



MOSQUITO LARVICIDAL POTENTIAL OF *Sargassum* SPECIES: A COMPREHENSIVE REVIEW

GANGA JOHNY^{a1} AND SINCY JOSEPH^b

^aDepartment of Botany, Maharajas College, Ernakulam, Kerala, India

^bDepartment of Botany, St. Stephen's College, Uzhavoor, Kerala, India

ABSTRACT

Mosquito-borne diseases remain a major global health concern, driving the search for eco-friendly alternatives to synthetic insecticides. The brown macroalgal genus *Sargassum* has emerged as a promising source of natural larvicidal agents due to its wide array of bioactive compounds, including fucoxanthin, phlorotannins, flavonoids, terpenoids, sulfated polysaccharides, and halogenated derivatives. Among the studied species, *Sargassum wightii* demonstrated high nutritional and biochemical content, with extracts rich in phytol acetate, octadecanoic acid, and n-hexadecanoic acid, all linked to larvicidal activity. Comparative investigations reveal considerable interspecific variation in efficacy, influenced by both extraction solvents and target mosquito species. Notably, *S. microcystum* exhibited exceptional potency, with LC₅₀ values as low as 0.099 ppm, while species such as *S. ilicifolium*, *S. polycystum*, and *S. swartzii* also showed significant activity. In addition, nanoparticle formulations derived from *Sargassum* extracts—particularly ZnO, Ag, and TiO₂ nanoparticles—further enhanced larvicidal performance against *Anopheles stephensi*, *Aedes aegypti*, and *Culex quinquefasciatus*. Importantly, these biosynthesized nanoparticles displayed negligible toxicity toward non-target organisms, reinforcing their environmental safety. Collectively, *Sargassum* species represent a sustainable and biodegradable resource with strong potential for developing botanical larvicides and nanoparticle-based strategies for integrated mosquito vector management.

KEYWORDS: *Sargassum*, Larvicidal Activity, Nano Particle, Ecofriendly

Mosquitoes serve as primary vectors in the transmission of numerous vector-borne diseases, including malaria, dengue, yellow fever, and filariasis, posing a significant threat to global public health (Aravinth *et al.*, 2023). Consequently, the effective control of their rapidly growing mosquito populations has become an urgent priority to mitigate the spread of these life-threatening diseases (Perumal *et al.*, 2022). The recent resurgence of mosquito-borne diseases can be attributed to the proliferation of breeding sites, largely driven by modern throwaway society practices that contribute to environmental degradation and improper waste management (Ali *et al.*, 2013; Deepak *et al.*, 2017).

Together, *Anopheles stephensi*, *Aedes aegypti*, *Culex tritaeniorhynchus*, and *Culex quinquefasciatus* represent four major mosquito species of public health importance, each serving as a key vector for distinct groups of pathogens affecting human populations across various geographic and ecological settings. While *An. stephensi* is a primary vector of malaria-causing protozoa such as *Plasmodium vivax* and *Plasmodium falciparum* (Liu *et al.*, 2024), *Ae. aegypti* transmits several viral pathogens, including dengue, chikungunya, Zika, and yellow fever viruses (LaReau & Gloria-Soria, 2025). In contrast, *Cx. tritaeniorhynchus* plays a central role in the

transmission of Japanese encephalitis virus through zoonotic cycles involving animals like pigs and birds (Auerswald *et al.*, 2021), whereas *Cx. quinquefasciatus* is the primary urban vector of lymphatic filariasis and is also capable of spreading a range of arboviruses such as West Nile virus and St. Louis encephalitis virus (Bhattacharya & Basu, 2016). Despite differences in their vectorial roles, these mosquitoes exhibit behavioral and ecological adaptations—such as endophily, endophagy, and breeding site preferences—that enhance their capacity to thrive in human-dominated environments and contribute significantly to the global burden of vector-borne diseases.

Traditional synthetic insecticides are commonly employed for pest control; however, their indiscriminate and excessive use has led to serious global challenges, including environmental pollution, toxicity to non-target organisms, biodiversity loss, and the emergence of insecticide-resistant pest populations (Elbrense & Gheda, 2021). The growing resistance of mosquitoes to chemical insecticides, coupled with the environmental and health concerns associated with their widespread use, underscores the urgent need for biological larvicides as a sustainable vector control strategy (Benelli *et al.*, 2016).

¹Corresponding author

Marine macroalgae, commonly referred to as seaweeds, are multicellular, photosynthetic eukaryotic organisms that are typically macroscopic in size and inhabit marine environments (El-Beltagi *et al.*, 2022). Seaweeds are broadly classified into three major groups based on their dominant pigments: Chlorophyceae (green algae), Phaeophyceae (brown algae), and Rhodophyceae (red algae) (Elbrense & Gheda, 2021). They have emerged as rich reservoirs of biologically active compounds such as agar, carrageenan, alginate, alkaloids, and phlorotannins, which exhibit a wide range of practical applications. These organisms are prolific producers of both primary and secondary metabolites, including polyphenols, terpenoids, sterols, lectins, protease inhibitors, fatty acids, enzymes, and polysaccharides, many of which are associated with significant therapeutic potential. The diverse array of bioactive compounds derived from marine algae has been extensively studied for their antiviral, antimicrobial, antifungal, and anticancer properties, underscoring their considerable value in pharmaceutical and biomedical research. In recent years, growing interest has focused on the application of these compounds in the development of environmentally sustainable mosquito control strategies (Poornasundari Baluchamy *et al.*, 2025).

Empirical studies have validated the mosquitocidal efficacy of several seaweed-derived metabolites, highlighting their dual potential as agents for vector control and medicinal intervention. This convergence of ecological utility and biomedical relevance positions marine macroalgae as promising candidates for integrated approaches to public health and therapeutic innovation (Negara *et al.*, 2021).

Phlorotannins are secondary metabolites produced by brown seaweeds, known for their larvicidal activities, and their structures are composed of dibenzodioxin, ether, and phenyl linkages (Negara *et al.*, 2021). *Sargassum*, a genus of brown macroalgae within the class Phaeophyceae, subclass Cyclosporeae, order Fucales, and family Sargassaceae, comprises approximately 400 species. Commonly known as gulfweed or sea holly, these species are widely distributed throughout tropical and subtropical regions. They are renowned for synthesizing a diverse array of secondary metabolites, including terpenoids, polysaccharides, polyphenols, sargaquinic acids, sargachromenol, plastoquinones, steroids, and glycerides (Yende *et al.*, 2014).

In this article, we reviewed the larvicidal potential of macro algal extracts of different *Sargassum* species on Mosquitoes larvae

Major insecticidal compounds in *Sargassum*

Numerous studies have demonstrated that seaweeds possess significant insecticidal properties, comparable to those of bioinsecticides derived from terrestrial plants, fungi, microalgae, and other marine organisms. Seaweeds contain a diverse range of bioactive components, including polysaccharides, phenolics, phlorotannins, proteins, peptides, amino acids, terpenes, terpenoids, lipids, and halogenated compounds. A distinctive feature of seaweeds, especially when compared to terrestrial plants, is their production of halogenated compounds. Predominantly derived from brown seaweeds, these halogenated substances are present across various classes of primary and secondary metabolites and play a significant role in mediating biological activities (Yu *et al.*, 2014).

Sargassum wightii contains a variety of bioactive compounds, including fucoxanthin, flavonoids, sterols, sulfated polysaccharides, polyphenols, proteins, and beta-carotene pigments (Afreen *et al.*, 2023). The biochemical composition of *Sargassum* species—*S. wightii*, *S. linarifolium*, *S. polycystum*, *S. plagiophyllum*, and *S. illicifolium*—revealed significant interspecific variation in nutrient content and elemental composition. *S. wightii* exhibited the highest levels of protein (47.5 ± 2.02 mg/g fr. wt.), amino acids (0.52 ± 0.13 mg/g fr. wt.), iodine (211.7 ± 3.99 mg/g fr. wt.), and total carbohydrates (0.70 ± 0.17 mg/g fr. wt.), highlighting its superior nutritional profile. The phytochemical screening, and FTIR analyses of the Seaweed extracts revealed the presence of common phytochemicals, including aliphatic amines, alkynes, and alkenes, with a predominance of phytol acetate, octadecanoic acid, and n-hexadecanoic acid (Perumal *et al.*, 2022). GC-MS analysis of *Sargassum wightii* extracts revealed the presence of key bioactive constituents, including heptanoic acid docosyl ester, linoleic acid, 1-monopalmitoylglycerol, palmitic acid, oleic acid methyl ester, and stearic acid. These compounds exhibit potential as eco-friendly larvicidal agents for effective parasite control (Mathivanan *et al.*, 2023).

Sargassum polycystum is a valuable source of bioactive compounds, notably polysaccharides, polyphenols, pigments, and essential fatty acids (Sarika *et al.*, 2024). It consistently showed lower values across most biochemical parameters. SEM-EDS elemental analysis identified key macro- and micro-elements—such as Na, Mg, Ca, Cl, Zn, and Mn—with notable tissue-specific distribution, including Ca predominance in cell walls and Mn specificity to medullary regions, reflecting functional differentiation. Seasonal variations influenced

mineral uptake, with *S. wightii* showing maximum calcium content during the post-monsoon period (Thillaivasan *et al.*, 2021). Phytochemical analysis of *Sargassum swartzii* revealed the presence of bioactive compounds such as terpenoids, tannins, phenolics, and steroids (Muthu *et al.*, 2022).

A Comparative Analysis of Extraction Efficacy

The genus *Sargassum*, a diverse group of brown macroalgae, is recognized for its rich secondary metabolite profiles and notable bioactivity, including promising larvicidal properties against significant mosquito vectors. Comparative evaluations reveal considerable variation in efficacy across different *Sargassum* species, influenced by the mosquito target species, and the solvent used for extraction.

Sargassum wightii has been extensively investigated, demonstrating broad-spectrum larvicidal activity against *Anopheles stephensi*, *Aedes aegypti*, and *Culex tritaeniorhynchus*. Ethanol extracts of *S. wightii* exhibited 24-hour LC₅₀ values ranging from 40.75 to 47.83 ppm. Furthermore, phlorotannin and ethyl acetate extracts of *S. wightii* showed enhanced potency, with LC₅₀ values as low as 3.98 µg/mL (Perumal *et al.*, 2022), suggesting that specific bioactive fractions contribute significantly to its larvicidal efficacy. Similarly, *Sargassum ilicifolium* displayed moderate to strong activity across various mosquito species, with ethyl acetate extracts recording LC₅₀ values of 18.93 to 40.73 µg/mL, reinforcing its potential for botanical larvicide development.

Among the species examined, *Sargassum microcystum* emerged as exceptionally potent, yielding remarkably low LC₅₀ values of 0.099 ppm against both *Aedes aegypti* and *Culex quinquefasciatus* in ethanol extracts (Ali *et al.*, 2013). This high potency indicates the presence of highly bioactive, potentially neurotoxic, compounds effective at very low concentrations. *Sargassum polycystum* and *S. swartzii* also demonstrated promising larvicidal potential, with LC₅₀ values of 52.2–53.2 ppm and 11.75 ppm, respectively, further highlighting the variability in bioefficacy even among structurally similar brown algae. (Table 1)

Mosquito Larvae Control Using Silver Nanoparticles

Murugan *et al.* (2018) reported that *S. wightii*-mediated ZnO nanoparticles exhibited strong larvicidal activity against all larval instars and pupae of *Anopheles stephensi*, with LC₅₀ values ranging from 57.19 to 90.74 ppm. Similarly, Khanavi *et al.* (2011) observed significant larvicidal effects of *S. swartzii* extracts, with LC₅₀ and

LC₉₀ values of 11.76 and 53.47 ppm, respectively. The biosynthesis of nanoparticles from marine algae is increasingly being recognized as an effective strategy to combat vector-borne diseases such as malaria, dengue, and filariasis, as well as for broader antimicrobial and anticancer applications. Further evidence from Balaraman *et al.* (2020) indicated that silver nanoparticles synthesized using *S. myriocystum* were effective against *Aedes aegypti* and *Culex quinquefasciatus*, with LC₅₀ values as low as 5.59–6.90 mg/L. TiO₂ nanoparticles synthesized from *S. wightii* demonstrated superior larvicidal activity against *A. subpictus* and *C. quinquefasciatus*, outperforming several earlier nanoparticle formulations. Importantly, biosynthesized nanoparticles, including those derived from *S. wightii*, *Morinda citrifolia*, and *Pergularia daemia*, exhibited no toxic effects on the non-target aquatic species *Poecilia reticulata*, confirming their ecological safety. Similar non-toxic outcomes were reported with extracts from *Plumbago zeylanica*, *Cestrum nocturnum*, and *Madhuca longifolia*, reinforcing the role of biosynthesized nanoparticles as environmentally benign alternatives for mosquito control (Mathivanan *et al.*, 2023). (Table 1)

Target-Specific Larvicidal Mechanisms

The larvicidal activity of algae against mosquitoes is attributed to multiple mechanisms, including structural damage to the larval gut, inhibition of feeding, suppression of digestive enzyme activity, disruption of ATPase production, and modulation of detoxification enzymes. Histological analyses have revealed pronounced alterations in the intestinal epithelial cells of larvae exposed to algal extracts, alongside exoskeletal damage that facilitates the entry of bioactive compounds, leading to physiological disruptions. Enzymatic studies further indicate that algal treatments significantly reduce α- and β-carboxylesterase activity while inducing dose-dependent increases in Glutathione-S-Transferase and Cytochrome P450 levels, collectively resulting in substantial physiological impairment of mosquito larvae (Tufan-Cetin & Cetin, 2023).

Fuoidan, a sulfated fucose polymer derived from marine seaweeds, demonstrates strong larvicidal potential. Chemical modifications, such as desulfation, drastically reduced its inhibitory activity against Dengue virus (DENV) 2 to just 1% of its original level, while carboxy-reduced derivatives eliminated infection by converting glucuronic acid to glucose. The antiviral action is linked to interactions between DENV2 envelope glycoproteins and glucuronic acid/sulfated fucose residues, with Lys295 and Lys/Arg310 playing key roles. Among dengue virus serotypes, Cladosiphon fuoidan

was most effective against DENV2, moderately active against DENV3 and DENV4, and inactive against DENV1 (Subhalakshmi *et al.*, 2024).

According to Yogarajalakshmi *et al.* (2020) Exposure to larval extracts elevated the activities of superoxide dismutase, catalase, and glutathione

peroxidase—key enzymatic indicators of oxidative stress—thereby contributing to mosquito larval mortality. The components of macroalgae exhibit significantly lower toxicity to non-target organisms compared to many conventional pesticide groups, and they undergo rapid degradation in aquatic environments (Tufan-Cetin & Cetin, 2023).

Table 1: Lethal concentration (LC₅₀/LC₉₀) values of different *Sargassum* species against various mosquito larvae

S.N.	Macro algae	Mosquito Larvae& instar Stage	Solvent/Extract	LC50 & LC90 values	Reference
1	<i>S. wightii</i>	<i>Anopheles stephensi</i> /third instar	Ethanol	LC50 - 40.75 and LC90 -81.24 ppm at 24 h	(Tufan-Cetin& Cetin, 2023)
2		<i>Aedes aegypti</i> /third instar	Ethanol	LC50- 43.96 and LC90- 86.99 ppm at 24 h	(Tufan-Cetin & Cetin, 2023)
3		<i>Culex tritaeniorhynchus</i> /third instar	Ethanol	LC50- 47.83 and LC90- 90.96 ppm at 24 h	(Tufan-Cetin & Cetin, 2023)
4		<i>Aedes aegypti</i>	Phlorotanin extract	LC50-84.82 ppm	(Negara <i>et al.</i> , 2021)
5		<i>Culex quinquefasciatus</i>	Phlorotanin extract	LC50-87.09 ppm	(Negara <i>et al.</i> , 2021)
6		<i>Anopheles stephensi</i>	Ethyl Acetate	LC 50-3.98 ppm	(Perumal <i>et al.</i> , 2022)
7		<i>Culex quinquefasciatus</i>	Ethyl Acetate	LC 50 -4.43 ppm	(Perumal <i>et al.</i> , 2022)
8		<i>Aedes aegypti</i>	Methanol	LC 50- 84.82 ppm	(Yu <i>et al.</i> , 2014)
9		<i>Cx. quinquefasciatus</i>	Methanol	LC 50-87.09 ppm	(Yu <i>et al.</i> , 2014)
10	<i>S. ilicifolium</i>	<i>An. stephensi</i>	Ethyl Acetate	LC 50- 18.93 ppm	(Perumal <i>et al.</i> , 2022)
11		<i>Ae. aegypti</i>	Ethyl Acetate	LC 50-34.10 ppm	(Perumal <i>et al.</i> , 2022)
12		<i>C.quinquefasciatus</i>	Ethyl Acetate	LC 50 40.73 ppm	(Perumal <i>et al.</i> , 2022)
13	<i>S. microcystum</i>	<i>Ae. aegypti</i>	Ethanol	LC 50 0.099ppm & LC 90 0.139ppm	(Ali <i>et al.</i> , 2013)
14		<i>C. quinquefasciatus</i>	Ethanol	LC 50 & LC 90 of 0.099ppm and 0.368 ppm	(Ali <i>et al.</i> , 2013)
15	<i>S. polycystum</i>	<i>Ae. aegypti</i>	Ethanol	LC 50- 52.2 ppm	(Desiyamani <i>et al.</i> , 2018)
16		<i>C.quinquefasciatus</i>	Ethanol	LC 50 - 53.2ppm	(Desiyamani <i>et al.</i> , 2018)
17	<i>S. swartzii</i>	<i>An. stephensi</i>	Ethyl acetate fraction	LC 50 -11.75 ppm	(Yu <i>et al.</i> , 2014)

CONCLUSION

Sargassum species represent a highly promising, eco-friendly alternative to synthetic mosquito larvicides, owing to their rich repertoire of bioactive compounds such as fucoxanthin, phlorotannins, flavonoids,

terpenoids, sulfated polysaccharides, and halogenated derivatives. The choice of extraction solvent plays a critical role in determining larvicidal potency, with ethyl acetate and methanol often yielding superior results by efficiently isolating key metabolites. Interspecific variations highlight the importance of species selection,

with *S. microcystum* demonstrating remarkable efficacy (LC₅₀ as low as 0.099 ppm), while species like *S. wightii*, *S. ilicifolium*, *S. polycystum*, and *S. swartzii* also show strong activity. Moreover, Sargassum-based nanoparticle formulations, including ZnO, Ag, and TiO₂, have further enhanced larvicidal effectiveness while maintaining environmental safety by exhibiting negligible toxicity to non-target organisms. These findings position Sargassum as a sustainable, biodegradable, and non-toxic resource for integrated vector management. However, to translate these promising results into large-scale applications, future research must prioritize the development of standardized extraction protocols, comprehensive toxicological assessments, and rigorous field evaluations.

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