Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 24(4): 293 – 302 (2020)
www.ejabf.journals.ekb.eg

The effect of magnetized water on some biological aspects of the mosquito, *Culex pipiens*: an approach to vector control

Ahmed I. Hasaballah[1, *] and Mohamed M. Mabrouk[2]

[1]Department of Zoology, Faculty of Science, Al-Azhar University, Nasr City, Cairo, Egypt.
[2]Fish Production, Animal Production Department, Faculty of Agriculture, Al-Azhar University, Cairo, Egypt

[*]Corresponding Author: ahscience09@azhar.edu.eg

ARTICLE INFO

Article History:
Received: June 1, 2020
Accepted: June 22, 2020
Online: June 26, 2020

Keywords:
Culex pipiens;
Magnetic water;
Biological aspects;
Vector control,
Feeding behavior.

ABSTRACT

Application of magnetized water as an alternative method for mosquito control is still in its infancy. This study was conducted as a step in order to gain a better understanding of the effect of magnetized water on different biological aspects of the mosquito, *Culex pipiens*. The present study investigates the effects of magnetized water on egg-hatchability, survival, development and feeding behaviour. Overall, the results revealed a moderate reduction in hatching percentages with a significant ($P<0.01$) delay in hatching time in the treated group as compared to the control. Larval mortality percentage recorded approximately 17.9% for the treated group versus 8.1% for the control one. Larval and pupal durations were prolonged as a response to inhabitation in the magnetized water. In addition, a significant ($P<0.05$) decrease in the adult emergence percentage (66.7±0.71 versus 83.3±3.0 for the control) was recorded. Feeding behaviour of adult mosquito females was investigated here for the first time; data revealed that blood-feeding behaviour was significantly ($P<0.01$) belated as compared with females that reared in normal water.

INTRODUCTION

Annually, mosquitoes are considered as the main causative of millions of deaths worldwide. They play a principal role as vectors of many vertebrate blood pathogens, such as Malaria, Dengue, Zika, Chikungunya, Yellow fever and other diseases (**WHO, 2019**), in addition to Hepatitis C virus, West Nile virus and Rift Valley fever virus. In Egypt, *C. pipiens* is a very common mosquito species, it is the main vector of the human filariasis (**Fouda *et al.*, 2013; Hassan *et al.*, 2013**). In addition, irritation and discomfort caused by their bites are very common problems.

The most common control methods for mosquitoes are mainly depend on chemical insecticides and it seems to be less effective due to the increased resistance to these synthesized chemicals. Additionally, chemical insecticides exhibit several adverse effects on both the environment and the public health (**Kumar *et al.*, 2012**). Hence, there is a critical need to develop a novel, practical, economic and environmental-safe method(s) for vector control. One of the most important strategies that prevent mosquito populations from increasing is through Larval Source Management (LSM). This method is usually used to control the immature stages of mosquitoes in their own habitat, and consequently inhibit maturation of the mosquito developmental stages (**Imbahale *et al.*, 2012**).

Understanding the magnetic field effects on physicochemical properties of water is still a vital issue although these effects have been documented for half of century. Many authors have published several articles studying effects of magnetic field for both laboratory and practical applications. Recently, a lot of published papers in related disciplines such as agriculture (**Surendran *et al.*, 2016; Zieliński *et al.*, 2017**), biology (**Duda *et al.*, 2011; Radhakrishnan *et al.*, 2012; Liu *et al.*, 2016**), and medicine (**Buchachenko, 2014; Neggers *et al.*, 2015; Silva *et al.*, 2017**) have documented the potential effects of the magnetized water in different aspects of life science.

Application of magnetic field on living organisms and its associated effects are interestingly increased in the last few decades particularly in fields of agriculture, biology, medicine, and physics. Many scientists have investigated the magnetic field effects on fecundity, oviposition and distribution of different species of insects (**Jackson and McGonigle, 2005; Starick *et al.*, 2005**). For mosquitoes, exposure to magnetic field exhibited promising biological effects (**Strickman *et al.*, 2000; Pan and Liu, 2004**).

Although there are several hypotheses explaining the effect of exposure to the magnetic field on living organisms, the implied mode of action for this effect is still unknown. The potential use of magnetic field as an alternative approach to control the immature stages of mosquitoes within their own habitat is a vital issue that worth examining.

The present study was carried out to evaluate the effect of the magnetized water on some biological aspects such as egg-hatchability, survival and development of the mosquito *Culex pipiens* and to study the feeding behavior of the adult females as affected by inhabitation of its immature stages in the magnetized water.

MATERIALS AND METHODS

Mosquito culture

Mosquito used in this study was *C. pipiens* L., it was provided by the Medical Entomology Research Center, Cairo, Egypt. It was reared for several generations in the insectary of medical entomology at the Department of Zoology, Faculty of Science, Al-Azhar University under a controlled condition of temperature (27±2 °C), relative humidity (70±10%) and 12-12 hrs light-dark regimen. Adult mosquitoes were kept in wooden cages with daily providing with a sponge pieces soaked in 10% sucrose solution for a period of 3-4 days after emergence. After this period, females were allowed to take a blood meal from a pigeon host, which is necessary for laying eggs (**Hasaballah, 2018**).

Magnetized water source

Magnetic source device (Fig. 1A) was from Delta water Co. for water treatment (Japan), with magnet strength of 11.000 Gauss (1.1 Tesla). This device is composed of an inner magnet surrounded by a copper housing and an outer magnet protected by a steel shield from outside with in and out one-way openings for water current (Fig. 1B). For applicable usage, females were allowed to lay egg rafts on the dechlorinated magnetized water, for accurate results, water was changed daily with freshly magnetized one till the adult emergence. For the control group, the same sequence at the same time was followed without the magnetized water.

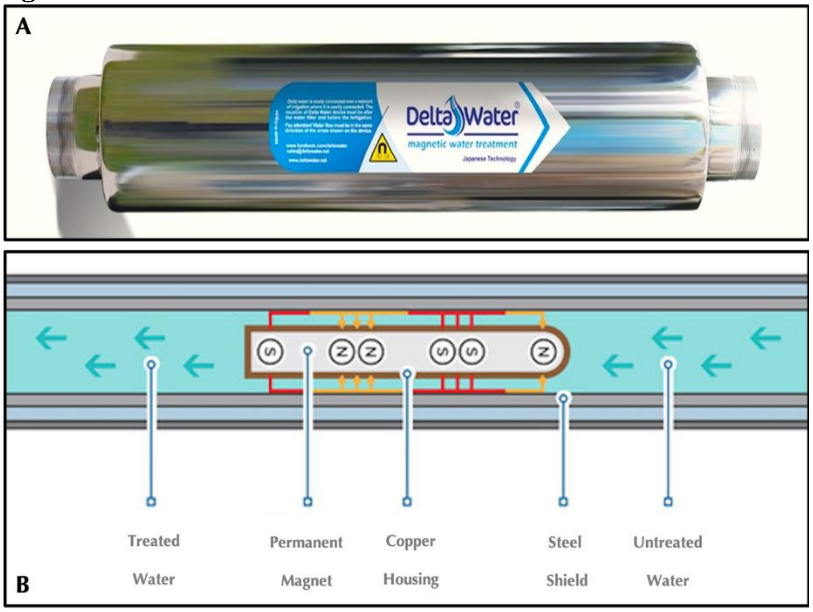

Fig. 1: Magnetic water device. Where: (A), a photograph of the whole device, and (B), A schematic diagram of the device showing the inner configuration.

Experimental Bioassay

Egg-Hatchability

After blood feeding, a caged group of mosquito females were allowed to lay egg rafts on the magnetized water, and another group on dechlorinated tap water (as control) under the same experimental conditions. In order to study the effect of magnetized water on egg-hatchability, egg rafts of treated group were daily supplied with freshly magnetized water till the end of investigations. Then, each group was transferred to a white plastic bowl (40 cm in diameter) for easier counting of hatched eggs (**Hasaballah, 2015**). Three replicates were performed for each group.

Survival, development and feeding behavior

The newly hatched larvae were observed, individual mortality was recorded daily till pupation, then mortality rates were calculated. larval and pupal developmental periods were recorded. Adults that succeed to emerge were also recorded for each group. For determining whether the magnetic field could disrupt the blood feeding of mosquitoes after adult emergence, females were separated from males using a battery-powered aspirator depending on their morphological characteristics, then a group of ten starved female mosquitoes of 5-days old in each group were allowed to blood-feeding on a pigeon host for 30 minutes (**Hasaballah, 2015**). Three replicates were performed for each group.

Statistical analysis

One-way analysis of variance (ANOVA) using statistical package for social sciences (SPSS), (ver. 22.0, SPSS Inc. Chicago, IL, USA) was used in analysing experimental data and significance among the samples was compared at ($P<0.01$) and ($P<0.05$) levels. Graphs were done using Excel of Microsoft office package 2011. Results were represented as mean ± standard deviation (SD). To elucidate accurate results, interpretation of egg-hatchability data was expressed for each replicate.

RESULTS

1. The Effect of the magnetized water on egg-hatchability of C. pipiens

Fig. (2) shows that, hatching percentages of eggs laid on the magnetized water were lower than those of the control group ($P<0.01$), the highest recorded hatching percentage for the treated group was 76%, versus 94% for the control. Additionally, the hatching time was significantly ($P<0.01$) prolonged to 89.7±3.6 hrs in the treated group versus 63.5±2.3 hrs for the control one.

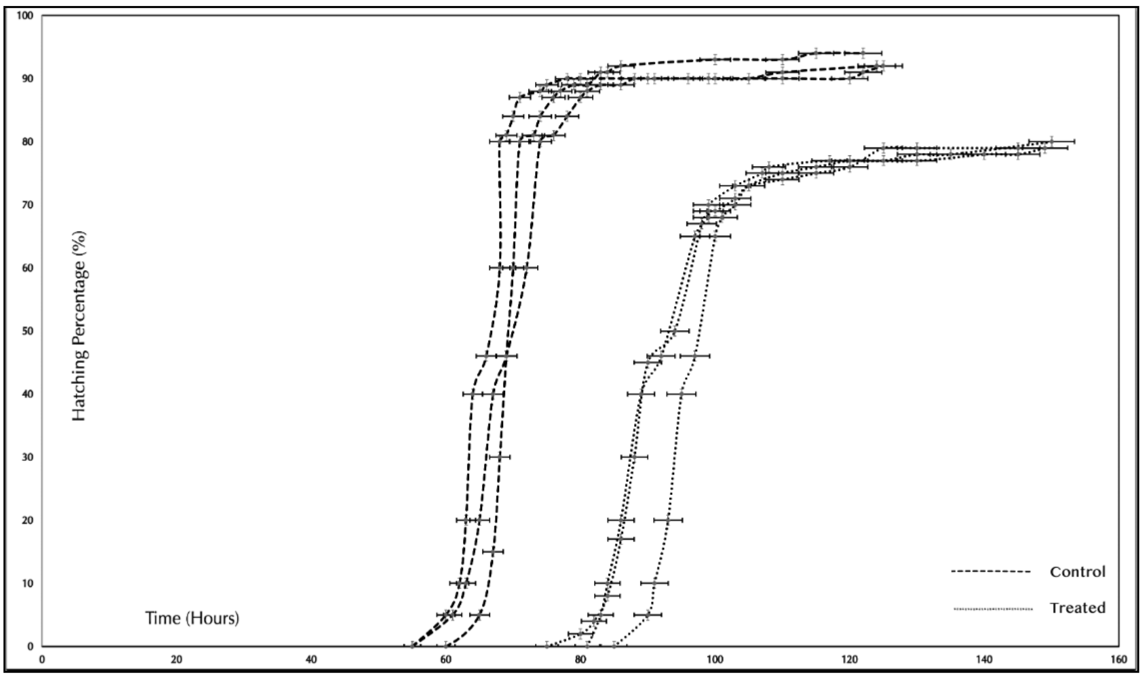

Fig. 2: The relationship between hatching percentages and hatching time for both the control and the treated groups.

2. The Effect of the magnetized water on the larval mortality of C. pipiens

The larval mortality percentages (1st, 2nd, 3rd and 4th larval instars) that resulted from eggs laid by *C. pipiens* in magnetized water was moderately higher than those of the control group (approximately 17.9% versus 8.1% for the control), (Fig. 3). Although the larval mortality percentage was low, but it seems to be affected by the magnetized water. In general, data obtained revealed that there was a correlation between rearing of mosquito larvae in magnetized water and their mortality.

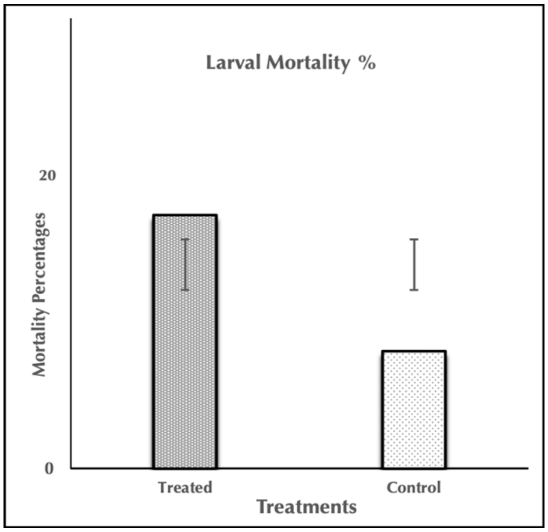

Fig. 3: Larval mortality percentages in both the treated and the control groups.

3. The Effect of the magnetized water on the development of C. pipiens

Results in (table 1) exhibited that the mean larval durations for the 2nd through the 4th larval instars were significantly prolonged versus the control group. The overall larval period was significantly (P<0.05) prolonged to 12.72±0.37 days compared to 10.62±0.23 days for the control. The mean duration of the resulted pupae was significantly (P<0.01) prolonged to 4.67±0.27 days as compared to 3.6±0.17 days for the control. In general, larval and pupal durations showed a prolonged activity in response to inhabitation in the magnetized water. In addition, a significant (P<0.05) decrease (around 16 %) in adult emergence was recorded.

Table 1: The effect of magnetized water on larval duration, pupal duration and adult emergence of *C. pipiens*.

Habitat	Larval Duration (days)				Larval Duration (days)	Pupal Duration (days)	Adult Emergence%
	1st instar	2nd instar	3rd instar	4th instar			
	Mean ± SD						
Magnetized water	1.57±0.11ns	3.41±0.17**	3.67±0.11*	4.07±0.23**	12.72±0.57*	4.67±0.27**	66.7±0.71*
Control	1.43±0.1	2.59±0.05	3.0±0.07	3.6±0.17	10.62±0.23	2.77±0.12	83.3±3.0

(*) Significant P < 0.05, (**) highly Significant, (P < 0.01), ns=non-significant P > 0.05. N=3

4. The Effect of the magnetized water on feeding behaviour of C. pipiens females

Data illustrated in Fig. (4) shows that, the mean bitting rate for adult mosquito females in treated group was three-times lower than those of the control group particularly for the first two-feeding days and this trend was reserved for the later days until the end of the experiment. Moreover, it was observed that, the blood feeding behaviour of females resulted from larvae reared in magnetized water was significantly (P<0.01) belated than those for the control. In addition, some other documented but not investigated abnormal behaviours of the adult mosquito males and females in the treated group such as, laziness, undirect flying, laying down on the ground of the cadges for long period were recorded. Even after denied access to sugar solution and blood meal source for two days the majority of females tend to consume a small size blood meal than control.

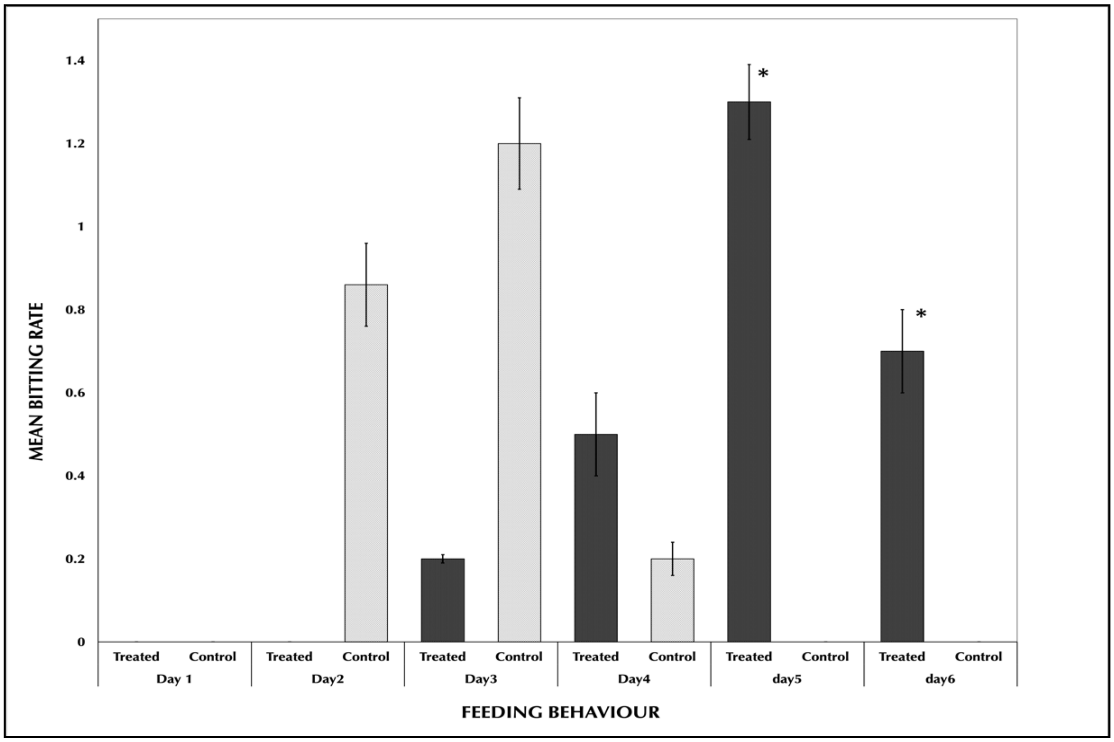

Fig. 4: The mean bitting rate for both the treated and the control adult females.

DISCUSSION

For the last several decades, there were many published papers regarding effects of magnetic water in different fields, such as agriculture, biology and medicine. A lot of these papers have focused on the effect of magnetized water on vertebrates with relatively few dealing with insects (**Zhuan-bin and Wen-xiang, 2001; Górski and Wachowiak, 2004; Shenga *et al.,* 2013**), specifically mosquitoes (**Strickman *et al.,* 2000; Pan and Liu, 2004**). While other studies on mosquitoes such as (**Kumar *et al.,* 2012; Hasaballah, 2015; 2018**) were done using insecticides, radiation, plant extracts or even insect growth regulators, our study revealed that, magnetized water possesses an impact on different biological aspects of the mosquito, *C. pipiens* at different developmental stages.

According to the obtained data, it could be concluded that hatching percentages of eggs laid on the magnetized water were lower than those of the control. Moreover, the hatching time for the control group was about 20 hrs earlier than the treated one. This implies that the magnetic field was able to delay the egg hatching. These effects could be due to egg-membrane hardening or weaker embryos as a result of exposure of eggs to the magnetized water, these results are in agreement with (**Pan and Liu, 2004; Ibrahim and Baz, 2017**) who studied the biological effect of a strong magnetic field on egg-hatchability of mosquitoes. Contrary, another study by **Denegre *et al.* (1998)** revealed that, even strong magnetic field did not show any significant impact on the hatching process of frog eggs.

The effect of magnetized water on the survival of larvae was tested; results showed a moderate larval mortality percentage in the treated group as compared with the control. This result indicates that there is a correlation between rearing of mosquito larvae in the magnetized water and their mortality. Contrary, **Tyari *et al.* (2014)** approved that, the magnetic field may induce some changes in the physical and chemical properties of water, such as increasing its minerals solubility which eventually may improve nutrient transfer and enhance the development of any circulating organism.

A significant prolongation of larval and pupal durations as compared with the control. This could be due to a direct effect of the magnetized water on larval and pupal metabolic profiles including total proteins, lipids, and carbohydrates that play an essential role in their development. In agreement with that, **Shivpuje *et al.* (2016)** stated that, the total protein content of silkworm, *Bombyx mori* (L) magnetized larvae was decreased. In addition, obtained data revealed a significant decrease in the adult emergence percentage. This result is in harmony with some previously published studies such as, (**He *et al.*, 2012**) who stated that, a highly significant effect of static magnetic field on the adult mortality (84%) was recoded; (**Tawfik *et al.*, 2018**) who found similar results when tested the effect of magnetized sea water on the adult emergence of *Etiella zinckenell* under the laboratory conditions.

Feeding behaviour of the adult *C. pipiens* mosquito females that reared in the magnetized water in their immature stages was recorded here for the first time. Data revealed that, blood feeding behaviour was significantly ($P<0.01$) belated as compared with females reared in normal water. There is no previous study reported the same finding, however, we personally believe that such prolonged interval between blood meals could be due to an osmoregulation process in which, adult female mosquitoes have to excrete the excess water before the next blood meal which may take a longer time.

CONCLUSION

Changes in physical properties of magnetized water apparently affect the biological properties of organisms that consumed it. As for *Culex pipiens*, egg hatchability percentages were affected by the magnetized water found in its surrounding habitat. Consumption of magnetized water adversely affected survival of larvae, prolonged larval and pupal durations and significantly decreased adult emergence percentages. Here, we report for the first time that consumption of magnetized water significantly delayed the blood feeding of adult females. As a conclusion, our results suggest that exposure of water to magnetic field may be considered as an alternate vector control method against the annoying mosquito, *C. pipiens* that in particular attack many vital establishments, such as social tourism entities, resorts, health spa, waterworks, and public, domestic swimming pools.

REFERENCES

Buchachenko, A. L. (2014). Magnetic field-dependent molecular and chemical processes in biochemistry, genetics and medicine. Russ. Chem. Rev. 83: 1-12.

Denegre, J.; Valles, J. Jr.; Lin, K.; Jordan, W. and Mowry, K. (1998). Cleavage planes in frog eggs are altered by strong magnetic fields. Proc. Natl. Acad. Sci. 95: 14729-32.

Duda, S.; Stout, J.E. and Vidic, R. (2011). Biological control in cooling water systems using nonchemical treatment devices. HVAS&R Research. 17: 872-90.

Fouda, M.A.; Hassan, M.I.; Hammad, K.M. and Hasaballah, A.I. (2013). Effects of Midgut Bacteria and Two Protease Inhibitors on the Reproductive Potential and Midgut Enzymes of *Culex Pipiens* Infected with *Wuchereria Bancrofti*. J. Egyptian Soc. Parasitol. 240: 1-10.

Górski, R. and Wachowiak, M. (2004). Effect of magnetized water on the effectiveness of selected zoocides in the control of red spider mite (*Tetranychus urticae* Koch.) and grain weevil (*Sitophilus granaries* L.). J. Plant Prot. Res. 44(1): 13-19.

Hasaballah, A. I. (2015). Toxicity of some plant extracts against vector of lymphatic filariasis, *Culex pipiens*. J. Egyptian Soc. Parasitol. 45(1): 183-192.

Hasaballah, A. I. (2018). Impact of gamma irradiation on the development and reproduction of *Culex pipiens* (Diptera; Culicidae). Int. J. Radiat. Biol. 94(9): 844-849.

Hassan, M.I.; Fouda, M.A.; Hammad, K.M. and Hasaballah, A.I. (2013). Effects of midgut bacteria and two protease inhibitors on the transmission of *Wuchereria bancrofti* by the mosquito vector, *Culex pipiens*. J. Egyptian Soc. Parasitol. 240: 1-7.

He, J.; Gao, H.H.; Zhao, H.Y.; Monika, W.; Hu, ZA. and Hu, X.S. (2012). Effect of static magnetic fields (SMF) on the viability and fecundity of aphid *Sitobion avenae* (Homoptera: Aphididae) under laboratory conditions. Arch. Biol. Sci. 64(2): 693-702.

Ibrahim, M. and Baz, M. (2017). Influence of low static magnetic field (SMF) on immature development and survival of the mosquito, *Culex pipiens* (Diptera: Culicidae). Arab J. Sci. Res. 1(1): 16-21.

Imbahale, S.S.; Githeko, A.; Mukabana, W.R. and Takken, W. (2012). Integrated mosquito larval source management reduces larval numbers in two highland villages in western Kenya. BMC Public Health. 12(1): 362.

Jackson, C. and McGonigle, D. (2005). Direct monitoring of the electrostatic charge of houseflies (*Musca domestica* L.) as they walk on a dielectric surface. J. Electrostat. 63(6-10): 803-808.

Kumar, P.S.; Mishra, A. and Malik, S.S. (2012). Housefly *Musca domestica* L. control potential of *Cymbopogon citratus* Staff (Poales: Poaceae) essential oil and monoterpenes. Parasitol. Res. 112: 69-76.

Liu, Y.; Suhartini, S.; Guo, L. and Xionget, Y. (2016). Improved biological wastewater treatment and sludge characteristics by applying magnetic field to aerobic granules. AIMS Bioengineering. 3: 412-424.

Neggers, S.; Petrov, P.I.; Mandija, S.; Sommer, I. and van den Berg, N. (2015). Understanding the biophysical effects of transcranial magnetic stimulation on brain tissue: The bridge between brain stimulation and cognition, in: Computational Neurostimulation, Computational Neurostimulation, Book Series Progress in Brain Research, (Bestmann, S.,Ed.). Elsevier, (222): 229-59.

Pan, H. and Liu, X. (2004). Apparent biological effect of strong magnetic field on mosquito egg hatching. Bioelectromagnetics. 25(2): 84-91.

Radhakrishnan, R.; Leelapriya, T. and Kumari, B.D.R. (2012). Effects of pulsed magnetic field treatment of soybean seeds on calli growth, cell damage, and biochemical changes under salt stress. BioElectroMagnetics. 33: 670-681.

Shenga. Z.; Gui-xinb, C.; Rui-xib, Z.; Wei-binga, W. and Jing-ana, F. (2013). Effects of Magnetized Water and Pesticide on Yield Increasing and Pest Control in Drip Irrigation under Mulch. Hubei Agri. Sciences. (9): 20.

Shivpuje, M.A.; Hanumant, V.; Belpatre, S.N. and Khyade, V.B. (2016). Influence of magnetic energy on protein contents in the fifth instar larvae of silkworm, *Bombyx mori* (L), (Race: PM x CSR2). World Scientific News. 42: 73-86.

Silva, L.H.A.; Cruz, F.F. and Morales, M.M. (2017). Magnetic targeting as a strategy to enhance therapeutic effects of mesenchymal stromal cells, Stem Cell. Res. Therapy. 8: 58.

Starick, N.T.; Longstaff, B.C. and Condon, B. (2005). The influence of fluctuating low-level magnetic fields on the fecundity and behaviour of *Rhyzopertha dominica* (F.). J. Stored. Prod. Res. 41(3): 255-270.

Strickman, D.; Timberlake, B.; Estrada-Franco, J.; Weissman, M.; Fenimore, P.W. and Novak, R.J. (2000). Effects of magnetic fields on mosquitoes. J. Am. Mosquito. Contr-Mosquito News. 16(2):131-137.

Surendran, U.; Sandeep, O. and Joseph, E.J. (2016). The impacts of magnetic treatment of irrigation water on plant, water and soil characteristics. Agr. Water Manage. 178: 21-29.

Tawfik, W.A.; Aziz, W.Z. and Shalaby, M.M. (2018). Effect of Magnetic Water on Adult Emergence of *Etiella zinckenella* (Treitschke) Pupa and Root-Knot Nematode (Meliodogyne incognita) Chitwood. J. Plant Protec. Pathol. 9(11): 751-754.

Tyari, E.; Jamshidi, A. and Neisy, A. (2014). Magnetic water and its benefit in cattle breeding, pisciculture and poultry. Adv. Environ. Biol. 1031-37.

World health organization (2019). Mosquito-borne diseases. Available from: https://www.who.int/neglected_diseases/vector_ecology/mosquito-borne-diseases/en/

Zhuan-bin, Z.J.M.W. and Wen-xiang, M.A. (2001). The Effects of Magnetized Water on the Reproductive Capacityand Life of *Drosophila melanogaster*. J. Liaocheng Teachers University. (2): 18.

Zieliński, M.; Cydzik-Kwiatkowska, A.; Zielińska, M.; Dębowski, M.; Rusanowska, P. and Kopańska, J. (2017). Nitrification in Activated Sludge Exposed to Static Magnetic Field. Water, Air and Soil Pollution. 228(4): 126.