Indian Journal of Entomology 86(2): 356-361 (2024) DoI. No.: 10.55446/IJE.2023.1607

STUDY OF THE TOXIC EFFECT OF CHEMICAL PESTICIDE ACTELLIC 50EC AGAINST *CULISETA LONGIAREOLATA* MOSQUITO LARVAE

Rabah Chaouch[1], Ali Bouaziz[2], Habiba Gacem[1] and Boudjema Saoudi[3]*

[1]Laboratory of Marine Ecobiology and Coastal Environments, Department of Natural Sciences, Higher School for Professors of Technological Education, Skikda (ENSET), Brother Bouceta city Azzaba 21000, Algeria
[2]Laboratory of Terrestrial and Aquatic Ecosystems (LTAE), Faculty of Science, Department of Biology, Mohamed Cherif Messaadia University, Souk-Ahras 41000, Algeria
[3]Laboratory of Organic Chemistry and Interdisciplinarity (LOCI), Faculty of Science and Technology, Mohamed Cherif Messaadia University, Souk Ahras, 41000 Souk Ahras, Algeria
*Email: b.saoudi@univ-soukahras.dz (corresponding author): ORCID ID 0000-0001-6379-7043

ABSTRACT

In this study, the toxicity of an insecticide, Actellic 50EC, was tested against L3 and L4 instars of mosquito larvae *Culiseta longiareolata* (Macquart). The newly exuviated larvae were subjected to various concentrations (25, 40, and 75 µg/ l) for 24 hr and out until the adult stage. Probit analysis for L3 stage showed that following obdsevations continued to adult stage LC_{50}=18.70 µg/ l and LC_{90}= 60.81 µg/ l. On the other hand, L4 stage shows these were LC_{50}= 36.42 µg/ l and the LC_{90}= 102.45 µg/ l, respectively, indicating that it is more toxic to L3. This study reveals that lipids and carbohydrates have decreased, while there is an increase in proteins, which has been associated in some cases with morphological deformations.

Key words: Organophosphate, pirimiphos-methyl, biochemical metabolite, Culicidian, L3 stage larvae, L4 stage larvae, lipids, carbohydrates, proteins, LC_{50}, LC_{90}, diseases, chemical stressors, morphological deformations.

Because of its role in the transmission of viral and parasitic diseases that can affect humans and animals, the Culicidian fauna has taken center stage in entomological news around the world (Salavati, et al., 2021). Several mosquito species are vectors of medical and veterinary zoonoses, responsible for the transmission of many human and animal diseases, including malaria, yellow fever, West Nile fever, dengue, and other arboviruses, causing millions of deaths (Abutaha et al., 2023; Das and Deobhankar, 2023). Controlling mosquito populations with insecticides is a key component of malaria prevention campaigns. Strategic approaches to vector control frequently rely on the use of multiple insecticides to avoid or overcome the recurrent emergence of resistance in natural populations (WHO, 2018). In this regard, various classes of insecticides have been developed (Ranson, 2011). Organophosphate pesticides are organic compounds containing phosphorus and are used as insecticides. They break down rapidly in sunlight and in contact with air and soil, although small amounts can be detected in food and drinking water (Grau-Bové et al., 2021). Pyrimiphos-methyl is a cheap organophosphate pesticide extensively used in mosquito control interventions for crop and food protection, particularly in Africa (Grau-Bové et al., 2021; Sherrard-Smith et al., 2018). Moreover, Pirimiphos-methyl is a fast-acting insecticide with less toxicity to humans and the environment (Tabbabi et al., 2017). Actellic 50EC is within pirimiphos-methyl, with excellent properties for protecting stored foodstuffs. It acts on the larval and adult forms of insects by contact, ingestion, and inhalation. This study evaluates the toxic effect of Actellic 50EC (pirimiphos-methyl 50%) against L3 and L4 Culiseta. *longiareolata* (Macquact) larvae. Additionally, the impact of lethal concentrations (LC_{50} and LC_{90}) on the metabolites of L4 mosquito larvae were estimated.

MATERIALS AND METHODS

Cs. longiareolata eggs and larvae were collected from untreated areas located in Annaba city (Algeria). The larvae were reared as previously described (Aissaoui et al., 2022). Each batch of 25 larvae being kept in small plastic bowl having 500 ml of tap water. They were fed daily with a diet of finely ground brewer yeast and Biscuit Petit Regal-dried yeast (3:1). Pirimiphos-methyl is a chemical compound belonging to organophosphates that inhibits acetylcholine esterase, an enzyme involved in the regulation of nerve impulses (Rambabu and Rao, 1994). It belongs to class III according to WHO classification, i.e. an insecticide of little danger to humans under normal conditions of use

(WHO, 2005a). The WHO has evaluated pirimiphos-methyl as a mosquito larvicide and adulticide. The trade name of pirimiphos-methyl is Actellic 50EC. Its chemical formula is O-[2-(diethylamino)-6-methyl-4-pyrimidinyl] O, O-dimethyl phosphorothioate. The larvicidal efficacy of pirimiphos-methyl has been determined against *Cs. longiareolata*. The toxicological tests were carried out with three concentrations (25, 40, and 75 µg/ l) of pirimiphos-methyl against newly exuviated larval stages (L3 and L4) of *Cs. longiareolata*, under laboratory conditions. Bioassays and control series were performed with three replicates of 25 larvae for each used concentration, prepared in a separate jar containing 500 ml of breeding water. After 24 hr of larvae exposure, according to the recommendations of the World Health Organization (WHO, 2005b), the water is changed, and the food is added every three days until when adults emerge. The mortality of the control series and the treated series is recorded daily and followed during the other stages of development until the emergence of the adults.

Carbohydrates, proteins, and lipids were extracted according to the method described by Shibko et al. (1966). Pooled samples (20 individuals of L4 larvae per pool) were weighed and extracted in 1 ml of trichloroacetic acid (20%). Briefly, protein quantification was performed by Bradford method (Bradford, 1976). Carbohydrates were determined by the anthracite method (Duchateau and Florkin, 1959). Lipids were measured by the vanillin method (Goldsworthy et al., 1972). The rate of mortality was corrected using Abbott's formula (Abbott, 1925) when mortality was observed in the control series. Subsequently, the toxicity data were subjected to probit analysis (Ficher, 1957) to determine the lethal concentrations (LC_{50} and LC_{90}) for the treated larvae of the tested species. The analysis included the calculation of confidence limits (95%) for the upper confidence limit values (LSC) and lower confidence limit (LSC), as well as the determination of the slope and regression equation of the concentration-mortality lines (Veerakumar et al., 2014). All statistical analyses were performed using MINITAB Software, and significance level of $p< 0.05$ was considered for determining statistically significant differences.

RESULTS AND DISCUSSION

Actellic 50EC exhibited a significant larvicidal effect ($p < 0.05$) against *Cs. longiareolata,* expressed by a relatively high mortality compared to control. The cumulative mortality rate varied between 64.4% (25 µg/ l) to 93.33% (70 µg/ l) in L3 larvae and from 34.66% to 80% in L4 larvae with a dose-response relationship. Both sublethal and lethal concentrations exhibited variation according to the periods after treatment (Table 1). The effectiveness of pirimiphos-methyl 50EC has been demonstrated in several studies across several mosquito species, including larvae of *Anopheles Culicifacies*, *Anopheles stephensi, Cx. quinquefasciatus*, and *Cx. pipiens* (Ansari et al., 2004). Kolaczinski et al. (2000) reported significant effectiveness of pirimiphos-methyl 50EC against adults of *Anopheles gambiae* and *Cx. quinquefasciatus*. Studies indicate that the combination of pirimiphos-methyl with *Bacillus thuringiensis* effectively killed both larvae and adult mosquitoes. Whether used alone or in combination with a biolarvicide, pirimiphos-methyl exhibits promising potential in the combatting *Ae. aegypti* (Lee et al., 2014). However, pirimiphos-methyl caused high levels of mortality in larvae and adults of *Tenebrio molitor* (Nickolas et al., 2019). In contrast, the utilization of carbamates, DDT, and pyrethroids has demonstrated substantial insecticidal activity against *An. gambiae, Culex* sp (Koumba et al., 2018). A similar observation was made by Aksorn and Mayura (2018) on *Aedes aegypti* larvae and nymphs, where mortality was found to be correlated with doses.

The effect on the development time of third and fourth instar larvae are shown in Table 2. The results show that Actellic 50EC interferes with larval growth in both L3 and L4 stages, leading to an extended duration of larval development. A significant difference was observed between the control and treated series, particularly with the concentrations (40 and 90 µg/ l) for the third and the fourth instar larvae ($p < 0.001$). Some morphological deformities were also observed in treated individuals

Table 1. Lethal concentrations (LC_{50} and LC_{90}, Fiducial limits (FL), µg/ l) of pirimiphos-methyl 50EC against third and fourth instar larvae of *Cs. longiareolata*

Larval stage	LC_{50}		LD_{90}		Hill slope	R^2	Regression equation
	µg/ l	95% FL	µg/ l	95% FL			
L3	18.70	15.84-21.87	60.81	51.53-71.75	2,48	0,97	y = 2,5049x + 1,8204
L4	36.42	32.51-40.79	102.45	91.47-114.74	1.91	0.99	y = 2,855x + 0,5534

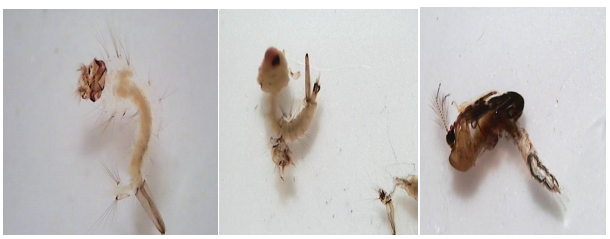
Table 2. Effect of Actellic 50EC on the duration of development of larvae of *Cs. longiareolata*

Concentration (µg/ l)	Third instar	Fourth instar
Control	3.91± 0.28	6.86 ± 1.60
25	4.13± 0.40	7.53± 0.64 P=0.013*
40	5.43± 0.40* p=0.013	9.35± 0.76 P=0.016*
70	5.86± 0,11**p=0.008	11.16± 0.76 P=0.003**

Data means ± standard deviation (n= 10). Values on the same row with asterisk significantly different based on student tests ($p<0.05$)

(Fig. 1). This aligns with studies on novaluron and RH-0345, which reported effects on *Cs. longiareolata* and *Cx. pipiens* larvae development, including various morphological aberrations (Bouaziz et al., 2011; Djeghader, 2014; Bouaziz et al., 2017; Bouabida et al., 2017). Alouani et al., (2018) showed an extension in the duration of larval and pupal development of *Cx. pipiens* after treatment with azadirachtin. Similar effects are indicated, after novaluron treatment against *Palpita unionalis* larvae (Ghoneim et al., 2017), Morphological transformation stopped, and abnormalities appeared during treatment with a chitin formation inhibitor on the pupa of *Lobesia botrana* (Saenz-de-Cabeson et al., 2006). Similar deformities were recorded during the moulting of a lufenuron-treated *Schistocerca gregaria* pupa in the fifth instar larvae, resulting in adult color change and the inability of adults to shed the old cuticle with deformed wings (Bakr et al., 2009).

Actellic 50EC was tested on the fourth instar larvae of *Cs. longiareolata* with two lethal concentrations (LC_{50}= 32.42µg/ l and LC_{90}= 102.45µg/ l). Its effects were assessed on the biochemical composition (carbohydrates, lipids, and proteins) throughout the whole body at 2, 4, and 6 days after treatment. The comparison of mean values as given in Table 3 shows a significant increase in the total protein content after treatment with the highest concentration (controls vs LC_{50}; p=0.0002, control vs LC_{90} p=0.001) with a dose effect (LC_{50} vs LC_{90}: p=0.0034). Various studies have indicated that exposure to an organism to the xenobiotic product can modify the synthesis of certain proteins (biotransformation enzymes, stress proteins) (Curtis et al., 2010). Proteins play a crucial role in the development, growth, and accomplishment of vital activities of insects, as they are essential for enzymes that carry out the cascades of metabolic activities in organisms (Preet and Sneha, 2011). Proteins, such as chitin production and cuticle development, play a crucial role in insect metamorphosis. When insects are subjected to plant-based biopesticides, their whole-body protein levels may vary due to down regulation or up regulation (Parthiban et al., 2021; Parthiban et al., 2019). Lawrence and Olorunfemi (2019) reported an increase in tissue protein levels in adult *Cx. quinquefasciatus* following treatment with sublethal concentrations of cypermethrin. Previous studies suggest that the synthetic pyrethroid deltamethrin and the insect neurotoxin imidacloprid could increase protein content in *Nilaparvata lugen*s (Ge et al., 2009). Similar results were observed in *Sitophilus granarius* treated with azadirachtin (Guettal, 2021). Moreover, Lawrence and Olorunfemi (2019) reported an increase in tissue protein levels in *Cx. quinquefasciatus* adults following treatment with the highest sublethal concentrations of cypermethrin. An elevation in protein levels was revealed in *Cx. pipiens* following treatment with *Rosmarinus officinalis* essential oil (Zeghib et al., 2020). In contrast, treatment of *Cx. pipiens* larvae with entomopathogenic fungi, *Origanum glandulosum* EO and *Ocimum basilicum* EO led to a drop in total protein concentrations (Bouguerra and Boukoucha, 2021; Hamama et al., 2021). Variations in protein content likely reflect the balance between synthesis, storage, transport, and degradation of structural and functional nutrients during ontogenesis as well as the response to particular physiological conditions (Shoukry et al., 2003).



(A) (B) (C)

Fig. 1. The morphological aberrations observed on the larvae after treatment A: Incomplete metamorphosis (L3- l4), B: Incomplete metamorphosis (larva - pupa), C: The adult undergoes partial pupation limited to the anterior part

Regarding carbohydrate content, the treatment causes a significant decrease with a dose-response effect (controls vs LC_{50}: p=0.0406; controls vs LC_{90}: $p<0.001$; LC_{50} vs LC_{90}: $p<0.001$). The results show a significant reduction in whole-body carbohydrate levels of treated larvae (Table 3**)**. Similar results were noticed by Lawrence and Olorunfemi (2019), who inferred that tissue carbohydrate levels decreased in larvae and adults of *Cx. quinquefasciatus* treated with cypermethrin. Ali Mohamadi et al. (2014) reported reduced glycogen content in fourth-instar larvae of *Hippodamia variegate* after treatment with hexaflumuron and spirodiclofen.

Table 3. Effect of Actellic 50EC (LC_{50}= 32,42µg/ l and LC_{90}= 102, 45µg/ l) on proteins, carbohydrates, and lipids amounts (µg/ individual) in the fourth instar larvae of *Cs. longiareolata*

Content (µg/ individual)	Time (days)	Control	LC_{50}=32,42 µg/ l	LC_{90}=102, 45 µg/ l
Proteins	2	123,5± 12,61[a]	185,336± 4,86[b]	230,5± 9,55[c]
	4	118,60± 1,50[a]	175,03± 1,86[b]	218,66± 2,36[c]
	6	113,16± 4,04[a]	144,33± 3,51[b]	216,66± 3,05[c]
Lipids	2	75,66± 5,13[a]	55,16± 3,01[b]	44,16± 3.83,01[c]
	4	63,11± 11,51[a]	54,66± 2,75[a]	50,33± 2,51[a]
	6	54,33± 6,02[a]	49,33± 1,52[a]	48,33± 3,21[a]
Carbohydrates	2	123,33± 11,93[a]	117,33± 4,53[a]	86,66± 9,01[b]
	4	118,83± 7,11[a]	111,66± 7,09[a]	79,33± 8,50[b]
	6	102,7± 7,26[a]	95,16± 10,20[a]	71,66± 11,71[b]

Data expressed as means ± standard deviation (n = 3 pools each containing 20 individuals of L4 larvae). Significance at $p<0.05$. Values on the same row with different letters (a, b, c) are significantly different.

Bouabida et al. (2017) showed a significant reduction in carbohydrate levels only with the highest dose. A significant increase in carbohydrate content was reported after treating *Cx. pipiens* larvae with *Tecoma stans* ethanolic extracts (Hafsi et al., 2022). The depletion of glucose may be attributed to the stress conditions, requiring more energy to cover energy expenditure via induction by neuropeptides (Yazdani et al., 2014).

The lipid content shows a significant decrease after treatment with Actellic 50EC with the two applied concentrations without dose effect (controls vs LC_{50}: $p=0.0245$; controls vs LC_{90}: $p=0.0036$; LC_{50} vs LC_{90} ($p>0.05$) (Table 3). Treatment of adult *Cs. longiareolata* with Actellic 50EC induced a significant decrease in lipid content. The same observations were made in *S. granarius* treated with lemon and azadirachtin (Guettal, 2021), The effects of spirodiclofen and hexaflumuron have also been studied on certain physiological changes of late-stage larvae of *H. variegate* by measuring total lipid contents (Ali Mohamadi et al., 2014); and after the treatment of *Cx. pipiens* and *Cs. longiareolata* larvae with methoxyfenozide (Draouet et al., 2020), and larval treatment with *Foenilucum vulgare* oil extracts (Keffous and Aissaoui, 2023). A similar reduction in these energy reserves has been observed in previous studies on different types of stressors: environmental (Muturi et al., 2011), nutritional or botanical (Vantaux et al., 2016), and chemical stressors (Preet and Sneha, 2011). The depletion of this biochemical component after treatment is due to the stress induced following exposure to an insecticide (Sancho et al., 1998), resulting in alteration in synthesis (Klowden, 2007), hormonal dysfunction controlling lipid metabolism, the use of this metabolic reserve (Sak et al., 2006), and increased lipolysis to provide energy (Lohar and Wright, 1993).

ACKNOWLEDGEMENTS

This work was supported by the Algerian Ministry of Higher Education and Scientific Research.

AUTHOR CONTRIBUTION STATEMENT

BS and AB conceived and designed research. RC and HG conducted experiments. AB, BS, RC and HG analyzed data. AB and BS wrote the manuscript. All authors read and approved the manuscript.

FINANCIAL SUPPORT

The authors declare no funding sources were involved.

CONFLICT OF INTEREST

No conflict of interest.

REFERENCES

Abbott W S. 1925. A method of computing the effectiveness of an insecticide. Journal of Economic Entomology. 18: 265-267.

Abutaha N, Al-Mekhlafi F, Wadaan M A, Rady A M, Baabbad A A A, ALKhalifa M S. 2023. The molecular interplay of known phytochemicals as *Culex pipiens* and Rift Valley fever virus inhibitors through molecular docking. Saudi Journal of Biological Sciences 30: 103611.

Aissaoui L, Bouaziz A. Boudjelida H, Nazli A. 2023. Phytochemical screening and biological effects of *laurus nobilis* (Lauraceae) essential oil against mosquito larvae, *Culex pipiens* (Linneaus, 1758) (Diptera: Culicidae) species. Applied Ecology and Environmental Research 21(1).

Aksorn C, Mayura S. 2018. Efficacies of four plant essential oils as larvicide, pupicide and oviposition deterrent agents against dengue fever mosquito, *Aedesa egypti* Linn. (Diptera: Culicidae). Asian Pacific Journal of Tropical Biomedicine 8: 217.

Ali mohamadi N, Samih M A, Izadi H, Shahidi-Noghabid S. 2014. Developmental and biochemical effects of hexaflumuron and spirodiclofen on the ladybird beetle, *Hippodamia variegate* (Goeze) (Coleoptera: Coccinellidae). Journal of Crop Protection 3(3): 335-344.

Alouani A, Rehimi N, Soltani N. 2018. Ovicidal activity of azadirachtin and *Bacillus thuringiensis* israelensis against eggs of mosquito *Culex pipiens*. Mintage Journal of Pharmaceutical and Medical Sciences 7: 8-12.

Ansari M A, Tirry L, Moens M. 2004. Interaction between *Metarhizium anisopliae* CLO 53 and entomopathogenic nematodes for the control of *Hoplia philanthus*. Biological Control 31(2): 172-180.

Bakr R F A, Mohammed M I, El-Gammal M A, Mahdy N M. 2009. Biological effects of chitin-synthesis inhibitor, hexaflumuron compound on the desert locust, *Schistocerca gregaria* (Forskal). Egyptian Academic Journal of Biological Sciences 1(1): 49-57.

Bouabida H, Tine-Djebbar F, Tine S, Soltani N. 2017. Activity of spiromesifen on growth and development of *Culex pipiens* (Diptera: Culicidae): Toxicological, biometrical and biochemical aspects. Journal of Entomology and Zoology Studies 5(1): 572-577

Bouaziz A, Djeghader N, Lynda A, Boudjelida H. 2017. Impact of an insect growth regulator on the development and the reproduction potency of mosquito. Journal of Entomology and Zoology Studies 5(3): 1662-1667.

Bouaziz A, Boudjelida H, Soltani N. 2011. Toxicity and perturbation of the metabolite contents by a chitin synthesis inhibitor in the mosquito larvae of *Culiseta longiareolata*. Annals of Biological Research 2(3): 134-143

Bouguerra N, Boukoucha M. 2021. GC – MS and GC FID analyses , antimicrobial and insecticidal activities of *Origanum glandulosum* essential oil and their effect on biochemical content of *Cx pipiens* larvae. International Journal of Tropical Insect Science 41: 3173-3186.

Bradford M M. 1976. A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. Analytical Biochemistry 72(1-2): 248-254.

Curtis J, Omiecinski John P, VandenHeuvel Gary H, Perdew Jeffrey M. Peters J M. 2010. Xenobiotic metabolism, disposition, and regulation by receptors: from biochemical phenomenon to predictors of major toxicities. Toxicological Sciences 120(1): 49-75

Das B P, Deobhankar K. 2023. Management of insect borne human diseases–a case study on novel bio-larvicide for mosquito borne diseases including dengue. Indian Journal of Entomology 84: 61-76.

Djeghader N, Aïssaoui L, Amira K, Boudjelida H. 2014. Impact of a chitin synthesis inhibitor, novaluron, on the development and the reproductive performance of mosquito *Culex pipiens*. World Applied Sciences Journal 29(7): 954-960.

Draouet C, Hamaidia K, Brakni A, Boutemedjet S, Soltani N. 2020. Ethanolic extracts of *Borago officinalis L*. affect growth, development and energy reserve profile in the mosquito *Culex pipiens*. Journal of Entomological Research 44(2) : 203-210.

Duchateau G, Florkin M. 1959. Sur la tréhalosémie des insectes et sa signification. Archives Insect Physiology and Biochimistry 67: 306-314.

Fisher R A, Yates F. 1957. Statistical tables for biological, agricultural and medical research. Edinburgh and London, 44 pp.

Ge L Q, Hu J H, Wu J C, Yang G Q, Gu H. 2009. Insecticide-induced changes in protein, RNA, and DNA contents in ovary and fat body of female *Nilaparvata lugens* (Hemiptera: Delphacidae). Journal of economic entomology 102(4): 1506-1514.

Ghoneim K, Hamadah K, Mansour A N, Abo Elsoud A A. 2017. Toxicity and disruptive impacts of Novaluron, a chitin synthesis inhibitor, on development and metamorphosis of the olive leaf moth *Palpita unionalis* (Hübner) (Lepidoptera: Pyralidae). International Journal of Trend in Research and Development 4(3): 184-193.

Goldsworthy G J, Mordue W, Guthkelch J. 1972. Studies on insect adipokinetic hormones. General and Comparative Endocrinology 18: 545-551.

Grau-Bové X, Lucas E, Pipini D, Rippon E, van 't Hof AE, Constant E, et al. 2021. Resistance to pirimiphos-methyl in West African *Anopheles* is spreading via duplication and introgression of the *Ace1* locus. PLOS Genetics 17(1).

Guettal S, Tine S S B, Tine-Djebbar F, Soltani N. 2021. Repellency and toxicity of azadirachtin against granary weevil *Sitophilus granarius* L. (Coleoptera: Curculionidae). Agriculture International. 2021.

Hafsi N H, Hamaidia K, Soltani N. 2022. Chemical screening, insecticidal and reprotoxic activities of *Tecoma stans* ethanolic leaf extract against the vector mosquito *Culex pipiens*. Physiological Entomology pp. 1-12.

Hamama H M, Zyaan O H, Ali O A A, Saleh D I, El-Akkad H A, El-Saadony MT, Farag S M. 2021. Virulence of entomopathogenic fungi against *culex pipiens*: impact on biomolecules availability and life table parameters. Saudi Journal of Biological Sciences.

Klowden M J. 2007. Endogenous factors regulating mosquito host-seeking behaviour. In Ciba Foundation Symposium 200-Olfaction in Mosquito-Host Interactions: Olfaction in Mosquito-Host Interactions: Ciba Foundation Symposium 200 (pp. 212-232). Chichester, UK: John Wiley & Sons, Ltd.

Kolaczinski J H, Fanello C, Hervé J P, Conway D J, Carnevale P, Curtis C F. 2000. Experimental and molecular genetic analysis of the impact of pyrethroid and non-pyrethroid insecticide impregnated bednets for mosquito control in an area of pyrethroid resistance. Bulletin of Entomological Research 90(2): 125-132.

Koumba A A, Zinga Koumba C R., Mintsa Nguema R, Bi Zahouli J Z. Ovono A M, Souza A, Mavoungou J F. 2018. Preliminary evaluation of the insecticide susceptibility in the culicid fauna, particularly malaria Plasmodium and arbovirus vectors in the Region of Mouila, South-West Gabon. Indian Journal of Medical Research and Pharmaceutical Sciences 5(4): 105-117.

Keffous B S, Aissaoui L. 2023. Activity of *Foeniculum vulgare* mill essential oil on biochemical compositions of *Aedes caspius* (pallas, 1771) mosquito larvae. Fresenius Environmental Bulletin 32(7): 2667-2672.

Lawrence A K, Olorunfemi O S. 2019. Investigation of changes in the levels of some tissue biochemicals in *Culex quinquefasciatus* (*Diptera: Culicidae*) exposed to sublethal toxicity of cypermethrin. Scientific African 4 : e00109.

Lee R M L, Choong C T H, Goh B P L, Ng L C, Lam-Phua S G. 2014. Bioassay and biochemical studies of the status of pirimiphos-methyl and cypermethrin resistance in *Aedes (Stegomyia) aegypti and Aedes (Stegomyia) albopictus* (*Diptera: Culicidae*) in Singapore. Tropical Biomedicine 31(4): 670-679

Lohar M K, Wright D J. 1993. Changes in the lipid content in haemolymph, fat body and oocytes of malathion treated *Tenebrio molitor* L. Adult females. Pakistan Journal of Zoology 25: 57-57.

Muturi E J, Kim C H, Alto B W, Berenbaum M R, Schuler M A. 2011. Larval environmental stress alters *Aedesa egypti* competence for

Sindbis virus. Tropical Medicine and International Health 16(8): 955-964.

Nickolas H, Harrison P A, Tilyard P, Vaillancourt R E, Potts B M. 2019. Inbreeding depression and differential maladaptation shape the fitness trajectory of two co-occurring Eucalyptus species. Annals of Forest Science 76(1): 1-13.

Parthiban E, Arokiyaraj C, Ramanibai R. 2020. Annona muricata: An alternate mosquito control agent with special reference to inhibition of detoxifying enzymes in *Aedes aegypti*. Ecotoxicology and Environmental Safety 189: 110050.

Parthiban E, Ramachandran M, Jayakumar M, Ramanibai R. 2019. Biocompatible green synthesized silver nanoparticles impact on insecticides resistant developing enzymes of dengue transmitted mosquito vector. S N Applied Sciences 1: 1-9.

Preet S, Sneha A. 2011. Biochemical evidence of efficacy of potash alum for the control of dengue vector *Aedesa egypti* (Linnaeus). Parasitology Research 108: 1533-1539.

Rambabu J P, Rao M B. 1994. Effect of an organochlorine and three organophosphate pesticides on glucose, glycogen, lipid, and protein contents in tissues of the freshwater snail *Bellamya dissimilis* (Müller). Bulletin of Environmental Contamination and Toxicology 53(1): 142-148.

Ranson H, N'Guessan R, Lines J, Moiroux N, Nkuni Z, Corbel V. 2011. Pyrethroid resistance in African anopheline mosquitoes: what are the implications for malaria control. Trends in Parasitology 27: 91-98.

Sáenz-de-Cabezón F J, Pérez-Moreno I, Zalom F G, Marco V. 2006. Effects of lufenuron on *Lobesia botrana* (Lepidoptera: Tortricidae) egg, larval, and adult stages. Journal of Economic Entomology 99(2): 427-431.

Salavati B, Zahirnia A H, Nasirian H, Azari-Hamidian S. 2021. Trend of mosquito (*Diptera: Culicidae*) monthly distribution in Sanandaj County of Iran. – Biodiversitas 22(11): 4705-4715.

Sancho E, Ferrando M D, Fernandez C, Andreu E. 1998. Liver energy metabolism of *Anguilla anguilla* after exposure to fenitrothion. Ecotoxicology and Environmental Safety 41(2): 168-175.

Sak O, Uçkan F, Ergin E. 2006. Effects of cypermethrin on total body weight, glycogen, protein, and lipid contents of *Pimpla turionellae* (L.) (Hymenoptera: Ichneumonidae). Belgian Journal of Zoology 136(1): 53-58.

Sherrard-Smith E, Griffin J T, Winskill P, Corbel V, Pennetier C, Djénontin A et al. 2018. Systematic review of indoor residual spray efficacy and effectiveness against *Plasmodium falciparum* in Africa. Nature Communications 9: 4982.

Shibko S, Koivistoinen P, Tratnyek C A, Newhall A R, Friedman L. 1966. A method for sequential quantitative separation and determination of protein, RNA, DNA, lipid, and glycogen from a single rat liver homogenate or from a subcellular fraction. Annals of Biochemistry 19(3): 514-528.

Shoukry I F, Khlaf A A, Hussein T H, Khater K S. 2003. Toxicological evaluation of some botanicals oils on biochemical aspects in the Indian meal moth *Plodia interpunctella* H.B. (Lepidoptera: Pyralidae). Egyptian Journal of Biology 5: 155-163.

Tabbabi A, Daaboub J, Laamari A, Ben Cheikh R, Ben Cheikh H. 2017. Pirimiphos-methyl resistance status of field populations of *Culex pipiens* (*Diptera: Culicidae*) from Grand Tunis Area, Northeast Tunisia. Hereditary Gentics 6: 175.

Vantaux A, Ouattarra I, Lefèvre T, Dabiré K R. 2016. Effects of larvicidal and larval nutritional stresses on *Anopheles gambiae* development, survival and competence for *Plasmodium falciparum*. Parasites and Vectors 9(1): 1-11.

Veerakumar K, Govindarajan M, Rajeswary M, Muthukumaran U. 2014. Low-cost and eco-friendly green synthesis of silver nanoparticles using *Feronia elephantum* (Rutaceae) against *Culex quinquefasciatus*, *Anopheles stephensi*, and *Aedesa egypti* (Diptera: Culicidae). Parasitology Research 113(5): 1775- 1785.

World Health Organization. 2018. Global report on insecticide resistance in malaria vectors: 2010-2016. Geneva, Switzerland.

World Health Organization. 2005a. The WHO recommended classification of pesticides hazard and guidelines to classification: 2004. Document WHO/IPCS/WA240/2005 a. Geneva, Switzerland.

World Health Organization. 2005b. Report of the eight WHOPES working group meeting. Review of: 2005Novaluron 10% EC. World Health Organization WHO); WHO /CDS /WHOPES / 2005.10.

Yazdani E, Sendi J J, Hajizadeh J. 2014. Effect of *Thymus vulgaris* L. and *Origanum vulgare* L. essential oils on toxicity, food consumption, and biochemical properties of lesser mulberry pyralid *Glyphodes pyloalis* Walker (Lepidoptera: Pyralidae). Journal of Plant Protection Research 54(1): 53-61.

Zeghib F, Tine-Djebbar F, Zeghib A, Bachari K, Sifi K, Soltani N. 2020. Chemical composition and larvicidal activity of *Rosmarinus officinalis* essential oil against west nile vector mosquito *Culex pipiens* (L.). Journal of Essential Oil Bearing Plants 23(6): 1463-1474.

(Manuscript Received: September, 2023; Revised: January, 2024;
Accepted: January, 2024; Online Published: January, 2024)
Online First in www.entosocindia.org and indianentomology.org Ref. No. e23597