were reared using rainwater (previously stored) as a rearing medium at the IRES (Insect Rearing and Experimental Station), Department of Zoology, Jahangirnagar University, Savar, Dhaka, at ambient temperature and relative humidity (28±2°C and 70±5% RH). In each rearing container (10x10x5 cm^3), about 500 ml rainwater was added and 500 larvae were released. An amount of 0.10 g of yeast granules as larval food was added to each rearing container once a

day. Each container was placed inside a rearing cage (30x30x30 cm^3) made of iron wire and covered with fine-mesh mosquito netting to prevent egg-laying by other mosquitoes. To avoid fungal contamination, the larvae were transferred to clean container every three days. Inspections were made in 6-h intervals to measure the water temperature, relative humidity, larval molting and wastage of food, if any. Periodically, surface film or scum food was removed with a syringe or brush and yeast granules (<0.02 g/100 ml) were added to the rearing medium, if needed. As the larvae developed, pupae were selected using a pipette and transferred to a glass jar (covered with gauze net). About 500 pupae were transferred to a new plastic bowl containing rainwater for adult emergence. No food was supplied for the non-feeding pupal stages. Adult mosquitoes were identified morphologically under stereomicroscopes using taxonomic keys (Barraud, 1934; Mattingly, 1971; Rattanarithikul, 1982; Amerasinghe, 1995; Rueda 2004) within a few hours after sampling.

A batch of 100 males and 300 females was housed together in a cage (30x30x30 cm^3) for about 5-6 days to mate. Cotton pads soaked with 10% glucose solutions were placed inside the cage as a food supplement for the adults. Gravid females were then placed in another cage and a rock pigeon (*Columba livia*) was fastened to the roof of rearing cage for about an hour to provide a sucking blood meal for the adult mosquitoes. Five plastic cups (125 ml) filled with distilled water were lined with a 7-cm-wide strip of filter paper and placed inside each cage for egg-laying. Eggs were removed at regular intervals and kept in air-dried conditions for subsequent use. When required, these eggs were released into rainwater in a plastic bowl for hatching. During the period of hatching, 0.02 g of glucose or yeast granules were added to each 100 ml of distilled water as larval food.

Preparation of stock solutions

Salt solutions of different concentrations were prepared by serial dilution. Serial dilution is a method used to stepwise dilute a substance into a solution with a constant dilution factor at each step. In this method, 0.1 g of salt was mixed with 100 ml of water for a stock solution of 1000 ppm. After that, 1 ml, 0.7 ml, 0.5 ml, 0.3 ml and 0.1 ml of stock solution were mixed with 99, 99.3, 99.5, 99.7 and 99.9 ml of water, respectively, to prepare 10, 7, 5, 3 and 1 ppm salt solutions.

Larvicidal testing procedure

To test each of the salt solutions, 36 plastic cups (125 ml) were cleaned with distilled water. They were then air-dried and arranged in groups numbered 1, 2, 3, 4, 5 and 6, with six cups in each group. Each cup in groups 2, 3, 4, 5 and 6 was filled with 99.9, 99.7, 99.5, 99.3 and 99 ml of rainwater, respectively. Afterward, 0.1, 0.3, 0.5, 0.7 and 1 ml of the stock solutions of salt were added to each cup of groups 2, 3, 4, 5 and 6, respectively. The cups in group 1, to which no salt solutions were added, were used as the control. The 1st and 3rd instar larvae were selected for the study because they are easily differentiated, and separate sets of experiments were carried out for each instar. Fourth instar larvae were avoided due to the possibility of immediate pupation. Thus, a batch of ten larvae of each instar stage was collected from the rearing container and released into each cup of groups 2, 3, 4, 5 and 6. An amount of 0.2g of yeast granules was added regularly to each cup as larval food. All the plastic cups along with larvae were placed inside the rearing cage to prevent any contamination and egg-laying by other mosquitoes. Cups with a particular type of salt were kept in separate cages. The larvae that showed no signs of motion were considered dead. Their number was counted and recorded at each inspection. Inspections were made at 6-h intervals. Decomposing larval food was removed with a syringe from each cup during the last inspection of the day to eliminate any possible impact. A small amount (<0.02 gm/100 ml) of larval food was added to each cup if needed. The mortality of larvae (after 24 h), as well as the duration of larval instar stages, number of pupae, mortality of pupae and adult emergence were recorded.

Statistical analysis

LC_{50}, LC_{90}, LT_{50}, LT_{90} at a 95% confidence interval (CI) were generated through probit analysis using the Statistical Package for Social Sciences (SPSS®) version 20 (SPSS 2007). Mean mortality of larvae, standard error, % of pupation, % of pupal mortality and % of adult emergence of mosquitoes were calculated using MS Excel (2013).

Results

Effects of salts on 1st and 3rd instar larvae

Data showing the LC_{50} and LC_{90} values along with a 95% CI of the different salts are presented in Table I. The LC_{50} and LC_{90} values of salts against 1st instar larvae ranged from 0.12 to 5.85 ppm and 2.00 to 11.50 ppm, respectively. The LC_{50} values of $AgNO_3$, $HgCl_2$, $CdCl_2$, $CuSO_4$ and $CuCl_2$ were 0.12, 0.81, 1.47, 1.99 and 5.85 ppm respectively, whereas the LC_{90} values were 2.00, 4.06, 5.69, 7.31 and 11.50 ppm. $AgNO_3$ had the lowest LC_{50} (0.12 ppm) and LC_{90} (2 ppm) values, and $CuCl_2$ registered the highest LC_{50} (5.85 ppm) and LC_{90} (11.50 ppm) values of the five salts tested.

The LC_{50} values of $AgNO_3$, $HgCl_2$, $CdCl_2$, $CuSO_4$ and $CuCl_2$ against 3rd instar larvae were 1.66, 1.84, 2.56, 3.29 and 7.84 ppm, respectively, and the LC_{90} values were 3.35, 4.22, 6.33, 8.08 and 19.38 ppm, respectively (Table I).

Table I. Lethal concentrations (LC) of 1st and 3rd instar larvae of *Ae. aegypti* at 95% confidence interval of the salt solutions. Data in brackets represent the 95% of LC values against 1st and 3rd instar larvae.

Type of salt	LC values (ppm)			
	1st instar		3rd instar	
	LC_{50}	LC_{90}	LC_{50}	LC_{90}
$AgNO_3$	0.12(0.09-0.14)	2.00(1.20-3.40)	1.66 (1.55-1.77)	3.35 (3.08-3.70)
$HgCl_2$	0.81(0.52-1.05)	4.06(3.15-6.42)	1.84 (1.72-1.96)	4.22 (3.89-4.64)
$CdCl_2$	1.47(1.23-1.68)	5.69(4.70-7.49)	2.56(2.39-2.74)	6.33(5.62-7.37)
$CuSO_4$	1.99(1.80-2.19)	7.31(6.01-9.79)	3.29 (3.08-3.54)	8.08 (6.96-9.88)
$CuCl_2$	5.85(5.51-6.30)	11.50(10.08-13.64)	7.84 (7.01-9.17)	19.38(15.31-26.85)

Results on the LT_{50} and LT_{90} values for 1st instar larvae at 1 ppm concentration of all salts are shown in Table II. Of all the salts, the lowest LT_{50} (0.58 h) and LT_{90} (6.00 h) values were found at 1 ppm concentration of $AgNO_3$. In contrast, higher LT_{50} values were 6.86, 23.37, 28.39 and 37.14 h at 1 ppm concentration for $HgCl_2$, $CdCl_2$, $CuSO_4$ and $CuCl_2$, respectively, whereas the higher LT_{90} values for the salts were 14.06, 140.98, 177.36 and 220.63 h, respectively.

Of all the tested salts, the lowest LT_{50} (30.42 h) and LT_{90} (67.49 h) values were found at 1 ppm concentration of the $AgNO_3$ solution; on the other hand, the highest LT_{50} (82.53 h) and LT_{90} (213.17 h) values were found at 1 ppm concentration of the $CuSO_4$ solution (Table II). The higher LT_{50} values (33.27, 62.07 and 82.53 h) and LT_{90} values (73.99, 149.36 and 213.17 h) were found at 1 ppm concentration of $HgCl_2$, $CdCl_2$ and $CuSO_4$, respectively. Furthermore, it was observed that out of the five salts, $AgNO_3$ showed the lowest LC_{50} and LC_{90} values and the lowest LT_{50} and LT_{90} values at each concentration.

Table II. Lethal time of 1st and 3rd instar larvae (*Ae. aegypti*) for different concentrations of salt solutions.

Type of salt	LT Values	Lethal time (LT) against each concentration of a salt									
		1 ppm		3 ppm		5 ppm		7 ppm		10 ppm	
		1st instar	3rd instar	1st instar	3rd instar	1st instar	3rd instar	1st instar	3rd instar	1st instar	3rd instar
$AgNO_3$	LT_{50}	0.58	30.42	0.30	3.11	0.18	2.14	0.09	1.32	0.02	1.31
	LT_{90}	6.00	67.49	3.01	11.28	2.84	6.83	2.21	5.32	1.06	3.48
$HgCl_2$	LT_{50}	6.86	33.27	3.17	6.29	2.86	4.18	2.32	2.26	1.23	1.99
	LT_{90}	14.06	73.99	12.04	24.55	7.52	20.64	3.26	8.90	2.08	7.73
$CdCl_2$	LT_{50}	23.37	62.07	9.49	10.55	7.49	10.31	4.97	6.13	3.68	3.69
	LT_{90}	140.98	149.36	31.79	36.57	17.89	33.39	12.20	20.60	10.00	10.74
$CuSO_4$	LT_{50}	28.39	82.53	11.15	21.96	7.99	18.42	5.57	9.75	3.57	5.32
	LT_{90}	177.36	213.17	46.41	36.90	31.22	35.37	17.02	25.16	10.92	13.34
$CuCl_2$	LT_{50}	37.11	93.14	21.88	30.14	13.21	22.65	10.45	16.54	5.64	13.61
	LT_{90}	220.63	257.09	165.96	57.10	60.57	43.90	40.69	42.16	13.94	38.79

Effects of salts on pupation and adult emergence

It was noted that 100% of 1st instar larvae died at all concentrations (1-10 ppm) of each salt within 7 days. All larvae died within 9, 6 and 3 h when exposed to 1 ppm, 3 ppm, and 5 ppm solutions of $AgNO_3$, respectively. On the other hand, 46%, 93% and 100% of 3rd instar larvae died within 24, 24 and 9 h when exposed to 1, 3 and 10 ppm solutions of $AgNO_3$, respectively. No pupation and adult emergence were observed of 3rd instar larvae at 7 and 10 ppm concentrations of the $CdCl_2$, $CuSO_4$ and $CuCl_2$ salt solutions (Table III).

Table III. Efficacy of salts on pupation, pupal mortality and adult emergence from 3rd instar larvae of *Ae. aegypti*

Type of salt	Concentrations (ppm)	Larval mortality (%)	Pupation (%)	Pupal mortality (%)	Adult emergence (%)
$CdCl_2$	1	78.34	21.66	53.84	46.16
	3	88.34	11.66	57.14	42.86
	5	95	05	66.66	33.33
	7	100	00	00	00
	10	100	00	00	00
$CuSO_4$	1	73.34	26.66	50	50
	3	86.67	15	55.55	44.45
	5	88.34	11.66	57.14	42.86
	7	100	00	00	00
	10	100	00	00	00
$CuCl_2$	1	63.34	36.66	36.36	63.64
	3	81.67	18.33	45.45	54.55
	5	86.67	13.33	50	50
	7	100	00	00	00
	10	100	00	00	00

Table III – continued

Type of salt	Concentrations (ppm)	Larval mortality (%)	Pupation (%)	Pupal mortality (%)	Adult Emergence (%)
$AgNO_3$	1	100	00	00	00
	3	100	00	00	00
	5	100	00	00	00
	7	100	00	00	00
	10	100	00	00	00
$HgCl_2$	1	100	00	00	00
	3	100	00	00	00
	5	100	00	00	00
	7	100	00	00	00
	10	100	00	00	00

Discussion

The efficacy of salt solutions on the development/mortality of mosquito larvae might be due to their impact on the cells of the anal gill. Parallel result was reported by Wigglesworth (1933a), who found that cells of the anal gills of *Ae. argenteus* (Poir.) became swollen, perhaps due to the diffusion of hypertonic NaCl into the cells that was caused by differences in the concentrations of hemolymph and the external medium. He also stated that the concentration of NaCl in the cells rises above that in the hemolymph and water from the latter moves into the cells by osmosis. This difference in osmotic pressure between the body fluids and the external medium is the main factor behind the swelling of cells. MacFie (1914) also found that the destructive action of a 2% salt solution or higher on the larvae of *Ae. aegypti* (synonym *Stegomyia fasciata*) is due to the hypertonicity of the solution. Bradley (1994) stated that only 5% of all extant species of the family Culicidae are capable of surviving in saltwater and those species of *Aedes* that do not possess a segment on the rectum for the regulation of ions cannot survive salty water. In the present study, it was also observed that the anal gills of *Aedes* larvae became swollen by absorbing salt solutions, after which the larvae died. It was noted that all the salt solutions were able to kill 1st instar larvae of *Ae. aegypti* at a lower concentration. It is pertinent to mention here the findings of Suzuki (1959), who found that the LC_{50} values of $AgNO_3$ and $HgCl_2$ were 1.7 ppm (0.00017%) and 1 ppm (0.0001%), respectively, against 4th instar larvae of *Culex pipiens pallens*.

In the present study, it was noted that $AgNO_3$ kills 60% of 3rd instar larvae at 1 ppm (0.0001%) concentration and when the concentration increased to 3 ppm (0.0003%), mortality also increased to 98.3%. Riaz *et al.* (2013) reported that a 10% NaCl solution killed the majority of *Ae. aegypti* larvae in the laboratory and 100% mortality was achieved within the minimum time when they were exposed to a 20% salt solution. MacFie (1922) reported that undiluted seawater killed the larvae of *Stegomyia fasciata* within 2 to 4 h, and 50% or more diluted seawater caused death after 24 h. Wigglesworth (1993) conducted experiments with NaCl and obtained good results with a 1.25% solution against *Aedes* species within 4-7 days. Wigglesworth (1933) also stated that 1% of NaCl is effective in killing larvae within a week and mortality increased with the increase in salt concentration. Suzuki (1959) studied the relation of the required time for death of 50% of larvae (LT_{50} or TD_{50}) to the concentration of the salts and calculated the order of decreasing toxicity of the heavy-metal salts. He also stated that TD_{50} increases in parallel to the decreases in salt concentration. A high larval toxicity of $AgNO_3$ against *Ae. aegypti* larvae was found in the present study. A similar result was found by Suzuki (1959) in Japan.

There was no pupation or adult emergence of 3rd instar larvae in solutions of $AgNO_3$ and $HgCl_2$. Though very few pupations (5.00-36.66%) were found in the other three salt solutions, they could not develop into adults (they died in the pupal stage) or the time of emergence might be prolonged. Our results support those of

Pappas & Pappas (1983) from Peru who reported that less than 50% of *Culiseta inornata* larvae reached the pupal stage at NaCl concentrations above 0.01 ppm.

Conclusion

In the present study, it was recorded that all the tested salt solutions were effective in killing both tested larval instars (1st and 3rd) of *Ae. Aegypti.* The salt solution with $AgNO_3$ showed the highest efficacy. Among the five salts, $AgNO_3$ had the lowest LT_{50} and LT_{90} values (0.58 and 6 h for 1st instar, and 30.42 and 67.49 h for 3rd instar, respectively). $AgNO_3$ and $HgCl_2$ solutions successfully prevented pupation and adult emergence of both instar (1st and 3rd) larvae. These promising results could be useful in the search for a more effective and eco-friendlier larvicidal product against *Ae. aegypti*, especially in regions where mosquitoes are highly resistant to chemical insecticides. However, the findings of this laboratory-based study need to be evaluated in the field. Additionally, further investigation into the residual toxicity on non-target organisms is very important and deserves attention.

Author contributions

KB and AJH designed the study. MZHI carried out the laboratory and field work and computed data and analysis. MZHI, KB and AJH collaborated in writing the manuscript. All authors read and approved the final manuscript.

Acknowledgments

We thank the respected teachers of the Department of Zoology, Jahangirnagar University, Dhaka, for their valuable suggestions. The authors acknowledge the laboratory of Entomology, Department of Zoology, Jahangirnagar University, Savar, Dhaka, Bangladesh, for providing laboratory facilities. We thank the University grant commission of Bangladesh for the award of PhD fellowship.

References

Amerasinghe, F. P. (1995). Illustrated keys to the genera of mosquitoes (Diptera: Culicidae) in Sri Lanka. *Journal of the National Science Council of Sri Lanka*, *23*(4), 183-211.

Barraud, P. J. (1934). *The fauna of British India, Including Ceylon and Burma, Diptera Vol. 5 Family – Culicidae. Tribes Megarhinini and Culicini*. Taylor and Francis, London, 463 pp.

Bradley, T. J. (1994). The role of physiological capacity, morphology and phylogeny in determining habitat use in mosquitoes. In P. C. Wainwright & S. M. Reilly, (Eds.), *Ecological morphology: integrative organismal biology*. Chicago, IL: University of Chicago Press, 303-318.

Brady, O. J., Gething, P. W., & Bhatt, S. (2013). Refining the Global Spatial Limits of Dengue Virus Transmission by Evidence-Based Consensus. *Nature*, *496*(7446), 504-507.

Brown, A. W. A. (1986). Insecticide resistance in mosquitoes: A pragmatic review. *Journal of the American Mosquito Control Association, 2*(2), 123-140.

Burdick, G. E., Harris, E. J., Dean, H. J., Walker, T. M., Skea, J., & Colby, D. (1964). The accumulation of DDT in lake trout and the effect on reproduction. *Transactions of the American Fisheries Society*, *93*(2), 127-136.

Curtis, C. F. (1991). *Control of disease vectors in the community*. Wolf Publishing, London, 233pp.

Gubler, D. J. (2004). Cities spawn epidemic dengue viruses. *Nature medicine, 10*(2),129-130.

Gubler, D. J. (1998). Resurgent vector-borne diseases as a global health problem. *Emerging infectious diseases*, *4*(3), 442.

Gubler, D. J., & Kuno, G. (1997). *Dengue and dengue hemorrhagic fever*. CAB International, New York, 478pp.

Jelinek, T. (2000). Dengue fever in international travelers. *Clinical Infectious Diseases*, *31*(1), 144-147.

Lee, H.L., & Lime, W. (1989). Are-evaluation of the susceptibility of field-collected *Aedes* to temephos in Malaysia. *Journal mosquito borne diseases bulletin*, *6*, 91-95.

MacFie, J. W. S. (1922). The effects of saline solutions and sea water on *Stegomyia fasciata*. *Annals of tropical medicine and parasitology*, *15*, 277-280.

MacFie, J. W. S. (1914). A note on the action of common salt and sea water on *Stegomyia fasciata*. (=*Aedes aegypti*). *Bulletin of entomological research*, *4*, 339-344.

Mammen, M. P., Pimgate, C., Koenraadt, C. J., Rothman, A. L., Aldstadt, J., & Nisalak, A. (2008). Spatial and temporal clustering of dengue virus transmission in Thai villages. *PLOS Med*, *5*(11), 205.

Mattingly, P. F. (1971). Contributions to the mosquito fauna of Southeast Asia. XII. Illustrated keys to the genera of mosquitoes (Diptera:Culicidae), Contributions of the American Entomological Institute, *7*(4),1-8.

Mohd., A. B., & Krishnamoorthy, K. (2017). Studies on the life cycle parameters of *Stegomyia aegypti*. *Academic journal of entomology*,*10(*2), 25-31.

Pappas, L. G. & Pappas, C. D. (1983). Laboratory studies on the significance of NaCl as an oviposition different in Culisetainornata. *Mosquito news*, *43*(2), 153-155.

Pinheiro, P. F. & Corber, S. J. (1997). Global situation of dengue and dengue hemorrhagic fever and its emergence in the America. *World Health Statistics Quarterly*, *50*, 161-169.

Pongsumpun, P., Garcia Lopez, D., Favier, C., Torres, L., Llosa, J., & Dubois, M. A. (2008). Dynamics of dengue epidemics in urban contexts. *Tropical medicine and international health*, *13*, 1180-1187.

Rattanarithikul, R. (1982). A guide to the genera of mosquitoes (Diptera: Culicidae) of Thailand with illustrated keys, biological notes and preservation and monitoring techniques. *Mosquito systematics*, *14*, 139-208.

Riaz, M. A., Riaz, A., Baqir, M., & Ijaz, B. (2013). The effect of different NaCl concentration on the survival of *Aedes aegypti* larvae in Wahga Town Lahore. *Journal of basic applied chemistry*, *2*(4),12-15.

Rudnick, A., & Lim, T. W. (1986). Dengue fever studies in Malaysia. Lim, T. W., (Ed), Bull. No. 23, *Ins. Med. Res.*, Malaysia, 162.

Rueda, L. M. (2004). Pictorial keys for the identification of mosquitoes (Diptera: Culicidae) associated with Dengue virus transmission. *Zootaxa*, *589*(1),1-60.

Samidurai, K., Jebanesan, A., Saravanakumar, A. Govindarajan, M., & Pushpanathan, T. (2009). Larvicidal, ovicidal and repellent activities of *Pemphis acidula* frost. (Lythraceae) against filarial and dengue vector mosquitoes. *Academic journal of entomology*, *2*(2), 62-66.

Samuel, P. P., Thenmozhi, V., & Tyagi, B. K. (2007). A focal outbreak of dengue fever in a rural area of Tamil Nadu. *Indian Journal of Medical Research*, *125*, 179-181.

SPSS® v 20. (2007). SPSS for Windows. *Spss Inc.* Chicago, IL.

Suzuki, K. (1959). The toxic influence of heavy metal salts upon mosquito larvae. *Journal of the Faculty of Science, Hokkaido University,* Series 6, Zoology *14*(2), 196-209.

Tewari, S. C., Thenmozhi, V., Katholi, C. R., Manavalan, R., Munirathinam, A., & Gajanana, A. (2004). Dengue vector prevalence and virus infection in a rural area in south India. *Tropical Medicine and International Health*, *9*, 499-507.

Wattanachai, P., Rielrangboonya, P., Boonyabuncha, S., & Phunurai, P. (1994). Susceptibility of *Aedes aegypti* to organophosphorus compound in Thailand. *Journal mosquito borne diseases bulletin*, *12*, 27.

WHO. (1996). Report of WHO informal consultation on the evaluation and testing insecticides, CTD/ WHO PES/IC/96.*1*, 69.

Wigglesworth, M. A. (1993). The adaptation of mosquito larvae to salt water. *Journal of experimental biology*, *10*(1), 27-37.

Wigglesworth, V. B. (1933). The effect of salts on the anal gills of the mosquito larva. *Journal of experimental biology*, *10*,1-15.

ЛАРВИЦИДНИ ЕФЕКАТ ОДАБРАНИХ СОЛИ НА КОМАРЦЕ ВЕКТОРЕ ДЕНГА ГРОЗНИЦЕ *AEDES AEGYPTI* (DIPTERA: CULICIDAE) У БАНГЛАДЕШУ

МОХАМАД ЗАГЛУЛ ХАИДЕР ИКБАЛ, КАБИРУЛ БАШАР И АБДУЛ ЈАБЕР ХАВЛАДЕР

Извод

Aedes aegypti (Linnaeus) је главни универзални вектор вируса који изазива денга грозницу (DF), денга хеморагичну грозницу (DHF) и синдром денга шока (DSS). Контрола вектора има важну улогу у смањењу случајева DHF/DSS код људи. Сврха овог рада је била да се процени ларвицидни ефекат раствора соли на ларве *Ae. aegypti*. Свеже сакупљене ларве су пребачене у лабораторију и узгајане користећи кишницу као медијум за узгој, са гранулама квасца којима се хране ларве. Пет соли, $AgNO_3$, $HgCl_2$, $CdCl_2$, $CuSO_4$, и $CuCl_2$, тестирано је да би се проценио ларвицидни ефекат на ларве 1. и 3. ступња *Ae. aegypti*. Серијске концентрације (0, 1, 3, 5, 7 и 10 ppm) сваке соли су припремљене коришћењем дестиловане воде као растварача. Сребро нитрат ($AgNO_3$) је забележен као најефикаснији ларвицид, а затим следе $HgCl_2$, $CdCl_2$, $CuSO_4$, и $CuCl_2$. Вредности LC_{50} $AgNO_3$ у односу на ларве 1. и 3. ступња биле су 0,118 и 1,659 ppm, а вредности LC_{90} биле су 2 и 3,347 ppm. Вредности LT_{50} $AgNO_3$ (1 ppm) у односу на ларве 1. и 3. ступња биле су 0,575 и 30,42 h, а вредности LT_{90} биле су 6,00 и 67,49 h. Све ларве 1. ступња су угинуле, не успевши да се улуткају у свакој концентрацији соли (1-10 ppm) у року од 7 дана. Ларве 3. ступња такође нису биле у стању да се улуткају у потпуности у растворима $AgNO_3$ и $HgCl_2$, али је пронађено врло мало (5,00-36,66%) лутки при 7 ppm, са вишим концентрацијама соли $CdCl_2$, $CuSo_4$ и $CuCl_2$. Поред тога, $CdCl_2$, $CuSo_4$ и $CuCl_2$ спречили су 66,66%, 57,14% и 50% изласка адулта из лутки при концентрацији од 5 ppm. Редослед смањења токсичности за морталитет ларви био је $AgNO_3$>$HgCl_2$>$CdCl_2$>$CuSO_4$>$CuCl_2$, а у спречавању улуткавања и изласка одраслих $AgNO_3$≥$HgCl_2$>$CdCl_2$>$CuSO_4$>$CuCl_2$. Утврђено је да $AgNO_3$ има веома добар потенцијал у убијању ларви *Aedes aegypti*, спречавању улуткавања и изласка одраслих. Стога се добијени резултати могу сматрати доприносом у потрази за еколошки прихватљивим ларвицидима природног порекла. Потребна су даља истраживања да би се разумела резидуална токсичност ове соли за воду на терену.

Received: October 12th, 2021
Accepted: February 16th, 2022