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THE GENUS BARLERIA: "A COMPREHENSIVE REVIEW OF ITS PHYLOGENETIC CHALLENGES AND MEDICINAL PROPERTIES"

Life Sciences

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ABSTRACT

The genus Barleria has about 300 species in the family Acanthaceae and is mainly found in the tropical and subtropical regions, but particularly it is abundant in the continents of Africa and Asia. This genus has a great deal of ecological as well as medicinal importance. Morphologically, the genus is highly diversified, and that is the reason why the taxonomy of the genus was considered challenging for a long time due to the overlapping of some floral and vegetative characters. Recent developments in molecular phylogenetics, such as DNA barcoding and chloroplast genome, have greatly enhanced the taxonomic definition of species and knowledge of phylogenetic relationships, thus eliminating ambiguities in taxonomy associated with homoplasy and an underestimation of taxa during global assessment. Phytochemically, the species of Barleria are abundant in bioactive compounds, such as flavonoids, phenolics, iridoids, and terpenoids, showing antioxidant, antibacterial, antiinflammatory, and anticancer activities. Some of the species, like B. prionitis and B. Lupulina have shown strong antioxidant activity, while B. albostellata possesses robust antibacterial and anticancer activities including specific cytotoxicity against different cell lines of cancer. However, for many species, a critical deficiency of extensive phytochemical research and clinical studies persists.

KEYWORDS

Barleria, Phylogenetics, Phytochemical, Antioxidant, Antimicrobial and Anticancer

INTRODUCTION

There are approximately 300 species occurrences of the genus Barleria, and the members have marked a preference for the tropical and subtropical regions of Africa and Asia (Darbyshire, Balkwill, and Froneman, 2022). The genus is variably disposed in its morphological features, especially the floral and vegetative characters that have made the classification a rather difficult endeavor in traditional morphological terms (Patil et al., 2019). The species of Barleria have multiple species that are well known for their medicinal values and have been used in traditional medicine for various diseases, of which health conditions are those due to respiratory infections, rheumatism, and inflammatory disorders (Tamboli et al., 2022). Moreover, the genus plays an important ecological role by contributing to the biodiversity of regions where the genus is indigenous, primarily in southern Africa and India (Malik et al., 2021).

Traditionally, the taxonomy of Barleria was based on morphological characteristics, however, this has proven to be uncertain in the identification of species as morphological characteristics are highly variable. This problem has been notably reported in regions such as Madagascar and India, where the native flora species of these regions have been underrepresented in the global phylogenetic assessments (Patil et al., 2019). In addition, taxonomic uncertainties often emerge as a result of homoplasy in morphological features where analogous characters are derived independently across unrelated taxa (Balkwill and Balkwill, 1998). These have contributed to incompatible classification systems and an ambiguity over the generic interrelationships of species.

The genus Barleria is pantropical in distribution but mainly occurs in the Old World. The highest levels are found in tropical regions and southern Africa, and then followed by South Asia, particularly India, in which genus is represented by 26 species, one subspecies, and one variety (Yadav and Shendage, 2010). Particularly well represented is the genus also on the island of Madagascar, with a single species, Barleria oenotheroides, which extends its range further into the Neotropics (Darbyshire et al., 2019). Barleria is markedly endemic. It is highlighted that key centers of endemism are Angola and Namibia. Here, it has been represented that around 70% of the species are endemic in Africa (Darbyshire et al., 2019). In India, the genus mainly takes place in the peninsular regions and contains broad, area-endemic species as well as localized endemic ones (Yadav and Shendage, 2010).

From a morphological point of view, Barleria is notable for its high variability. In contrast, there is a wide variation from herbaceous forms to shrubby structures. Key taxonomic features comprise the remarkable four-partite calyx, honeycombed pollen grains, and double cystoliths (Balkwill and Balkwill, 1997; Yadav and Shendage, 2010). A great diversity of corolla morphologies is observable in the genus, which relates to different pollination syndromes. The corolla lobes can be subregular, "4+1," or "2+3" patterns, which reflects a mode of evolutionary divergence, and the taxonomic character that distinguishes the sections and subgenera involves the presence of spines in the axils of the leaves (Darbyshire et al. 2019). For example, in subgenus Prionitis, spines originate from lower buds that sprout from axils and in subgenus Barleria they develop from sterile inflorescences. Balkwill and Balkwill (1997), Darbyshire et al.

The morphology of the capsule is also essential for sorting out classification. Species classified in subgenus Barleria have usually unbeaked, four-seeded capsules, but those in subgenus Prionitis normally have two-seeded capsules with beak or un-beaked (Balkwill and Balkwill, 1997; Yadav and Shendage, 2010). Seeds such as hygroscopic hairs also convey crucial taxonomic information in terms of morphology (Balkwill and Balkwill, 1997).

The genus Barleria is indeed an ecologically intense taxonomic unit in the geographical areas of Namibia and Angola since this genus encompasses all sorts of species that extensively occupy large areas of territory and is a very important source of foraging for herbivorous fauna (Darbyshire et al., 2019). This genus indicates excellent adaptability in arid and semi-arid ecosystems, with many species showing adaptations to survive under extreme climatic conditions. For example, ecological niches within the Namibia species of Barleria varied from extremely arid desert environments to relatively more humid environments within the interior regions (Darbyshire et al., 2019). A few species of the Indian subcontinent have specifically adapted to rocky and arid conditions. A particular taxa also occurs in parts of the peninsular region, especially on the Western Ghats (Yadav and Shendage, 2010). This distribution pattern observed highlights the exceptional adaptability of the genus toward a variety of ecological conditions on diverse continents.

Despite the base of the current taxonomy of Barleria being laid by classical morphological studies, new molecular studies are continuously improving our understanding of the phylogenetic relationships within the genus. Some molecular data are gathered from species endemic to southern Africa (Darbyshire et al., 2019). As Darbyshire et al. (2019) note, continuing molecular investigations are likely to further divide the present grouping and rationalize the present taxonomic ambiguities. Nevertheless, intensive molecular phylogenetic investigations of Barleria throughout its whole geographic range are at a very rudimentary stage.

According to history, Barleria was a plant respected for its medicinal

values, which included the mitigation of pain, inflammation, fever, and infectious diseases. The therapeutic activity of these applications is attributed to the bioactive constituents present in Barleria, which includes flavonoids, terpenoids, iridoids, and phenolic acids, and that combine antioxidant, anti-inflammatory, antimicrobial, and anticancer properties (Gangaram et al., 2022; Banerjee et al., 2024; Morshed et al., 2024). The growing interest in natural antioxidants, which has been fuelled by the demand for alternative compounds with fewer side effects than synthetic ones, has spurred intensive studies on Barleria and its allied plant species (Finkel & Holbrook, 2000; Gaayathiri & Nisha, 2024).

Traditionally, many species of Barleria have been used in ethnomedicine to treat a vast range of health problems. Its pharmacological activities are also seen to be in sync with the traditional uses of the genus. For instance, the genus Barleria prionitis has been studied and found to possess significant analgesic activity; further, the species of this genus, Barleria cristata and Barleria lupulina, have been reported to have therapeutic values against fever and infections. Recent studies prove the potential therapeutic applications of these species, highlighting differences in their phytochemistry, which are vital to its traditional application in medicines. Sudheer & Praveen, 2021; Ismail-Suhaimy et al., 2021.

Molecular Techniques

For addressing the problems posed by classic taxonomic practices, researchers have used high-through put molecular techniques in analyzing the genus Barleria. DNA barcoding, which is the sequencing of specific domains within the plant genome like matK, rbcL, and ITS, was particularly use for the identification of taxa and justifying taxonomic confusion (Khan et al. 2020; Safhi et al. 2023). DNA barcoding has also been used successfully in medicinal plants of this genus for the study that consequently provides better intra-species differentiation of species that morphologically resemble one another. Many recent studies have also taken advantage of the potential of next-generation sequencing technologies, including RADseq to delineate species boundaries and provide phylogenetic information (Comito et al. 2022).

Of great significance, in that category, was the taxon description of Barleria lavaniana as a new species. This was based on collaborative methodology-integrating stem anatomy analysis, karyotype evaluation, and a set of molecular markers like matK and rbcL (Patil et al. 2019). In that way, such an integrated methodology combining molecular and morphological information much advances species classification at a more accurate level.

Sequencing of chloroplast genomes across different species of Barleria greatly contributed to improving the taxonomy. Molecular markers such as the ccsA-ndhD and ndhA-ndhH-rps15 genes increased the accuracy with which species could be identified (Kaewdaungdee et al., 2022). Generally, molecular-based methods have allowed scientists to distinguish species that might exhibit overlapping morphological features.

Phytochemical Constituents

The medicinal value for species of Barleria lies in its diverse phytochemical constituent. Some of the main bioactive constituents identified in various species of Barleria include flavonoids, phenolics, tannins, iridoids, and terpenoids; all these contribute to their therapeutic properties. Studies on Barleria lupulina, a species of immense recognition in the South and Southeast Asian traditional medical sciences, showed that the extract possesses higher flavonoid and phenolic content. Such content has direct correspondence with its antioxidant properties demonstrated via various assays such as DPPH, NO scavenging and H_2O_2 assay (Morshed et al., 2024).

In correspondence, Barleria terminalis has a phytochemical profile in flavonoids and tannins, in keeping with the well-documented antioxidant and anti-inflammatory activities described latter (Otari et al., 2022). In contrast, less observed species such as B. albostellata, have been identified containing distinct compounds such as alpha-amyrin and stigmasterol demonstrating activity against both Gram-positive and Gram-negative bacterial cultures, thus inhibiting growth as per microbiological studies by Gangaram et al., (2023). Despite these findings, systematic phytochemical studies of many Barleria species have not yet been concluded satisfactorily and additional research might reveal more biologically active compounds with promising potential in drug discovery.

Pharmacological Properties

Antioxidant Activity

The determination of antioxidant activity is a significant aspect of Barleria studies, especially since oxidative stress has been implicated in the pathogenesis of aging, oncogenesis, and chronic inflammatory diseases. For example, Barleria prionitis contains massive antioxidant activity that closely relates with its phenolic compound content (Sharma et al., 2014). Even more, extraction methods to B. lupulina which have been improved indicate a large scavenging activity for radicals that helps support it in the prevention of the oxidative-induced damage (Ismail-Suhaimy et al., 2021). Related studies on Barleria cuspidata and Barleria strigosa prove the fact that these species can be used to reduce oxidative stress, which is relevant in the treatment of chronic diseases and inflammatory disorders (Gaayathiri & Nisha, 2024; Lei et al., 2023).

Antibacterial and Immunomodulatory Activity

This review supports the antibacterial and immunomodulatory activities of Barleria which has great relevance in the present world where antibiotic-resistant bacterial strains are emerging as an urgent need to be overpowered. The extracts of B. lupulina have been reported to possess outstanding antibacterial activity against many pathogenic microorganisms like Staphylococcus aureus and Salmonella typhi. In addition, the same species has also shown immunomodulatory characteristics, which may enhance immunity; hence, it would also be useful in infections as well as in immunity augmentation (Kumari et al., 2017). These findings make Barleria a promising lead compound in the development of drugs made from natural antibacterial origin especially in scenarios where it is difficult to overcome the complications of antibiotic resistance (Gangaram et al., 2023).

Cytotoxic and Anticancer Activity

The cytotoxic property of Barleria species draws much attention because of potential anticancer treatment protocols. For instance, B. albostellata was known to be cytotoxic toward various cancer cell lines and extracts from B. were also found to have antimicrobial activity. The results from B. cuspidata and B. strigosa showed that these compounds is to have growth inhibiting activities on oral squamous carcinoma cells due to the induction of apoptosis and as well as interruption of cell cycle progression (Gangaram et al., 2023; Gaayathiri & Nisha, 2024). Such a profile indicates Barleria as one of the important candidates in natural lead compounds that demonstrate selective cytotoxicity against neoplastic cells, and thereby, its future is ahead in the field of study in oncology.

Safety Profile and Toxicity

The safety assessment is relevant to the therapeutic use of the species Barleria. Toxicology studies, especially with respect to B. lupulina, have proven the plants to be nontoxic at the indicated concentration limits, which vindicate the traditional uses and their scope in pharmaceutical formulations for future times (Banerjee et al., 2024). Yet further experiments need to be done in detail to establish standardized doses to test safety profiles over extended periods.

CONCLUSION

The most striking and effective approach to unravelling the taxonomic complexities attributed to the genus Barleria has been through integrative approaches that employ cutting-edge molecular methods such as DNA barcoding and chloroplast genome sequencing. This approach has allowed extremely accurate identification of species and unveiled evolutionary interrelations within its genus.

For instance, the taxonomic identification of Barleria lavaniana and resolution of the different morphotypes in Barleria cristata reflect how the integration of morphological observation and molecular analysis can help in species understanding (Patil et al. 2019; Tamboli et al. 2022). Yet, despite such advances, the boundary around the species of Barleria remains too little understood, particularly regarding species like B. cristata that are relatively highly morphologically diverse but show little genetic differentiation.

The current study highlights the medicinal significance of the Barleria species through the marked antioxidant, anticancer and antimicrobial potentials, hence supporting traditional claims associated with the efficacy of Barleria in medicinal activity. The high phenolic and flavonoid contents in the species are responsible for extraordinary

antioxidant activity and cytotoxicity studies suggest anticancer therapy. Besides these, the antibacterial and immunomodulatory activities of Barleria species, particularly B. lupulina, have established a scope of infection prevention and enhancement in the immune response. All these promising results offer a scope to further investigate the modern therapeutic practices of Barleria species (Morshed et al., 2024; Gangaram et al., 2023). Further detailed research, especially in the isolation of bioactive compounds and clinical studies, would validate and further solidify therapeutic applications for Barleria species, which would give them a future potential in meeting current health crises, such as oxidative stress, cancer, and antibiotic resistance.

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