

Original Article

Baseline Susceptibility of *Culiseta longiareolata* (Diptera: Culicidae) to Different Imagicides, in Eastern Azerbaijan, Iran

Teimour Hazratian¹; Azim Paksa¹; Mohammad Mahdi Sedaghat²; Hassan Vatandoost^{2,3}; Seyed Hassan Moosa-Kazemi²; Alireza Sanei-Dehkordi^{4,5}; Yaser Salim-Abadi⁶; Masoumeh Pirmohammadi²; Saideh Yousefi²; Masoumeh Amin²; *Mohammad Ali Oshaghi²

¹Department of Parasitology, Faculty of Medicine, Tabriz University of Medical Sciences, Tabriz, Iran

²Department of Medical Entomology and Vector Control, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran

³Department of Environmental Chemical Pollutants and Pesticides, Institute for Environmental Research, Tehran University of Medical Sciences, Tehran, Iran

⁴Department of Medical Entomology and Vector Control, Faculty of Health, Hormozgan University of Medical Sciences, Bandar Abbas, Iran

⁵Infectious and Tropical Diseases Research Center, Hormozgan Health Institute, Hormozgan University of Medical Sciences, Bandar Abbas, Iran

⁶Department of Health Services and Health Promotion, School of Health, Rafsanjan University of Medical Sciences, Rafsanjan, Iran

(Received 25 Oct 2019; accepted 30 Dec 2019)

Abstract

Background: *Culiseta longiareolata* is an important vector for many human diseases such as brucellosis, avian influenza and West Nile encephalitis. It is likely an intermediate host of avian *Plasmodium* that can transmit Malta fever. The aim of this study was to determine the susceptibility level of *Cs. longiareolata* to different classes of imagicides which are recommended by World Health Organization.

Methods: Larval stages of the *Cs. longiareolata* were collected from their natural habitats in Marand County at East Azerbaijan Province, northwestern of Iran in 2017. Adult susceptibility test were carried out with using impregnated papers to insecticides including DDT 4%, Cyfluthrin 0.15%, Deltamethrin 0.05%, Propoxur 0.1% and Fenitrothion 1% by standard test kits.

Results: Results showed that *Cs. longiareolata* adult is more susceptible to pyrethroid and carbamate insecticides. Among tested insecticides, Cyfluthrin was the most toxic against *Cs. longiareolata* with LT_{50} value of 11.53 minutes and Fenitrothion had the least toxic effect (LT_{50} : 63.39 min).

Conclusions: This study provided a guideline for monitoring and evaluation of insecticide susceptibility tests against *Cs. longiareolata* mosquitoes for further decision making.

Keywords: Baseline susceptibility; *Culiseta longiareolata*; Insecticides

Introduction

Mosquitoes transmit many important human diseases such as malaria, filariasis, several types of encephalitis, many arboviral diseases and also cause serious nuisance and irritation (1-5). West Nile virus has been detected in 62 mosquito species, including genera of *Aedes*, *Anopheles*, *Culiseta* and *Culex* in the United State of America (6-9). About 3500 species of mosquitoes reported worldwide, and approximately 64 of those can be found in Iran (10-17). *Culiseta*

longiareolata is a vector for brucellosis, avian influenza and West Nile encephalitis. These mosquitoes are likely an intermediate host of avian *Plasmodium* and can transmit Malta fever (18, 19). The mosquito *Cs. longiareolata* is a common and abundant species in many countries of Europe, Africa and also Asia, such as Iran, Albania, Azores, Botswana, Bulgaria, Canary islands, Croatia, Cyprus, Djibouti, Egypt, southern England, Ethiopia, France, Greece,

*Corresponding author: Dr Mohammad Ali Oshaghi,
E-mail: moshaghi@sina.tums.ac.ir

Hungary, India, Iraq, Italy, Jordan, Lebanon, Lesotho, Madeira, Mauritania, Morocco, Namibia, Pakistan, Portugal, Romania, Russia, Slovakia, Somalia, South Africa, Spain, Sudan, Switzerland, Syria, Tajikistan, Tunisia, Turkey, Ukraine and Yemen (1). Eggs and larvae of *Cs. Longiareolata* is found mostly in tires, so it can be spread across the world through tire trading (20). *Culiseta longiareolata* is found common in human habitations. The larvae are rarely found in natural waters that are found mostly in temporary pools, rock pools, artificial containers, wooden and metal barrels and tanks built of concrete, which are rich in decaying organic materials (18). Early growth stages larvae of *Cs. longiareolata* are more found in shallow areas of pools, whereas late growth stages are found deeper areas of the pools (21).

Chemical insecticides such as organophosphates, organochlorine, carbamate, and pyrethroid are principal weapon against both adult and larval stages of mosquitoes vectors (22-24). Increasing and inappropriate use of synthetic insecticides in mosquito control in parallel to pest control agriculture is one of the main causes of increased tolerance and resistance in different species of mosquitoes across the world (25-27). According to reports in recent years, the level of tolerance and resistance of some mosquitoes and other arthropods has increased in some parts of the world which is a major barrier to the success of vector control programs (28-34). In our knowledge, there was no comprehensive study on monitoring the susceptibility level of *Cs. longiareolata* to various insecticides in the world. The aim of this study was to evaluate the susceptibility of *Cs. longiareolata* to five common insecticides recommended by World Health Organization.

Materials and Methods

Study area

This study was carried out in Marand County in East Azerbaijan Province, northwestern of

Iran. The county located at latitude 38°42'N, longitude 45°76'E and altitude 1342 Meter (Fig. 1).

Bioassay procedure

In this experimental study larval stage of *Cs. longiareolata* were collected from larval habitats, then all specimens were transferred to insectary of Department of Medical Entomology and Vector Control with 27±1 °C temperature, 12:12 light and dark period and 60±5% of relative humidity. Adult susceptibility test of mosquitoes were carried out using standard impregnated papers insecticides such as DDT 4%, Cyfluthrin 0.15%, Deltamethrin 0.05%, Propoxur 0.1% and Fenitrothion 1%. According to the standard procedures recommended by the World Health Organization (WHO). In brief, twenty-five unfed female mosquitoes were exposed to insecticide-impregnated papers at different exposure interval times, moreover for each different exposure time 4 replicates of mosquitoes were used and 2 replicates of 25 adult mosquitoes were considered as controls with untreated papers.

Probit analysis was conducted on mortality data collected after 24 hours exposure to different times of insecticides using Finney's statistical method to determine the lethal time causing for 50% and 90% mortality (LT₅₀ and LT₉₀) values and their 95% confidence limit of upper and lower confidence levels (35-37). The percentage mortality was calculated and corrections for mortality when necessary were done by Abbot's formula (38). According to the WHO criteria, the susceptibility level of the mosquitoes was considered in three classes as susceptible, tolerant and resistant. The mortality between 98–100% was considered as susceptible, less than 90% demonstrated resistance and between 90–97% was determined as resistance candidate (36, 39, 40).

Results

Table 1 and 2 show the probit regression line parameters for females of *Cs. longiareolata* to

different insecticides. In addition, Probit regression lines of insecticides against adult of *Cs. longiareolata* were drawn which showed a linear relationship between mortality and time (Fig. 2).

The LT_{50} values were 52.38, 28.79, 11.53, 63.39 and 28.05min after treatment with DDT

4%, deltamethrin 0.05%, cyfluthrin 0.15%, fenitrothion 1% and propoxur 0.1%, respectively (Fig. 3). The highest toxicity against *Cs. longiareolata* was found on cyfluthrin (LT_{50} : 11.53 and LT_{90} : 43.37min) while the lowest toxicity was observed for fenitrothion 1% (LT_{50} : 63.39 and LT_{90} : 183.26min) (Table 1).

Table 1. The Parameters of probit regression line of five insecticides on *Culisita longiareolata* in Marand County at East Azerbaijan Province, northwestern of Iran, 2017

Insecticide Name	A	B±SE	LT_{50} , (LCL-UCL) 95% C.I.	LT_{90} , (LCL-UCL) 95% C.I.	X^2 (df)	P value
Cyfluthrin	-2.37	2.23±0.27	9.18	32.05	4.36 (3)	> 0.05
			11.53	43.37		
			14.27	68.03		
DDT	-4.41	2.57±0.32	43.35	125.78	5.8 (3)	> 0.05
			52.38	165.47		
			63.02	250.91		
Deltamethrin	-3.67	2.53±0.30	23.72	70.17	6.46 (3)	> 0.05
			28.79	92.24		
			34.8	138.22		
Fenitrothion	-5.01	2.78±0.34	53.26	140.51	2.39 (3)	> 0.05
			63.39	183.26		
			75.85	274.31		
Propoxur	-5.85	4.04±0.46	24.19	48.64	2.81 (3)	> 0.05
			28.05	58.2		
			32.36	74.68		

A= y-intercept, B= the slope of the line, SE= Standard error

LT_{50} , 95% CI= Lethal Time causing 50% mortality and its 95% confidence interval

LT_{90} , 95% CI= Lethal Time causing 90% mortality and its 95% confidence interval

LCL: Lower Confidence Limit, UCL: Upper Confidence Limit

X^2 = Heterogeneity about the regression line

df= degree of freedom, p= Represent heterogeneity in the population of tested

Table 2. Susceptibility level of *Culisita longiareolata* exposed to different groups of insecticides at diagnostic dose in Marand County at East Azerbaijan Province, northwestern of Iran, 2017

Insecticides	MR±EB*	Resistance status**
Cyfluthrin	95±0.25	RC
DDT	42.5±0.25	R
Deltamethrin	70±0.41	R
Fenitrothion	37.5±0.48	R
Propoxur	87.5±0.48	R

*Mortality Rate±Error Bar

**RC: Resistance Candidate

***R: Resistance



Fig. 1. Map showing Iran, highlighting the location of East Azerbaijan Province and Marand County

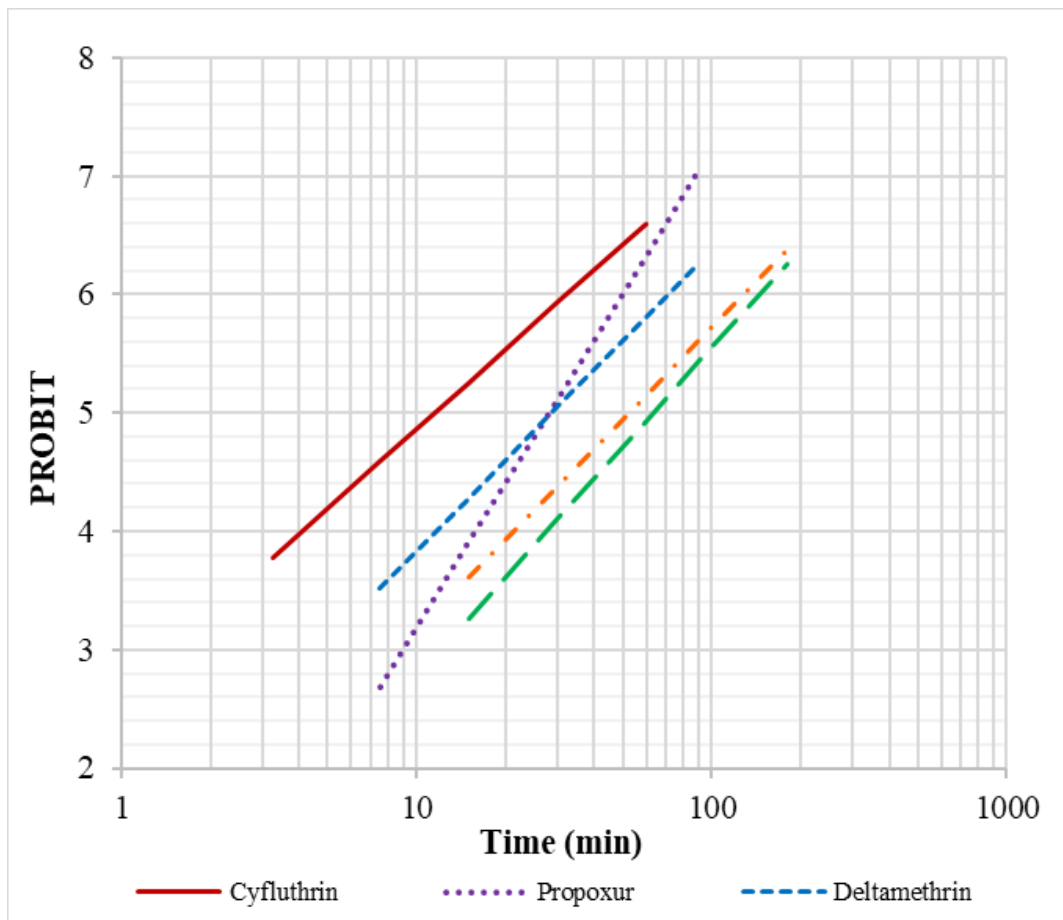


Fig. 2. Regression lines of *Culiseta longiareolata* exposed to different group of insecticides in Marand County at East Azerbaijan Province, northwestern of Iran, 2017

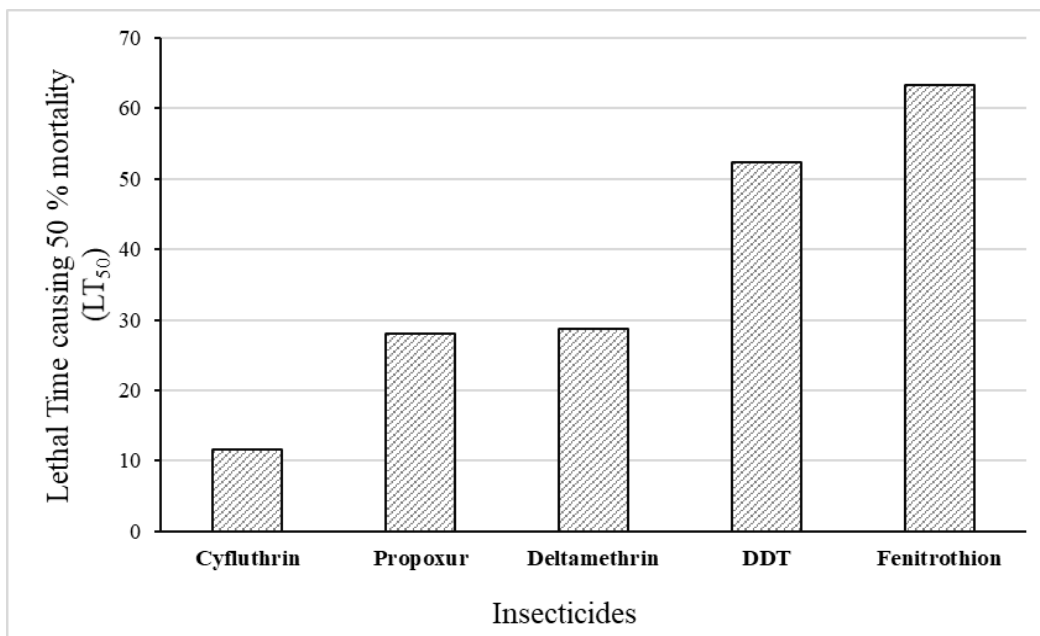


Fig. 3. Lethal time causing 50% mortality of *Culiseta longiareolata* exposed to different group of insecticides in Marand County at East Azerbaijan Province, northwestern of Iran, 2017

Discussion

The excessive use of synthetic pesticides in agriculture plays an important role in the development of insecticide resistance in arthropods (41, 42). Resistance in medically important arthropods is developing and this is a major problem in their control (43).

Considering the current WHO criteria for insecticide resistance evaluation, *Cs. longiareolata* is resistant to Fenitrothion, DDT, deltamethrin, propoxur and candidate of resistance to cyfluthrin. Some studies showed that *Cs. longiareolata* is resistance to DDT, propoxur, lambda-cyhalothrin and tolerant to malathion and deltamethrin more over LT₅₀ value found as 131.94, 5.21, 17.60, 5.19 and 29.12min for DDT, deltamethrin, lambda-cyhalothrin, malathion and propoxur respectively (43). LT₉₀ value of *Cs. longiareolata* for DDT, deltamethrin, lambda-cyhalothrin, malathion and propoxur calculated as 588.13, 29.24, 229.26, 26.69 and 371.76 minutes respectively(41). Our results based on probit regression line showed that adult of *Cs. longiareolata* is more susceptible to pyrethroid

and carbamate insecticides. LT₅₀ value of this species for DDT, cyfluthrin, deltamethrin, fenitrothion and propoxur calculated as 52.28, 11.53, 28.79, 63.39 and 28.05 minutes respectively. LT₉₀ value found as 165.47, 43.37, 92.27, 183.26 and 58.2 minutes for DDT, cyfluthrin, deltamethrin, fenitrothion and propoxur respectively.

Previous studies reported that *Cs. Longiareolata* larvae was susceptible to *Bacillus sphaericus* and *B. thuringiensis* (44). Some reports showed that the LC₅₀ and LC₉₀ values of Novaluron (Insect Growth Regular) against *Cs. longiareolata* were reported as 0.51–0.91µg/l and 2.32–4.30µg/l, respectively (45).

In many regions of Iran, results of susceptibility test on *Cx. pipiens*, *Cx. quinquefasciatus*, *Anopheles stephensi*, and *Cs. longiareolata* showed that high resistant to different classes of insecticides, such as DDT, deltamethrin, lambda-cyhalo-thrin, propoxur and cyfluthrin and this finding is similar to our results for *Cs. longiareolata* (29-31, 41, 46, 47).

The lack of data on mosquito susceptibility to insecticides is a limiting factor for the success of control programs. Therefore, this finding can be useful in future vector control programs and investigations in order to prevent the development of resistance to insecticides.

Due to the emergence of resistance in mosquitoes to different classes of insecticides, the use of biological agents can be an effective method to control mosquitoes (42). However, the use of botanical insecticide, which have no adverse effects on the environment and humans, can be appropriate and an alternative control method for insecticide in vector control programs (48-55).

Conclusion

This study confirms the resistance of the *Cs. longiareolata* to fenitrothion, DDT, deltamethrin, propoxur and candidate of resistance to cyfluthrin. When we observed the high resistance level of *Cs. longiareolata* increases to the insecticides in the study area, therefore, in order to avoid increasing resistance to insecticides, appropriate and effective strategies should be used such as: use of regular monitoring of current insecticides resistance, interventions in combination, rotations of insecticides, mixtures insecticides and plant insecticides. By using these appropriate methods and by decreasing the level of mosquitoes resistance to insecticides, it could be hopeful to better control the vector-borne diseases in the future.

Acknowledgements

This study was financially supported by the Deputy for Research, Tehran University of Medical Sciences Project no. 35904. The authors declare that there is no conflict of interests.

The authors declare that there is no conflict of interest

References

1. Becker N, Hoffmann D (2011) First record of *Culiseta longiareolata* (Macquart) for Germany. *Eur Mosq Bull.* 29: 143–150.
2. Brogdon WG, McAllister JC (1998) Insecticide resistance and vector control. *Emerg Infect Dis.* 4(4): 605–613.
3. Azari-Hamidian S, Norouzi B, Harbach RE (2019) A detailed review of the mosquitoes (Diptera: Culicidae) of Iran and their medical and veterinary importance. *Acta Trop.* 194: 106–122.
4. Mullen G, Durden L (2009) *Medical and Veterinary Entomology*, 2^{ed} edition, Mosquitoes (Culicidae) Woodbridge A. Foster and Edward D Walter. Vol. 2. Elsevier, Burlington.
5. Paksa A, Sedaghat MM, Vatandoost H, Yaghoobi-Ershadi MR, Moosa-Kazemi SH, Hazratian T, Sanei-Dehkordi A, Oshaghi MA (2019) Biodiversity of mosquitoes (Diptera: Culicidae) with emphasis on potential arbovirus vectors in East Azerbaijan Province, northwestern Iran. *J Arthropod Borne Dis.* 13(1): 62–75.
6. Bernard KA, Maffei JG, Jones SA, Kauffman EB, Ebel G, Dupuis A (2001) West Nile virus infection in birds and mosquitoes, New York State, 2000. *Emerg Infect Dis.* 7(4): 679.
7. Hayes CG (2001) West Nile virus: Uganda, 1937, to New York City, 1999. *Ann N Y Acad Sci.* 951: 25–37.
8. Smithburn K, Hughes T, Burke A, Paul J (1940) A neurotropic virus isolated from the blood of a native of Uganda. *Am J Trop Med Hyg.* 1(4): 471–492.
9. Bagheri M, Terenius O, Oshaghi MA, Motazakker M, Asgari S, Dabiri F, Vatandoost H, Mohammadi Bavani M, Chavshin AR (2015) West Nile Virus in Mosquitoes of Iranian Wetlands. *Vector Borne Zoonotic Dis.* 15(12): 750–754.
10. Knight KL, Stone A (2011) A catalog of the mosquitoes of the world (Diptera: Cu-

- licidae). Thomas Say Found. Ann Entomol Soc Am. p. 611.
11. Lotfi M (1976) Key to Culicinae of Iran, genus *Culex* and their biology (Diptera: Culicidae). Iran J Public Health. 5: 71–84.
 12. Ward RA (1984) Second supplement to a catalog of the mosquitoes of the world (Diptera: Culicidae). Mosquito Systematics. 16(3): 227–270
 13. Ward RA (1992) Third supplement to 'A catalog of the mosquitoes of the World' (Diptera: Culicidae). Walter reed army INST of research Washington DC. p.55
 14. Koosha M, Oshaghi MA, Sedaghat MM, Vatandoost H, Azari-Hamidian S, Abai MR, Hanafi-Bojd AA, Mohtarami F (2017) Sequence analysis of mtDNA COI barcode region revealed three haplotypes within *Culex pipiens* assemblage. Exp Parasitol. 181: 102–110.
 15. Hanafi-Bojd AA, Vatandoost H, Oshaghi MA, Charrahy Z, Haghdoost AA, Sedaghat MM, Abedi F, Soltani M, Raeisi A (2012) Larval habitats and biodiversity of anopheline mosquitoes (Diptera: Culicidae) in a malarious area of southern Iran. J Vector Borne Dis. 49(2): 91–100.
 16. Oshaghi MA, Vatandoost H, Gorouhi A, Abai MR, Madjidpour A, Arshi S, Sadeghi H, Nazari M, Mehravaran A (2011) Anopheline species composition in borderline of Iran-Azerbaijan. Acta Trop. 119(1): 44–49.
 17. Doosti S, Azari-Hamidian S, Vatandoost H, Oshaghi MA, Hosseini M (2006) Taxonomic differentiation of *Anopheles sacharovi* and *An. maculipennis* S.l. (Diptera: Culicidae) larvae by seta 2 (antepalpal hair). Acta Medica Iranica. 44(1): 21–27.
 18. Maslov AV, Ward RA, Rao P (1989) Blood-sucking mosquitoes of the subtribe Culisetina (Diptera: Culicidae) in world fauna. p. 262.
 19. Romi R, Pontuale G, Sabatinelli G (1997) Le zanzare italiane: generalità e identificazione degli stadi preimaginali (Diptera, Culicidae): Università degli Studi di Roma "La Sapienza", Dipartimento di Biologia Animale e dell'Uomo. p. 106
 20. Roiz D, Eritja R, Escosa R, Lucientes J, Marquès E, Melero-Alcázar R (2007) A survey of mosquitoes breeding in used tires in Spain for the detection of imported potential vector species. J Vector Ecol. 32(1): 10–15.
 21. Blaustein L, Margalit J (1995) Spatial distributions of *Culiseta longiareolata* (Culicidae: Diptera) and *Bufo viridis* (Amphibia: Bufonidae) among and within desert pools. J Arid Environ. 29(2): 199–211.
 22. Clark GG, Rangel YN (1998) Mosquito vector control and biology in latin america, An Eighth Symposium. J AM Mosquito Control. 14(3): 219–233.
 23. Davis DL, Ahmed AK (1998) Exposures from indoor spraying of chlorpyrifos pose greater health risks to children than currently estimated. Environ Health Persp. 106(6): 299.
 24. Van den Berg H (2009) Global status of DDT and its alternatives for use in vector control to prevent disease. Environ Health Persp. 117(11): 1656.
 25. Abuelmaali SA, Elaagip AH, Basheer MA, Frah EA, Ahmed FT, Elhaj HF (2013) Impacts of agricultural practices on insecticide resistance in the malaria vector *Anopheles arabiensis* in Khartoum State, Sudan. PLoS One. 8(11): e80549.
 26. Diabate A, Baldet T, Chandre F, Akoobeto M, Guiguemde TR, Darriet F (2002) The role of agricultural use of insecticides in resistance to pyrethroids in *Anopheles gambiae* sl in Burkina Faso. Am J Trop Med Hyg. 67(6): 617–622.
 27. Vatandoost H, Ezeddinloo L, Mahvi A, Abai M, Kia E, Mobedi I (2004) Enhanced tolerance of house mosquito to different insecticides due to agricultural and household pesticides in sewage system of Teh-

- ran, Iran. Iran J Environ Health Sci Eng. 1(1): 4245.
28. Corbel V, N'guessan R, Brengues C, Chandre F, Djogbenou L, Martin T (2007) Multiple insecticide resistance mechanisms in *Anopheles gambiae* and *Culex quinquefasciatus* from Benin, West Africa. Acta Trop. 101(3): 207–216.
 29. Gorouhi MA, Vatandoost H, Oshaghi MA, Raeisi A, Enayati AA, Mirhendi H (2016) Current susceptibility status of *Anopheles stephensi* (Diptera: Culicidae) to different imagicides in a malarious area, southeastern of Iran. J Arthropod Borne Dis. 10(4): 493–500.
 30. Salim-Abadi Y, Asadpour M, Sharifi I, Sanei-Dehkordi A, Gorouhi MA, Paksa A (2017) Baseline susceptibility of filarial vector *Culex quinquefasciatus* (Diptera: Culicidae) to five insecticides with different modes of action in southeast of Iran. J Arthropod Borne Dis. 11(4): 453–462.
 31. Salim-Abadi Y, Oshaghi MA, Enayati AA, Abai MR, Vatandoost H, Eshraghian MR (2016) High insecticides resistance in *Culex pipiens* (Diptera: Culicidae) from Tehran, capital of Iran. J Arthropod Borne Dis. 10(4): 483–492.
 32. Gorouhi MA, Oshaghi MA, Vatandoost H, Enayati AA, Raeisi A, Abai MR (2018) Biochemical basis of cyfluthrin and DDT resistance in *Anopheles stephensi* (Diptera: Culicidae) in malarious area of Iran. J Arthropod Borne Dis. 12(3): 310–320.
 33. Dehkordi AS, Abadi YS, Nasirian H, Hazratian T, Gorouhi MA, Yousefi S (2017) Synergists action of piperonyl butoxide and S, S, S-tributyl phosphorotrithioate on toxicity of carbamate insecticides against *Blattella germanica*. Asian Pac J Trop Med. 10(10): 981–986.
 34. Salehi A, Vatandoost H, Hazratian T, Sanei-Dehkordi A, Hooshyar H, Arbabi M (2016) Detection of bendiocarb and carbaryl resistance mechanisms among German cockroach, *Blattella germanica* (Blattaria: Blattellidae) collected from Tabriz Hospitals, East Azerbaijan Province, Iran in 2013. J Arthropod Borne Dis. 10(3): 405–414.
 35. Finney DJ, Probit Analysis (1971) 3d Ed: Cambridge University Press. p. 333.
 36. World Health Organization (WHO) (2005) Guidelines for laboratory and field testing of mosquito larvicides. p. 41.
 37. World Health Organization (WHO) (1981) Instructions for determining the susceptibility or resistance of mosquito larvae to insecticides. p. 6.
 38. Abbott WS (1925) A method of computing the effectiveness of an insecticide. J Eco Entomol. 18(2): 265–267.
 39. World Health Organization (WHO) (1998) Test procedures for insecticide resistance monitoring in malaria vectors, bio-efficacy and persistence of insecticides on treated surfaces: report of the WHO informal consultation, Geneva, 28–30 September 1998. p. 46.
 40. World Health Organization (WHO) (2016) Test procedures for insecticide resistance monitoring in malaria vector mosquitoes. 2nd edition. p. 54.
 41. Ataie A, Moosa-Kazemi SH, Vatandoost H, Yaghoobi-Ershadi MR, Bakhshi H, Anjomruz M (2015) Assessing the susceptibility status of mosquitoes (Diptera: Culicidae) in a dirofilariasis focus, Northwestern Iran. J Arthropod Borne Dis. 9(1): 7–12.
 42. Salima Abadi Y, Vatandoost H, Rassi Y, Abai MR, Sanei Dehkordi AR, Paksa A (2013) Evaluation of biological control agents for mosquitoes control in artificial breeding places. Asian Pac J Trop Med. 3(4): 276–277.
 43. Farajollahi A, Fonseca DM, Kramer LD, Kilpatrick AM (2011) “Bird biting” mosquitoes and human disease: a review of the role of *Culex pipiens* complex mosquitoes in epidemiology. Infect Genet Evol. 11(7): 1577–1585.

44. Katbeh Bader A, Khyami-Horani H, Mohsen Z (1999) Effect of temperature on the susceptibility of *Culiseta longiareolata* (Macquart)(Diptera: Culicidae) to two standard strains of biocontrol bacteria. J Appl Entomol. 123(10): 629–631.
45. 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*. Ann Biol Res. 2(3): 134–143.
46. Nazari M, Janbakhsh B (2000) A survey of the susceptibility level of *Culex theileri* and *Cx. pipiens* to DDT, Dieldrin, Propoxur and Malathion in the southern area of Tehran. Urmia Med J. 11(1): 13–19.
47. Zare M, Soleimani-Ahmadi M, Davoodi SH, Sanei-Dehkordi A (2016) Insecticide susceptibility of *Anopheles stephensi* to DDT and current insecticides in an elimination area in Iran. Parasit Vectors. 9(1): 571–575.
48. Sanei-Dehkordi A, Soleimani-Ahmadi M, Akbarzadeh K, Salim Abadi Y, Paksa A, Gorouhi MA (2016) Chemical composition and mosquito larvicidal properties of essential oil from leaves of an Iranian indigenous plant *Zhumeria majdae*. J Essent Oil Bear Pl. 19(6): 1454–1461.
49. Soleimani-Ahmadi M, Abtahi SM, Madani A, Paksa A, Abadi YS, Gorouhi MA (2017) Phytochemical profile and mosquito larvicidal activity of the essential oil from aerial parts of *Satureja bachtiarica* Bunge against malaria and lymphatic filariasis vectors. J Essent Oil Bear Pl. 20(2): 328–336.
50. Soleimani-Ahmadi M, Gorouhi MA, Azani S, Abadi Y, Paksa A, Rashid G (2017) Larvicidal effects of essential oil and methanol extract of *Achillea wilhelmsii* C. Koch (Asteraceae) against *Anopheles stephensi* Liston (Diptera: Culicidae), a malaria vector. J Kerman Univ Med Sci. 24(1): 58–67.
51. Soleimani-Ahmadi M, Sanei-Dehkordi A, Turki H, Madani A, Abadi YS, Paksa A (2017) Phytochemical properties and insecticidal potential of volatile oils from *Tanacetum persicum* and *Achillea kella-lensis* against two medically important mosquitoes. J Essent Oil Bear Pl. 20(5): 1254–1265.
52. Vatandoost H, Sanei-Dehkordi A, Sadeghi S, Davari B, Karimian F, Abai M (2012) Identification of chemical constituents and larvicidal activity of *Kelussia odoratissima* Mozaffarian essential oil against two mosquito vectors *Anopheles stephensi* and *Culex pipiens* (Diptera: Culicidae). Exp Parasitol. 132(4): 470–474.
53. Sanei-Dehkordi A, Soleimani-Ahmadi M, Salim-Abadi Y, Paksa A (2019) Wild chive oil is an extremely effective larvicide against malaria mosquito vector *Anopheles stephensi*. Asian Pac J Trop Med. 12(4): 170–174.
54. Sedaghat MM, Sanei-Dehkordi AR, Khanavi M, Abai MR, Mohtarami F, Vatandoost H (2011) Chemical composition and larvicidal activity of essential oil of *Cupressus arizonica* E.L. Greene against malaria vector *Anopheles stephensi* Liston (Diptera: Culicidae). Pharmacogn Res. 3(2): 135–139.
55. Davari B, Vatandoost H, Oshaghi MA, Ladonni H, Enayati AA, Shateghi M, Basseri HR, Rassi Y, Hanafi-Bojd AA (2007) Selection of *Anopheles stephensi* with DDT and dieldrin and cross-resistance spectrum to pyrethroids and fipronil. Pestic Biochem Phys. 89(2): 97–103.