BioThink, Vol -2, Issue -2
ISSN: 3048-7943

Bioactivity of Thyme Essential Oil: A Promising Botanical Tool for Controlling Insect Pests

Kasturi Sarmah[1*], Rahul Borah[2], Thandra Rakesh[3]

[1,3]Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India, [2]Department of Entomology, Assam Agricultural University, Jorhat, Assam, India

Corresponding authors E-mail: kasturisarmah5005@gmail.com

Introduction

Thyme is a perennial aromatic shrub of the Lamiaceae family, originating from the Mediterranean region. This shrub is widely recognized for its significance in the food, pharmaceutical, and cosmetic industries. Rich in phytonutrients, minerals, and vitamins, thyme is known for its pungent flavor and high content of moisture, protein, crude fiber, and essential nutrients (Ouknin et al. 2025). Although its chemical composition may vary depending on geographical location, it is predominantly composed of flavonoids and antioxidants (Hammoudi Halat et al. 2022). The genus *Thymus* L. comprises more than 214 species and 36 subspecies worldwide (Saez 2002). Various *Thymus* sp. have been recently explored for their bioactivity against insect pests due to increasing environmental issues and heath problems caused by the indiscriminate use of chemical pesticides. Essential oils have now became an important area of research for testing their potential in managing insect pest (Sarmah et al. 2024). Essential oils from different plants have demonstrated insecticidal, antifeedant, repellent, oviposition deterrent, and growth inhibitory properties (Kayedi et al. 2014). They function as toxins or neurotropes of the insect nervous system by disrupting octopamine, a neuromodulator of insect nervous system (Kostyukovsky et al. 2002) or by blocking GABA-gated chloride channels (Priestley et al. 2003). These oils interfere with insect respiration by inhibiting cellular oxidation or inducing asphyxiation by forming an impermeable layer (Li et al. 2014). They also have enzyme inhibitory activities (Duque et al. 2023). Hence, this study was undertaken to study the insect killing properties and chemical compositions of various *Thyme* species.

Composition of Thyme oil

Gas chromatography–mass spectrometry (GC-MS) analysis of thyme oil obtained from *T. vulgaris* consisted of thymol, *p*-cymene, linalool, and carvacrol in 26.9, 14.54, 13.39 and 5.7 %, respectively (Goharrostami et al. 2022). In another study, the major components of *T. vulgaris* oil were thymol, α-pinene and o-Cymene in 21.53, 17.43, and 15.37%, respectively. In *T. cariensis*, the key components were germacrene D and carvacrol in 33.59, and 14.86% , whereas the primary composition of of *T. cilicicus* essential oil were borneol, 1,8-cineol, camphor in 16.97, 16.78, and 12.54% (Ngongang et al. 2022). The major components identified in *T. broussonnetii* essential oil were *p*-cymene, borneol, α-pinene, and thymol in 21.0, 16.5, 11.8, 11.3 % whereas *T. maroccanus* oil was primarily composed of carvacrol, *p*-cymene, and α-pinene in 33.0, 25.3 and 11.6% (Belaqziz et al. 2010). In a comparative study, the essential oils of five Moroccan *Thymus* species were analyzed for their chemical composition (Ouknin et al. 2025). The oils were predominantly composed of oxygenated monoterpenes and monoterpene hydrocarbons at a concentration of 40.1–58.9 and 30.7-46.6% respectively, along with lesser amounts of hydrocarbon sesquiterpenes and oxygenated sesquiterpenes. Each species exhibited a distinct chemical profile characterized by specific dominant compounds. *T. willdenowii* oil was rich in compunds like thymol, γ-terpinene, and *p*-cymene, which were present in 48.3, 15.9 and 13.2%, respectively with minor constituents such as linalool and borneol in 3.4 and 3.2%. In *T. zygis* subsp. *gracilis*, the key component was thymol (41.5%) followed by *p*-cymene, γ-terpinene, borneol, and linalool in 23.0, 8.9, 4.8 and 3.7%. *T. broussonnetii* subsp. *broussonnetii* showed a more balanced composition, with thymol (17.4%), borneol (16.8%), and *p*-cymene (16.9%) as dominant components, along with camphene (7.2%) and α-pinene (9.1%). *T. maroccanus* oil contained high levels of thymol (38.1%), *p*-cymene (18.8%), and carvacrol (12.9%), with minor constituents like α-terpineol and linalool. Finally, *T. satureioides* was notable for its high borneol content (19.4%), along with moderate levels of thymol (13.8%), camphene (12.5%), and *p*-cymene (10.4%), as well as α-pinene (6.8%) and trans-caryophyllene (6.1%). In *T. numidicus* from Algeria thymol (51.0 %) followed by carvacrol (9.4 %), linalool (3.3 %), thymolmethyl-ether (3.2 %) and *iso*-caryophyllene (2.7 %) were the primary components (Saidj et al. 2008).

Insecticidal activity of Thymus oil

Ouknin et al. (2025) studied the aphicidal activity of five *Thymus* species. The effectiveness of the *Thymus* essential oils (EOs) varied among the species. Among the five EOs evaluated, *T. willdenowii* exhibited the highest insecticidal activity (LC_{50}: 6.2 µL/mL) and maximum toxicity effect on *Aphis gossypii* adults. *T. maroccanus* (LC_{50} :7.2 µL/mL) and *T. zygis* (7.1 µL/mL) showed moderate toxicity. In contrast, *T. broussonnetii* (10.9) and *T. satureioides* (15.9 µL/mL) demonstrated comparatively lower toxicity.

In young larvae of *Alphitobius diaperinus*, treatment with 1% concentrations of thyme oil, thymol, and carvacrol resulted in mortality rates of 50.0, 86.67% and 85.0%, respectively (Szczepanik et al. 2012). In contrast, the same treatments produced significantly lower mortality in older larvae, with rates of 17.5%, 27.5%, and 27.5%, respectively. At 2%, thyme oil, thymol, and carvacrol caused mortality rates of 62.5, 91.67, and 97.5% in young larvae. These findings indicate that thymol and carvacrol are more potent than crude thyme oil in controlling *A. diaperinus* larvae, suggesting their potential as effective botanical insecticidal agents. The ovicidal, larvicidal, and biochemical effects of *T. vulgaris* (thyme) oil and the carbamate insecticide methomyl were evaluated against the cotton leafworm, *Spodoptera littoralis* (El-Aw et al. 2021). Thyme oil reduced egg hatchability by 32.5% and 57.1% at 2% and 4%, respectively, while methomyl caused 21.3% and 28.2% reduction at 2 and 4 ppm. At higher doses (12% thyme oil and 20 ppm methomyl), both achieved 100% egg mortality. In larval feeding assays, LC_{50} values for thyme oil decreased over time (0.701%, 0.324%, and 0.108% at 24, 48, and 72 h), while for methomyl they were 1.60, 0.918, and 0.51 ppm, respectively. Topical assays showed higher LC_{50} values for both. AChE inhibition in 4th instar larvae showed that 6% thyme oil caused 68.6% (head) and 68.7% (midgut) inhibition, while 20 ppm methomyl resulted in 81.8% and 80.4% inhibition, respectively. *T. algeriensis* oil showed strong insecticidal activity (LC_{50}: 44.25–112.75 µl/l air) against cotton leafworm larvae (Ali et al. 2015).

Khaled et al. (2017) evaluated the insecticidal potential of *Thymus capitatus* essential oil and two natural abrasives, *viz*., kaolin and diatomaceous earth against *Myzus persicae*. In vitro applications showed significant toxicity via both fumigation and spray, with LC_{50} values of 20.01 and 13.26 µL/L air after 24 h, respectively. In vivo bioinsecticide formulations (LC_{50} thyme oil + abrasive) caused 74.19% and 97.84% mortality when combined with kaolin and diatomaceous earth, respectively. Additionally, emulsions containing 1 µL of thyme oil induced 55.55% mortality within 24 h. The abrasives' mechanical action caused dehydration, shrinkage, and cuticle deformation, with the thyme oil–diatomaceous earth combination proving the most effective in aphid control. Thyme oil (*T. vulgari*s) demonstrated significant knockdown and larvicidal effects against the tomato borer, *Tuta absoluta (*Ngongang et al. 2022). In contact toxicity assays, the KD_{50} and LD_{50} values were 0.592 and 0.608 µL/mL, respectively, while in fumigation assays, KD_{50} and LD_{50} values were 2.565 and 3.046 µL/mL, indicating effective insecticidal potential through both application methods .

Nazarahari et al. (2024) evaluated the insecticidal efficacy of water, ethanol, and n-hexane extracts of *Eucalyptus* and *T. vulgaris* (thyme), along with their wettable powder formulations against the cotton bollworm, *Helicoverpa armigera*. Larvae treated with these extracts showed developmental abnormalities and dose-dependent mortality. N-hexane extracts were most toxic, with LC_{50} values of 0.404% (eucalyptus) and 0.490% (thyme). Ethanol extracts showed moderate toxicity (LC_{50}: 10.171% and 23.264%), while water extracts were least effective. Wettable powder formulations enhanced activity, particularly for ethanol extracts, with LC_{50} values of 36.17% (thyme) and 74.65% (eucalyptus). These results highlight the potential of formulated eucalyptus and thyme extracts as effective botanical insecticides for *H. armigera* management.

Baş et al. (2023) investigated various thyme species *viz*., *Origanum majorana*, *Origanum saccatum*, and *Thymbra spicata* var. *spicata* (Lamiaceae) for their insecticidal activity against wheat weevil, *Sitophilus granarius* L. and rice weevil, *S. oryzae* L. On day 4, 100% mortality of *Sitophilus granarius* adults was recorded at the highest treated doses of *T. spicata* var.

spicata and *O. majorana*, while *O. saccatum* caused 73.75% mortality. Corresponding LC_{90} values were 0.9, 0.1, and 1.3 µl/mL, respectively. For *S. oryzae* adults, *O. majorana* (0.5% and 1% v/v) achieved 100% mortality, whereas 1% *T. spicata* and *O. saccatum* resulted in 72.5 and 46.25% mortality, respectively.

Conclusion

Thymus species, particularly *Thymus vulgaris*, possess a diverse and potent array of bioactive constituents such as thymol, carvacrol, p-cymene, and linalool, which contribute significantly to their insecticidal efficacy. Variations in chemical composition among different species and regions further enhance the versatility of thyme oils in pest control applications. Extensive laboratory investigations have demonstrated the oils' strong ovicidal, larvicidal, and adulticidal activities against a range of economically important pests, including *Spodoptera littoralis*, *Helicoverpa armigera*, *Aphis gossypii*, and *Sitophilus* spp. These effects are mediated through multiple modes of action, including neurotoxicity, respiratory inhibition, and enzymatic disruption. Additionally, thyme oils have shown synergistic potential when combined with inert carriers or formulated into wettable powders, enhancing their applicability in integrated pest management (IPM) strategies. Given their broad-spectrum bioactivity, environmental safety, and reduced risk of resistance development, thyme essential oils represent a promising, eco-friendly alternative to synthetic pesticides for sustainable pest management.

References

Ali, I. B. E. H., Chaouachi, M., Bahri, R., Chaieb, I., Boussaïd, M., & Harzallah-Skhiri, F. 2015. Chemical composition and antioxidant, antibacterial, allelopathic and insecticidal activities of essential oil of *Thymus algeriensis* Boiss. et Reut. Industrial crops and products, 77, 631-639.

Baş, Ş. Y., Aşkin, A. K., Saruhan, I., İzzet, A. K. Ç. A., Küçüktopçu, Y., Bayhan, E., ... & Tekin, F. 2023. Determining the toxicity of thyme essential oils against *Sitophilus granarius* L. and *Sitophilus oryzae* L.(Coleoptera: Curculionidae) adults. Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Agriculture, 80(2), 1-7.

Belaqziz, R., Harrak, R., Romane, A., Oufdou, K., & ElFels, M. A. E. 2010. Antimicrobial and Insecticidal Activities of the Endemic *Thymus broussonett*i Boiss. and *Thymus maroccanus* Ball. Records of Natural Products, 4(4), 230.

Duque, J.E, Urbina, D.L., Vesga, L.C., Ortiz-Rodríguez, L.A, Vanegas, T.S., Stashenko, E.E., & Mendez-Sanchez, S.C. 2023. Insecticidal activity of essential oils from American native plants against *Aedes aegypti* (Diptera: Culicidae): an introduction to their possible mechanism of action. Scientific Reports,13(1):2989.

El-Aw, M. A. M., Draz, K. A., El Naggar, E. A., & Abd Elsalam, F. H. 2021. Ovicidal, larvicidal and biochemical effects of Thyme, *Thymus vulgaris*, on the cotton leafworm, *Spodoptera littoralis* (boisd.). Journal of Plant Protection and Pathology, 12(5), 389-394.

Goharrostami, M., Sendi, J. J., Hosseini, R., & Mahmoodi, N. O. A. 2022. Effect of thyme essential oil and its two components on toxicity and some physiological parameters in mulberry pyralid *Glyphodes pyloalis* Walker. Pesticide Biochemistry and Physiology, 188, 105220.

Hammoudi Halat, D., Krayem, M., Khaled, S., & Younes, S. 2022. A focused insight into thyme: Biological, chemical, and therapeutic properties of an indigenous Mediterranean herb. Nutrients, 14(10), 2104.

Kayedi, M.H., Haghdoost, A.A., Salehnia, A.,& Khamisabadi, K .2014. Evaluation of repellency efect of essential oils of *Satureja khuzestanica* (Carvacrol), *Myrtus communis* (Myrtle), *Lavendula ofcinalis* and *Salvia sclarea* using standard WHO repellency tests. Journal of Arthropod Borne Diseases, 8(1):60

Khaled, W., Ben Fekih, I., Chaieb, I., Souissi, R., Harbaoui, I., & Boukhris-Bouhachem, S. 2017. Insecticidal activity assessment of *Thymus capitatus* essential oils in combination with natural abrasives against *Myzus persicae*. Tunisian Journal of Plant Protection, Vol. 12, No. Special Issue, 49-59

Kostyukovsky, M., Rafaeli, A., Gileadi, C., Demchenko, N., & Shaaya, E . 2002. Activation of octopaminergic receptors by essential oil constituents isolated from aromatic plants: possible mode of action against insect pests. Pest Management Science, 58(11):1101–1106.

Li, Y., Fabiano-Tixier, A.S., Chemat, F. 2014. Essential oils as reagents in green chemistry. In: Sharma SK (ed) Essential oils as insecticides. Springer Switzerland, vol 1, pp 41–51.

Nazarahari, M., Sadeghi, R., Atapour, M., Jamshidnia, A., & Ebadollahi, A. 2024. Insecticidal Effects of the Extracts and Wettable Powder Formulations of Eucalyptus and Thyme on Cotton Bollworm, *Helicoverpa armiger*a (Hübner)(Lepidoptera: Noctuidae). Entomological News, 131(5), 233-253.

Ngongang, M. D. T., Eke, P., Sameza, M. L., Mback, M. N. L. N., Lordon, C. D., & Boyom, F. F. 2022. Chemical constituents of essential oils from *Thymus vulgaris* and *Cymbopogon citratus* and their insecticidal potential against the tomato borer, *Tuta absoluta* (Lepidoptera: Gelechiidae). International Journal of Tropical Insect Science, 1-13.

Ouknin, M., Alahyane, H., Ait Aabd, N., Elgadi, S., Lghazi, Y., & Majidi, L. 2025. Comparative Analysis of Five Moroccan Thyme Species: Insights into Chemical Composition, Antioxidant Potential, Anti-Enzymatic Properties, and Insecticidal Effects. Plants, 14(1), 116.

Priestley, C.M., Williamson, E.M, Waford, K.A, & Sattelle, D.B . 2003. Thymol, a constituent of thyme essential oil, is a positive allosteric modulator of human GABAA receptors and a homo-oligomeric GABA receptor from *Drosophila melanogaster*. British Journal of Pharmacology,140(8):1363–1372.

Saez, F. (2002). Thyme: the genus Thymus.

Saidj, F., Rezzoug, S. A., Bentahar, F., & Boutekedjiret, C. 2008. Chemical composition and insecticidal properties of *Thymus numidicus* (Poiret) essential oil from Algeria. Journal of essential oil bearing plants, 11(4), 397-405.

Sarmah, K., Anbalagan, T., Marimuthu, M., Mariappan, P., Angappan, S., & Vaithiyanathan, S. 2024. Innovative formulation strategies for botanical-and essential oil-based insecticides. Journal of Pest Science, 1-30.

Szczepanik, M., Zawitowska, B., & Szumny, A. 2012. Insecticidal activities of *Thymus vulgaris* essential oil and its components (thymol and carvacrol) against larvae of lesser mealworm, *Alphitobius diaperinus* Panzer (Coleoptera: Tenebrionidae). Allelopathy Journal, 30(1), 129-142.