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REVIEW ARTICLE

Plagiochasma spp.: A Review of Biological and Pharmacological Properties

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ABSTRACT
This review explores the chemistry, properties, and applications of Plagiochasma spp. (Aytoniaceae family), highlighting their antioxidant, anti-inflammatory, antimicrobial, and ethnomedicinal uses, along with wound-healing activity and potential for bioaccumulation and biomonitoring of heavy metals. These properties underscore their value in developing bioactive compounds and innovative food products, emphasizing their ecological, nutraceutical, and pharmaceutical significance.
Keywords*: Bryophytes, liverwort, Plagiochasma, antibacterial, antifungal and antioxidant*

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INTRODUCTION

Bryophytes contain several active compounds that exhibit a range of activities, including antimicrobial, antifungal, cytotoxic, antitumor, and insecticidal effects (1, 2) which can also be applied in agricultural and medicinal practices (3, 4). Bryophytes, once disregarded for their medicinal potential, are now recognized for containing new biologically active compounds with therapeutic potential. However, only a small number of species have been studied in detail so far (5). Marchantiophyta (Liveworts) species contain cellular oil bodies and produce various terpenoids, aromatic compounds, and acetogenins. Many of these compounds exhibit significant biological activities, including allergenic contact dermatitis, insecticidal and antifeedant properties, cytotoxic effects, piscicidal action, muscle relaxation, plant growth regulation, anti-HIV effects, inhibition of DNA polymerase β, anti-obesity properties, neurotrophic effects, nitric oxide production inhibition, as well as antimicrobial and antifungal activities (6). Oil bodies in liverworts are distinct intracellular structures enclosed by a single membrane, containing lipid globules suspended in a protein matrix. These organelles are important in taxonomy and chemosystematics, and their bioactive secondary metabolites show potential for medicinal use. However, their origin, development, and functions remain poorly understood (7). Because of their tiny morphology and difficulty in gathering in significant amounts, liverwort phytochemistry was long disregarded (8). Most bryophyte species are resistant to damage from fungi, bacteria, and insect larvae (9) due to the presence of bioactive compounds such as phenylquinones, aromatic and phenolic substances, oligosaccharides, polysaccharides, sugar alcohols, amino acids, fatty acids, and aliphatic compounds. These compounds offer protection against such organisms, highlighting the potential of bryophytes for medicinal applications (10,11,12). GC–MS analysis of *Asterella wallichiana* showed the presence of β-myrcene, hexadecanoic acid methyl ester, and carbamic acid monoammonium salt, indicating the occurrence of biologically important compounds in the species (13). Bryophytes have been widely used as bioindicators of air pollution as well as water pollution (14). Liverworts (Marchantiophyta), the second-largest group of bryophytes, encompass around 8,000 species across 74 families and 380 genera. They are recognized as some of the earliest plants to adapt to both aquatic and terrestrial environments. Research into the

bioactive compounds found in liverworts holds promise for the development of new pharmaceuticals. This interest largely stems from their unique and biologically potent terpenoids. Liverwort oil bodies contain numerous novel lipophilic terpenoids and aromatic compounds, each with diverse carbon skeletons that often exhibit a distinct fragrance and a strongly bitter taste (15, 16,17).

Liverworts (Marchantiophyta) are found globally, inhabiting damp soils, rocks, tree bark, and even Antarctica, though not in marine environments. With around 6,000 species, they are categorized into four orders: Calybryales, Jungermanniales, Marchantiales, and Monocleales. Considered among the earliest land plants, liverworts resemble ancient plant fossils dating back 350-400 million years (1). The studies of phytochemical constituents of revealed presence of flavonoids, coumarins, phenols, tannins, steroids, and sugars in the *Plagiochasma articulata* and also, they showed antibacterial activity (18). Pawar *et al*. (2024) (19) documented phytoconstituents with bioactive potential in the methanolic extract of *Plagiochasma intermedium* using GC-MS, identifying compounds based on retention times and mass spectra, highlighting its value for phytopharmaceutical applications and herbal drug discovery. Numerous essential oils have demonstrated a substantial ability to suppress inflammatory cancer activities (20). In liverworts, unique organelles called oil bodies accumulate various components specific to these plants. Different types of oil bodies have been identified, with distinctions in size, shape, colour, quantity, and distribution serving as key taxonomic characteristics of liverworts. The secondary metabolites within these oil bodies also provide valuable insights for taxonomic studies (21).

MATERIAL AND METHODS

Using a variety of topic-specific keywords, we accessed reputable search platforms such as Google Scholar, Web of Science, PubMed, ScienceDirect, and Scopus to gather relevant literature.

MEDICINAL PROPERTIES

Table1: Summary of studies on Bioactive compounds from *Plagiochasma* species.

Activity	Species name	Reference
Antioxidant Activity	*Plagiochasma appendiculatum*	22
	Plagiochasma rupestre	23
	Plagiochasma appendiculatum	24
Antibacterial	*Plagiochasma appendiculatum*	22
	Plagiochasma articulata	25
	Plagiochasma rupestre	23
	Plagiochasma articulata	18
	Plagiochasma articulata	26
	Plagiochasma appendiculatum	27
antifungal	*Plagiochasma appendiculatum*	22
	Plagiochasma rupestre	23
	Plagiochasma intermedium	1
	Plagiochasma intermedium	29
	Plagiochasma articulata	26
Ethnomedicinal Use	*Plagiochasma appendiculatum*	22
	Plagiochasma intermedium	30
	Plagiochasma appendiculatum	31
Wound Healing Activity	*Plagiochasma appendiculatum*	22
Anti-inflammatory	*Plagiochasma appendiculatum*	28
Bioaccumulation and Biomonitoring of heavy metals.	*Plagiochasma appendiculatum*	32, 36-38

Ethnomedicine

The "doctrine of signatures," a concept introduced by Paracelsus, suggests that the physical characteristics of plants resemble the body parts or organs they can help heal. Following this philosophy, liverworts have traditionally been used in the treatment of liver-related ailments (29). The people of Gaddi tribes of Himachal Pradesh, India used *Plagiochasma appendiculatu*m for treating skin diseases (31). *Plagiochasma appendiculatu*m used by Gaddi tribe in Kangra valley to treat skin diseases in paste form (22). For treating skin diseases, a fine paste made from thoroughly washed thalli of *Plagiochasma intermedium* is applied externally to the affected area (30).

Wound healing

Plagiochasma intermedium has been shown to enhance wound contraction and significantly improve tensile strength (22).

The wound healing potential of *Plagiochasma* sp., a thalloid liverwort of the order Marchantiales, has been increasingly recognized due to its diverse phytochemical composition and pharmacological properties. Extracts derived from *Plagiochasma* species have demonstrated significant efficacy in promoting wound repair through the stimulation of key biological processes such as fibroblast proliferation, collagen deposition, and rapid re-epithelialization. These effects are largely attributed to the presence of bioactive constituents, including phenolics, flavonoids, and terpenoids, which exhibit strong antioxidant activity and help in reducing oxidative stress at the wound site [1]. Furthermore, *Plagiochasma* extracts possess notable antimicrobial activity against a range of pathogenic microorganisms, thereby minimizing the risk of infection and supporting an optimal healing environment [33]. The anti-inflammatory properties of the plant, mediated through the downregulation of pro-inflammatory cytokines such as tumor necrosis factor-alpha (TNF-α) and interleukins, further contribute to tissue regeneration and repair. Experimental studies have reported enhanced wound contraction rates and improved tensile strength in treated tissues, highlighting its therapeutic potential [34]. Overall, *Plagiochasma* sp. represents a promising natural candidate for the development of novel wound healing formulations, although further clinical validation is required to establish its efficacy and safety in human applications.

Antibacterial

The methanol extract of *Plagiochasma rupestre* showed higher antibacterial activity (5-4 mm) compared to the aqueous (2.5-2 mm) and acetone (1.5-1 mm) extracts against *Salmonella typhimurium* and *Bacillus subtilis* (23). Alcoholic and aqueous extracts of *Plagiochasma appendiculatu*m showed significant activity against *E. coli, Proteus mirabilis, S. typhimurium* (MIC: 2.5 µg/disc) (22). Bodade *et al.* (26) found that the ethanolic extract demonstrated superior activity over other fractioned extracts, with *Plagiochasma articulata* being the most effective against bacterial and fungal strains. Singh *et al*. (27) also reported that *Plagiochasma appendiculatum* possesses antibacterial effect.

Antifungal

Plagiochasma intermedium exhibit antifungal activity (29). The antifungal assay revealed that all tested extracts inhibited *Aspergillus niger* and *Rizopus oryzae* to varying degrees, with larger inhibition zones at higher concentrations (1, 5, and 10 mg/ml). The strongest activity was observed at 10 mg/ml, comparable to the standard drug itraconazole, while *Rizopus oryzae* displayed slightly more resistance than *Aspergillus niger*. No inhibition was noted with the DMSO negative control. Marchantin A, H, M, Riccardin C and F isolated from *Plagiochasma intermedium* antifungal activity against *candida* spp (23). Methanol extracts of the liverwort *Plagiochasma rupestre* exhibited significant antifungal activity against plant pathogens, including *Trichoderma viridae*, *Aspergillus niger*, and *Phytophthora infestans*, demonstrating strong growth inhibition through in vitro microdilution assays.

Plagiochasma rupestre exhibit antifungal activity against *Candida spp.* (1). Bodade *et al.* (26) found that the ethanolic extract demonstrated superior activity over other fractioned extracts, with *Plagiochasma articulata* being the most effective against fungal strains.

Antioxidant

The antioxidant assay showed that AgNPs from *Plagiochasma rupestre* extract had significantly higher antioxidant activity than the plant extract alone, as measured by DPPH (2,2-diphenyl-1-picrylhydrazyl) scavenging at 517 nm. AgNPs had the greatest antioxidant effect with an IC60 (Inhibitory Concentration) value of 86.754 µg/ml, while the plant extract exhibited an IC60 (Inhibitory Concentration) value of 53.53 µg/ml (23). *Plagiochasma appendiculatum* exhibits antioxidant properties by generating flavonoids via its PaCHS enzyme, which produces naringenin chalcone. This antioxidant capacity may be further stimulated under environmental stress, as PaCHS expression responds to stress-related compounds like methyl jasmonate, salicylic acid, and abscisic acid (24). *Plagiochasma appendiculatum* exhibited strong antioxidant effects by: Inhibited lipid peroxidation; increased SOD and catalase activity (22).

Anti-inflammatory

Plagiochasma appendiculatum, a flavonoid-rich liverwort, exhibits significant anti-inflammatory activity, with luteolin isolated from its methanolic extract demonstrating potent effects, including 74% inhibition in protein denaturation assays and notable reduction in carrageenan-induced rat paw edema, supporting its ethnobotanical use in treating inflammation (28).

Bioaccumulation and biomonitoring of heavy metals

Plagiochasma appendiculatum is sensitive to mercury and copper but resistant to lead, zinc, and chromium, showing potential as a biomonitor for heavy metal pollution in water through thallus deterioration (24).

The liverwort *Plagiochasma* sp. has emerged as a promising organism for studying bioaccumulation and biomonitoring of heavy metals due to its unique morphological and physiological traits. As a non-vascular

plant lacking a protective cuticle, *Plagiochasma* absorbs water and dissolved substances directly across its thallus surface, enabling efficient uptake of metal ions from both atmospheric deposition and the surrounding substrate [36]. This characteristic facilitates the accumulation of toxic metals such as lead (Pb), cadmium (Cd), chromium (Cr), copper (Cu), and zinc (Zn) within its tissues at levels that often reflect environmental availability. The metal-binding capacity of *Plagiochasma* is largely attributed to cell wall components, extracellular polysaccharides, and intracellular chelating molecules, which aid in sequestration and detoxification [37].

In addition to its accumulation efficiency, *Plagiochasma* sp. is well suited for biomonitoring applications because it responds sensitively to variations in environmental pollution. Changes in physiological parameters, including chlorophyll content, membrane integrity, and antioxidant enzyme activity, provide measurable indicators of metal-induced stress. Its widespread occurrence, ease of collection, and ability to integrate pollutant exposure over time make it a reliable bioindicator for assessing spatial and temporal trends in heavy metal contamination. Consequently, *Plagiochasma* sp. offers a cost-effective and ecologically relevant tool for environmental monitoring, particularly in regions affected by industrial emissions, urbanization, and mining activities [37]. Further research focusing on standardization of analytical protocols and molecular response mechanisms would enhance its applicability in environmental risk assessment and pollution management strategies.

RESULT

Plagiochasma spp., with their abundance of secondary metabolites, have the potential to provide a prolific reservoir of bioactive compounds with significant therapeutic possibilities. The Compounds extracted from *Plagiochasma* shown diverse characteristics, encompassing ethnomedicine use, wound healing activity, anti-inflammatory antibacterial, antioxidant, antifungal and biomonitoring of heavy metals is due to the presence of multiple potentially significant compounds.

DISCUSSION

The liverwort *Plagiochasma* has emerged as a notable species due to its abundant secondary metabolites, which offer a wide spectrum of pharmacological and ecological applications. Ethnomedicinal studies frequently highlight its traditional use in treating wounds and infections, suggesting its potential therapeutic relevance. These applications are supported by research indicating significant antibacterial properties, likely driven by its flavonoid and phenolic content. These bioactive compounds are recognized for their mechanisms of action, such as disrupting microbial cell walls and inhibiting enzymatic pathways. Antibacterial activity was detected in the dichloromethane extract of *P. intermedium* (33).

Antioxidant activity is another key attribute of *Plagiochasma*. This activity stems from its phenolic and terpenoid components, which serve as effective free radical scavengers. Such properties position *Plagiochasma* as a promising candidate for managing oxidative stress and associated conditions, including delayed wound healing.

Furthermore, the antifungal efficacy of this liverwort demonstrates its capacity to inhibit fungal pathogens, presenting opportunities for developing natural antifungal agents. Given the rising challenges of antifungal resistance, the exploration of bryophytes like *P. intermedium* is timely and relevant.

Ecologically, *Plagiochasma* has shown potential as a biomonitor for heavy metals, with studies suggesting its ability to bioaccumulate pollutants. This trait not only emphasizes its role in environmental monitoring but also highlights its resilience and adaptability in contaminated habitats.

Despite its promising bioactivities, detailed research is required to isolate specific compounds responsible for its therapeutic effects. Advances in chromatographic and spectrometric techniques, coupled with bioassay-guided fractionation, can facilitate the development of standardized extracts or synthetic derivatives.

The dual pharmacological and ecological roles of the genus *Plagiochasma underscore* its significance, warranting further investigation to unlock its full potential.

CONCLUSION

These findings emphasize their potential in pharmaceutical and biotechnological applications. Future work should focus on sustainable sourcing and exploring synergistic effects to harness the full potential of liverwort metabolites. Herbal medicines are gaining global interest, with research on bioactive compounds for treating diseases. *Plagiochasma* is a versatile plant with diverse medicinal properties, serving as a basis for discovering potent compounds and exploring its full therapeutic potential.

AUTHOR CONTRIBUTION

Akshayraj A. Pawar: Conceptualization, Writing – review & editing. Manda M. Ghatge: Conceptualization, Writing – review & editing, Supervision.

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COMPETING OF INTEREST

The authors confirm that there are no financial interests or personal relationships that could have biased or impacted the findings reported in this study.

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