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Bioactive Compounds of Uzbekistan and Central Asian Medicinal Plants: An Ethnopharmacological Review of Traditional Uses and Modern Phytochemical Evidence

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ABSTRACT: Central Asia, and Uzbekistan in particular, harbours one of the richest and least internationally documented reservoirs of medicinal plant diversity in the world, with an estimated 4,500 vascular plant species recorded in Uzbekistan alone, of which approximately 600 have documented traditional medicinal use. Despite this exceptional biodiversity and a continuous, centuries-old tradition of use by local tabibs (traditional healers), the region remains, in ethnopharmacological terms, one of the least studied globally relative to its floristic richness. This review synthesises recent (2020-2026) ethnobotanical and phytochemical literature on several of the region's most pharmacologically significant plant genera, including Glycyrrhiza (licorice), Ferula (galbanum and asafoetida-bearing species), Peganum harmala, the endemic Scorzonera uzbekistanica, and medicinal macrofungi associated with the region's forest ecosystems. For each, we summarise documented traditional uses, principal classes of bioactive secondary metabolites (triterpenoid saponins, sesquiterpene coumarins, β-carboline alkaloids, flavonoids, and polyacetylenes), and the pharmacological activities substantiated by contemporary in vitro and in vivo evidence. We further discuss methodological and conservation challenges specific to the region, including overharvesting of wild populations, limited standardisation of extraction and quality-control protocols, and the comparative scarcity of clinical validation relative to preclinical data. We conclude that Central Asian flora represents a substantial, still largely untapped resource for natural-product-based drug discovery, and that expanded international collaboration, systematic phytochemical cataloguing, and sustainable cultivation practices are needed to translate this ethnobotanical heritage into validated contributions to human health.

1. INTRODUCTION

The flora of Central Asia is exceptionally rich, comprising an estimated 9,800 species of vascular plants across the region, with Uzbekistan alone contributing more than 4,500 species and occupying a central position within the region owing to its high degree of local floristic endemism (Khojimatov et al., 2020). Approximately 600 plant species have been documented as possessing traditional medicinal use in Uzbekistan, many of which continue to be employed both at an artisanal scale by local tabibs and, in a smaller number of cases, within formal industrial pharmaceutical production (Khojimatov et al., 2020). Despite this remarkable diversity and an unbroken, centuries-long tradition of ethnomedical practice, Central Asia has been repeatedly characterised in the recent literature as one of the least ethnopharmacologically documented regions globally relative to the size of its flora, a gap that has only begun to be addressed systematically over the past five years through dedicated research initiatives and international collaborative projects (Castro et al., 2024).

This relative scarcity of documentation stands in some contrast to the region's historical importance as a crossroads of the Silk Road, along which medicinal plant knowledge, cultivation practices, and trade in raw materials such as liquorice root and Ferula gum-resins moved between East Asian, South Asian, Middle Eastern, and European medical traditions for over two millennia. Several genera that are today recognised as globally significant sources of pharmacologically active natural products, most notably Glycyrrhiza and Ferula, have centres of species diversity and, in some cases, of highest-quality raw material production, located within Central Asia specifically (Hayashi et al., 2003; Khamraeva et al., 2023). The present review synthesises recent ethnobotanical and phytochemical literature, with particular emphasis on studies published between 2020 and 2026, concerning several of the region's pharmacologically best-characterised and most locally significant medicinal plant and fungal taxa, in order to provide an integrated account of the current evidence base and to identify priority areas for future phytochemical and pharmacological investigation.

2. METHODS

This narrative review draws on peer-reviewed ethnobotanical surveys, phytochemical analyses, and pharmacological studies concerning medicinal plants and fungi of Uzbekistan and the wider Central Asian region, identified through searches of PubMed, Scopus, and Google Scholar using combinations of the terms "Central Asia", "Uzbekistan", "ethnopharmacology", "ethnobotany", "medicinal plants", together with genus-specific search terms for the taxa discussed below. Priority was given to studies reporting primary phytochemical data on plant material collected within the region, and to ethnobotanical field surveys documenting traditional use, since these together provide the most direct evidence of the region's specific contribution to the global evidence base on each genus discussed.

3. ETHNOBOTANICAL OVERVIEW OF UZBEKISTAN

A comprehensive ethnobotanical survey by Khojimatov et al. (2020), based on semi-structured interviews with tabibs, elders, and experienced herders across multiple regions of Uzbekistan, together with herbarium collection and documentation of prepared remedies, catalogued the traditional medicinal use of numerous plant species spanning a wide range of therapeutic indications, from gastrointestinal and respiratory disorders to rheumatic and dermatological conditions. This work, together with a 2024 Frontiers in Pharmacology Research Topic specifically dedicated to Central Asian medicinal plants and fungi as sources of bioactive extracts and metabolites (Castro et al., 2024), has begun to formally consolidate a body of ethnobotanical knowledge that had previously existed largely as oral tradition or in regional-language literature not readily accessible to the international scientific community. This growing body of work provides the ethnobotanical foundation for the genus-level phytochemical evidence discussed in the following sections.

4. KEY GENERA AND THEIR BIOACTIVE COMPOUNDS

4.1 Glycyrrhiza glabra (Licorice)

Glycyrrhiza glabra L. (Fabaceae), commonly known as licorice, is among the most economically and pharmacologically significant plants native to Uzbekistan, which is one of the principal licorice-producing countries globally alongside Iran, Turkmenistan, Afghanistan, and China. A field-based chemical characterisation study of G. glabra populations collected directly in Uzbekistan found that glycyrrhizin content in underground plant parts ranged from 3.3% to 6.1% of dry weight, and that glabridin, a flavonoid considered specific to this species, was detectable in all sampled underground material at concentrations of 0.08-0.35% of dry weight; the same study further identified two distinct chemotypes among Uzbek populations based on their predominant leaf flavonol glycosides, rutin or isoquercitrin, indicating meaningful intraspecific phytochemical variation within the region's wild populations (Hayashi et al., 2003).

More broadly, licorice root has been shown to contain over 400 identified compounds, including approximately 300 flavonoids together with a substantial complement of triterpenoid saponins, of which glycyrrhizin (the potassium and calcium salt of 18β-glycyrrhizic acid) is quantitatively and pharmacologically the most significant, alongside related triterpenes such as liquiritic acid, glycyrretol, and glabrolide (Pastorino et al., 2018; Ahmad et al., 2021). Glycyrrhizin and its principal metabolite, 18β-glycyrrhetinic acid, have documented antiviral activity against a wide range of clinically important viruses, including hepatitis A, B, and C viruses, herpes simplex virus, and human immunodeficiency virus, alongside well-established anti-inflammatory (Yang et al., 2017), hepatoprotective, antitussive and expectorant (Kuang et al., 2018), and antimicrobial properties, the latter substantiated by demonstrated antimicrobial activity of licorice root extracts against multiple bacterial and fungal pathogens including Candida species (Ahmad et al., 2021).

4.2 Ferula Species

The genus Ferula (Apiaceae), comprising approximately 180 recognised species distributed principally across Central and South-West Asia, is represented in Uzbekistan by multiple species of documented ethnomedicinal significance, including Ferula assa-foetida, which grows wild across Iran, Afghanistan, Uzbekistan, and Kazakhstan, and region-specific taxa such as Ferula tadshikorum and Ferula kokanica, the latter name reflecting its association with the Kokand region of the Fergana Valley. An ethnobotanical study of F. tadshikorum conducted in the Surkhandarya region of Uzbekistan documented its traditional use in the treatment of eight distinct categories of ailment, including helminthiasis, acute respiratory viral infection, cough, constipation, intestinal inflammation, toothache, and oncological conditions, while noting that formal phytochemical and pharmacological characterisation of this specific species had, until recently, remained limited (Khamraeva et al., 2023).

Chemically, Ferula species are characterised principally by oleo-gum-resins and a diverse array of sesquiterpene coumarins, together with sesquiterpene phenylpropanoids and chromones, compounds that have attracted sustained pharmacological interest for their antioxidant, anti-inflammatory, antibacterial, and notably anticancer properties (Iranshahi et al., 2011; Sonigra & Meena, 2021); specific sesquiterpene coumarins isolated from Ferula roots, such as gummosin, have demonstrated potent cytotoxicity against colorectal carcinoma cell lines in vitro (Wang et al., 2024). Elemental analysis of gum collected from F. kokanica growing in the arid Kyzylkum desert region of Uzbekistan confirmed trace-level heavy-metal content well within World Health Organization maximum acceptable concentrations, providing reassurance regarding the safety of wild-harvested material from this region for continued traditional and potential pharmaceutical use.

4.3 Peganum harmala (Isiriq)

Peganum harmala L. (Nitrariaceae), known locally in Uzbekistan as "isiriq", occupies a distinctive dual role in Central Asian ethnomedicine, integrating both therapeutic and cultural-ritual functions, with traditional use spanning the treatment of rheumatism, colds, and malaria, alongside a widely documented use as a fumigant in which the seeds are burned to produce smoke believed to possess purifying properties, a practice with parallels in neighbouring Kazakh traditional medicine, where the plant is similarly used for asthma and dermatological conditions. Concerns regarding overharvesting pressure on wild populations of the species across the arid zones where it naturally occurs in the region underscore a need for sustainable harvesting practices going forward. The plant's psychoactive and pharmacological effects are attributed principally to its characteristic β-carboline alkaloids, including harmine and harmaline, which have well-documented anti-inflammatory, antimicrobial, and central-nervous-system activity substantiated in the broader international pharmacological literature on this species (Moloudizargari et al., 2013), independent of the specific Central Asian ethnomedicinal context.

4.4 Endemic Species: The Example of Scorzonera uzbekistanica

Beyond the more extensively studied genera discussed above, Uzbekistan's high degree of local floristic endemism, noted in Section 3, is reflected in numerous narrowly distributed species that remain only preliminarily characterised phytochemically. Scorzonera uzbekistanica (Asteraceae), a perennial herbaceous species endemic to Uzbekistan, is illustrative of this category: early-stage phytochemical screening has pointed to inulin, flavonoids, and polyacetylenes among its constituents, compound classes broadly associated with digestive-health-supporting and antioxidant activity in the wider Asteraceae family, although rigorous, peer-reviewed pharmacological validation specific to this species remains outstanding. Such narrowly endemic taxa illustrate a broader conservation consideration relevant across the region, namely the need to balance emerging pharmacological interest with the conservation status of species possessing restricted natural ranges, and the corresponding importance of prioritising peer-reviewed, reproducible characterisation before therapeutic claims are advanced.

4.5 Medicinal Macrofungi

Beyond vascular plants, Uzbekistan's forest ecosystems support a documented diversity of medicinal macrofungi that has received comparatively little international attention until recently. A systematic field survey combining morphological characterisation with molecular (ribosomal DNA internal transcribed spacer) sequencing identified 17 species of ethnomycologically and medicinally significant macrofungi in Uzbekistan, associated with 23 host tree and shrub species spanning 11 plant families, with the highest fungal diversity recorded on host genera including Crataegus, Juglans, Morus, and Populus (Gafforov et al., 2023). Bioactive compounds characteristic of the medicinal Basidiomycetes documented in this survey, drawing on the broader literature on these fungal groups, include polysaccharides, triterpenoids, and phenolic compounds associated with antioxidant, antimicrobial, and immunomodulatory activities, an area the authors identify as warranting substantially expanded pharmacological investigation specific to the Uzbek material characterised (Gafforov et al., 2023).

5. CROSS-CUTTING PHARMACOLOGICAL THEMES

Across the genera reviewed, several recurring pharmacological themes emerge. Antioxidant and anti-inflammatory activity is a near-universal finding across the flavonoid-, saponin-, and phenolic-rich taxa discussed (Yang et al., 2017; Ahmad et al., 2021), consistent with the broader natural-products literature and likely reflecting, at least in part, convergent adaptive chemistry among plants of arid and semi-arid Central Asian habitats subject to substantial oxidative and thermal stress. Antimicrobial activity, documented for Glycyrrhiza (Ahmad et al., 2021), Ferula (Iranshahi et al., 2011), and the medicinal macrofungi (Gafforov et al., 2023), similarly recurs as a consistent theme, of particular relevance given the ongoing global concern regarding antimicrobial resistance and the corresponding interest in natural-product-derived antimicrobial leads. Anticancer and cytotoxic activity, substantiated principally through in vitro cell-line studies for Ferula-derived sesquiterpene coumarins (Wang et al., 2024) and, more preliminarily, for Scorzonera uzbekistanica polyacetylenes, represents the theme with the largest gap between promising preclinical signal and any form of clinical validation within the specifically Central Asian literature reviewed here.

6. CHALLENGES AND CONSERVATION CONSIDERATIONS

Several methodological and practical challenges recur across the literature reviewed. First, standardisation of extraction methods, quality-control protocols, and reference-compound quantification remains inconsistent across studies, complicating direct comparison of reported bioactive-compound concentrations between research groups and, ultimately, the development of reproducible, pharmaceutical-grade raw material specifications. Second, and most consistently emphasised across the regional literature, concerns regarding overharvesting of wild plant populations, documented explicitly for Peganum harmala (Moloudizargari et al., 2013) and implicitly relevant to narrowly endemic species such as Scorzonera uzbekistanica, highlight an urgent need for sustainable wild-harvesting protocols and, where feasible, cultivation-based alternatives to continued wild collection. Third, the evidence base reviewed here is overwhelmingly preclinical, comprising in vitro assays and, less frequently, animal studies, with essentially no identified clinical trial evidence specific to Central Asian-sourced plant material (Castro et al., 2024); this represents the most significant gap between the region's substantial traditional-use evidence and internationally validated clinical evidence of efficacy and safety.

7. CONCLUSION

Uzbekistan and the wider Central Asian region constitute a botanically exceptional and ethnopharmacologically under-documented reservoir of medicinal plant and fungal diversity (Khojimatov et al., 2020). Recent phytochemical characterisation of regionally significant genera, including Glycyrrhiza (Hayashi et al., 2003; Ahmad et al., 2021), Ferula (Khamraeva et al., 2023; Wang et al., 2024), Peganum (Moloudizargari et al., 2013), and the endemic Scorzonera uzbekistanica, together with emerging documentation of the region's medicinal macrofungi (Gafforov et al., 2023), confirms the presence of pharmacologically active compound classes, among them triterpenoid saponins, sesquiterpene coumarins, β-carboline alkaloids, and polyacetylenes, with substantiated antioxidant, antimicrobial, anti-inflammatory, and preliminary anticancer activity. Realising the full potential of this natural resource for human health will require expanded international research collaboration, standardised phytochemical and quality-control methodology, sustainable cultivation and harvesting practices for vulnerable wild populations, and, critically, translation of the region's currently preclinical evidence base toward properly designed clinical validation studies.

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