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In vitro larvicidal efficacy of *Lantana camara* essential oil and its nanoemulsion and enzyme inhibition kinetics against *Anopheles culicifacies*

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Mosquitoes are important vectors for the transmission of several infectious diseases that lead to huge morbidity and mortality. The exhaustive use of synthetic insecticides has led to widespread resistance and environmental pollution. Using essential oils and nano-emulsions as novel insecticides is a promising alternative approach for controlling vector borne diseases. In the current study, *Lantana camara* EO and NE were evaluated for their larvicidal and pupicidal activities against *Anopheles culicifacies*. The inhibitory effect of EO and NE on AChE, NSE (α/β), and GST was also evaluated and compared. GC-MS analysis of oil displayed 61 major peaks. The stable nano-emulsion with an observed hydrodynamic diameter of 147.62 nm was formed using the o/w method. The nano-emulsion exhibited good larvicidal (LC50 50.35 ppm and LC90 222.84 ppm) and pupicidal (LC50 54.82 ppm and LC90 174.58 ppm) activities. Biochemical evaluations revealed that LCEO and LCNE inhibited AChE, NSE (α/β), and GST, displaying LCNE to be a potent binder to AChE and NSE enzyme, whereas LCEO showed higher binding potency towards GST. The nano-emulsion provides us with novel opportunities to target different mosquito enzymes with improved insecticidal efficacy. Due to its natural origin, it can be further developed as a safer and more potent larvicide/insecticide capable of combating emerging insecticide resistance.

Malaria, filariasis, and dengue are some of the vectors borne infectious diseases that are major health problems worldwide¹. More than a hundred species of mosquitoes have been reported for transmitting diseases in humans and vertebrates, leading to significant economic crises within the disease-endemic countries². Worldwide, around 247 million cases of malaria were reported in 2021, and the estimated number of malaria deaths increased to 619,000³. The indispensable approach is to reduce adult mosquito population density by eliminating the larval hatching or development sites⁴. The use of larvicides, insecticides, and natural predators of mosquito larvae can pave the way for alternative methods of disease control. Targeting the mosquito larvae is one of the successful methods because the larvae are limited in movement and they cannot change their habitat to avoid the controlling activities^{4,5}. Synthetic insecticides such as Dichloro Diphenyl Trichloroethane (DDT), malathion, deltamethrin, and temephos have been extensively used as larvicides⁶. Increasing resistance to current therapies and environmental pollution, including those from synthetic larvicides or insecticides, has created a need for alternative and natural approaches that are safe and acceptable to both humans and the environment⁵ for controlling vector-borne diseases.

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