Review

Ethnopharmacological and Medicinal Properties of *Allophylus dimorphus* Radlk.: An Update

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Abstract: *Allophylus dimorphus* Radlk., a member of the Sapindaceae family, is a shrub or tree primarily found in the Nicobar Islands, Malaysia, and the Philippines. Despite its potential relevance in traditional medicine, research on the ethnopharmacological and medicinal properties of this species is currently limited. However, a few closely related species, such as *Allophylus cobbe* and *Allophylus serratus*, have been studied for their bioactive compounds with antioxidant, antimicrobial, and anti-inflammatory properties. The World Health Organization (WHO) recognizes the significance of traditional medicine, which remains a vital healthcare source for many communities worldwide. The rapid loss of plant diversity and the potential for discovering novel medicinal compounds highlight the necessity of documenting and investigating *A. dimorphus* and related species. This update consolidates existing knowledge on the phytochemistry, ethnomedicinal uses, and pharmacological properties of *A. dimorphus*, providing a foundation for future research and conservation efforts.

Keywords: *Allophylus dimorphus*; ethnopharmacology; medicinal properties; phytochemicals; pharmacological activity

1. Introduction

Nature has been an excellent source of therapeutic agents for thousands of years, and several modern drugs have originated from natural sources, many based on their use in traditional medicine [1]. Medicinal plants have served as an essential source of therapeutic agents for centuries, with approximately 80% of the global population relying on them for disease prevention and treatment [2]. Over 40% of pharmaceutical formulations are derived from natural sources, underscoring their significant role in drug development [3]. The Sapindaceae family, comprising over 1000 species, includes *Allophylus dimorphus*, a plant with potential medicinal value that remains underexplored [4,5].

The importance of medicinal plants in traditional healthcare systems cannot be overstated, particularly in regions where access to modern healthcare is limited. Indigenous communities have utilized plant-based treatments for generations, and many of these traditional remedies are now being scientifically validated [5]. The growing interest in ethnomedicine is driven by the increasing need for novel bioactive compounds that can serve as alternatives to synthetic pharmaceuticals, which often come with adverse side effects [1]. The *Allophylus* L. genus has been extensively used in traditional medicine in various cultures, with *Allophylus cobbe* (L.) Forsyth fil. and *Allophylus serratus* (Roxb.) Kurz. showing promising pharmacological activities, including antioxidant, antimicrobial, and anti-inflammatory properties [6,7].

Allophylus dimorphus remains relatively unexplored in terms of its chemical composition and medicinal potential, despite its similarity to well-studied species, *A. cobbe* and *A. serratus*. This lack of research is concerning, given that other members of the genus have been shown to contain phytochemicals with therapeutic benefits. Moreover, the loss of biodiversity due to habitat destruction, climate change, and unsustainable harvesting practices poses a threat to the availability of medicinal plants, making conservation efforts imperative [8].

The study of *A. dimorphus* is particularly significant in the context of sustainable medicine, as it could contribute to the development of natural drug alternatives while supporting ecological conservation. This review highlights the need for further research into this species to validate its traditional uses and explore its potential applications in modern medicine. By synthesizing available data and identifying research gaps, this work aims to encourage future studies on *A. dimorphus*, ensuring that its medicinal potential is fully realized while promoting conservation efforts to protect this valuable plant species. In addition, it provides insights into potential research directions, facilitating comprehensive studies that could lead to novel drug discoveries and the sustainable utilization of this species. Therefore, the primary objective of this update is to consolidate and analyze existing knowledge on *A. dimorphus*, covering its botanical characteristics, phytochemical composition, ethnomedicinal applications, pharmacological activities, and conservation status, while also proposing future research directions.

2. Methods

A systematic approach was adopted to gather information on *Allophylus dimorphus* Radlk. Relevant data were collected from various scientific databases using specific search keywords, including "*Allophylus dimorphus* Radlk". + medicinal properties", "*Allophylus dimorphus* Radlk. Radlk. + biological activities", "*Allophylus dimorphus* Radlk. + phytochemicals", and "*Allophylus dimorphus* Radlk. + ethnomedicinal uses". The search focused on compiling insights into the botanical description, ethnobotanical significance, phytochemical composition, and pharmacological properties of the species. Taxonomic classification was verified using authoritative botanical references, and relevant studies were critically analyzed to identify gaps in existing knowledge and potential areas for future research. A schematic representation (Figure 1) was developed to summarize the findings and guide the update. Moreover, the study emphasized the necessity of exploring *A. dimorphus* for its therapeutic potential, given its status as a vulnerable species and the scarcity of scientific reports. This methodological framework ensures a comprehensive and structured analysis of the available literature, contributing to a deeper understanding of this underexplored species.

Figure 1. Schematic representation for a review on *Allophylus dimorphus* Radlk.

3. Botanical and Morphological Characteristics

3.1. Botanical Characteristics

Allophylus dimorphus is a small to medium-sized tree or shrub that thrives in humid tropical climates, particularly in the Nicobar Islands, Bangladesh, China, Malaysia, Thailand, and the Philippines [9–11]. *Allophylus dimorphus* is found in coastal forests, mangrove ecosystems, and tropical evergreen forests, where it plays a vital role in maintaining ecological stability by preventing soil erosion and supporting biodiversity [11]. It is a medium-sized shrub or tree typically ranging from 2 to 4 m in height, characterized by slender, few-branched stems that are green and pubescent. The taxonomy and classification of *A. dimorphus* is as follows: Kingdom: Plantae; Phylum: Tracheophyta; Class: Magnoliopsida; Order: Sapindales; Family: Sapindaceae; Genus: *Allophylus* L.; Species: *Allophylus dimorphus* Radlk. [11–13].

3.2. Morphological Characteristics

Morphologically, *A. dimorphus* is characterized by pinnate leaves that are alternately arranged, with elliptical to oblong leaflets possessing serrated margins [12]. The leaflets have petiolules of 1–1.5 cm, with the outermost one being nearly sessile. The blades are papery and display tufts of hairs in the lateral vein axils, with 9 to 10 prominent lateral veins on both sides [12,13]. The terminal leaf blade is broadly lanceolate or narrowly elliptic, measuring 8–18 × 3–6.5 cm, with a cuneate base, sharply serrulate margins above the middle, and a caudate-acuminate apex (Figure 2) [14].

Figure 2. The specimen diagram of *Allophylus dimorphus* leaves [12] and its flower [14].

The plant produces small, greenish-white flowers that are borne in panicles (Figure 2), which later develop into bright red, fleshy berries that serve as a food source for birds and small mammals [14]. The species exhibits high adaptability to various soil conditions and is often found thriving in nutrient-poor sandy or lateritic soils, making it a resilient species in disturbed habitats.

4. Geographical and Habitat Distribution

Geographically, *A. dimorphus* is primarily found in the tropical belts of Southeast Asia, extending beyond Bangladesh and India to other regions within its native range. This species thrives in tropical forests, particularly in the Sylhet and Chittagong regions of Bangladesh and the Sundarbans of West Bengal, India [11]. Locally known as “Si Sa Calaai” or “Kro Kaya Dung” among the Marma people, *A. dimorphus* adapts well to diverse soil types, contributing to tropical forest biodiversity. Its fruits serve as a food source for birds and animals, facilitating seed dispersal [11,12]. However, habitat destruction poses a significant threat, highlighting the need for conservation efforts. A detailed geographical map provides comprehensive information on the habitats where *Allophylus* species occur (Figure 3) [8,12]. The insights from the mapping resources enhance the understanding of the ecological context in which *A. dimorphus* exists and emphasize the urgency of conservation strategies to preserve this vulnerable species and its habitat [13]. Access to such geographical data is crucial for guiding future research initiatives and conservation efforts aimed at protecting biodiversity.

Figure 3. A detailed geographical map of *Allophylus* species [13].

Several members of the *Allophylus* genus, including *A. cobbe* and *A. serratus*, have been studied for their medicinal potential due to their similar morphological characteristics and phytochemical compositions [6,7,15]. The documented ethnomedicinal uses of these related species suggest that *A. dimorphus* may also possess bioactive compounds with therapeutic properties [15]. Future studies should prioritize mapping the full distribution range of *A. dimorphus*, assessing its ecological roles, and evaluating the impact of environmental changes on its populations. The synthesis of a variety of phytochemicals is greatly affected by several factors including genetics, climate, and soil [16]. In the past few decades, rising global temperatures, changes in rainfall patterns, increased carbon dioxide (CO_2) levels, and frequent extreme weather events have altered the growth, distribution, and levels of phytochemicals in medicinal plants. These changes have implications for global health [17]. Moreover, sustainable harvesting practices and habitat restoration initiatives must be implemented to prevent further decline of this valuable species [10].

5. Ethnobotanical and Traditional Uses

The ethnobotanical uses of *A. dimorphus* are deeply rooted in local traditions and practices. Among the Gor tribe in northeastern Bangladesh, the fruits of *A. dimorphus*, when combined with the crushed tubers of *Alocasia macrorrhizos* (Giant taro) and juices from *Calotropis gigantea* (Giant calotrope) and *Cynodon dactylon* (Scutch grass), are used as a remedy for erectile dysfunction [5,11]. The roots exhibit notable astringent properties, making them effective for treating piles and managing nasal bleeding. In some regions in India, the roots are reputed for their ability to enhance lactation, while a hot infusion made from the root barks plays a role in preventing both diarrhea and rheumatic pain [7,11]. In addition, the leaves are utilized to induce lactation, and a paste derived from the leaves is applied topically to treat ulcers [18,19]

Allophylus dimorphus has been utilized in traditional medicine across various indigenous cultures, particularly in Southeast Asia and the Nicobar Islands. The plant has been used by tribal communities for treating gastrointestinal ailments, and inflammatory conditions, and as a general health tonic [18,19]. Several reports indicate that decoctions made from the leaves and bark are commonly used for their analgesic and anti-inflammatory effects, particularly in treating joint pain and rheumatism [7,18,19]. In traditional Indian and Bangladeshi medicine, *A. dimorphus* and closely related species such as *A. cobbe* have been prescribed for managing diarrhea, dysentery, and stomach ulcers. The leaves are often chewed raw or boiled into herbal infusions to soothe digestive discomfort [5]. The presence of tannins and flavonoids, is known for their astringent and anti-inflammatory properties.

Among the indigenous Nicobarese communities, *A. dimorphus* has been used as a natural remedy for skin infections and wound healing. The crushed leaves are applied topically to cuts, burns, and ulcers to promote faster recovery and prevent microbial infections [18,19]. The antimicrobial potential of *Allophylus* species has been documented, and preliminary studies suggest that bioactive compounds such as phenolic acids and alkaloids may contribute to their antibacterial activity [7]. The plant is also valued in Ayurvedic medicine as a blood purifier and detoxifying agent. In India and Bangladesh, traditional practitioners prepare a concoction using roots and bark to treat fever, colds, and respiratory ailments [11]. The antioxidant-rich composition of *A. dimorphus* aligns with its traditional use in immune-boosting formulations Ethnopharmacological surveys conducted in Malaysian and Indonesian villages have highlighted the use of *A. dimorphus* in reproductive health. Women consume infusions made from the leaves to alleviate menstrual pain and hormonal imbalances [9–11].

In African traditional medicine, related *Allophylus* species have been used in the treatment of malaria, and it is speculated that *A. dimorphus* may share similar therapeutic effects [4]. The presence of alkaloids and saponins in the genus suggests potential anti-malarial activity, which warrants further scientific investigation. Despite its extensive traditional applications, scientific validation of many of these claims remains limited. Future studies should focus on conducting rigorous pharmacological evaluations, including in vitro and in vivo assessments, to establish the efficacy and safety of *A. dimorphus* in treating these ailments. The integration of scientific inquiry with traditional knowledge surrounding *A. dimorphus* strengthens the case for further exploration of its therapeutic potential, highlighting the need for comprehensive studies to validate its applications in modern healthcare. The ethnopharmacological uses of *A. dimorphus* are highlighted in Table 1. Scientific validation for many of these traditional uses remains limited, necessitating further pharmacological research to establish efficacy and safety

Table 1. Ethnopharmacological uses of *Allophylus dimorphus.*

Part Used	Traditional Use (s)	Region	References
Fruits	Combined with *Alocasia macrorrhizos*, *Calotropis gigantea*, and *Cynodon dactylon* for erectile dysfunction	Bangladesh (Gor tribe)	[5,11]
Roots	Astringent properties used for treating piles and nasal bleeding	Various regions	[7,11]
Roots	Enhancing lactation	India	[7,11]
Root Bark	Hot infusion used to prevent diarrhea and rheumatic pain	India	[7,11]
Leaves	Inducing lactation and applied as a paste for ulcers	Various regions	[18,19]
Leaves & Bark	Decoctions for analgesic and anti-inflammatory effects (joint pain, rheumatism)	Southeast Asia, Nicobar Islands	[7,18,19]
Leaves	Chewed raw or boiled into herbal infusions for digestive issues (diarrhea, dysentery, stomach ulcers)	India, Bangladesh	[5]
Leaves	Applied topically for skin infections, wound healing, burns, and ulcers	Nicobarese communities	[18,19]
Roots & Bark	Concoctions for fever, colds, and respiratory ailments	India, Bangladesh	[11]
Leaves	Infusions consumed for menstrual pain and hormonal imbalance	Malaysia, Indonesia	[9–11]
Various parts	Speculated anti-malarial properties based on related *Allophylus* species	Africa	[4]

6. Phytochemical Constituents

Phytochemical studies on *A. dimorphus* are limited and have remained unexplored for new chemical entities. There are no recent reports on the isolation and characterization of compounds from the various parts (fruits, seeds, leaves, stem) of *A. dimorphus* available. Previous reports indicate the presence of benzylamide, phenylacetamide, and phytosterols in *Allophylus* species, supporting their potential medicinal applications. It has also been reported that leaves of other species such as *A. cobbe* contain an alkaloid-enriched fraction [17].

In another study, the bark of this species along with the leaves also showed the presence of alkaloids in trace amounts [20]. These compounds are associated with antimicrobial, anti-inflammatory, and antioxidant activities, which justify their traditional medicinal use [18,19].

However, research on related species suggests the presence of flavonoids, phenolics, alkaloids, and terpenoids, which are known for their diverse therapeutic properties [6,7]. β-Sitosterol is a common phytosterol found in *Allophylus* species and has been linked to cholesterol-lowering and cardioprotective effects [18]. Further phytochemical investigations using advanced chromatographic techniques such as high-performance liquid chromatography (HPLC) and gas chromatography-mass spectrometry (GC-MS) could enhance the understanding of its potential for pharmaceutical applications. [21]. Since the species is underutilized and other species have been explored thoroughly the scientific community could and investigate each part of this species qualitatively and quantitatively using modern analytical and computational tools such as mass spectrometry combined with metabolomics and chemometrics. The chemical structures of identified phytochemicals in various *Allophylus* species are depicted in Figure 4.

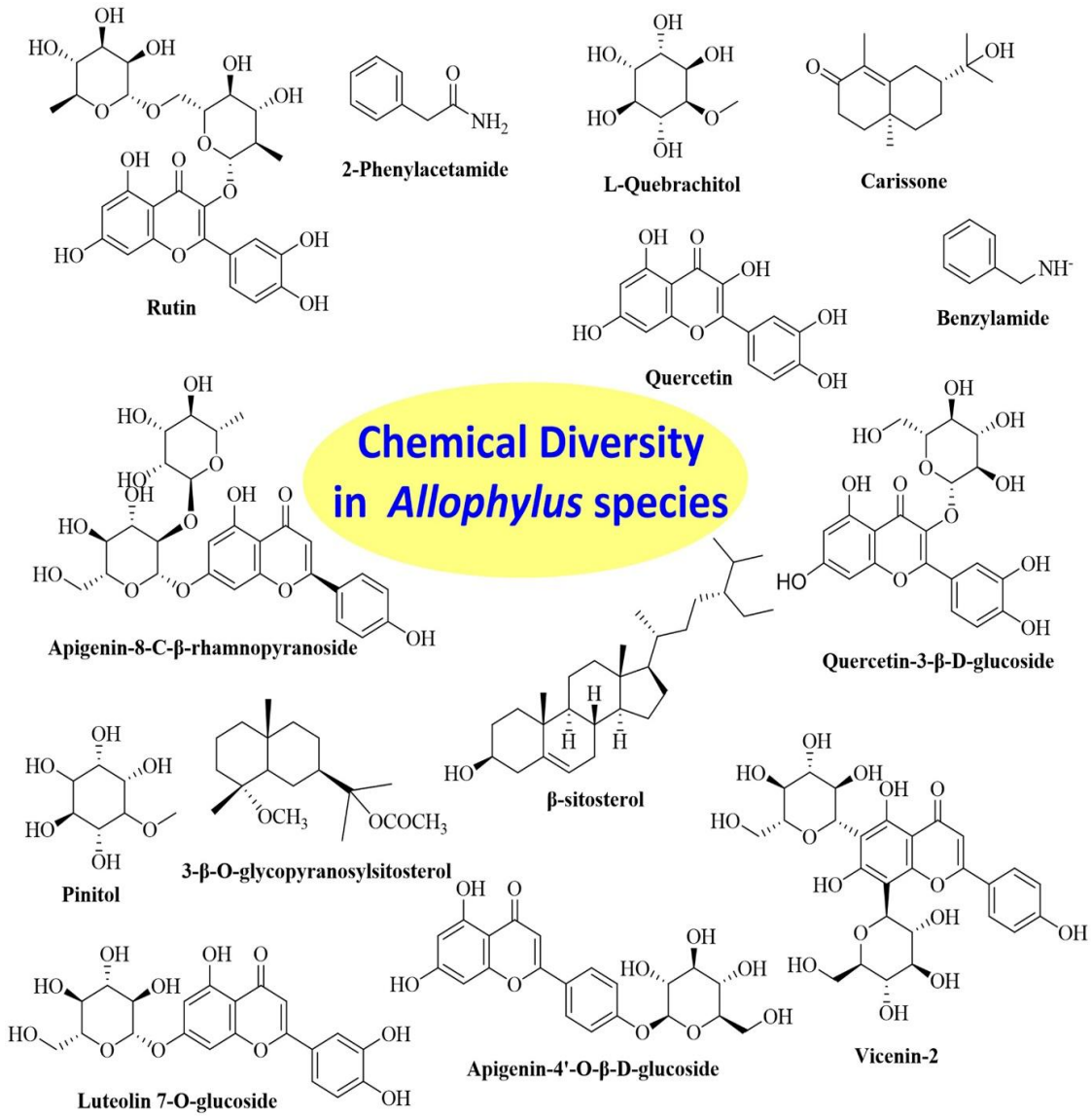

Figure 4. Chemical structures of identified phytochemicals in various *Allophylus* species.

7. Medicinal Properties

For millennia, humans have utilized plants for medicinal purposes, and a significant portion of modern pharmaceuticals are either derived from or inspired by natural products [1]. While direct pharmacological studies on *Allophylus dimorphus* are limited, research on related *Allophylus* species reveals a broad spectrum of bioactivities, suggesting similar potential for *A. dimorphus*. *A. serratus* exhibits notable anti-inflammatory and antioxidant properties [7], while *A. cobbe* demonstrates significant antimicrobial and antidiabetic effects [6]. Moreover, *A. africanus* displays anticancer and antiulcer properties highlighting the potential for discovering novel therapeutic agents within this genus [22]. The pharmacological properties of some of the common *Allophylus* species are shown in Figure 5.

The antioxidant potential is attributed to polyphenols and flavonoids, which neutralize oxidative stress and prevent chronic diseases such as cancer, cardiovascular disorders, and diabetes [1]. *A. cobbe* has demonstrated radical scavenging activity, suggesting that *A. dimorphus* may exhibit similar properties [6]. The presence of rutin, quercetin, and catechin in related species supports this assumption [7]. The antioxidant properties observed in related *Allophylus* species are likely due to their flavonoid and phenolic content. These compounds neutralize free radicals and reduce oxidative damage linked to chronic diseases like cancer, diabetes, and cardiovascular disorders [1]. In vitro and in vivo studies are necessary to confirm the extent of antioxidant efficacy. The presence of β-sitosterol in *A. serratus* [7], also points towards possible benefits in managing hyperlipidemia and improving cardiovascular health [18].

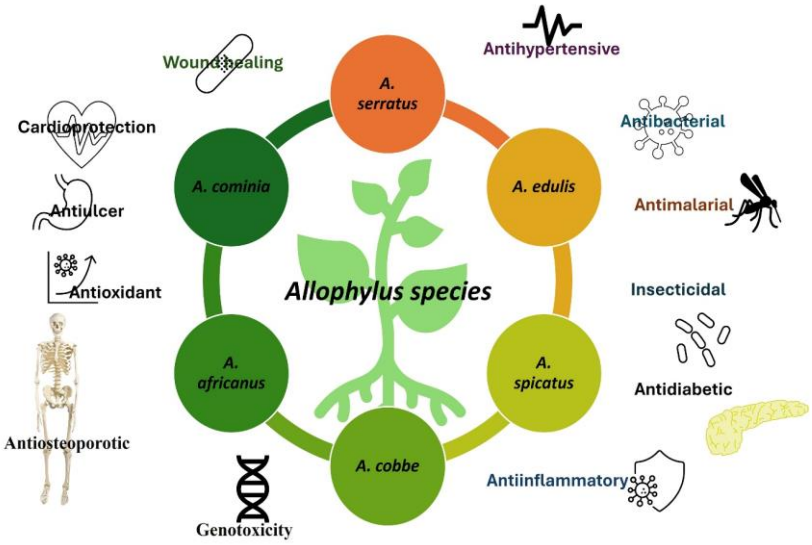

Figure 5. Pharmacological properties of some of the common *Allophylus* species.

Antimicrobial screening of *A. cobbe* and *A. serratus* has shown activity against Gram-positive bacteria such as *Staphylococcus aureus* and *Bacillus subtilis*, but limited efficacy against Gram-negative bacteria [6,7]. The anti-inflammatory properties of *Allophylus* species are due to flavonoids, which inhibit TNF-α and IL-6. The presence of alkaloids and terpenoids in *Allophylus* species further suggests potential antimicrobial and anti-inflammatory properties, with applications in treating infectious diseases and inflammatory conditions [6,7]. The medicinal properties of *A. dimorphus* and its related species are shown in Table 2.

Research suggests that *Allophylus dimorphus* extracts may have similar effects because of their chemical similarities. Further studies should use bioassay-guided fractionation to identify active compounds. While *A. dimorphus* has demonstrated promising medicinal applications, its toxicity profile remains unassessed. Related species have been found to exhibit mild cytotoxicity at high concentrations [7]. Long-term safety studies, including acute and chronic toxicity assessments, are necessary before clinical application. Further pharmacological studies, including in vitro and in vivo experiments, are needed to confirm the medicinal potential of *Allophylus dimorphus*. Long-term safety and toxicity assessments should be prioritized before clinical applications. To investigate the medicinal and pharmacological properties of *A. dimorphus*, research should first focus on its phytochemical aspects. A thorough inspection on biological-guided fractionation for each part and various polarity extracts may provide some potential leads to understanding the phyto-pharmacological profile of this species.

Table 2. Medicinal properties of *A. dimorphus* and its related species.

Property	Observed in Species	Bioactive Compounds	Potential Applications	References
Antioxidant Activity	*A. cobbe*, *A. serratus*	Polyphenols, flavonoids (rutin, quercetin, catechin)	Protection against oxidative stress, cardiovascular disorders, diabetes	[1,7]
Anti-inflammatory	*A. cobbe*, *A. serratus*	Flavonoids, alkaloids, terpenoids	Inhibition of TNF-α and IL-6, treatment of inflammatory diseases	[6,7]
Antimicrobial	*A. cobbe*, *A. serratus*	Alkaloids, terpenoids	Activity against Gram-positive bacteria (*S. aureus*, *B. subtilis*)	[6,7]
Anticancer	*A. africanus*	Unknown	Potential for novel cancer therapies	[22]
Antiulcer	*A. africanus*	Unknown	Protection against gastric ulcers	[22]
Antidiabetic	*A. cobbe*	Unknown	Regulation of blood sugar levels	[6]
Cardiovascular Health	*A. serratus*	β-sitosterol	Management of hyperlipidaemia, heart health	[7,18]

8. Conservation Concerns

Many plant species are threatened by habitat transformation, over-exploitation, invasive alien species, pollution, and climate change, and are now in danger of extinction [24]. The conservation status of *A. dimorphus* is a critical concern. The primary causes of its threat include land conversion and habitat degradation due to commodity-driven desertification, fluctuating agricultural practices, urbanization, and forestry activities such as logging [8]. Its limited distribution and vulnerability to habitat loss [8] necessitate immediate conservation efforts [23,24]. The reliance of many populations on this species for food and medicine highlights its ecological and socio-economic importance. Habitat destruction, driven by deforestation and agricultural expansion poses a significant threat to its continued survival [23,24]. The vulnerability of *A. dimorphus* necessitates the development and implementation of sustainable management strategies including habitat protection, cultivation, and the integration of traditional knowledge with modern scientific practices [3]. To stop population decline, the interventions are highly recommended together with the introduction of species to botanic gardens for *ex-situ* conservation to safeguard its continued survival [8,24].

9. Future Research Directions

Future research on *Allophylus dimorphus* should prioritize several key areas. A comprehensive phytochemical analysis is critical to fully characterize its bioactive compounds [1]. Advanced techniques such as metabolomics and proteomics will provide detailed information on its biochemical pathways and the interactions of its various components. This knowledge will provide a more comprehensive understanding of the mechanisms underlying its observed bioactivities and will aid in the identification of specific lead compounds for the development of potential therapeutics [1].

Future research should prioritize comprehensive phytochemical analyses to isolate and characterize the bioactive compounds present in *A. dimorphus* and its relatives. Pharmacological investigations should focus on evaluating the antioxidant, antimicrobial, anti-inflammatory, and anticancer activities of *A. dimorphus*, emphasizing unique properties that distinguish it from other *Allophylus* species. Integrating traditional knowledge with scientific methodologies will not only validate its therapeutic uses but also promote the sustainable utilization of this valuable species in natural product research and drug development. Integrating sustainable harvesting practices with conservation efforts is critical [23,24]. The available information on the morphology, geographical distribution, and ecological context of *A. dimorphus* can help with the selection of appropriate cultivation methods and promote successful propagation efforts [8,13–17].

10. Conclusions

Allophylus dimorphus, a vulnerable species with a long history of ethnomedicinal use, represents a promising yet underexplored source of bioactive compounds for modern medicine. This review synthesizes existing knowledge on the botanical, ethnopharmacological, and pharmacological aspects of *A. dimorphus* and related species, highlighting its potential therapeutic applications. While direct research on *A. dimorphus* remains limited, the promising bioactivities demonstrated by related *Allophylus* species, along with its ethnomedicinal uses and rich phytochemical profile, warrant further investigation. Future studies focusing on comprehensive phytochemical analysis, rigorous bioactivity testing, and the development of sustainable cultivation practices are urgently needed to realize the full therapeutic potential of *A. dimorphus* while simultaneously safeguarding this valuable species and its associated biodiversity. A multidisciplinary approach integrating traditional knowledge with modern scientific methods is key to achieving this goal. The phytochemical studies on other *Allophylus* species show a wide variety of compounds, including flavonoids and other phenolics, that are responsible for a broad range of bioactivities. To develop novel drugs and nutraceuticals, detailed investigations into their phytochemistry using conventional and advanced tools may help to enrich the bioactive fraction followed by the purification of newer chemical entities [21]. This approach could facilitate the discovery of novel or known compounds that may aid in the treatment of certain diseases [1]. Most importantly, failing to implement effective conservation and sustainable use strategies will jeopardize the future availability of this and other valuable medicinal plant resources.

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