

Bioactivities and phytochemical profiles of *Colpomenia peregrina* Sauv. and *Catenella* Grev. from the Sundarbans, Bangladesh

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Abstract

The bioactivities and phytochemical composition of the crude extracts of marine macroalgae *Colpomenia peregrina* and *Catenella* sp., collected from the Sundarbans mangrove forest, were investigated in the current study. The chloroform-methanol (2:1, v/v) extract of *Colpomenia peregrina* demonstrated antibacterial activity, with inhibition zones between 8.53 and 12.27 mm, the highest against *Vibrio* sp. In contrast, the *Catenella* sp. exhibited insignificant antibacterial effects, with inhibition zones ranging from 8.07 to 8.13 mm. *C. peregrina* showed moderate antioxidant activity, with 43.18% DPPH scavenging at 600 µg/mL, whereas *Catenella* sp. showed notable antioxidant capacity, 77.50% DPPH scavenging at a concentration of 600 µg/mL. Both extracts exhibited minimal cytotoxicity against brine shrimp nauplii and larvicidal activity against mosquito larvae. Comparative phytochemical screening of the extracts revealed a wide range of bioactive compounds, with significant similarities and differences among them. Moderate to high concentrations of terpenoids, carbohydrates, steroids, and saponins were present in both macroalgae. *Catenella* sp. showed the presence of alkaloids, and *C. peregrina* had a distinct presence of flavonoids and glycosides.

Key words: Bioactivity, phytochemical profile, *Colpomenia peregrina*, *Catenella* sp., Sundarbans.

INTRODUCTION

Natural substances are typically favored because of their reduced danger to target species and their ability to be decomposed naturally. The phytochemicals from plants can also be used as larvicides and insect growth regulators (Nicoletti, 2020). The diversity of the marine ecosystem provides significant supplies of chemical compounds with medicinal properties, including antifertility, antiviral, antifungal, antibacterial, and anticancer activities (Kamaraj *et al.*, 2011; Tennyson *et al.*, 2012). Over the past forty years, many new compounds have been found in marine species, and several of these have been shown to have fascinating biological effects (Faulkner, 1988). The chemical components that had previously been separated from algae offered significant inspiration for the creation of novel medications to treat various illnesses. Overall, the marine macroalgae play a crucial role in biodiversity and hold potential for pharmaceutical and nutritional applications (Tabarsa *et al.*, 2012 and Pereira *et al.*, 2012).

The edible brown algae *Colpomenia peregrina* Sauv. is a member of the Scytosiphonaceae family [phylum- Ochrophyta] and is more widely distributed in both

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intertidal and subtidal zones. It is typically found clinging to rocky substrates, on mussels and oysters, and on coral pieces in shallow seas (Cherry *et al.*, 2019). The red alga *Catenella* sp. belongs to the family Caulacanthaceae [phylum Rhodophyta], is a small, creeping, dark-purplish algae grow in estuarine areas and consists of branching thalli. *Catenella* is widely distributed in the estuaries of coastal regions, especially in the waters of tropical, subtropical, and temperate regions. Certain species of *Catenella* grow in calm water, often as noticeable epiphytes attached to pneumatophores and root systems of mangroves in marshy areas and even on the bark of maritime palms (Kundu *et al.*, 2023).

Seaweeds produce secondary metabolites that exhibit a wide range of bioactivities, including neurological effects in humans and nematocidal and insecticidal properties in lower animals (Chen *et al.*, 2010). *Colpomenia sinusa* has been reported to contain valuable chemicals that have inspired the development of drugs (Cherry *et al.*, 2019). Studies on *Catenella* species, particularly *C. repens* and *C. caespitosa*, have revealed the presence of carrageenan, astaxanthin, phenolic compounds, sterols, and carbohydrates with both nutritional and pharmacological potential (Kundu *et al.*, 2023). Although research on bioactivities and phytochemical properties of marine algae in Bangladesh is advancing, it remains a comparatively nascent discipline within the broader field of seaweed studies. Certain research has concentrated on the phytochemical analysis and antioxidant capabilities of particular seaweed species, like *Ulva intestinalis*, *Sargassum polycystum*, *Padina tetrastromatica*, and *Gracilaria tenuistipitata* (Tubril *et al.*, 2023). Recent research has explored the antibacterial efficacy and cytotoxic potential of bioactive compounds derived from the marine macroalgae *Ulva lactuca* and *Halimeda opuntia* Tubril *et al.*, 2023. However, to date, no phytochemical investigations have been conducted on algal extracts of *Colpomenia peregrina* or *Catenella* sp. collected from the Sundarbans mangrove ecosystem of Bangladesh. Thus, the primary focus of this work is the evaluation of antibacterial activity, antioxidant activity, cytotoxicity, and mosquito larvicidal activity, followed by the phytochemical analysis of the crude extracts of these two algae.

MATERIALS AND METHODS

Colpomenia peregrina and *Catenella* sp. were collected from the Sundarbans Mangrove Forest of Bangladesh. They were brought to the Department of Botany, Jahangirnagar University, for accurate identification. Standard herbarium procedures were followed in the preparation of the voucher specimens (MAP 23-1 and MAP-23-2), and Professor Dr. Gazi Mosharof Hossain of the Department of Botany at Jahangirnagar University identified the species as *Colpomenia peregrina* and *Catenella* sp., respectively. The samples were first dried in the open sun, and then they were dried in a hot air oven (Gallenkamp hot box oven-Size 1) at 45° C. Grinded algal samples were steeped in 2000 mL of 100% Chloroform (CHCl₃) and methanol (2:1, v/v) separately (Floch *et al.*, 1957). The contents were sealed in a container and stored for seven days in a dark area with sporadic shaking and stirring. Whatman No. 1 filter paper was used for filtration. A rotary evaporator was used to concentrate the Chloroform-methanol extract by evaporating it at 45° C and 130 rpm under low pressure. (Dragon Lab RE-100 Pro model).

This research evaluated antibacterial sensitivity through the disc diffusion method as outlined by Bauer *et al.* (1966). After preparing the sample discs, 50 μ l, 100 μ l, 200 μ l, and 300 μ l of sample solutions were applied, and the discs were subsequently air-dried. The brine shrimp lethality experiment was utilized to evaluate the cytotoxicity of extracts from *Colpomenia peregrina* and *Catenella* sp., adhering to the protocol established by Mayer *et al.* (1982). A concentration of 2 mg/mL was used to prepare the crude extract stock solution. For the cytotoxicity test, a range of concentrations—10, 20, 40, 80, 160, and 200 μ g/mL were obtained from this stock. Vincristine sulphate (trade name Criston IV Injection) was used as the positive control.

DPPH functions as a reactive electron acceptor, serving as an oxidant that facilitates the oxidation of other substances. The antioxidant activities of the algal extracts were assessed according to the methodology established by Blois (1958). 10 mg of algal crude extracts were dissolved in 8 mL 100% Chloroform-methanol (2:1) to prepare a stock solution, and it was serially diluted to 25 μ g/mL, 75 μ g/mL, 150 μ g/mL, 300 μ g/mL and 600 μ g/mL concentrations to determine the antioxidant activities. The mosquito larvicidal bioassay was performed using the standard methods set out by the World Health Organization (WHO, 2005). *Culex quinquefasciatus* larvae were collected from the local area of Savar and identified by Professor Dr. Kabirul Bashar, Dept. of Zoology, JU. For the preparation of 200 mg/L, 100 mg/L, and 50 mg/L concentrated 100 mL solutions, 20 mg, 10 mg, and 5 mg crude extracts were added in three different 100 mL distilled water-containing cups.

The qualitative phytochemical analysis of *Colpomenia peregrina* and *Catenella* sp. extracts was performed to ascertain the principal classes of compounds, including tannins, saponins, alkaloids, flavonoids, phenols, steroids, glycosides, and terpenoids, following the established methodologies of Evans (1989), Trease (1989), Sofowara (1983), and Ghani (1998).

RESULTS AND DISCUSSION

Whole thalli of *Colpomenia peregrina* and *Catenella* sp. were collected from the Sundarbans mangrove forest of Bangladesh and the dried and powdered algae were subjected to extraction with 100% Chloroform-methanol (2:1, v/v). This method was adopted for algae because its chloroform-methanol mixture penetrates tough cell walls, solubilizes both neutral and membrane lipids, and enables clean biphasic recovery. The resulting mixtures were filtered and evaporated to obtain maximum yield. From 610 g of *C. peregrina* and 492 g of *Catenella* sp. dry powder, 10 g (1.64%) and 7 g (1.42%) of crude extract were obtained, respectively.

Antibacterial activity:**Table 1. Bacterial inhibition zone produced by crude extract of *Colpomenia peregrina* and *Catenella* sp.**

Name of bacteria	Negative control	Antibacterial activities (Inhibition zone in mm)								Positive control
		50 µg/mL		100 µg/mL		200 µg/mL		300 µg/mL		
		E1	E2	E1	E2	E1	E2	E1	E2	
<i>Escherichia coli</i>	8.0	9.87b	8.0a	11.47c	8.07a	10.4b	8.13a	9.87b	8.191a	22.0
<i>Enterobacter</i> sp.	8.0	9.87b	8.0a	9.53ab	8.03a	10.4b	8.20a	11.47bc	8.31ab	24.0
<i>Pseudomonas</i> sp.	8.0	8a	8.0a	8.53a	8.0a	8.53a	8.07a	8.0a	8.0a	21.0
<i>Staphylococcus</i> sp.	8.0	9.07ab	8.0a	10.4b	8.0a	9.07ab	8.13a	9.87b	8.20a	22.0
<i>Vibrio</i> sp.	8.0	8.53a	8.0a	9.87ab	8.07a	11.73c	8.07a	12.27c	8.17a	30.0

Note: The data represent averages derived from three replications. Positive control = antibiotic disc Ciprofloxacin @ and Negative control = 8mm blank disc. In a column, means associated with common letters do not differ significantly at the 5% level according to DMRT. E1 = Crude extract of *Colpomenia peregrina*, E2= Crude extract of *Catenella* sp.

Table 1 displays the crude extract's antibacterial sensitivity results against various microorganisms. The crude extract yielded bacterial inhibition zones that ranged from 8.53 to 12.27 mm. The maximum inhibition zone against *Vibrio* sp. was 12.27 mm at 300 µg/mL, while the lowest inhibition zone was 8.53 mm at 50 µg/mL. The zone of maximal inhibition against *Vibrio* sp. was 8.07 mm at 100 µg/mL, 150 µg/mL and 200 µg/mL, while at 50 µg/mL show no activity. Earlier, the diethyl ether extract exhibited notable antibacterial activity against pathogens such as *Escherichia coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Staphylococcus aureus* and *Bacillus subtilis* (Omar *et al.* 2019). A separate investigation examined the biosynthesis of silver nanoparticles utilizing *Colpomenia peregrina* and evaluated their antibacterial properties. The synthesized nanoparticles demonstrated significant antibacterial activity, highlighting the potential of *C. sinuosa* in antimicrobial applications (Kiran and Murugesan, 2014).

Antioxidant activity: This study reports the DPPH free radical scavenging activity of *Colpomenia peregrina* extract at various concentrations: 15% at 25 µg/mL, 27.27% at 75 µg/mL, 24.77% at 150 µg/mL, 40.68% at 300 µg/mL, and 43.18% at 600 µg/mL. The DPPH free radical scavenging activity of the *Catenella* sp. extract was measured at 12.95% for 25 µg/mL, 30.91% for 75 µg/mL, 47.95% for 150 µg/mL, 72.27% for 300 µg/mL, and 77.50% for 600 µg/mL concentration. The scavenging activity of both extracts increased with higher concentrations. A study on epiphytic red algae, including *Catenella* sp., identified mycosporine-like amino acids (MAAs), compounds recognized for their UV-absorbing and antioxidant properties. The presence of these compounds indicates the potential antioxidative capabilities of *C. impudica* (Karsten *et al.*, 2000, Kiran and Murugesan, 2014).

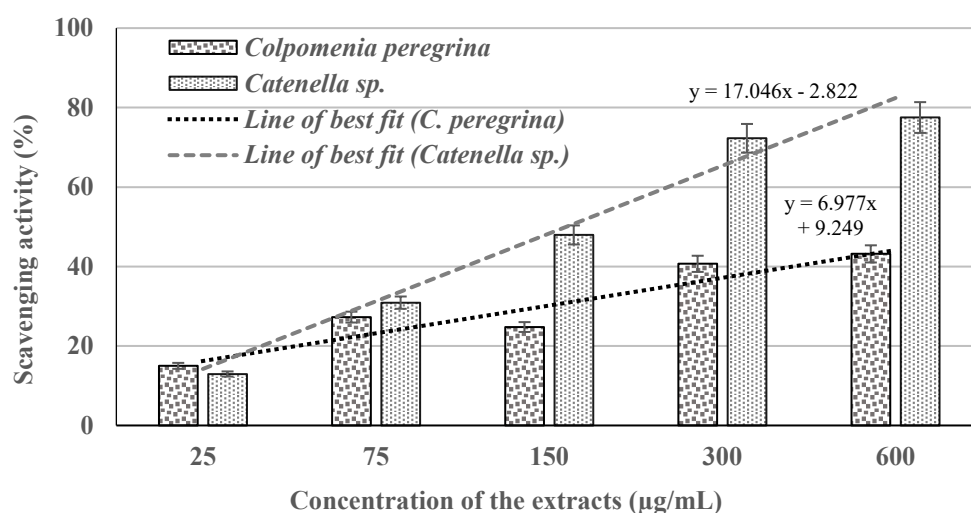


Fig. 1. Free radical scavenging activity of the crude extract of *C. peregrina* and *Catenella sp.*

Cytotoxicity Bioassay of *Colpomenia peregrina* : Data on cytotoxicity were collected at 6-hour, 12-hour, and 24-hour intervals (Table 2). The mortality rate after 6 hours varied from 3.33 to 13.33%. The mortality percentage ranged from 3.33 to 23.33% after 12 hours and from 3.33 to 36.67% after 24 hours for the two algal extracts. As the content of the Chloroform-methanol crude extract rises, so does the death rate accordingly.

Brine shrimp nauplii were found to be less susceptible to the crude extract of *Colpomenia peregrina*. After six hours, the LC_{50} value was 1,263.43 µg/mL, and the LC_{90} value was 713.73 µg/mL. In comparison, vincristine sulfate exhibited an LC_{50} of 0.107 µg/mL. The crude extract demonstrated an LC_{50} of 393.43 µg/mL and an LC_{90} of 752.5 µg/mL after 12 hours, while after 24 hours, the LC_{50} decreased to 313.09 µg/mL, with an LC_{90} of 588.02 µg/mL. Meanwhile, vincristine sulfate maintained an LC_{50} of 0.069 µg/mL. Similarly, brine shrimp nauplii showed lower susceptibility to the crude extract of *Catenella sp.* This is evidenced by vincristine sulfate, which had an LC_{50} of 0.166 µg/mL after six hours. After 12 hours, the LC_{50} of the crude extract was 438.62 µg/mL with an LC_{90} of 812.45 µg/mL, whereas vincristine sulfate continued to exhibit high toxicity with an LC_{50} of 0.107 µg/mL. After 24 hours, the LC_{50} for the crude extract was 333.36 µg/mL, and the LC_{90} was 632.98 µg/mL.

Table 2. Cytotoxicity bioassay of crude extracts of *Colpomenia peregrina* and *Catenella* sp. after 6, 12 and 24 hours.

Counting time	Crude extract (µg/mL)	No. of nauplii taken	Mortality for <i>Colpomenia peregrina</i>	LC ₅₀ (µg/mL)	LC ₉₀ (µg/mL)	Mortality for <i>Catenella</i> sp.	LC ₅₀ (µg/mL)	LC ₉₀ (µg/mL)	LC ₅₀ (µg/mL) of VCR
6 hours	Control	30	0	1263.43	2316.06	0	809.67	1475.23	0.166
	10	30	3.33			0			
	20	30	3.33			3.33			
	40	30	3.33			6.67			
	80	30	6.67			6.67			
	160	30	6.67			10			
	200	30	10			13.33			
12 hours	Control	30	0	393.43	752.5	0	438.62	812.45	0.107
	10	30	6.67			3.33			
	20	30	13.33			6.67			
	40	30	13.33			6.67			
	80	30	16.67			16.67			
	160	30	20			16.67			
	200	30	30			23.33			
24 hours	Control	30	0	313.09	588.02	0	333.36	632.98	0.069
	10	30	10			3.33			
	20	30	13.33			13.33			
	40	30	16.67			13.33			
	80	30	23.33			20			
	160	30	23.33			26.67			
	200	30	36.67			30			

Note: VCR: Vincristine sulfate.

Siam *et al.* (2021) established the larvicidal effectiveness of three native plant extracts against the mosquito larvae *Culex quinquefasciatus*. Sharower and Latif (2018) demonstrated the efficacy of various indigenous medicinal plant extracts against *Aedes aegypti*. However, before this study, no report on the cytotoxicity assay was claimed on the marine algae *Colpomenia peregrina* and *Catenella* sp.

Mosquito Larvicidal activity: The mosquito larvicidal bioassay of the crude extract of *Colpomenia peregrina* was conducted to evaluate its effectiveness over 6, 12, and 24 hours at different concentrations (100, 200, and 300 mg/L) compared to a control group. Thirty larvae were used per test, and mortality was recorded in three replicates. The results showed that mortality increased with both concentration and exposure time, with the highest mortality observed at 300 mg/L. The results of a mosquito larvicidal lethality bioassay conducted using crude extracts of *Colpomenia peregrina* and *Catenella* sp. are presented in Table 3. The study evaluated the mortality rates of mosquito larvae at different concentrations of crude extract (100 mg/L, 200 mg/L, and 300 mg/L) and exposure times (6 hours, 12 hours, and 24 hours).

Table 3. Mosquito larvicidal lethality bioassay of crude extract of the *Colpomenia peregrina* and *Catenella* sp.

Time	Crude extract (mg/L)	No. of larvae taken	Mortality for <i>Colpomenia peregrina</i>	LC ₅₀ (mg/L)	LC ₉₀ (mg/L)	Mortality for <i>Catenella</i> sp.	LC ₅₀ (mg/L)	LC ₉₀ (mg/L)
6 hours	Control	30	0	1131.69	2055.38	0	2483.45	4483.45
	100	30	6.67			3.33		
	200	30	10			3.33		
	300	30	13.33			6.67		
12 hours	Control	30	0	600.25	1080.44	0	1233.28	2233.27
	100	30	10			6.67		
	200	30	13.33			6.67		
	300	30	26.67			13.33		
24 hours	Control	30	0	446.47	832.19	0	966.68	1766.68
	100	30	20			10		
	200	30	23.67			10		
	300	30	33.33			16.67		

Note: Control= Water served as a negative control.

Water acted as a negative control to confirm that any observed effects are attributable solely to the test substance, excluding other environmental variables. For *Colpomenia peregrina*, mortality rates increased with higher concentrations and longer exposure times, whereas *Catenella* sp. showed a similar trend. The bioassay demonstrated that crude extracts of *Colpomenia peregrina* and *Catenella* sp. exhibit larvicidal activity against mosquito larvae, with effectiveness increasing at higher concentrations and longer exposure times. The LC₅₀ and LC₉₀ figures show the amounts of the substance that would kill 50% and 90% of the larvae, respectively. For *Colpomenia peregrina*, LC₅₀ values decreased from 1131.69 mg/L at 6 hours to 446.47 mg/L at 24 hours, indicating increased effectiveness over time. *Catenella* sp. also showed LC₅₀ values decreased from 2483.45 mg/L at 6 hours to 966.68 mg/L at 24 hours. LC₅₀ and LC₉₀ values of both extracts showed the same pattern, decreasing with longer exposure times for both extracts. But as of now, there is no information on the mosquito larvicidal activity of *Colpomenia peregrina* and *Catenella* sp.

The selection of these bioactivities, namely antibacterial, antioxidant and cytotoxicity were based on the need to explore the marine algae's potential as sources for safe medicines (antibacterial/antioxidant) and natural bio-pesticides (larvicidal). *C. peregrina* showed antimicrobial potential and *Catenella* sp. showed antioxidant potential, both maintaining low toxicity.

Phytochemical analysis: Table 4 shows the phytochemical profile of Chloroform-methanol extracts from two types of marine algae, *Colpomenia peregrina* and *Catenella* sp., obtained from the Sundarbans mangrove forest in Bangladesh. A series of qualitative phytochemical screening tests were conducted to determine the presence and relative abundance of various bioactive compounds. The results of the presence of chemical compounds in the extract corroborate with findings of Zhang *et al.* (2007) to some extent.

Studies on *Catenella* species, particularly *C. repens* and *C. caespitosa*, have revealed the presence of carrageenan, astaxanthin, phenolic compounds, sterols and carbohydrates with both nutritional and pharmacological potential (Kundu *et al.*, 2023). Catenelline and an ‘imino-cyclohexenone structure’ have been reported from *Catenella repens* (Hartmann *et al.*, 2015).

Table 4. Phytochemical composition of crude extract of *Colpomenia peregrina* and *Catenella* sp. collected from Sundarbans mangrove forest of Bangladesh

Name of the test	Specific test name	Crude extract of <i>Colpomenia peregrina</i>	Crude extract of <i>Catenella</i> sp.
Carbohydrate test	Molisch test	++	++
	Fehling's test	++	++
Alkaloid test	Mayer's reagent	-	+
	Dragendorff's reagent test	-	++
Glycoside test	Borntrager's test	+	-
	Keller killiani Test	+	-
Flavonoids Test	Lead Acetate Test	+	-
	Ferric chloride test.	-	-
Terpenoid test	Test for terpene	+++	+++
Test for Phenol	Ammonia test	-	-
Steroid test	Salkowski's test	++	++
Saponin test	Foam test	++	++

Note: "+" indicates a weak positive outcome, "++" indicates a moderate positive result, "+++" indicates a strong positive result, and "-" indicates a negative result.

The comparative phytochemical analysis of CHCl₃-MeOH extracts from *Colpomenia peregrina* and *Catenella* sp. revealed moderate antibacterial activity, whereas *Catenella* sp. showed prominent antioxidant capacity (77.5% DPPH scavenging at 600 µg/mL). Both extracts showed minimal cytotoxicity against brine shrimp and mild mosquito larvicidal activity, indicating a favorable safety profile. Both species showed a diverse array of bioactive compounds, with notable similarities and differences between them; exhibited moderate to high levels of carbohydrates, terpenoids, steroids, and saponins. *Catenella* sp. was rich in alkaloids, and *Colpomenia peregrina* demonstrated a unique presence of glycosides and flavonoids. These findings highlight the potential of marine algae from the Sundarbans as valuable sources of natural compounds for pharmaceutical and nutraceutical research. The researchers suggest conducting further studies on compound isolation from these two potential algae in future endeavors in that context.

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REFERENCES

- Bauer, A.W., Kirby, W.M., Sherris, J.C. and Turck, M. 1966. Antibiotic susceptibility testing by a standardized single disk method. *Am. J. Clin. Pathol.* **45**(4): 493-496.
- lois, M.S. 1958. Antioxidant determinations by the use of a stable free radical. *Nature* **181**: 1199-1200.
- Cherry, P., O'Hara, C., Magee, P.J., McSorley, E.M. and Allsopp, P.J. 2019. Risks and benefits of consuming edible seaweeds. *Nutr. Rev.* **77**: 307-329.
- Chen, L.H. and Wilson M.E. 2010. Dengue and chikungunya infections in travelers. *Curr. Opin. Infect. Dis.* **23**(5): 438-444.
- Evans, W.C. 1989. **Trease and Evan's Text book of Pharmacognosy**, 13th edn. University Press, Cambridge, pp. 546.
- Faulkner, D.J. 1988. Marine natural products. *Nat. Prod. Rep.* **5**: 613-663.
- Folch, J., Lees, M. and Stanley, G.H.S. 1957. A simple method for the isolation and purification of total lipids from animal tissues. *J. Biol. Chem.* **226** (1): 497-509. [https://doi.org/10.1016/S0021-9258\(18\)64849-5](https://doi.org/10.1016/S0021-9258(18)64849-5).
- Ghani, A. 1998. **Medicinal plants of Bangladesh**, Asiatic Society of Bangladesh, Dhaka, pp. 78-83.
- Hartmann, A., Becker, K., Karsten, U., Remias, D. and Ganzera, M. 2015. Analysis of mycosporine-like amino acids in selected algae and cyanobacteria by hydrophilic interaction liquid chromatography and a novel MAA from the red alga *Catenella repens*. *Mar. Drugs* **13**(10):6291–6305.
- Kamaraj, C., Bagavan, A., Elango, G., Zahir, A.A., Rajakumar, G., Marimuthu, S., Santhoshkumar, T. and Rahuman, A.A. 2011. Larvicidal activity of medicinal plant extracts against *Anopheles subpictus* & *Culex tritaeniorhynchus*. *Indian J Med Res.* **134**(1):101-106.
- Karsten, U., Sawall, T., West, J. and Wiencke, C. 2000. Ultraviolet sunscreen compounds in epiphytic red algae from mangroves. *Hydrobiologia* **432**: 159-171.
- Kiran, M.V. and Murugesan, S. 2014. *In vitro* antioxidant activity of silver nanoparticles from *Colpomenia peregrina* and *Halymenia poryphyroides*. *World J. Pharm. Sci.* **2**(8): 817-820.
- Kundu, A., Paul, S., Biswas, S.J., Halder, P., Prasad, R.K., Dey, R., Dhara, B. and Mitra, A.K. 2023. Nature to lab transfer story of the nutritious alga *Catenella*: a comprehensive review. *Vegetos* **36**:743–749.
- Meyer, B.N., Ferrigni, N.R., Putnam, J.E., Jacobsen, L.B., Nichols, D.E.J. and McLaughlin, J.L. 1982. Brine shrimp: a convenient general bioassay for active plant constituents. *Planta Med.* **45**(5): 31-34.
- Nicoletti, M. 2020. New solutions using natural products. In: Nicoletti, M. (eds.). **Insect-Borne Diseases in the 21st Century**, pp. 263-351. Academic Press, Elsevier Inc., UK.
- Omar, F.M., Godeh, M.M. and Said, A.A. 2019. Study the effectiveness of different seasons of extracts *Colpomenia peregrina* against some types of human pathogenic bacteria. *International Journal of Applied Science*, **5**(4):15-19.
- Pereira, R., Yarish, C. and Critchley, A.T. 2013. Seaweed aquaculture for human foods in land-based and IMTA systems. In: Christou, P., Savin, R., Costa-Pierce, B.A., Misztal, I. and Whitelaw, C.B.A. (eds), **Sustainable Food Production**. pp. pp 1405–1424, Springer, New York, NY.
- Sharower, M.G. and Latif, M.A. 2018. Larvicidal impact of some local medicinal plant extracts against *Aedes aegypti* (L.). *J. Asiat. Soc. Bangladesh, Sci.* **44**(1): 61-67.
- Siam, M.A.H., Nasiruddin, M., Azadi, A.M. and Chowdhury, M.R. 2021. Larvicidal efficacy of three indigenous plant extracts against mosquito larvae *Culex quinquefasciatus* Say. *Bangladesh J. Environ. Sci.*, **40**: 60-69.

- Sofowora, A. 1993. **Medicinal plants and traditional medicine in Africa**. Spectrum Books Ltd. Ibadan, pp. 191-289.
- Tabarsa, M., Rezaei, M., Ramezanpour, Z., Waaland, J.R. and Rabiei, R. 2012. Fatty acids, amino acids, mineral contents, and proximate composition of some brown seaweeds. *J. Phycol.* **48**: 285-292.
- Tennyson, S., Ravindran, K.J. and Arivoli, S. 2012. Screening of twenty-five plant extracts for larvicidal activity against *Culex quinquefasciatus* Say (Diptera: Culicidae). *Asian Pac. J. Trop. Biomed.* **2**(2): 1130-1134.
- Trease, G.E. and Evans, W.C. 1983. **Textbook of Pharmacognosy**, 12th ed. Tindall and Co., London, pp. 343-383.
- Tubril, M.M.A., Hamim, F.A., Rahman, M.M. and Khatun, M.M. 2023. Phytochemical screening, cytotoxic activity, antibacterial assay and proximate analysis of *Ulva intestinalis* algae from the Bay of Bengal, Bangladesh. *Bioresearch Commun.* **10**(01):1424-1431.
- World Health Organization. 2005. Guidelines for laboratory and field testing of mosquito larvicides (WHO/CDS/WHOPES/GCDPP/2005.13). Geneva: WHO.
- Zhang, W.W., Duan, X.J., Huang, H.L., Zhang, Y. and Wang, B.G. 2007. Evaluation of 28 marine algae from the Qingdao coast for antioxidative capacity. *J. Appl. Phycol.* **19**: 97-108.