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MORPHOLOGICAL AND ECOLOGICAL CHARACTERISTICS OF REPRESENTATIVES OF THE LAMIACEAE FAMILY IN CENTRAL ASIA

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Abstract

The family Lamiaceae (Labiatae) represents one of the largest groups of dicotyledonous flowering plants, comprising, according to modern estimates, about 7,000 species in more than 230 genera, with centers of diversity in the Mediterranean region, the Irano-Turanian province, and several arid regions of Eurasia. The family is characterized by a stable set of morphological traits-quadrangular stem, opposite leaves, bilabiate zygomorphic corolla, and schizocarp fruit dividing into four nutlets-as well as high essential oil content and pronounced ecological plasticity.This article provides an extended morphological and anatomical characterization of Lamiaceae representatives and analyzes their adaptive traits and morphometric variability (including seed productivity) based on examples from Central Asia, particularly Uzbekistan. Issues related to the conservation of rare and endemic taxa of the family are also discussed.

Keywords

Lamiaceae, Labiatae, flower morphology, Lagochilus, Dracocephalum, Salvia korolkowii, Central Asia, Uzbekistan, adaptation.

INTRODUCTION

The family **Lamiaceae** (synonym *Labiatae*), or the mint family, has long been regarded as one of the most morphologically well-defined groups of dicotyledonous plants. Classical sources on higher botany and angiosperm systematics emphasize a set of consistent diagnostic traits: in most species, the stem is square (quadrangular) in cross-section; the leaves are opposite (less commonly whorled), and stipules are generally absent; the surface of the leaves and young shoots often bears essential-oil glands or hairs, which impart the characteristic aroma of the plants; the flower is zygomorphic, typically with a bilabiate corolla; the fruit is a dry schizocarp breaking into four small nutlet-like segments. These features are consistently reproduced in botanical literature and widely used in diagnostic keys, as they allow reliable identification of Lamiaceae under field conditions [1].

Current estimates of the family's diversity indicate approximately 7,000 species and more than 230 genera. Centers of species richness are particularly pronounced in the Mediterranean region and the Irano-Turanian floristic province, i.e., the arid and semi-arid zones of Western and Central Asia. Central Asia-including Uzbekistan, Tajikistan, southern Kazakhstan, and adjacent territories of Afghanistan-is not merely a peripheral extension of the Mediterranean flora; on the contrary, it represents one of the key hotspots of endemism and evolutionary differentiation within the mint family. This is confirmed by the presence of genera such as *Lagochilus* Bunge and *Dracocephalum* L., which are widely distributed on rocky slopes and foothills of the region, as well as by the occurrence of narrowly distributed *Salvia* species, such as *Salvia korolkowii*, considered to be threatened with extinction [3,4].

The flora of Uzbekistan and neighboring areas is rich in essential-oil-bearing and medicinal members of Lamiaceae, which historically led to their use in traditional medicine, particularly as antispasmodic, sedative, astringent, and anti-inflammatory agents. *Lagochilus inebrians*-traditionally collected on dry rocky slopes of Samarkand and Bukhara regions-serves as a prominent example of a pharmacologically important subshrub. Recent floristic discoveries, such as *Dracocephalum baldshuanicum*, reliably recorded for the first time in southern Uzbekistan (Babatag Range, Surkhandarya Region), indicate that the Lamiaceae flora of the region remains incompletely studied, and the actual distribution limits of some species continue to be revised [3].

The purpose of the present study is to provide an integrated characterization of the Lamiaceae family from morphological-anatomical and ecological-adaptive perspectives, emphasizing species of particular significance in Central Asia. To achieve this goal, the following research objectives are set: to describe key vegetative and generative characteristics of Lamiaceae in light of contemporary literature; to examine morphometric variability and seed productivity in selected species; and to analyze examples of local, endemic, and protected taxa of Uzbekistan, highlighting their relevance in a conservation context.

LITERATURE REVIEW

Historically, the mint family (Lamiaceae) has been described primarily from the standpoint of classical morphology. Encyclopedic sources and university-level botany courses emphasized the combination of traits that clearly distinguish Lamiaceae from other families: a quadrangular stem, opposite leaf arrangement, absence of stipules, essential-oil glands on leaves and stems, a zygomorphic bilabiate corolla, and a dry fruit splitting into four nutlets. This morphological

"matrix" is considered so stable that it gave rise to the common Russian name *"gubotsvetnye"* (referring to the bilabiate corolla).

Since the late 20th and early 21st centuries, research focus on Lamiaceae has shifted in new directions.

The first direction is biogeography and endemism. Central Asia (including Uzbekistan) is increasingly viewed not as a peripheral extension of Mediterranean taxa but as one of the key zones of diversity for the family. Reports of species newly recorded for the flora of Uzbekistan-for example, *Dracocephalum baldshuanicum*-indicate that some members of the family previously believed to be restricted to Tajikistan or Afghanistan actually form stable populations within Uzbekistan, particularly on the slopes of the Babatag Range at elevations of approximately 900–1300 m [3]. These findings reveal previously undocumented migration pathways and distributional bridges among the mountain systems of the Pamirs, Alai, and southern Tien Shan.

The second direction concerns the conservation of rare and narrow-range species. Several species of *Lagochilus* in Uzbekistan are regarded as endemic or quasi-endemic and face high conservation risk due to their restricted ranges and anthropogenic pressures. *Lagochilus inebrians*, which grows on dry gravelly and rocky foothill slopes of Samarkand and Bukhara regions, is subject to harvesting for use in traditional medicinal practices. *Salvia korolkowii*, considered a species of high conservation priority, is characterized by its extremely narrow distribution and habitat vulnerability [4]. This research direction links classical morphology with real-world biodiversity conservation challenges.

The third direction is morphometrics and molecular phylogeny. Modern studies extend far beyond descriptions of external morphology. Quantitative analyses of trait variability (stem length, leaf blade size, inflorescence density, seed productivity) are conducted under different cultivation or introduction conditions. For example, a comparative study of *Hyssopus officinalis* L. and *Nepeta pannonica* L. found that coefficients of variation (CV) for several morphological and reproductive traits can reach 25–40%, indicating high plasticity even within a single species [2]. Parallel to this, genetic research has intensified: complete chloroplast genomes have been sequenced for some Uzbek representatives of *Lagochilus*, followed by comparative analyses that clarify the phylogenetic placement of species, reconstruct their evolutionary history, and substantiate the need for in situ conservation.

Thus, contemporary literature views the Lamiaceae family not merely as a "classical model of bilabiate flowers and quadrangular stems," but as a dynamic system in which speciation continues, adaptation to arid niches of Central Asia

progresses, narrow-range endemics emerge, and vulnerability traits accumulate-necessitating targeted conservation measures [3,4].

MATERIALS AND METHODS

The present study has a review-analytical character. The materials for analysis included academic sources on the systematics of flowering plants, university-level courses in higher botany, as well as peer-reviewed scientific studies devoted to the morphology, morphometry, ecology, and phylogeography of Lamiaceae representatives in Central Asia. Particular attention was paid to publications documenting the flora of Uzbekistan and adjacent territories, including descriptions of *Lagochilus inebrians*, recent records of *Dracocephalum baldshuanicum* on the Babatag Range in Surkhandarya Region, and assessments of the conservation status of species such as *Salvia korolkowii* and several narrowly distributed species of *Lagochilus*.

The method consisted of comparing classical morphological characteristics of the family (structure of stems, leaves, generative organs, and fruit type) with modern data on the variability of quantitative traits (morphometric parameters of shoots, leaves, and inflorescences, as well as seed productivity) and with ecological parameters of local populations (substrate type, altitudinal range, and habitat features). The systematization of results is presented in the form of comparative tables summarizing both the "standard" traits of the family and regionally significant adaptations.

RESULTS

From the standpoint of vegetative morphology, representatives of Lamiaceae are characterized by stems that most commonly have a quadrangular cross-section. In many species, the lower portion of the shoot becomes partially woody, which is particularly evident in subshrubs and dwarf shrubs of arid regions. This structural feature increases the plant's stability under conditions of moisture deficit and wind erosion on rocky slopes. Leaves are predominantly opposite, often entire or lobed, and lack stipules. Essential-oil glands and pubescence develop on the leaf blade surface and on young stems. These structures are responsible for the pronounced aroma of many members of the family and for their high pharmacological significance in traditional medicine of Central Asia. Such traits are strongly expressed in the genera *Phlomis*, *Lagochilus*, and *Hyssopus* [1].

The generative characteristics of the family are likewise highly conservative. In most species, the flower is bilaterally symmetrical (zygomorphic), with a bilabiate corolla: the upper lip is usually formed by two fused lobes and functions as a protective "hood" covering the stamens and stigma, while the lower lip is three-lobed and serves as a landing platform for pollinators. The calyx is typically five-

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toothed and fused. The androecium consists of two or four stamens, often directed forward and adapted for entomophilous (insect-mediated) pollen transfer. The gynoecium is cenocarpous, formed by two carpels, but at maturity the superior ovary divides into four chambers, and the fruit splits into four nutlet-like segments. This dry schizocarpic fruit is one of the key taxonomic characteristics of the family [1].

Trait	Characteristic
Stem	Usually quadrangular; the lower part may become partially woody; shoots erect or slightly ascending
Leaves	Opposite, rarely whorled; usually without stipules; entire or lobed; often with essential-oil glands
Corolla	Zygomorphic, bilabiate; the upper lip (2 lobes) protects the reproductive organs; the lower lip (3 lobes) serves as a landing platform for pollinators
Androecium	2 or 4 stamens, oriented toward the lower lip of the corolla for entomophilous pollination
Fruit	Superior ovary; a dry schizocarp dividing into four small nutlets
Essential-oil glands and aroma	Present on leaves and young shoots; determine pharmacological and ethnobotanical value

Table 1. Typical morphological and reproductive characteristics of the Lamiaceae family (summary of literature data)

Morphometric data confirm that even under favorable conditions, Lamiaceae exhibit considerable intra-specific and inter-population variability in quantitative traits. In particular, studies of *Hyssopus officinalis* L. and *Nepeta pannonica* L. conducted on medicinal plant collections have shown that the coefficients of variation (CV) for traits such as shoot length, leaf blade size, inflorescence density, and seed productivity may reach 25–40%.

Species	Range of coefficient of variation (CV) for vegetative traits (shoot length, leaf)	Range of CV for generative traits (inflorescence, seed productivity)	Comment
Hyssopus officinalis L.	~15–30%	~15–25%	Stable seed productivity with moderate morphological variability
Nepeta pannonica L.	~25–40%	~25–40%	Higher variability associated with conditions of introduction and environment

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Table 2. Ranges of morphometric variability in representatives of Lamiaceae (based on data for *Hyssopus officinalis* L. and *Nepeta pannonica* L.)

These data are important for understanding how representatives of the family adapt to arid and rocky biotopes of Central Asia. High variability values indicate the ability of plants to modify shoot biomass and generative structure parameters in response to stress without fully losing their reproductive potential.

Regionally significant taxa demonstrate these adaptations through concrete examples.

Lagochilus inebrians Bunge is a low-growing perennial subshrub with numerous shoot bases that become partially woody near the root. It is characteristic of dry, stony, and gravelly foothill slopes of the Samarkand, Bukhara, and neighboring regions and is traditionally harvested as raw material in folk medicine. The plant bears opposite leaves, often lobed, with dense glandular trichomes, and forms inflorescences with pale, sometimes pinkish-white bilabiate flowers partially protected by a rigid, sometimes spiny calyx. Such morphology indicates xerophytic adaptations: compact growth form, basal shoot lignification, reduced evaporative surface, and mechanical protection of generative organs [4].

Dracocephalum baldshuanicum (A.L. Budantzev) was recently reliably recorded for the flora of southern Uzbekistan (Babatag Range, Surkhandarya Region) at elevations of approximately 900–1300 m above sea level. This species is characterized by a compact growth habit pressed close to the substrate surface and inflorescences composed of intensely colored blue-violet bilabiate flowers with a tubular corolla. This floral architecture suggests entomophilous pollination with a strongly directed access pathway for the pollinator toward the anthers and stigma. From a biogeographical standpoint, the appearance of *D. baldshuanicum* in Uzbekistan revises previous assumptions about the boundaries of its distribution range and highlights the importance of the southern Uzbek foothills as zones of endemism.

Salvia korolkowii Regel & Schmalh. is regarded as a narrow-range species with a high risk of extinction. It is characterized by aromatic leaves, a distinctly bilabiate corolla typical of *Salvia*, and adaptation to dry, eroded slopes of semi-desert landscapes. This species is listed among conservation priorities in Uzbekistan, demonstrating that the Lamiaceae family holds not only botanical interest but also significant conservation value within the national flora.

Species	Distribution in Uzbekistan	Habitat and Elevation	Characteristic Morphological Features	Conservation Status and Importance
Lagochilus	Samarkand,	Dry	Low-growing	Medicinal

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Species	Distribution in Uzbekistan	Habitat and Elevation	Characteristic Morphological Features	Conservation Status and Importance
inebrians Bunge	Bukhara, and adjacent regions; also southwestern Tajikistan and Turkmenistan	foothill slopes; stony and gravel substrates; 200–800 m	perennial subshrub; opposite, dissected leaves with essential-oil glands; pale pinkish bilabiate flowers; rigid calyx	and ethnobotanical value; vulnerable due to harvesting pressure
Dracocephalum baldshuanicum A.L. Budantzev	Southern Uzbekistan (Surkhandarya Region, Babatag Range); newly confirmed record	Rocky and gravelly slopes; 900–1300 m	Compact growth form; bright blue-violet bilabiate flowers with tubular corolla; entomophilous pollination	Local, potentially vulnerable endemic; important for floristic inventories and conservation
Salvia korolkowii Regel & Schmalh.	Southern and southwestern Uzbekistan; semi-desert and foothill areas with eroded slopes	Semi-desert and dry foothill slopes	Aromatic leaves; bilabiate *Salvia*-type corolla; adaptations to arid environments	Narrow-range, threatened species; conservation priority

Table 3. Selected representatives of Lamiaceae in Central Asia (Uzbekistan): distribution, ecology, morphology, and conservation status

DISCUSSION

The obtained data allow several important conclusions to be drawn regarding the biology of the Lamiaceae family and its significance in Central Asia.

First, the conservative complex of morphological traits (quadrangular stem, opposite leaves, bilabiate corolla, and a schizocarp splitting into four nutlets) is not only useful for systematics but is also functionally linked to adaptation to arid conditions. The quadrangular stem and partial lignification of shoots in semi-desert and dry foothill species contribute to the plant's mechanical stability and longevity under moisture deficit and strong winds. This is clearly observed in *Lagochilus inebrians*, which forms dense, low-growing cushions resistant to desiccating climates and grazing pressure [4].

Second, the bilabiate zygomorphic flower of Lamiaceae represents a highly specialized structure adapted for entomophilous pollination. The lower lip of the corolla serves as a landing platform for pollinators, directing them toward the anthers and stigma, which are protected by the upper lip. This floral architecture is consistently found across members of the family in various ecosystems, including montane and foothill environments where pollinator activity may be seasonally

limited. *Dracocephalum baldshuanicum*, recorded at elevations of 900–1300 m in Surkhandarya Region, clearly demonstrates this flower type adapted to specific pollinators. This indicates that even in harsh conditions of southern Uzbekistan-dry rocky slopes, high solar radiation, and shallow soils-members of the family maintain an effective pollination and seed reproduction strategy.

Third, the morphometric plasticity revealed, for example, in *Hyssopus officinalis* and *Nepeta pannonica*, highlights the evolutionary success of Lamiaceae. Quantitative variability in shoot biomass, leaf parameters, inflorescence density, and seed productivity enables species to sustain their life cycle even when introduced into new environments or when growing on stressful substrates. High coefficients of variation (up to 40%) indicate that species of the family can flexibly adjust their morphology and reproductive strategy without losing their capacity for seed regeneration [2]. This is especially important in the arid ecosystems of Central Asia, where seasonal fluctuations in moisture and temperature are extreme.

Finally, the results emphasize the increasing importance of conserving endemic and rare Lamiaceae species in Central Asia. *Salvia korolkowii* and several *Lagochilus* species are regarded as taxa with high conservation priority. They possess extremely localized distributions and are exposed to anthropogenic pressures such as grazing, harvesting for medicinal raw materials, and habitat degradation. *Dracocephalum baldshuanicum*, recently recorded in Uzbekistan, is also potentially vulnerable because its known populations occupy a limited area of the Babatag Range. From a botanical perspective, this means that Lamiaceae in the region represent not only academic interest but also strategic value for national and regional biodiversity conservation programs.

CONCLUSION

Summarizing the analysis, it can be concluded that the Lamiaceae family combines morphological conservatism of key traits with high ecological plasticity. The quadrangular stem, opposite leaves, bilabiate corolla, and a schizocarp dividing into four nutlets constitute a stable diagnostic complex confirmed both by classical sources and by modern regional studies. At the same time, morphometric variability of individual traits-such as shoot length, leaf size, inflorescence density, and seed productivity-reaches values that reflect the adaptive potential of the family to the extreme conditions of Central Asia [1].

Examples from the flora of Uzbekistan-*Lagochilus inebrians*, *Dracocephalum baldshuanicum*, and *Salvia korolkowii*-demonstrate that Lamiaceae is not an abstract taxonomic unit, but a group represented by concrete, often endemic species that possess both pharmacological and ethnobotanical value, as well as critical conservation status. Studying such species requires an integrated approach that

includes not only traditional morphology, but also morphometry, population ecology, genetic and genomic methods (including chloroplast genome analysis), and monitoring of habitat conditions. Under increasing anthropogenic pressure on natural ecosystems in Central Asia and ongoing climate change, integrating botanical, ecological-genetic, and conservation approaches to the study of Lamiaceae becomes not merely a scientific objective but a practical necessity.

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