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RESEARCH ARTICLE

The tribe Lychnideae A. Br., 1843 (Caryophyllaceae Juss., 1789) in the flora of Southern Siberia: opportunities and prospects for utilization*

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Abstract

This study investigates the biodiversity and biochemical potential of the tribe Lychnideae (Caryophyllaceae) within the unique and extreme environments of Southern Siberia. The research is motivated by the premise that the region's specific climatic stressors drive the synthesis of unique secondary metabolites, such as ecdysteroids and phenolic compounds, with prospective pharmacological applications. Through integrated field studies (2017-2023), herbarium specimen analysis, and a systematic literature review, we evaluated the species composition, distribution, and phytochemical profiles of the local Lychnideae flora. Applying a standardized resource assessment algorithm, we categorized the 44 documented species. Results indicate that 19 species (43.2%) possess significant bioprospecting potential, meriting further investigation for sustainable use via wild harvest or controlled cultivation. Concurrently, five species (11.4%) were identified as threatened, underscoring an urgent need for dedicated conservation measures. This work highlights the critical dual mandate in phytochemical research: the sustainable utilization of promising plant resources for drug discovery and the imperative conservation of biodiversity to ensure the resilience and continuity of these natural pharmacopeias.

Keywords: Lychnideae, Southern Siberia, biodiversity conservation, medicinal plants, secondary metabolites, ecdysteroids, flavonoids, sustainable use, phytochemistryharmacology, ecdysteroids, flavonoids, sustainable use

Introduction

The rapid advancement of pharmacology has intensified the search for new sources of biologically active compounds, with medicinal plants representing a critical frontier. Southern Siberia, characterized by its unique biodiversity and extreme climatic conditions, is a particularly promising region for phytochemical discovery. Local flora offers a diverse reservoir of compounds with potential anti-inflammatory, antioxidant, antimicrobial, and immunomodulatory properties, among others.

Plants that evolve under environmental stressors, such as sharp temperature fluctuations, water scarcity, and high solar radiation, often synthesize unique secondary metabolites as adaptive mechanisms (Yeshi et al. 2022). These specialized compounds frequently exhibit significant biological activity, making them valuable candidates for the development of natural therapeutics and preventive agents. Beyond its pharmacological potential, the study of such flora contributes essential data for the conservation of biodiversity and ecosystem management. Findings on plant distribution and bioactivity can inform evidence-based strategies for the sustainable use and conservation of plant populations, thus helping to preserve species diversity. Within this context, species of the tribe Lychnideae A. Br., 1843 (Caryophyllaceae Juss., 1789) have emerged as a notable focus. Their potential was initially identified during phytochemical screening of the Altai Mountain flora and has been substantiated in subsequent studies (Revina et al. 1988; Volodin et al. 2013). These results underscore the importance of further investigation into the Lychnideae tribe to systematically identify and characterize its biologically active compounds.of the priority tasks of modern science.

Materials and methods

Study Area and Rationale

Southern Siberia was selected as the study region due to its rich floristic diversity and pronounced ecological gradients. The defined area encompasses latitudes 49-57 °N and longitudes 65-120 °E, spanning approximately 850 km north-south and 4,000 km west-east. This vast territory includes a mosaic of ecosystems, from the southeast Siberian Plain to the mountainous regions of Altai, Khakassia, Tuva, and the western Sayan, providing a representative range of habitats for phytochemical investigation.

Taxon Focus

The research focuses on the Lychnideae tribe A. Br., 1843 (Caryophyllaceae Juss., 1789), a group noted for its significant biochemical potential in preliminary screenings (Revina et al. 1988; Volodin et al. 2013).

Field and Herbarium Studies

Field studies were conducted between 2017 and 2023 in key regions of Southern Siberia, including the southeastern West Siberian Plain, the Altai Mountains, Khakassia, Tuva, and the Western Sayan Mountains. These investigations aimed to determine species composition, distribution patterns, and ecological characteristics. Data were supplemented by examining herbarium specimens from the P.N. Krylov

Herbarium of Tomsk State University (TK) and the Herbarium of Moscow State University (MW).

Additionally, critical floristic literature was consulted to verify and complement field findings (Shishkin 1936; Kovtonyuk & Zuev 1993; Vlasova 2012; Ebel 2012).

Systematic Literature Review

A systematic review of the scientific literature was performed to collate and analyze data on key secondary metabolites within the Lychnideae tribe, including ecdysteroids, phenols, flavonoids, and their glycosides. Priority was given to recent screening studies and systematic reviews; where these were unavailable, data from focused phytochemical investigations were considered. The literature search utilized PubMed, Scopus, and Google Scholar databases and was restricted to publications from 2000 to 2024 to ensure contemporary relevance. Key references informing the analysis include Zibareva (2000, 2009). Ramazonov et al. (2007), Bajpai et al. (2008), Munkhzhargal et al. (2010), Smolyakova et al. (2010), Darmogray et al. (2015, 2017), Novozhilova et al. (2015), Plotnikov et al. (2017), Olennikov (2019), Kozhanova et al. (2020), Zibareva et al. (2022) and Smakosz et al. (2024).

Evaluation of Bioprospecting Potential

The potential of each species as a source of biologically active compounds was evaluated based on a set of practical and ecological criteria: habitat range, frequency of occurrence, population abundance, and the feasibility of introduction into cultivation. This assessment was structured using a standardized algorithm developed to evaluate the potential of plant resources (Revushkin et al. 2023).

Results

Taxonomic Composition of Lychnideae in Southern Siberia

The investigation identified 44 species from the Lychnideae tribe (Caryophyllaceae) within the Southern Siberian region, distributed in 10 genera: *Agrostemma* L. (1 species), *Coccyganthe* Rchb. (1), *Elisanthe* (Fenzl ex Endl.) Rchb. (4), *Gastrolychnis* (Fenzl) Rchb. (6), *Lychnis* L. (3), *Melandrium* Röhl. (2), *Oberna* Adans. (2), *Otites* Adans. (6), *Silene* L. (18), and *Steris* Adans. (1).

Conservation and Sustainable Use Assessment

Using the standardized algorithm (Revushkin et al. 2023), the species were categorized into four groups based on their potential for sustainable use and conservation priority.

Category I: Species with Documented Negative Agroeconomic Impact. No extant species within the tribe in Southern Siberia fall into this category. The historical agroeconomic impact of *Agrostemma githago* L., a former weed toxic due to the content of gipsogenin (Nadezhkin 2010), has been neutralized by modern agricultural practices.

Category II: Species with Demonstrated Bioprospecting Potential. This group comprises 19 species (43.2%) with documented ethnopharmacological use and/or preliminary phytochemical evidence supporting further investigation. They are subdivided by the recommended resource management pathway:

IIa: Species Suitable for Sustainable Wild Harvest. Twelve species (15.6% of the total), characterized by a sufficient population size and distribution, are candidates for regulated wild collection. These include the following: *Agrostemma githago*, *Coccyganthe flos-cuculi* (L.) Fourr., *Elisanthe noctiflora* (L.) Rupr., *Lychnis chalcedonica* L., *Melandrium album* (Mill.) Garcke, *M. dioicum* (L.) Coss. & Germ., *Oberna behen* (L.) Ikonn., *Silene amoena* L., *S. chlorantha* (Willd.) Ehrh., *S. graminifolia* Otth., *S. jenisseensis* Willd., and *S. nutans* L.

IIb: Species Recommended for Ex Situ Conservation and Cultivation. Seven species (15.6%), including several with restricted ranges, are prioritized for introduction into cultivation to reduce harvest pressure on wild populations. This group includes: *Elisanthe firma* (Siebold & Zucc.) Devyatov & V.N.Tikhom., *Otites parviflorus* (Ehrh.) Grossh., *O. wolgensis* (Hornem.) Grossh., *Silene armeria* L., *S. dichotoma* Ehrh., as well as the regionally threatened *E. viscosa* (L.) Rupr. and *S. sibirica* (L.) Pers. (listed in the Red Data Books of Tomsk Region, 2023, and Tyumen Region, 2020, respectively).

IIc: Species Requiring Biotechnological Approaches (e.g., Tissue Culture). No species were assigned to this category based on current propagation data. However, biotechnological methods remain a prospective research avenue to improve metabolite yield, particularly for species adapted to extreme environments (Thakur et al. 2019).

Category III: Species with Undetermined or Low Current Bioprospecting Potential. This group consists of 21 species (47.7%) for which phytochemical and pharmacological data are currently lacking or insufficient to assess practical application. This classification is not definitive and may be revised with future research. The group includes: *Elisanthe aprica* (Turcz.) Peschkova, *Gastrolychnis brachypetala* (Hornem.) Tolm. & Kozhanch., *G. gracilis* (Tolm.) Czerep., *G. saxatilis* (Turcz. ex Fisch. & C.A.Mey.) Peschkova, *G. uniflora* (Ledeb.) Tzvelev, *Lychnis sibirica* L., *Oberna procumbens* Murr., *Otites baschkirorum* (Janisch.) Holub, *O. exaltatus* (Friv.) Holub, *O. jenissensis* Klokov, *O. medius* (Litv.) Klokov, *Silene chamarensis* Turcz.,

S. fruticulosa Bieb., *S. intramongolica* Lazkov, *S. multiflora* (Ehrh.) Pers., *S. stylosa* Bunge, *S. turgida* Bieb. ex Bunge, *S. turczaninovii* Lazkov, *S. zuntoreica* Zuev, and *Steris viscaria* (L.) Raf.

Category IV: Species of High Conservation Priority (Threatened). Five species (11.4%) are identified as conservation priorities due to their threatened status and inclusion in regional Red Data Books, necessitating in situ protection measures: *Gastrolychnis popovii* Peschkova (Red Data Book of the Republic of Buryatia 2013), *G. tristis* (Bunge) Czerep. (Red Data Book of Altai Krai 2016; Red Data Book of Kuzbass, 2021), *Lychnis fulgens* Fischer (Red Data Book of the Transbaikal Territory 2016), *Silene altaica* Pers., and *S. incurvifolia* Kar. et Kir. (Red Data Book of Altai Krai 2016).

Conclusion

Investigation of the Lychnideae tribe (Caryophyllaceae) in Southern Siberia substantiates its considerable value as a reservoir of diverse biologically active compounds, particularly ecdysteroids, flavonoids, and phenolic derivatives. Through a comprehensive analysis of the composition, distribution, and ecological characteristics of the species, this study has systematically identified taxa with a high bioprospecting potential, categorizing them according to sustainable use pathways: direct utilization of stable wild populations, introduction into cultivation and, where applicable, biotechnological propagation.

A critical finding is the identification of several threatened species requiring urgent conservation measures, highlighting the intrinsic link between biodiversity preservation and sustainable development of phytochemical resources. The protection of these rare species is essential to maintain both regional biodiversity and potential genetic resources.

These results underscore the need for continued interdisciplinary research, focusing on detailed phytochemical profiling, pharmacological validation, and ecological study of prioritized species. Such efforts are fundamental in translating the inherent chemical diversity of the Lychnideae into novel, evidence-based natural products with targeted pharmacological activities, while concurrently informing strategies for the conservation and sustainable management of this important botanical resource.

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