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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

Table 1: 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

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).
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.* (2008) (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 exhibits 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.* (2008) (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).

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 genus *Plagiochasma* has attracted increasing scientific interest because of its diverse repertoire of secondary metabolites and the associated pharmacological and ecological significance. Its traditional use in the management of wounds and infections provides an important basis for investigating its therapeutic potential, while phytochemical studies suggest that phenolic compounds, flavonoids, terpenoids, and other specialized metabolites may contribute substantially to its biological effects. In particular, antibacterial activity has been reported for the dichloromethane extract of *P. intermedium* (33),

supporting the antimicrobial potential of this liverwort. The observed antimicrobial effects may be associated with the ability of its bioactive constituents to interfere with microbial membrane integrity, cellular metabolism, and essential enzymatic processes. In addition to antibacterial activity, reported antifungal effects indicate that *Plagiochasma* may possess a broader spectrum of antimicrobial action, thereby highlighting bryophytes as promising sources of naturally derived antimicrobial compounds.

Antioxidant activity represents another important biological attribute of *Plagiochasma*. Its phenolic and terpenoid constituents may contribute to free-radical scavenging and attenuation of oxidative stress, mechanisms that are particularly relevant to tissue injury, inflammation, and impaired wound repair. The antioxidant potential may also complement its anti-inflammatory and cytoprotective activities, providing a possible biochemical basis for the traditional use of the plant in wound-associated conditions. Furthermore, the reported hepatoprotective potential of *Plagiochasma* warrants attention because antioxidant and membrane-protective mechanisms may help limit cellular injury caused by oxidative or chemical stress. Such findings suggest that liverwort-derived metabolites could provide useful leads for the development of hepatoprotective phytopharmaceutical preparations, although detailed in vivo and mechanistic investigations remain necessary [27, 29].

The antiulcer activity of *Plagiochasma* is another promising area of pharmacological investigation. Protection of the gastric mucosa, reduction of oxidative damage, modulation of inflammatory responses, and enhancement of mucosal defense mechanisms may collectively contribute to its gastroprotective effects. Similarly, the reported anticancer potential deserves further exploration, particularly because secondary metabolites from bryophytes may influence pathways involved in oxidative stress, cellular proliferation, apoptosis, and tumor progression. However, anticancer observations should presently be regarded as preliminary unless supported by well-controlled cellular, animal, and clinical investigations. The combination of antioxidant, antimicrobial, anti-inflammatory, hepatoprotective, antiulcer, cytoprotective, and anticancer properties indicates that *Plagiochasma* may possess a multifaceted pharmacological profile rather than a single therapeutic action [2, 9, 32].

Beyond pharmacological applications, *Plagiochasma* also has considerable ecological relevance. Its capacity to accumulate environmental contaminants, including heavy metals, indicates potential utility as a biomonitor of environmental pollution. Bioaccumulation studies may therefore provide valuable information regarding pollutant distribution, environmental exposure, and the adaptability of bryophytes under stressful ecological conditions. This dual significance—as a potential source of biologically active natural products and as an ecological indicator—makes *Plagiochasma* particularly valuable for interdisciplinary research [6, 29, 30].

Despite these promising observations, the biological activities of *Plagiochasma* require systematic validation. Future investigations should focus on comprehensive phytochemical characterization, isolation and identification of active constituents, mechanism-based assays, bioassay-guided fractionation, toxicity evaluation, and appropriate in vivo models. Advanced chromatographic, spectrometric, molecular, and pharmacological approaches could facilitate the identification of lead compounds and the establishment of standardized extracts. Such research may ultimately clarify the relationship between the phytochemical composition and the antimicrobial, antioxidant, hepatoprotective, antiulcer, anticancer, anti-inflammatory, and cytoprotective activities of *Plagiochasma*, thereby strengthening its prospects for pharmaceutical, nutraceutical, and environmental applications.

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.

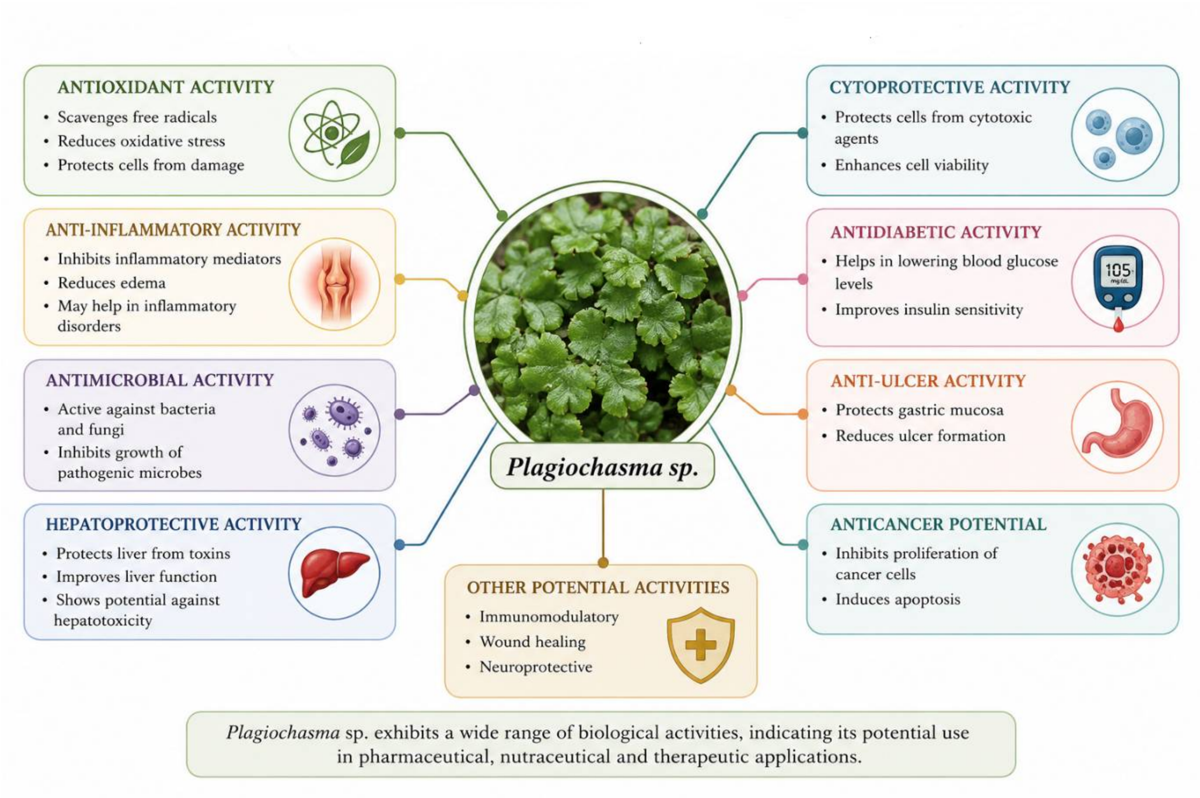

Fig 1: *Plagiochasma :* Biological activities

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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