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WETLAND VEGETATION OF AZERBAIJAN

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Abstract. *Wetland ecosystems play a crucial role in biodiversity conservation, maintaining hydrological balance, and providing essential ecosystem services. This study investigates the distribution, floristic composition, and ecological characteristics of wetland vegetation in Azerbaijan, based on scientific principles. Wetland phytocenoses have been recorded across various regions with diverse hydrological and edaphic conditions, including the Kura-Araz lowland, Caspian Sea coastal zones (Samur-Shabran and Lankaran lowlands), Absheron Peninsula, Greater and Lesser Caucasus Mountains, Talysh Mountains, Nakhchivan Autonomous Republic, Sumgaitchay Basin, Neftchala District, Gizilagach Bay, and Lake Vaykhyr. The study identifies Phragmiteta, Junceta, and Typheta phytocenoses as the dominant vegetation formations in Azerbaijan's wetland ecosystems. Wetland plants are highly sensitive to ecological changes, undergoing significant structural and compositional alterations in response to hydrological regime changes, nutrient enrichment, sediment accumulation, and pollutants. These shifts directly affect water chemistry, soil properties, and trophic interactions within ecosystems. The findings confirm that wetland plants serve as reliable bioindicators of ecosystem health. However, oil pollution, soil erosion, and anthropogenic alterations to land and water regimes have caused the degradation of some wetland ecosystems. To mitigate these threats and ensure resilience, the implementation of phytoremediation and ecological restoration measures is strongly recommended. This research provides essential scientific and practical foundations for the monitoring and conservation of Azerbaijan's wetland ecosystems.*

Keywords: *wetland ecosystems, phytosociology, bioindicators, ecological restoration, anthropogenic impacts, Azerbaijan.*

Introduction

Wetlands play a crucial role in maintaining the ecological balance of our planet by providing essential ecosystem services, such as hydrological regulation, water retention, pollution filtration, biodiversity conservation, and carbon sequestration. They are also essential in mitigating the effects of climate change and promoting ecological resilience.

Within the context of COP29, the protection and restoration of wetland ecosystems have been identified as key components of global climate strategies. Wetlands are essential for absorbing greenhouse gases and regulating the water cycle, making them vital in the fight against climate change.

In Azerbaijan, wetland ecosystems can be found in various regions, such as the Kura-Aras Lowland, Caspian Sea coastal zone, Samur-Shabran and Lankaran lowlands, Absheron Peninsula, Greater and Lesser Caucasus Mountains, Talysh Mountains, Nakhchivan Autonomous Republic, Sumgayit Basin, Neftchala District, Gizilagaj Bay, and Vaykhyr Lake. These ecosystems have developed due to specific climate, hydrology, and soil conditions, resulting in a unique plant community. Some of the dominant plant communities in these wetlands include Phragmitetum, Juncetum, and Typhetum, which are sensitive to environmental changes and can serve as indicators for the health of the wetland ecosystem.

However, these ecosystems are facing increasing threats from urbanization, industrial and household waste pollution, agriculture, land reclamation, oil spills, and the wider effects of climate change. This has led to wetland areas shrinking, changes in plant cover, and declines in certain species' populations. To monitor these changes and devise effective conservation strategies, it is crucial to use plant-based bioindicator methods.

At the international level, efforts to conserve wetlands are supported by various frameworks, including the Ramsar Convention (1971), the United Nations Framework Convention on Climate Change (UNFCCC), the Convention on Biological Diversity (CBD), and the European Landscape Convention. Azerbaijan has committed to these international agreements and is implementing strategies to protect its wetland ecosystems and manage them sustainably.

As COP29 focuses on enhancing ecosystem resilience to climate change, the restoration of wetlands and biodiversity conservation have been recognized as key priorities on the global environmental agenda.

The primary goal of this research is to analyze the floral composition and ecological features of wetland vegetation in Azerbaijan, as well as to assess their role as biological indicators in evaluating the health of ecosystems. The results of this study will help to improve ecological monitoring systems and advance biodiversity conservation efforts, ensuring the sustainable management of wetlands. Furthermore, the findings of this research will provide a scientific basis for Azerbaijan's compliance with its international environmental obligations and the development of climate policies in line with the COP29 strategy to combat climate change.

Materials and Methods

This study investigates the wetland vegetation of Azerbaijan. The research areas encompass the Kur-Araz plain, Samur-Shabran, and Lankaran plains. The main objective of the study is to analyze the morphological characteristics, life forms, ecological groups, and floristic structures of plant species in these regions. Floristic-geobotanical observations, herbarium materials, and modern geobotanical methods were used in the study (Qurbanov, 2024;

Qurbanov & Cabbarov, 2017).

Wetland vegetation includes areas with excessive moisture. The distribution of wetlands depends on climate, topography, and the ecological parameters of the soil. Y.D. Sinzerling (1938) divided wetland landscape vegetation into permanently excessively moist and slightly moist peatlands, noting that the moisture levels of both variants change according to the season of the year.

In the classification and analysis of plant species, special attention was paid to the life forms and ecological groups defined by Serebyakov (1962) and Raunkier (1934). The analysis of ecological groups was carried out using the approaches proposed by Shennikov (1964). The type, class, and groups of the area were determined based on Grossheim (1936), and the issue of endemism was analyzed by Asgarov (2016). A. I. Ilinski, V.V. Alyoxin, and others classified wetland vegetation as types or "pan-formations," while V.N. Sukachev and Y.N. Kas referred to wetlands as landscape types.

The floristic diversity was assessed using Drude's (1890) 5-point scale. In the classification of vegetation, ecological-phenomenological and dominance principles were primarily considered. In accordance with the study's objectives, the composition, structure, and number of species, as well as the dominant and edifying species, were determined. Additionally, the floristic-geobotanical indicators of the areas were evaluated.

Plant specimens were collected based on field observations. Herbarium materials were collected and analyzed using relevant literature (Qurbanov, 2009; Asgarov, 2016). The analysis of specimens involved key sources such as WFO, POWO, and APG4. For mapping and geographic data analysis, GIS software was used. With this software, geographic data of the study areas were collected, and the floristic structure of the region was visualized. GIS technologies were employed to create analytical maps of the plant cover in the area, including the maps titled "Vegetation map of Azerbaijan" (scale 1:600 000) and "Botanical-geographical regions of Azerbaijan" (scale 1:200 000) (Qurbanov, 2023; Qurbanov, 2018) (Figure 1; 2).



Figure 1. Vegetation map of Azerbaijan (scale 1:600 000)



Figure 2. Botanical-geographical regions of Azerbaijan" (scale 1:200 000)

Results and Discussion

In the modern classification of wetland vegetation that spreads in the natural flora of Azerbaijan, the following formation classes are listed (Table 1).

Coastal Cane Mixed Grain Wetland Formation Class.

In the Samur-Shabran plain, the wetland vegetation type is classified into two formation classes, seven formation groups, and nine associations. This formation class includes the *Phragmiteta* formation group, as well as the associations of *Phragmites australis*, *Junceta-Phragmitetum*, *Juncus acutus-Phragmitetum australis*, *Arundeta-Phragmitetum*, *Arundo donax-Phragmitetum australis*, *Puccinellieta-Phragmitetum*, *Puccinellieta gigantea-Phragmitetum australis*, *Bolboschoeneta-Phragmitetum*, *Bolboschoenus maritimus-Phragmitetum australis*, *Typheta-Phragmitetum*, *Caspian Typheta caspica-Phragmitetum australis*, *Calamagrostieta-Phragmitetum*, and *Calamagrostieta epigeios-Phragmitetum australis*.

In the Caspian coastal ecosystem of Azerbaijan, the wetland vegetation is formed by the Australian reed-bed association, which extends over a broader area. This phytocenosis has been recorded around the Agzibirchala and Liman lakes in the Shabran district of the Samur-Shabran plain. The dominant and monodominant species in this formation is *Phragmites australis* (Cav.) Trin. ex Steud., which spreads in marshy soils and is abundant with a rating of 4-5 points.

In the plain area, the wetland vegetation is found in marshy soils, as well as in oil-contaminated soils within the "Siyazanneft" boundaries, where interzonal fragments are encountered. Along this, a marshy phytocenosis has been formed from Nabran, extending southeast toward the Shabran port with a width of 150-200 meters. The association consists of 22 species, including 2 shrub species, 16 perennial species, 2 biennial species, and 2 annual grasses. According to ecological analysis, 19 species belong to hydrophytes, and 3 to mesophytes.

Based on the phytosociological structure, the first layer of vegetation consists of

Phragmites australis (Cav.) Trin. ex Steud., *Rubus caesius* L., *Tamarix hohenackeri* Bunge, etc.; the second layer consists of *Juncus inflexus* L., *Potamogeton amblyophyllus* C.A. Mey., and other perennial grasses; and the third layer consists of *Bolboschoenus maritimus* (L.) Palla, *Cirsium elodes* Bieb., and other hydrophytes. The overall canopy coverage ranges from 80-95% (on the water surface of the lake). In the vegetation, common *Polytrichum commune* L. from the moss family is widespread.

Notably, in the Shabran district, wetlands can also be found along the shores of Karachay, Ilikhchi, Tikhanyoba, Tazakend, Sayad, Muqtadir, and also along the Velvelachay River and the Caspian coast in the psammophytic and marshland phytocenoses. *Phragmites australis* (Cav.) Trin. ex Steud. is considered an indicator of waters near the ground surface. The reedbed it creates is used as a shelter by waterfowl and other animals. In terms of forage value, when the vegetation starts in the spring, the stems and leaves of *Phragmites australis* (Cav.) Trin. ex Steud. are eaten by cattle and horses.

In addition to the mentioned *Phragmiteta* phytocenosis in the plain, *Phragmiteta-Juncetum*, *Junceta-Phragmitetum*, *Bolboschoeneta-Phragmitetum*, and *Phragmiteta-Juncetum* associations are found in lakes, ponds, marshes, and groundwater. However, the *Junceta* and *Junceta-Typhetum* phytocenoses are encountered in the "Siyazanneft" area (Qurbanov & Huseynova, 2011).

Sedge- Spiny rush-Reedmace-Mixed Grain Wetland Formation Class.

This formation class includes *Cariceta-Juncetum-Typhosum*, *Cariceta*, *Phragmiteta-Caricetum*, *Junceta*, *Typheta-Juncetum*, and *Phragmiteta-Agropyretum-Juncosum* formation groups.

The *Cariceta-Juncetum-Typhosum* formation group is represented by the *Carex riparia-Juncus acutus-Typha latifolia* association. This association is recorded in the "Siyazanneft" area, specifically in the Zarat-Candahar zone, where it is located in depressions contaminated with oil and tar. The phytocenosis consists of 13 species, including 1 shrub species, 1 semi-shrub

species, 1 sub-shrub species, and 10 perennial grasses. According to ecological groups, 7 species are hydrophytes, 3 species are mesoxerophytes, 2 species are mesophytes, and 1 species is a halophyte. The dominant species in the association are *Typha latifolia* L., with a coverage rating of 3-4 points, *Juncus acutus* L., and *Carex riparia* Curt., with coverage ratings of 2-3 and 2 points, respectively.

The structure of the phytocenosis consists of *Tamarix ramosissima* Ledeb., *Typha latifolia* L., *Juncus acutus* L. in the first half; *C. riparia* in the second half; and *Arundo donax* L., *Pycnus flavescent* (L.) Beauv. ex Reichenb. in the third half. The overall coverage is between 40-80%.

Additionally, in the Samur-Shabran plain, in the "Siyazanneft" area, wetland vegetation in oil and tar-contaminated soils is found in small and narrow areas. The level of groundwater and anthropogenic and technogenic impacts intensify the contamination and degradation of soil-vegetation cover, requiring reclamation or remediation measures to be implemented.

Grain-Mixed Herb-Spiny rush Wetland Formation Class.

This formation class includes the *Phragmiteta-Artemisietum-Juncosum* formation group. The formation group is made up of the associations *Phragmiteta australis-Artemisia szowitziana-Juncus acutus* and *Artemisia szowitziana-Juncus littoralis*. This association has been encountered on the marshy soils along the Karachay River in the Khachmaz administrative district of the Samur-Shabran plain.

The dominant species in the phytocenosis are *Juncus acutus* L. and *Juncus littoralis* C.A. Mey., with subdominants *Artemisia szowitziana* (Bess.) Grossh. and *Phragmites australis* (Cav.) Trin. ex Steud. *Juncus littoralis* C.A. Mey. has a coverage rating of 3-4 points, *Artemisia szowitziana* has a rating of 2-3 points, and *Phragmites australis* has a rating of 2 points.

In terms of structure, the first layer of vegetation includes *Phragmites australis* (Cav.) Trin. ex Steud., *Tamarix ramosissima* Ledeb., *Juncus acutus* L., *Typha latifolia* L.; the second layer contains *Artemisia szowitziana* (Bess.) Grossh., *Alhagi pseudalhagi* (Bieb.) Fisch., etc.; and the

third layer contains *Juncus littoralis* C.A. Mey., *Pycnus flavidus* (Retz.) T. Koyama, etc. The overall coverage ranges from 50-90%. *Artemisia szowitziana* and common gentian are mesohydrofit species, and *Artemisia szowitziana* is an endemic plant with essential oils from the Caucasus region, considered poisonous to livestock.

Shrubby-cane -Spiny rush -Wetland Formation Class

This formation class includes the *Tamariceta-Phragmitetum-Juncosum* formation group. The formation group is composed of the associations *Tamariceta hohenackeri-Phragmitetum australis-Juncus inflexus* and *Tamariceta ramosissima-Phragmitetum australis-Juncus littoralis*. This association is found along the Caspian Sea coast, specifically in the marshy soils of the Yashma administrative region.

The dominant species in the phytocenosis are *Juncus littoralis* C.A. Mey., with subdominants *Phragmites australis* (Cav.) Trin. ex Steud. and *Tamarix ramosissima* Ledeb. The coverage of *Juncus littoralis* C.A. Mey. is rated at 3-4 points, *Phragmites australis* at 2-3 points, and *Tamarix ramosissima* at 2 points.

The structure of the phytocenosis consists of *Tamarix ramosissima* Ledeb., *Juncus acutus* L., *Typha latifolia* L. in the first half; *Phragmites australis* (Cav.) Trin. ex Steud. and others in the second half; and *Juncus littoralis* C.A. Mey., *Arundo donax* L. in the third half. The overall coverage is between 60-90%.

The wetland vegetation of the Absheron Peninsula consists of two formation classes, four formation groups, and five associations (A.A. Akhundova, 2012). The wetland vegetation formed in the area includes the *Tamariceta-Phragmitetum-Juncosum* formation found in oil-contaminated grey-brown and tarry soils. The soil-vegetation cover in the region is subject to anthropogenic and technogenic impacts, continuing to degrade and turn into dead mass (E.M. Qurbanov & A.A. Akhundova, 2009, 2010).

Grass-Sedge Wetland Formation Class

This formation class includes the *Festuca-Caricetum* formation group, represented

by the *Festuceta arundinacea-Caricetum hirta* association. This vegetation is found in the marshy soils surrounding Kekilnohur Lake in the Shamakhi district, in the northern part of the Sumqayitchay basin.

The phytocenosis consists of 15 species, including 1 shrub species and 14 perennial grasses. Ecological analysis shows that 9 species are hydrophytes, 4 species are mesophytes, and 2 species are mesoxerophytes. The dominant species in the formation is *Carex hirta* L., with a coverage rating of 3-4 points, and the subdominant is *Festuca arundinacea* Schreb., with a coverage rating of 2-3 points.

In terms of structure, the first half of the vegetation includes *Scirpus lacustris* L., *Carex hirta* L.; the second half contains *Festuca pratensis* Huds., *Carex caucasica* Stev.; and the third half includes *Mentha aquatica* L., *Elymus repens* (L.) Nevski, and others.

Swampy wetland formation class

In Azerbaijan, swampy riverside wetland vegetation is found in the Greater Caucasus, the Lesser Caucasus, as well as in the high mountain belt of the Nakhchivan Autonomous Republic and Talysh (E.M. Gurbanov, 2004). The wetland vegetation to which this formation class belongs is characterized by various phytocenoses in the Atropatan province, especially in Nakhchivan: Arundetum, Phragmitetum, Agrostietum, Caricetum, Typhetum, Calamagrostietum, etc. In the wetland phytocenoses, the following plants are found: *Bolboschoenus maritimus* (L.) Palla, *Typha minima* Funck, *Equisetum arvense* L., *Phragmites australis* (Cav.) Trin. ex Steud., *Poa pratensis* L., *Juncus effusus* L., *Rumex crispus* L., *Rumex pulcher* L. In the alpine and subalpine zones, the following hydrophyte species are mainly found on swampy river banks: *Caltha polypetala* Hochst., *Filipendula ulmaria* (L.) Maxim., *Carex diandra* Schrank, *Doronicum macrophyllum* Fisch. ex Hornem., *Poa nemoralis* L., *Calamagrostis epigeios* (L.) Roth, etc. (E.M. Gurbanov, 2004).

In the Nakhchivan Autonomous Republic, the wetland vegetation of the Nakhchivanchay basin is distributed around ponds, creeks, waterfalls, river branches, springs and snowdrifts

located in all altitude zones along the right and left banks of the river. 4 formation classes, 13 formation groups and 16 associations have been identified in the wetland vegetation type. In the ponds, stagnant, calmly flowing water environments in the area and on the water of Lake Vaykhir, *Eleocharis palustris* (L.) Roem. et Schult., *Catabrosa aquatica* (L.) Beauv., *Alisma plantago-aquatica* L.) etc., *Lemna minor* L., *Periscaria hydropiper* (L.) Spach, *Zannichellia palustris* L. etc. true aquatic plants are distributed. Here, in alpine and subalpine marshes, *Carex vesicaria* L., *Bolboschoenus maritimus* (L.) Palla, *Triglochin palustre* L., *Typha latifolia* L., *Phragmites australis* (Cav.) Trin. ex Steud., *Butomus umbellatus* L., *Caltha polypetala* Hochst., *Allopecurus arundinaceus* Poir., etc. species are found. In the alpine swamps of the basin, moisture-loving mosses are encountered, which dominate in swamps or springs.

Geobotanical studies of J.A. Aliyev, E.M. Gurbanov and others on the wetland vegetation of Lankaran (Talysh) can be cited. In the post-glacial period in the region, the wetland vegetation of Talysh was formed. This vegetation of the area has an azonal character, spreading on meadow-marsh soils and in small areas.

In the high mountainous belt of Talysh, in the subalpine meadows, mesophyllous grasses and leguminous grasses are distinguished by their nutritional value or forage quality, as well as grassy meadows, which are similar to swampy meadows in origin and mix with each other under certain ecological conditions of the area where they are distributed. Mesophyllous meadows differ from neighboring phytocenoses due to the large number of hydrophyte species in their composition. The wetland vegetation distributed in the high mountainous part of this region has been reanalyzed and its classification has been clarified. The phytocenoses of Talysh consist of 2 formation classes, 4 formation groups and 5 associations.

In the mountainous part of Lankaran, the wetland vegetation of the area mainly includes swampy riverside hydrophyte and springside hydrophyte formation classes.

Swampy riverside wetland formation class

This formation class includes the Junceta and Cariceta formation groups.

Junceta formation group. This formation group is represented only by the Junceta inflexus association, spreading in the upper reaches of the Vilashchay River in the region, in the subalpine meadows, and is distributed in the form of small spots in the mountainous-forest and meadow-marsh soils of the area up to the broad-leaved forests. According to the species composition, the phytocenosis consists of hydrophytes distributed along the river banks. 20 species of hydrophytes are found in the high mountainous belt. The abundance of the monodominant and edificator of the association, the bent rush, is estimated at 2-3 points.

According to the phytocenotic structure, *Juncus inflexus* L., *Carex divisa* Huds., etc., are found in the I layer of the Junceta inflexus association; *Juncus bufonius* L., *Carex sylvatica* Huds., *Ranunculus repens* L., etc. are found in the II layer. The average height of the formation reaches 40-60 cm. The total project cover varies between 60-80%.

The Cariceta formation group includes the associations of Cariceta hordeistichos and the forest sedge Cariceta sylvatica. This association is represented by 25 species on the banks of the Sors River in the Lerik region. Of these, 22 species are perennial herbs and 3 species are annual herbs. According to the analysis of ecological groups, 23 species of these species are hydrophytes, 1 species is mesoxerophyte and 1 species is typical of mesophytes.

According to the phytocenotic structure, the vegetation cover of the associations is observed in two tiers, of which, in the first tier, *Carex hordeistichos* Vill., *Carex divisa* Huds., *Catabrosa aquatica* (L.) Beauv., *Lycopus europaeus* L., *Poa pratensis* L., etc. (abundance with 1-2 points); In the second layer, *Carex sylvatica* Huds., *Kobresia humilis* (C.A.Mey. ex Trautv.) Serg., *Festuca drymeja* Mert. et Koch, *Epilobium nervosum* Boiss. et Buhse, *Cyperus glaber* L., etc. plants were encountered, as well as in the coenosis along Sorschay, the design cover varies between 70-90%. Although the vegetation cover of the Cariceta sylvatica association

is found on meadow-marsh lands, on the banks of Amburchay in the Lerik region, its species composition is similar to Cariceta hordeistichos. In this phytocenosis, while the grasses of hydrophyte species create a dense cover, the species *Cyperus glaber* L., *Cyperus difformis* L., *Festuca drymeja* Mert. et Koch, etc. are sparsely distributed (with 1-2 points).

In general, the biodiversity of riverside hydrophyte vegetation depends on the characteristics of the substrate, river flow, relief, and ecological parameters of wetlands.

Swampy spring-side wetland

This formation class is represented by the Mentheta and Rumexeta-Menthethum formation groups. The Mentheta formation group is characterized by the Mentheta aquatica association, and the Rumexeta-Menthethum formation group is characterized by the Rumexeta confertus-Menthethum pulegium association.

The corresponding vegetation has been partially studied until recent years, but it is known from the study that this association is found in the high mountains of the region, especially in the form of small patches on swampy soils in the summer pastures around springs in swampy conditions. In those places, *Mentha aquatica* L. is monodominant, its abundance is characterized by 4-5 points. The species *Mentha aquatica* L. forms microassociations in mesophyll subalpine meadows. The composition of this association includes *Carex hordeistichos* Vill., *Poa pratensis* L., *Alisma plantago-aquatica* L., *Equisetum ramosissimum* Desf., etc. species.

Rumexeta-Menthethum formation group. In the formation group, the Rumexeta confertus-Menthethum pulegium association is widespread. Although this formation is considered a riverside hydrophyte vegetation, it is found in meadow-marsh lands around springs in the summer pastures of the mountainous part of Lankaran (in springs in the Lerik region) (E.M. Gurbanov et al., 2014). The composition of the formation consists of 27 species of these, 20 species are perennial, 2 species are biennial and 5 species are annual grasses. According to ecological analysis, 9 species are hydrophytes, 12 species are mesophytes and 6 species are mesoxerophytes. The dominant phytocenosis

is *Mentha pulegium* L. and *Mentha aquatica* L. with an abundance of 3-4 and 2-3 points, and the subdominant is *Rumex confertus* Willd. with an abundance of 2 points.

According to the structure of the vegetation cover, *Rumex confertus* Willd., three-leafed bulrush, *Scirpus triqueter* L., *Dipsacus pilosus* L. are found on the first floor; *Mentha aquatica* L., etc. on the second floor; and *Mentha pulegium* L., *Veronica lysimachioides* Boiss., etc. on the third floor. The total design cover of the area around the spring varies between 55-85%.

Thus, the rich flora diversity of the swampy

riverbank and spring-side wetland vegetation spread in the mountainous part of Lankaran depends on the relief, soil-climatic conditions, vertical zonation and the influence of a number of ecological factors. In the mountainous part of the area, wetland vegetation is formed at an altitude of 1500-2500 m above sea level.

Preventing the ongoing degradation of wetland vegetation spread across the territory of Azerbaijan, protecting and efficiently using biodiversity, and implementing ecological and phytocenological measures on a scientific basis are of great importance.

Table 1

Classification of Azerbaijan's Wetland Plant Formations

Type	Formation Class	No	Formation Group
Wetland	Coastal cane-mixed grass wetland	1.	<i>Phragmiteta</i>
		2.	<i>Junceta-Phragmitetum</i>
		3.	<i>Arundeta-Phragmitetum</i>
		4.	<i>Puccinellieta-Phragmitetum</i>
		5.	<i>Bolboschoeneta-Phragmitetum</i>
		6.	<i>Typheta-Phragmitetum</i>
		7.	<i>Calamagrostieta-Phragmitetum</i>
	Sedge- Spiny rush-Reedmace-Mixed Grain Wetland	8.	<i>Cariceta-Juncetum-Typhosum</i>
		9.	<i>Cariceta</i>
		10.	<i>Phragmiteta-Caricetum</i>
		11.	<i>Junceta</i>
		12.	<i>Typheta-Juncetum</i>
		13.	<i>Phragmiteta-Agropyretum-Juncosum</i>
	Grain-Mixed Herb-Spiny rush Wetland	14.	<i>Phragmiteta-Artemisietum-Juncosum</i>
	Shrubby-cane -Spiny rush -Wetland	15.	<i>Tamariceta-Phragmitetum-Juncosum</i>
	Grass-sedge wetland	16.	<i>Festuceta-Caricetum</i>
	Swampy riverside wetland	17.	<i>Junceta</i>
		18.	<i>Cariceta</i>
	Swampy spring-side wetland	19.	<i>Mentheta</i>
		20.	<i>Rumexeta-Menthethum</i>

Conclusion

This study offers a detailed analysis of the floristic and ecological features of wetland vegetation ecosystems in Azerbaijan, enhancing our understanding of their biodiversity and ecosystem services. The results reveal that wetland vegetation in Azerbaijan develops under various climatic and soil conditions, leading to widespread ecosystems that integrate different formation classes, groups, and associations.

A significant finding of the study was the identification of dominant species in wetland vegetation and their ecological roles. *Phragmites australis*, *Juncus acutus*, *Typha latifolia*, and other hydrophyte species are the primary components driving ecosystem functions in these areas. These species provide essential ecosystem services such as water purification, regulation, and biodiversity conservation in wetlands.

The study also highlights the detrimental effects of anthropogenic factors—particularly oil-contaminated soils and pollution of water bodies—on wetland vegetation and its ecosystem services. Pollution has weakened vegetation cover, reduced species diversity, and diminished ecosystem services. Therefore, implementing phytoremediation and reclamation techniques for wetland restoration should be prioritized.

Another key outcome of this study is the

need for the establishment of ecological reserves and the application of scientifically grounded measures to ensure the protection and restoration of wetland areas. These ecosystems are vital for conserving biodiversity and effectively managing water resources while providing crucial ecosystem services.

Future research should explore ecosystem changes, anthropogenic impacts, and the effectiveness of restoration methods for wetland ecosystems. Such studies will lay the scientific groundwork for the protection and management of Azerbaijan's wetland ecosystems and contribute to the development of environmental policies.

In conclusion, to ensure the sustainability of wetland vegetation, it is essential to implement scientifically-based ecological-phyto-sociological measures and strategic management methods. Furthermore, extensive research and appropriate government policies are needed to preserve these critical areas. The insights from this study will significantly contribute to wetland ecosystem protection and management and inspire further scientific advancements in environmental conservation. Long-term strategies for the restoration and protection of these ecosystems will support the sustainable delivery of ecosystem services in Azerbaijan's wetland areas.

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**BIOMORPHOLOGICAL AND BIOECOLOGICAL CHARACTERISTICS OF THE LAMIACEAE FAMILY
DISTRIBUTED IN THE SOUTHERN REGION OF AZERBAIJAN****Sayyara Ibadullayeva^{1*} | ORCID: 0000-0003-0397-1593****Afsana Guliyeva² | ORCID: 0009-0007-2526-014X**^{1*}Institute of Botany of the Ministry of Science and Education of the Republic of Azerbaijan²Baku State University, Baku, Azerbaijan^{1*}Correspondence: ibadullayeva.sayyara@mail.ru

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Abstract. *This study examines the biological and geographical diversity of the Lamiaceae family within the flora of Azerbaijan, particularly in the Lankaran region, which encompasses the Lankaran Plain, mountainous areas, Lankaran-Mughan, and Diabar (Zuvand). The findings highlight the region's rich ecosystems and significant floristic heritage. The identified species have been systematically classified based on their aromatic, spice-producing, essential oil-bearing, medicinal, and technical properties. Their morphological characteristics have also been analyzed. This research provides a scientific foundation for biodiversity studies and the conservation of regional flora. The results confirm that Lamiaceae exhibits substantial biological and ecological diversity in the Lankaran region and Azerbaijan. This diversity is crucial for the study of local flora, conservation strategies, and sustainable biodiversity management. Understanding the ecological roles of these species contributes to environmental sustainability, emphasizing the importance of preserving native plant diversity for maintaining ecological balance and supporting sustainable development.*

Keywords: Azerbaijan, Lamiaceae, Lankaran, Talysh, biomorphology, bioecology

Introduction

Our country's rich flora is characterized by its diverse plant resources, which are extensively utilized across various sectors. These resources play a crucial role in the food industry, pharmacology, technical production, and cosmetics. Notably, certain plant species have valuable applications, including their use as food additives, in preservation processes, pharmaceutical production, and the perfumery industry (Gasimov, 2003; Ibadullayeva et al., 2018).

The *Lamiaceae* Lindl. family holds particular significance in this regard. Species within this family are widely used in both the food and pharmaceutical industries. However, a comprehensive study of *Lamiaceae* species in Azerbaijani flora has been lacking, and their potential applications remain underexplored. Previous

research has been limited in scope and primarily focused on a small number of species (Mammedova, 2013; Alakbarov, 2015; Ibadullayeva et al., 2018).

The study of the ethnobotanical foundations of useful plant resources and the conservation of biological diversity is a priority in modern research. Many species found in the flora of Azerbaijan have been extensively investigated for their bioactive properties. Establishing the scientific basis for their use in industrial sectors—such as pharmaceuticals, preservation, food additives, and perfumery—has been a key objective (Aliyev et al., 2004; Gasimov, 2009). At the same time, the current status of plants historically used by Azerbaijanis for various purposes has been analyzed. Species with abundant raw material reserves and broad usage

have been identified, while conservation efforts have focused on rare and endangered species. Additionally, the population structure, distribution, and reserves of endemic and valuable species have been monitored, and new methodologies for their sustainable use have been developed and implemented.

Particularly, species belonging to the *Lamiaceae* family—such as thyme, catnip, mountain mint, basil, mint, pennyroyal, sage, and marjoram—possess significant pharmacological and nutritional value. In addition to their medicinal properties, these species are widely used as food additives and vegetables. Globally, aromatic and spicy plants play an essential role as food additives (Gasimov et al., 2009). These plants, characterized by their pleasant aroma, distinct flavor, and bactericidal properties, are crucial in the production and preservation of canned products, wine, juice, sausages, and other food

products (Gasimov et al., 1980; Ibadullayeva et al., 2016).

This research decisively aims to conduct a comprehensive study of aromatic and spicy plants from the *Lamiaceae* family in the southern region of Azerbaijan. It will thoroughly assess their natural resources and identify potential new applications for their use.

Materials and Methods

The study was conducted using contemporary geobotanical methods adopted in 2023–2024, following precise route-based and semi-stationary approaches. The research focused on aromatic species of the *Lamiaceae* family distributed across the flora of the southern region of Azerbaijan, particularly within the Lankaran botanical-geographical area. During expeditions and fieldwork, selected study areas were investigated, as summarized in Table 1.

Table 1

Geobotanical Routes

No	Administrative districts	Regions	Date	Altitude (in meters)
1	Lankaran	Adjacent villages	15.08.2024–30.08.2024	0–500
2	Hyrcanian National Park	Forest Areas	15.08.2024–30.08.2024	500–1500
3	Astara District	Sandy Habitats	15.08.2024–30.08.2024	0–500

The processing of research materials combined classical and modern methodologies, incorporating botanical-floristic, systematic, areological, ecological, and statistical approaches. Phenological observations were conducted according to the methodology of Beideman (1954) and Gagnidze (1974).

The taxonomic identification of plant species was based on the multi-volume work *Synopsis of the Flora of the Caucasus* (2003–2006) and *Flora of Azerbaijan* (*Flora of Azerbaijan*, Vol. 7). Additionally, species nomenclature was verified and aligned with modern taxonomic standards, referencing *The Plant List: A Working List of All Plant Species* (2017). Distribution maps were generated to illustrate the specific range of each species.

Results and Discussion

The family *Lamiaceae* Lindl., comprising more than 3,500 species across 200 genera worldwide, is represented in the flora of Azerbaijan by 43 genera and 224 species. Wild species are primarily concentrated within the subfamilies *Ajugoideae*, *Scutellarioideae*, and *Lamioideae*. Additionally, widely cultivated genera such as rosemary (*Rosmarinus*), basil (*Ocimum*), and lavender (*Lavandula*) are classified as independent subfamilies.

Plants of the *Lamiaceae* family are predominantly xerophytic, adapted to arid environments found in both mountainous and lowland regions. However, some species are also found in mesophytic vegetation communities, particularly within forest and meadow ecosystems.

The majority of the family members are herbaceous plants, though some develop as subshrubs or shrubs. Notable examples include *Rosmarinus officinalis* L. (medicinal rosemary), which is cultivated in Azerbaijan, and various species of the genus *Thymus* L. (thyme), which exhibit a subshrub growth form.

Representatives of the Lamiaceae family are characterized by opposite, sessile, entire, and often dentate or winged leaves. Their flowers exhibit a zygomorphic structure and are hermaphroditic; however, actinomorphic flowers are occasionally observed. The perianth is pentamerous, with the calyx being gamosepalous, winged, dentate, or bilabiate. The corolla is typically bilabiate, with the lower lip divided into three segments, and the tube varying in length. The corolla limb may be four- or two-winged.

The number of stamens is four, with two being longer and the others relatively shorter. The pistil forms as a result of the fusion of two carpels. The ovary is positioned superiorly, is 2-4 locular, and typically has a four-lobed structure. The ovary consists of a single integument and four subbasal anatropous ovules. Initially, it is bi-locular, with two ovules in each locule. Over time, each locule becomes divided by false septa, resulting in a four-chambered ovary with one ovule in each chamber. As a result, when the ovary fully develops, it takes on a four-chambered structure. The style generally originates from the lower part of the ovary and is located in the center of the locules; this is referred to as the “kino-basic style.” In this case, the style does not extend completely to the terminal (upper part) of the ovary. The mouth of the style, distinguished by its length, is typically bifid. A fully terminal style—rising from the apex of the ovary—is rarely encountered. When the fruit is fully mature, it divides into four nutlets.

The flower formula is: $\uparrow K(5) C(2+3) A(2+2) G(2)$. The fruits are divided into four sections. The seeds are endosperms and are sometimes poorly developed. Representatives of this family are characterized by the presence of various aromatic compounds, including essential oils, alcohols, phenols, aldehydes, and ketones.

The Lamiaceae family is distinct from similar families, such as Myrtaceae and Plantaginaceae, due to its unique characteristics. It has a four-lobed ovary with a kino-basic style and its fruits are divided into four nutlet-like sections,

a feature also found in the Verbenaceae family.

The floral structure of the Lamiaceae family is defined by the arrangement of the stamens beneath the upper lip in two distinct tiers, a bilabiate corolla that is sharply differentiated, and the presence of a nectar-producing corolla. These traits have evolved alongside their primary pollinators, the Hymenoptera (such as bees and wasps).

Flowers in the Lamiaceae family are primarily pollinated by various insects, including hummingbirds, and exhibit a range of adaptations for effective natural pollination. For instance, in flowers of the genus *Salvia*, there are only two stamens; one half of each stamen is fertile while the other half is sterile and forms a trigger-like structure.

The fertile and sterile portions are united by lever-like structures, and pollination occurs once the sterile portions are joined. When wild bees enter the area where the sterile portions are fused, the levers are triggered, resulting in the transfer of pollen, which adheres to the bee's body, to the stigma of another flower. Although the representatives of the Lamiaceae family predominantly exhibit bilabiate corollas, they differ significantly in various biomorphological characteristics. For instance, while the flowers of the genus *Mentha* are predominantly actinomorphic, in some cases, as seen in the genus *Ajuga*, only the development of the lower lip of the corolla is observed.

The classification of the *Lamiaceae* family in the flora of the Caucasus was first provided by Y. Menitski. In the work *Flora of Azerbaijan*, 36 genera growing in the wild and 2 cultivated genera were reported within the Republic (1957, vol. 7). The most recent nomenclatural system of the family was presented in the book *Plant World of Azerbaijan* and was revised by the new conspectus of the flora of the Caucasus (Asgarov, 2016; Conspect Flora of Caucasian, 2003–2006). Consequently, the current flora of Azerbaijan comprises 37 genera and 220 species in the wild, alongside 5 cultivated genera and 8 species. Among these, 107 species are found in the southern regions of Azerbaijan, particularly in the Lankaran highlands and the Diabar (Zuvand) areas (Figure 1).

Below, the spice-like species of the family distributed in the area are presented:

Clinopodium (Wild Basil)

- *Clinopodium vulgare* L. – Common Wild Basil

Glechoma (Ground Ivy)

- *Glechoma hederacea* L. – Ivy-like Ground Ivy

Hyssopus (Hyssop)

- *Hyssopus angustifolius* M.B. – Narrow-Leaved Hyssop

Majorana (Marjoram)

- *Majorana hortensis* Moench. – Summer Marjoram

Marrubium (Horehound)

- *Marrubium vulgare* L. – Common Horehound

Mentha (Mint)

- *Mentha longifolia* (L.) Huds. – Long-Leaved Mint
- *Mentha aquatica* L. – Water Mint
- *Mentha piperita* L. – Peppermint
- *Mentha pulegium* L. – Pennyroyal Mint
- *Mentha suaveolens* Ehrh. – Round-Leaved Mint

Melissa (Lemon Balm)

- *Melissa officinalis* L. – Medicinal Lemon Balm

Molucella (Moluccella)

- *Molucella laevis* L. – Smooth Moluccella

Nepeta (Catnip)

- *Nepeta cataria* L. – Common Catnip

Ocimum (Basil)

- *Ocimum basilicum* L. – Common Basil

Origanum (Oregano)

- *Origanum vulgare* L. – Common Oregano

Rosmarinus (Rosemary)

- *Rosmarinus officinalis* L. – Medicinal Rosemary

Salvia (Sage)

- *Salvia aethiopis* L. – Ethiopian Sage
- *Salvia glutinosa* L. – Sticky Sage
- *Salvia officinalis* L. – Apothecary Sage
- *Salvia sclarea* L. – Clary Sage
- *Salvia verbenaca* L. – Wild Clary Sage
- *Salvia verticillata* L. – Whorled Sage
- *Salvia viridis* L. – Green Sage

Satureja (Savory)

- *Satureja hortensis* L. – Summer Savory
- *Satureja spicigera* (C. Koch) Boiss. – Spiked Savory

Teucrium (Germander)

- *Teucrium canum* Fish. et C.A. Mey – Gray Germander
- *Teucrium chamaedrys* L. – Common Germander
- *Teucrium scordioides* Schreb. – Scordium Germander

Thymus (Thyme)

- *Thymus collinus* Bieb. – Upland Thyme
- *Thymus migricus* Klok. et Des.-Shost. – Mehri Thyme

Ziziphora (Mountain Mint)

- *Ziziphora tenuior* L. – Slender Mountain Mint

Scientific research in contemporary times has significantly expanded in the field of identifying the biomorphological characteristics of plant families, contributing to the development of the field of plant ecomorphology within botanical science. In extreme and near-extreme environments, the adaptive characteristics of plants become more pronounced. In open plant communities, intense competition fosters the formation of biormorphs. The biomorphological analysis of representatives of the Lamiaceae family distributed in the local flora has been presented based on the classifications of Serebryakov I.G. (1964) and Raunkiaer C. (1934). According to Zozulin G.M.'s system, three main life form types are distinguished in petrophytic communities: stress-tolerant (or stress-resistant), opportunistic (or pioneer), and colonizing (or invasive, irruptive) types.

The proportion of the stress-tolerant type (11.8%) is relatively small compared to the other types. Species within this group are found exclusively in their specific habitats and do not extend into the distribution areas of other plant species. Additionally, this type includes species whose aggregation has not yet been fully established.

The proportion of the first life form (11.8%) is relatively small compared to other life forms. The species included in this group are restricted to their specific habitats and do not extend into the distribution areas of other plant species. Additionally, this group includes species whose classification has not yet been fully completed. The importance of first-type life forms is increasing in the development of closed phytocoenosis. The 14 species in this category account for 3.5% of the total species. This suggests that the primary factor contributing to the stabilization of petrophyte communities is senogenesis, a process occurring through the realization of adaptation opportunities in already existing areas. Moreover, it should be noted that perennial root-form species are less promising in these areas. The life forms belonging to the second type are most commonly found

in areas where anthropogenic influences are more pronounced.

The third life form constitutes the dominant category within the *Lamiaceae* family, representing 65.8% of the species. This type includes both expanding and proliferative species, accounting for an additional 5.9%. The gradual increase in the number of shoots around the primary shoot and the slow progression of new syngensis processes over time contribute to the annual rise in the prevalence of irruptive life forms.

Ephemerality is one of the most distinctive traits observed among the representatives of the family, primarily evident in species distributed near riverbanks.

The analysis of life forms indicates that certain representatives of the *Lamiaceae* family belong to the restorative types. Under conditions of open associations, the broad biological potential of these species enables them to cover larger territories. These patterns support the classification of such species into facultative and obligate petrophytes.

In high-altitude vegetation, perennial herbaceous species dominate (85%), while other life forms, including annual and biennial plants, are comparatively less abundant (10-15%).

The biomorphological analysis of the *Lamiaceae* family indicates that herbaceous plants constitute the predominant component of the flora. A total of 186 herbaceous species have been documented. Additionally, the flora includes 2 shrub species and 36 subshrub species.

In the flora of Azerbaijan, herbaceous species of the *Lamiaceae* Lindl. family is categorized into various ecobiomorphs: graminoid plants, spiny plants, including fully spiny, tuberous-spiny, bulbous-spiny, tuberous-soft spiny, and bulbous-soft spiny species; as well as tuberous plants, including short tuberous, long tuberous, and bulbous-tuberous species. This classification enables a deeper understanding of the biomorphological and ecological diversity within the *Lamiaceae* family.

Table 2

Life Form Indicators	Abundance			
	According to Azerbaijan		According to Lankaran	
	Absolute quantity	%	Absolute quantity	%
Main biormorphs				
Shrubs	2	0,89	1	0,9
Subshrubs	36	16,11	11	10,3
Herbaceous plants	186	83	95	88,8
Duration of the major life cycle				
Polycarpic Plants	193	86	90	84,1
Monocarpic Plants	31	14	17	15,9

Based on Raunkiaer's classification, four biormorphs have been identified in the study area. According to this classification, plants belonging to the hemicryptophyte (*Hemicryptophyta* – HK) group are herbaceous and initiate bud development at the soil surface.

This group includes rosette-type, biennial, turf-forming, and short-rhizomatous herbs. The study results indicate that genera such as *Salvia*, *Mentha*, *Nepeta*, and *Teucrium* dominate among hemicryptophytes. Overall, hemicryptophytes play a key role in the biormorphological composition of the Lamiaceae family.

Table 3

**Life Forms of Useful Species in the *Lamiaceae* Lindl. Family
According to the Raunkiaer System (1934)**

№	Life forms	In Azerbaijan		In Lankaran	
		Number of species	Percentage of total count	Number of species	Percentage of total count
1	Chamaephytes (Ch)	38	17	12	11
2	Hemicryptophytes (Hk)	157(159)	70(71)	79 (78)	74(73)
3	Therophytes (Th)	29(27)	13(12)	16(17)	15(16)
Total		224	100	107	100

The group Chamaephyta (Chamaephytes – Ch) comprises plants with perennating buds situated above the soil surface. This category primarily includes subshrubs, shrubs, and cushion-forming plants that persist on the ground during the winter. Within the family Lamiaceae Lindl., species of the genus *Thymus* L. are predominant among the Chamaephytes. This biormorph is particularly adapted to mountain xerophytic habitats on southern slopes, where it frequently exhibits ecological dominance.

Therophytes (Therophyta – T) encompass annual herbaceous plants with a stem height ranging from 0.15 to 2 meters. According to the research findings, species from the genera *Galeopsis* L. and *Lallemantia* Fisch. & C.A. Mey. are particularly dominant within this group among the Lamiaceae family. In total, therophytes are represented by 29 (27) species within the study area.

Cryptophytes (Cryptophyta – K) are plants whose vegetative buds develop below the

ground or underwater. However, no species from this group have been recorded among the representatives of the Lamiaceae Lindl. family.

From an ontogenetic perspective, the external morphology of plants is determined by the processes of growth and development under specific environmental conditions. Historically, this reflects the plants' ability to adapt to particular pedoclimatic and synoptic conditions. Based on morphological traits, I.G. Serebryakov formulated a distinctive new classification system for plant life forms. The core of this system is grounded in the duration of the plant's life cycle and the morphological characteristics of the structural axes. Thus, following these principles, he devised a taxonomic framework for plant life forms, categorizing them hierarchically, beginning with the highest taxon and progressively subdividing them into subordinate categories: division, class, subclass, group, subgroup, section, and true life form.

According to Serebryakov's classification, plant life forms are divided into four main categories:

Tree plants—characterized by fully lignified stems; *Semi-lignified plants*—with partially woody stems; *Terrestrial herbaceous plants*—encompassing herbaceous plants adapted to the terrestrial environment; *Aquatic herbaceous plants*—encompassing herbaceous plants that live in aquatic environments.

This system offers scientific foundations for a deeper understanding and classification of

plants' adaptive characteristics to various environmental conditions.

The divisions outlined in the classification encompass several classes, which are subsequently divided into biomorphs. This approach presents two distinct and opposing concepts regarding plant life forms. According to the first approach, the life form is considered the primary taxonomic unit within the plant's ecosystem. The second approach, however, holds greater significance for the settlement of plants in specific habitats and for the areological analysis of plants in floristic studies.

The biomorphological spectrum of life forms within the *Lamiaceae* family in the flora of Azerbaijan has been systematically investigated, yielding the following results (Table 4). Among the taxa of this family, shrubs are represented by only 2 species, comprising 0.89% of the total spectrum. Subshrubs account for 36 species, making up 16.07%. Perennial herbaceous plants dominate significantly, with 159 species, which represent 71% of the total spectrum. In contrast, annual herbaceous plants are represented by 27 species, constituting 12.04% of the spectrum.

These indicators vividly demonstrate the biomorphological diversity of the Lamiaceae family and its significance within the flora of Azerbaijan.

Table 4

Life forms of species belonging to the Lamiaceae family according to the Serebryakov system

No	Life Forms	Number of Species Distributed in Azerbaijan	Percentage According to the Count	Number of Species Distributed in the Lankaran Botanical-Geographical Region	Percentage According to the Count
1	Shrubs	2	0,89	1	1
2	Subshrubs	36	16,07	11	10
3	Perennial Herbs	159	71	78	73
4	Annual Herbs	27	12,04	17	16
Total:		224	100	107	100

To investigate the geographical structure of the *Lamiaceae* Lindl. family within the flora of Azerbaijan, the distribution ranges of the species were identified and classified according to their geographical elements. The determination of these geographical elements was based on the studies of various phytogeographers, including Grossheim, Portenier, and others.

This approach, which relies on the geographical distribution ranges of species, enables their classification according to floristic regions. By analyzing geographical elements in this manner, it becomes possible to elucidate certain aspects of florogenesis, providing insights into the evolutionary and historical development of the flora. Moreover, this methodology is of considerable importance from both theoretical and practical perspectives, as it not only enhances our understanding of plant biodiversity and its origins but also informs conservation strategies and the sustainable use of floral resources. Specifically, the success of species introduction depends on accurately determining their phylogenetic relationships with a given flora. A more precise identification of these relationships contributes to enhancing the success of the introduction of *Lamiaceae* representatives.

The classification of the distribution ranges of the representatives of the *Lamiaceae* family in the conducted studies was based on the approaches proposed by A.A. Grossheim (1967), R.I. Gagnidze (1974), and Zazulin (1976). Within the framework of this classification, the representatives of the *Lamiaceae* family encompass 10 distinct geographical elements. A brief overview of several of these elements is provided below.

The Mediterranean Element: This group comprises species whose distribution centers are associated with the Mediterranean floristic region. In total, the representatives of the *Lamiaceae* family belonging to this geographical element are represented by 30 species.

The Caucasian Element: This geographical element encompasses the mountain systems of the Greater and Lesser Caucasus and represents a significant component of the *Lamiaceae* family within the region. This element, which holds a critical role in the development of

Azerbaijan's flora, includes a total of 19 species. The ecological characteristics and geographical distribution of these species demonstrate substantial diversity. Most species are classified as obligate and facultative chasmophytes, along with glyrophytes. These species are predominantly found in rocky and gravelly habitats. In terms of the distribution range, this geo-element also extends into the northern regions of the Mediterranean and Irano-Turanian floristic provinces.

The Irano-Turanian Element: Species belonging to this element are primarily distributed across various regions of the Irano-Turanian floristic province. Within Azerbaijan, this element comprises 25 species. Typical representatives include *Lallemantia royleana* (Benth.) Benth. (Royal Lallemantia), *Ziziphora tenuior* L. (Slender Mountain Mint), and *Satureja confinis* Boiss. (Border Savory). These species are characteristic of the Irano-Turanian element.

The Palearctic Element: This element encompasses 21 species of the *Lamiaceae* family. These species exhibit a broad distribution range and thrive across multiple ecological zones. However, as elevation above sea level increases, the prevalence of these species decreases. Representative species of the Palearctic element include *Ajuga reptans* L. (Creeping Bugle), *Galeobdolon luteum* Huds. (Yellow Archangel), *Ballota nigra* L. (Black Horehound), and *Betonica officinalis* L. (Common Betony).

The Holarctic Element: This geographical element includes only three species of the *Lamiaceae* family: *Scutellaria galericulata* L. (Common Skullcap), *Stachys palustris* L. (Marsh Woundwort), and *Prunella vulgaris* L. (Common Self-heal).

The Boreal Element: Species belonging to this geographical element are widely distributed across all floristic regions of the boreal subrealm of the Holarctic. A.A. Grossheim (1967) noted the inclusion of boreal elements in the alpine and forest floras of the Caucasus, stating: "The species of the boreal element resemble a covering draped over most regions of the Caucasus." This observation emphasizes the dominance of boreal species in the flora of the Caucasus and highlights their extensive ecological

adaptability. However, no representatives of the *Lamiaceae* family associated with the boreal geographical element have been recorded in the flora of Azerbaijan.

The Pontic Element: This geographical element includes species associated with ecosystems characterized by the humid and temperate climate of the Black Sea region. A subset of these species has exhibited local adaptation within the flora of Azerbaijan, establishing themselves in specific ecological conditions. Notable species within this element include *Leonurus glaucescens* Bunge (Glaucous Motherwort), *Phlomis tuberosa* (L.) Moench (Tuberous Phlomis), *Salvia tesquicola* Klok. et Pobed. (Steppe Sage), *Salvia verticillata* L. (Whorled Sage), and *Scutellaria altissima* L. (Tall Skullcap).

Analysis of the spectrum of geographical elements indicates that the majority of species diversity in the *Lamiaceae* family is comprised of species belonging to the Atropatan and Caucasian elements. Specifically, the dominance of species belonging to the Caucasian element can be explained by the isolation of mountain ranges in this region, which limits species migration.

When analyzing the species composition across various ecological zones, it is evident

that species from the Caucasian element are dominant. These species account for 63.6% of the flora within the *Lamiaceae* family. While species from the Caucasian element are found in various ecological zones, the majority are predominantly located in the subalpine zone.

The classification of the *Lamiaceae* family according to geographical elements provides significant scientific foundations for a more detailed study of species ecology and distribution characteristics. The details of this classification for the Lankaran region are presented in Figure 1.

The results of the geographical analysis indicate that, according to Portenier (2012), the primary species composition of the *Lamiaceae* family is represented by the Iranian (9.37%), Atropatan (8.93%), and Caucasian (8.48%) geographical elements. These elements significantly influence the wide distribution and ecological diversity of the flora. The following elements are Eastern Asia (6.69%), Hyrcanian (2.23%), Holarctic, and Pontic-Sarmatian (1.34%). The remaining geographical elements collectively constitute 61.62% of the flora.

This analysis reflects the geographical distribution of the *Lamiaceae* family and the proportion of various geographical elements in the structure of the flora.

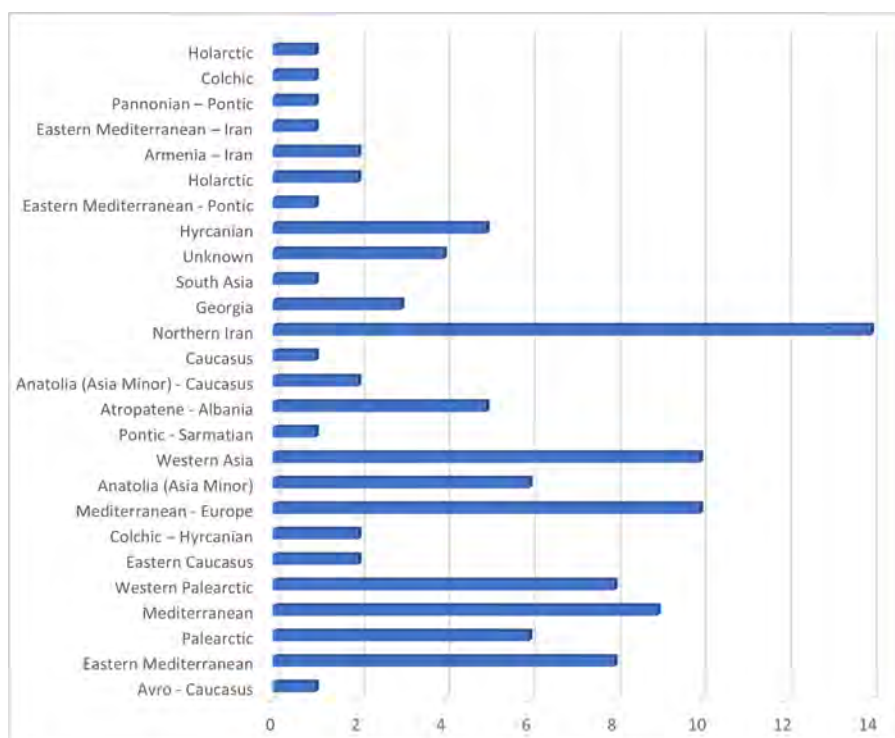


Figure 1. Geographical elements of the *Lamiaceae* family in the Lankaran flora.

The widely distributed and polymorphic species of the *Lamiaceae* Lindl. family are primarily found in Asian countries, as well as in temperate and non-tropical regions, with the Caucasus also included in this range.

From a historical perspective of Azerbaijani species, the Neogene period holds significant importance. During the geological processes that facilitated the formation of high mountains, various natural-historical complexes and numerous regions of Azerbaijan were established, which led to the formation and fragmentation of the country's zones. These processes resulted in the isolation of species' ranges in different areas during the Neogene period, subsequently stimulating the development of geographically adapted morphotypes.

Species such as *Nepeta panonica* and *Nepeta grandiflora*, which are steppe species, primarily occur in the steppe regions of Eurasia and have migrated into the Caucasus. The mountain-steppe species of *Nepeta*, on the other hand, are native to the Caucasus flora, and some species, such as *Nepeta sulphurea*, have originated in areas that are shared with the *Near East*. These findings support A.A. Grossheim's hypothesis that certain steppe elements have migrated from the steppes of Southern Russia into the Caucasus. Furthermore, they suggest a connection between the steppe flora of the Caucasus and the flora of the *Near East*, thereby corroborating several scientific theories.

The endemic species of the *Lamiaceae* family are primarily represented by species that have adapted to the high-altitude regions of the Greater and Lesser Caucasus. According to A.A. Grossheim's proposal, the endemic species of the Greater Caucasus are classified as "true Caucasian endemics." In his view, the development and distribution areas of these species are particularly closely linked to the Caucasus mountain range.

Based on their distribution characteristics, these species are divided into three distinct groups:

➤ *First group*: This group consists of species that are exclusively endemic to the main Caucasus mountain range. These species, classified by A.A. Grossheim as the "home-Caucasian

group," exhibit restricted distribution ranges and represent taxa that are in the early stages of geographical expansion. They have not yet entered the phase of widespread dissemination and are confined to specific, localized regions.

➤ *Second group*: The species of this group are more broadly distributed across various regions of the Greater Caucasus but remain primarily associated with the Caucasus and, in some cases, the Near East. These taxa demonstrate multiple irradiation patterns, reflecting both ecological adaptability and geographical heterogeneity.

➤ *Third group*: This group encompasses species that are predominantly characteristic of the natural zones of the Lesser Caucasus. Their distribution ranges are distinct from those associated with the Greater Caucasus, and their origins are most likely rooted in the Lesser Caucasus region. These taxa are confined to narrower, more specific habitats and exhibit a higher degree of ecological and geographical specialization relative to the other groups.

Unlike the Greater Caucasus, the group of endemics in Transcaucasia constitutes a portion of the remaining species. The southern part of Transcaucasia, particularly the Iranian territories, has not been fully studied, making it difficult to determine the exact number of endemic species in these areas. However, based on existing data, the number of these species is relatively small. This is due to the constant connection and proximity of the Lesser Caucasus mountain system to Anatolia and Iran, which allows for the continuation of ecosystems across these regions. As a result, some species that initially appear to be endemic to Transcaucasia may, in fact, also occur in neighboring countries and may not be considered strictly endemic.

The development of the *Lamiaceae* family in Azerbaijan demonstrates that these plants represent distinct phylogenetic branches. A considerable number of species are primarily native to the Caucasian and Near Eastern floras, while only a few species occur as introduced elements in Azerbaijan. The spread of steppe and Pontic elements in Azerbaijan is explained by their primary migration route, which is associated with the northern part of the South Caucasus.

Among the endemic species of Azerbaijan, representatives of the *Lamiaceae* family indicate that the phylogenetic relationships of these species primarily extend to Anatolia, while the connections to Central Asia are relatively weak.

This finding suggests that the evolutionary processes of Azerbaijan's flora are continuing at a rapid pace, as they have in previous geological

periods, and that the process of form formation remains active.

In the flora of Azerbaijan, 19 species of the *Lamiaceae* family are recorded as endemic, while 26 species are endemic specifically to the Caucasus region (Figure 2).

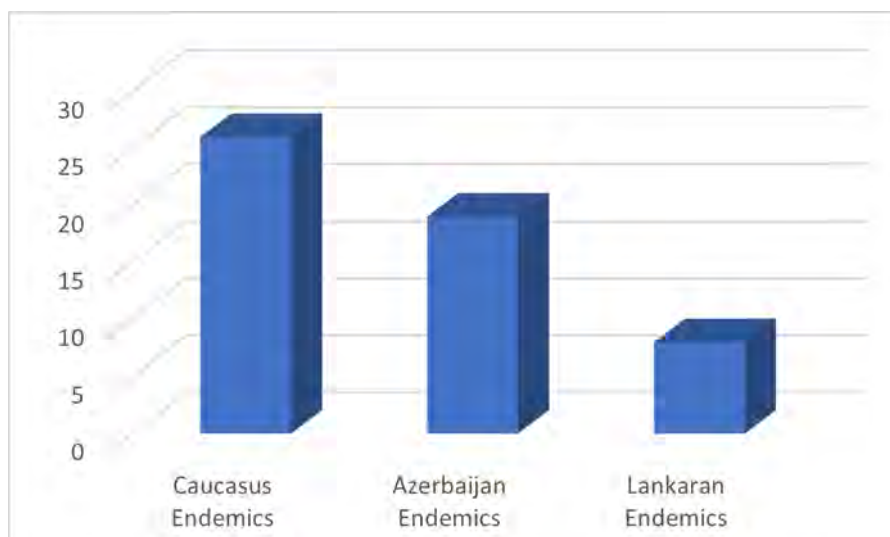


Figure 2. Endemic Species of the *Lamiaceae* Lindl. Family"

The distribution ranges of 224 species from 42 genera of the *Lamiaceae* family in the flora of Azerbaijan have been determined. An analysis of the literature reveals that 107 species from 30 genera are characteristic of the botanical-geographical regions of the Lankaran region, specifically the Lankaran plain, Lankaran mountains, Lankaran-Mugan, and Diabar (Zuvand) regions. These species have been classified based on their various beneficial properties (aromatic-spicy, food, essential oils, medicinal, and technical) and their biomorphological characteristics have been defined. The majority of these species are perennial herbs (78 species). Areal analysis indicates that, overall, the distribution of *Lamiaceae* representatives in the flora of Azerbaijan predominantly corresponds to the following geographical elements: Palaearctic (21 species), Iran-Turan (25 species), Atropatene (20 species), and Caucasus (19 species). Among these, 26 species are endemic to the Caucasus, 19 are endemic to the flora of Azerbaijan, and 8 species have been recorded in the respective region.

Conclusion

This study has thoroughly explored the floristic and biomorphological diversity of the *Lamiaceae* family in Azerbaijan, as well as the ecological and geographical distribution of its species. A total of 224 species belonging to the *Lamiaceae* family have been identified within the flora of Azerbaijan, with a significant representation in the Lankaran region. The high number of species and their biomorphological characteristics underscore the richness and diversity of the region's ecosystems. The research also highlights how plants have adapted to various climatic and topographical conditions in Azerbaijan, and the essential role these species play in local flora.

The findings indicate that the *Lamiaceae* family predominantly develops under the influence of three main geographical elements: Caucasian, Irano-Turanian, and Palaearctic elements. The dominance of the Caucasian element explains the widespread presence of local endemic species and the existence of highly adapted plant communities in this region. In

the Lankaran region, 107 species of the Lamiaceae family have been recorded, with aromatic and medicinal species being of particular significance. Additionally, these species are distributed across various geographical areas, reflecting their adaptation to different ecological and microclimatic conditions.

The species of the Lamiaceae family, especially the endemic species, hold ecological importance. The high diversity and abundance of these species in Azerbaijan's flora necessitate consideration of their geographical distribution and ecology. Anthropogenic pressures, such as urbanization, overgrazing, and land use changes, have led to the degradation of these plant communities. Therefore, effective conservation strategies are essential for the preservation and restoration of these species.

The results of this study emphasize the vital ecological, cultural, and economic roles of the Lamiaceae family within Azerbaijan. Sustainable management and conservation of these species should be prioritized to ensure the maintenance of ecological balance and the continued provision of ecosystem services. The findings demonstrate the importance of understanding the bioecological roles of these plants and the contributions they make to local economies. As such, this research provides significant scientific insights into the ecological and economic value of the Lamiaceae family, offering a foundation for broader-scale conservation and restoration efforts in Azerbaijan.

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PHYTOCHEMISTRY, TRADITIONAL USES AND PHARMACOLOGICAL POTENTIAL OF
JURINEA DOLOMIAEA SUSTAINING IN HARSH ALTITUDES OF PIR PANJAL RANJE POONCH,
JAMMU AND KASHMIR

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Abstract. *Jurinea dolomiaea* is a plant that belongs to the Asteraceae family and is native to alpine regions in Myanmar, China, India, Nepal, and Pakistan. It contains a variety of bioactive compounds such as sesquiterpene lactones, sterols, triterpenoids, saponins, tannins, flavonoids, glycosides, steroids, phenolic compounds, fixed oils, fats, terpenes, and lignans.

Traditionally, this plant has been used in herbal medicine for its aphrodisiac properties and for treating rheumatism, fever, colic, gout, and puerperal fever. It is also used in the incense industry and as an insect repellent due to its pleasant aroma.

Pharmacological studies have shown that *J. dolomiaea* has antileishmanial, antioxidant, antibacterial, antimalarial, analgesic, and hepatoprotective properties. It also has potential benefits for reproductive health and may help protect DNA. In addition, silver nanoparticles synthesized from *J. dolomiaea* have significant pharmacological potential. Moreover, its phytochemicals have analgesic, antinociceptive, anxiolytic, sedative, anticancer, immunomodulatory, antimicrobial, lipid-regulating, anti-inflammatory, hepatoprotective, wound-healing, respiratory-protective, antidiabetic, and antioxidant effects.

Keywords: Keywords: *Jurinea dolomiaea*, *Jurinea macrocephala*, silver nanoparticles, Pir Panjal Range, reproductive health.

Introduction

Plants have been substantially used in all ancient medicine systems, including Ayurveda, Chinese, and Unani traditional medicine systems, as well as in the Indian traditional system of medicine (Prajapati et al., 2003). Modern drugs are primarily derived from medicinal plants; plants contribute to 20–30% of modern pharmaceuticals, and even synthetic compounds are

analogues of natural plant compounds (Brower, 2008). There are twelve mega biodiversity centers, and India is one of them, hosting 45,000 plant species across sixteen different agro-climatic zones, ten vegetation types, and fifteen biotic provinces (Kala & Sajwan, 2007). The Himalayas are globally famed as a treasure trove of medicinal plants. Approximately 30% of indigenous species are found in India (Nautiyal,

1998). Many high-medicinal-value plant species are native to the Himalayas. The genus *Jurinea*, from the Asteraceae family and Cardueae tribe, comprises 21 species worldwide, specifically found in the alpine regions of Myanmar, Nepal, India, Pakistan, and China (Wang et al., 2007; Shih & Raab-Straube, 2011; Shen et al., 2020). A few species of this genus also exist in Turkey and Iran (*eFlora of India*). It was previously classified under *Saussurea*; species from this genus can survive at elevations of up to 5000 m (Kasana et al., 2021). Plants belonging to the genus *Jurinea* in the family Compositae are ubiquitous. *J. dolomiaea* has synonyms such as *J. himalaica*, *J. macrocephala*, *Jurinea macrocephala*, *Tibetica*, and *Dolomiaea macrocephala* (common names: dhup, dhuplakdi, and googl) (*e-Flora of India*; *Flora of Peninsular India*; Kasana et al., 2021). *J. dolomiaea* has been used in indigenous healing remedies to treat various health issues such as colic, puerperal fever, aphrodisiac use, gout, and rheumatism. It is also utilized for its fragrant roots in the aromatics industry and to repel insects (Sharma et al., 2004). The roots are brewed into a decoction and recommended as a soothing remedy for colic and puerperal fever. The roots of *J. dolomiaea* are applied as a poultice for epidermal eruptions, and its juice is used to treat fever (Chopra et al., 1986). Rustaiyan et al. (1981) found sesquiterpene lactones as the major constituents of the plant. *J. dolomiaea*, in addition to its use in traditional medicine, has also shown potential in various pharmacological activities, including antibacterial, antileishmanial, hepatoprotective, and anticancer properties. It has also demonstrated applications as a DNA-protective, antiulcer, antitoxic, antioxidant, and analgesic agent. Besides the plant's numerous properties benefiting human health, compounds extracted from it have exhibited a wide range of pharmacological properties, making it a potential therapeutic agent for further research and studies.

Materials and Methods

Jurinea dolomiaea samples were collected from the Pir Panjal Range, Poonch, Jammu, and Kashmir, India, and identified based on morphological characteristics. The dried plant

material was powdered and extracted using methanol, ethanol, chloroform, ethyl acetate, n-hexane, and aqueous solvents via Soxhlet extraction. Phytochemical screening was conducted to detect flavonoids, tannins, saponins, terpenoids, alkaloids, phenolic compounds, and glycosides. High-performance liquid chromatography (HPLC) was used to quantify caffeic acid, apigenin, rutin, and gallic acid.

Silver nanoparticles (AgNPs) were synthesized by mixing aqueous root extract with silver nitrate (AgNO_3) and incubating at room temperature. The formation of AgNPs was confirmed using UV-Vis spectrophotometry, FTIR, and TEM analysis. The antioxidant potential was assessed using DPPH and FRAP assays, while antibacterial activity was evaluated against *Escherichia coli*, *Staphylococcus aureus*, *Xanthomonas vesicatoria*, and *Ralstonia solanacearum* via agar well diffusion and minimum inhibitory concentration (MIC) tests.

The anticancer activity of *J. dolomiaea* extracts and AgNPs was tested against HeLa and MCF-7 cell lines using the MTT assay, with apoptosis confirmed via fluorescence microscopy. Hepatoprotective effects were studied in CCl_4 -induced liver toxicity models, measuring SGOT, SGPT, ALP, and bilirubin levels. Reproductive health effects were analyzed by evaluating testosterone levels and testicular tissue histopathology in experimental animals.

All experiments were performed in triplicate, and data were analyzed using one-way ANOVA (SPSS v25), expressed as mean $\pm$ SD, with statistical significance set at $p < 0.05$.

Results and Discussion

J. dolomiaea Morphology

J. dolomiaea is a stemless perennial herb that thrives in the harsh alpine climate. Its unique structural adaptations enable it to survive at such high altitudes (Table 1 & Figure 1). The leaves are elliptic, densely woolly on the underside, and hairy on the upper surface, measuring 20–30 cm in length with petioles. The lobes are pinnatifid with denticulate margins. This plant produces numerous floral capitula (3–15 in number), either sessile or borne on short stalks, measuring 4–5 $\times$ 2.5–3.2 cm, and

covered in pubescence. Its involucre bracts are multilayered, varying from ovate to narrowly elliptical in shape, with a rough texture, generally membranous and dry. The linear tubular corollas reach up to 3.5 cm in length and are typically purple in color. *J. dolomiaea* flowers from July to September. The cypselae are obovate, compact, curved, and glabrous, with black wavy fringes at the apex. Its pappus is plumose, brown, and deciduous (Kasana et al., 2021).

Habitat and Distribution

J. dolomiaea is found in alpine habitats, including open grassy slopes, rocky terrains, morainic deposits, and scree fields (Figure 2). It thrives at elevations ranging from 3,500 to 4,600 meters (Kasana et al., 2021). It is endemic to the Himalayas and is commonly found at elevations between 3,000 and 4,300 meters on open slopes (Chauhan, 1999). The genus *Jurinea*, belonging to the Cardueae tribe of the Asteraceae family, comprises 21 species globally. It is distributed across northwest India, Myanmar, Nepal, China, and Pakistan (Funk et al., 2009; Shih & Raab-Straube, 2011; Shen et al., 2020).

Traditional Medicinal Uses

J. dolomiaea is widely utilized in traditional medicinal systems, including Unani, Homeopathy, Naturopathy, Ayurveda, and Traditional Chinese Medicine (Table 2 & Figure 2). The roots are brewed into a decoction and recommended as a soothing remedy for colic and puerperal fever, and they are also applied as a poultice for epidermal eruptions (Chopra et al., 1986; Verma & Tewari, 2016). In Nepal, its aromatic properties make it valuable in the incense industry, and its root extract is used for fever treatment (Manandhar, 2002). Traditionally, this plant is also employed as an aphrodisiac to enhance libido and sexual vitality (Sekar et al., 2005). In the Jammu and Kashmir region, *J. dolomiaea* is used to treat eye infections, while oil extracted from its roots is applied in the treatment of gout, diarrhea, rheumatism, and stomach ailments. Additionally, it serves as an insect repellent and antiseptic (Kumar et al., 2009; Sharma et al., 2004; Kunwar et al., 2006; Haq et al., 2021). The raw roots of *J. dolomiaea* are used for dental hygiene (Haq et al., 2023a). In some regions, the roots are cooked with maize flour and consumed for the treatment of internal fractures, while root extracts are used as a tonic to aid bone recovery (Ahmad & Habib, 2014).

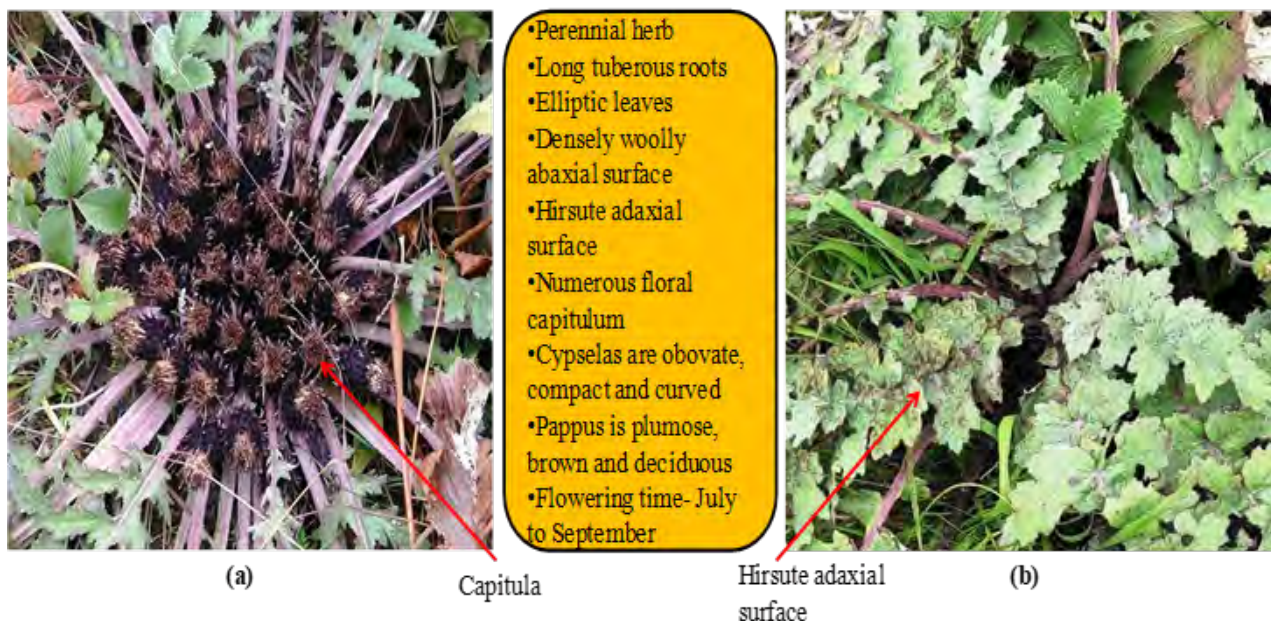


Figure 1. A schematic representation of *Jurinea dolomiaea* taxonomy: (a) Capitula (sessile and shortly peduncled). (b) Leaves are hirsute adaxial and densely woolly beneath.

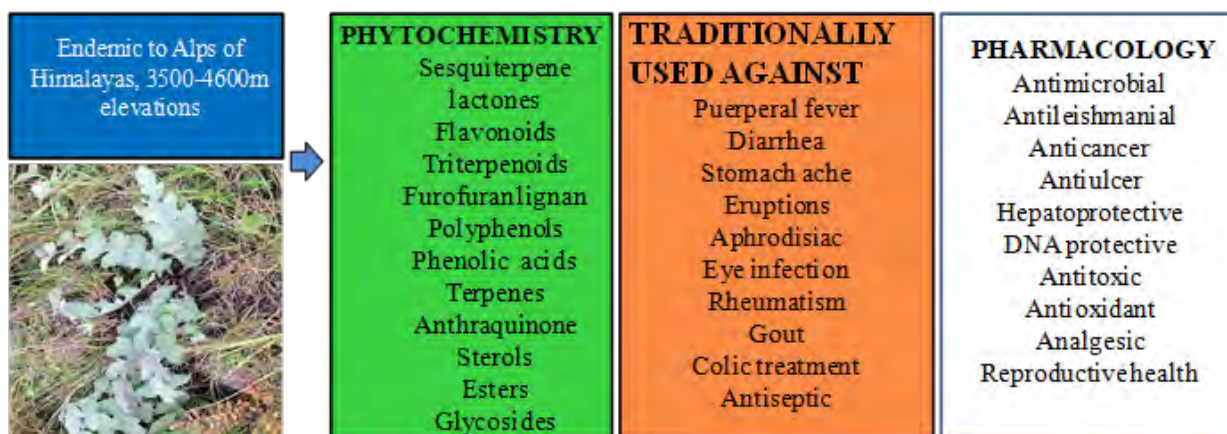


Figure 2. A schematic representation of *Jurinea dolomiaea* distribution, phytochemistry, pharmacology and traditional medicinal uses.

Phytochemistry

Phytochemical investigations of *J. dolomiaea* have identified a diverse range of bioactive compounds present in its roots and aerial parts (AP), including saponins, tannins, flavonoids, glycosides, steroids, phenolic compounds, fixed oils, fats, terpenes, and lignans (Table 3 & Figure 2) (Bhat et al., 2022a; Bhat et al., 2022c; Shah et al., 2014a). Kumar and Agnihotri (2020) isolated several bioactive compounds from the roots, including lupenone, β -sitosterol, physcion, 20, 21 α -epoxytaraxastan-3 β -ol, chlorogenic acid, and ptiloepoxide. Among these, β -sitosterol is a well-known phytosterol with reported anticancer, antidiabetic, hypolipidemic, neuroprotective, and chemopreventive properties (Babu & Jayaraman, 2020). Lupenone, a major compound of *J. dolomiaea*, exhibits therapeutic potential against viral infections, inflammation, diabetes, Chagas disease, and cancer (Xu et al., 2018).

Further research has identified three novel compounds—4-hydroxy pectorolide, pinorelinol monomethyl ether- β -D-glucoside (PMG), and hydroxypectorolide-14-O-acetate—extracted using adsorption chromatography on dichloromethane (DCM) extract. These compounds were tested for cytotoxic activity against human cervical cancer (HeLa) and metastatic breast carcinoma (MDA-MB-231) cell lines, with PMG demonstrating the highest potency against HeLa cells (IC₅₀ = 3.54 μ g/mL) (Atabaki et al., 2021). Gürbüz et al. (2022) identified 12 compounds from the aerial parts of the plant

using chloroform and butanol extraction, including four triterpenes (lupeol, hennadiol, taraxasterol acetate, and lupeol acetate) and eight flavonoids. These flavonoids were assessed for cytotoxicity against A549 lung cancer and MCF-7 breast cancer cell lines and docked against aromatase binding sites, revealing that flavonoids lacking sugar moieties exhibited the highest binding affinities. The pharmacokinetic properties of these flavonoids suggest their potential as promising oral drug candidates for breast cancer treatment.

Pharmacological Activities of *J. dolomiaea* Compounds

Phytochemicals isolated from *J. dolomiaea* exhibit a broad spectrum of pharmacological activities (Table 4). β -sitosterol has been extensively studied for its neuroprotective, chemopreventive, antioxidant, and antidiabetic properties (Babu & Jayaraman, 2020). Khan et al. (2022) further highlighted its hepatoprotective, antioxidant, anti-inflammatory, antimicrobial, cardioprotective, and anticancer effects. Lupenone has demonstrated anticancer, antidiabetic, anti-inflammatory, and antiviral properties (Xu et al., 2018). Physcion has been reported to exhibit antimicrobial, hepatoprotective, anticancer, antiproliferative, laxative, and anti-inflammatory activities (Pang et al., 2016). Chlorogenic acid (CGA) is recognized for its liver-protective, immunomodulatory, anticancer, hypoglycemic, antiviral, antibacterial, anti-inflammatory, and antioxidant properties (Miao & Xiang, 2020). Pentanoic acid (C₅H₁₀O₂) is

primarily utilized for its hepatoprotective effects against cancer (Han et al., 2020).

Pharmacological Activities of *J. dolomiaea*

Pharmacological studies on *J. dolomiaea* have demonstrated its antileishmanial, anti-oxidant, antimalarial, antibacterial, antiulcer, DNA-protective, analgesic, hepatoprotective, and anticancer potential. Additionally, *J. dolomiaea* has applications in reproductive health (Table 5, Figure 2).

Antibacterial Activity

J. dolomiaea extracts prepared using different solvents (methanol, aqueous, ethanol, chloroform, and ethyl acetate) and its silver nanoparticles (AgNPs) have exhibited antibacterial activity against multiple bacterial strains, including *Escherichia coli*, *Staphylococcus aureus*, *Xanthomonas vesicatoria*, and *Ralstonia solanacearum* (Dwivedi et al., 2014; Singh et al., 2015; Riaz et al., 2018). The methanolic extract demonstrated the highest zone of inhibition (ZOI), measuring 9, 10, 12, and 12 mm against *S. aureus*, *E. coli*, *R. solanacearum*, and *X. vesicatoria*, respectively. The chloroform extract (CHCl_3) of *J. dolomiaea* also exhibited significant inhibitory activity, with ZOI values of 4, 8, 4, and 4 mm against the same bacterial strains (Dwivedi et al., 2014). The minimum inhibitory concentration (MIC) for both phytopathogenic and clinical bacteria ranged from 0.25 to 4.0 mg/mL and 0.35 to 4.0 mg/mL, respectively (Dwivedi et al., 2014). Riaz et al. (2018) synthesized AgNPs from the aqueous root extract of *J. dolomiaea* and evaluated their biological activities. The nanoparticles exhibited significant antimicrobial activity against *Pseudomonas aeruginosa* and *E. coli*, with an inhibition zone of 11.0 mm, which was greater than that of the methanolic root extract (8.0 mm).

Antileishmanial Activity

Crude methanolic extract and solvent fractions of varying polarity (n-hexane, chloroform, ethyl acetate, n-butanol, methanol, and water) were evaluated against *Leishmania tropica* promastigotes (KWH23). The ethyl acetate fraction (JDEE) exhibited the highest potency, with an

IC_{50} value of $5.3 \pm 0.2 \mu\text{g/mL}$, in comparison to the crude methanolic extract ($\text{IC}_{50} = 10.9 \pm 1.1 \mu\text{g/mL}$) and the standard drug Glucantime ($\text{IC}_{50} = 5.6 \pm 0.25 \mu\text{g/mL}$) (Shah et al., 2014b). The toxicity of *J. dolomiaea* extracts and their fractions was further assessed using the brine shrimp lethality assay, with all extracts demonstrating toxicity within the safety range ($\text{LC}_{50} > 100 \mu\text{g/mL}$) (Shah et al., 2014b).

DNA Protection Activity

High doses of the water, chloroform, and hexane fractions exhibited DNA protective effects, while the butanol fraction induced DNA degradation instead of protection. In contrast, the methanol and ethyl acetate fractions remained inactive, providing no protection against Fenton reaction-induced DNA degradation (Shah et al., 2014a).

Antioxidant Activity

The antioxidant activity of *J. dolomiaea* root extracts was evaluated in methanolic, n-hexane, chloroform, ethyl acetate, butanol, and aqueous fractions using various in vitro assays. The study assessed total phenolic content (TPC) and total flavonoid content (TFC), revealing that the ethyl acetate fraction (JDEE) had the highest TFC ($807 \pm 7.2 \text{ mg rutin equivalent/g sample}$), while the chloroform extract (JDCE) contained the highest TPC ($757 \pm 9.4 \text{ mg gallic acid equivalent/g sample}$) (Shah et al., 2014a). Riaz et al. (2018) evaluated the total phenolic acid and flavonoid content of methanolic *J. dolomiaea* extract, which demonstrated strong antioxidant potential due to its high phenol and flavonoid concentration. Furthermore, Ahmed et al. (2019) investigated the antioxidant potential of aqueous crude extracts from roots and leaves, along with their AgNPs. The study revealed that *J. dolomiaea* leaf extract and its nanoparticles exhibited higher antioxidant activity compared to the root extract and its nanoparticles.

Antimalarial Activity

The antimalarial activity of ethanol root extract of *J. dolomiaea* was assessed in both in vitro and in vivo models. The extract exhibited moderate activity, with an in vitro IC_{50} value of

65.39 ± 1.22 µg/mL and an in vivo IC₅₀ value of 49.27 ± 1.02 µg/mL (Misra et al., 1991).

Antiulcer Activity

J. dolomiaea demonstrated significant antiulcer activity against ethanol (70%)-induced gastric mucosal injuries in rats. Pretreatment with the aqueous root extract inhibited mucosal damage in a dose-dependent manner (Bhat et al., 2022b).

Anticancer Activity

The anticancer activity of *J. dolomiaea* was evaluated using Ehrlich Ascites Carcinoma cell lines. Root and leaf extracts exhibited significant scavenging activity compared to the standard antioxidant butylated hydroxytoluene (BHT). Goat red blood cells (RBCs) (2%) were agglutinated by *J. dolomiaea* root and leaf extracts at concentrations of 12.5 µg/mL and 50.0 µg/mL, respectively. The extracts demonstrated 53.96 ± 2.34% and 62.54 ± 2.41% cell growth inhibition, while the standard anticancer drug bleomycin exhibited 79.43 ± 1.92% inhibition. Nuclear condensation and fragmentation, indicative of apoptosis, were observed under a fluorescence microscope (Bhat et al., 2022a). Further studies on crude extracts and AgNPs synthesized from *J. dolomiaea* roots and leaves demonstrated potent cytotoxic effects against HeLa cervical cancer cell lines, with a comparatively lower effect on MCF-7 breast cancer cell lines (Ahmed et al., 2019).

Analgesic Effect

Treatment with the aqueous root extract of *J. dolomiaea* significantly inhibited acetic acid-induced writhing in mice. The inhibitory effects followed a dose-dependent pattern (Bhat et al., 2022b).

Hepatoprotective Activity

The hepatoprotective effects of hydroalcoholic root extracts of *J. dolomiaea* were

evaluated against carbon tetrachloride (CCl₄)-induced liver injury by assessing serum glutamate pyruvate transaminase (SGPT), serum glutamate oxaloacetate transaminase (SGOT), and alkaline phosphatase (ALP) levels. A significant reduction in these serum enzyme levels was observed following a seven-day treatment with *J. dolomiaea* extract (Bhat et al., 2022b).

Reproductive Health

Shah and Khan (2017) evaluated the antioxidant effects of *J. dolomiaea* ethyl acetate fraction (JDEE) in mitigating oxidative stress induced by CCl₄ in rat testes. CCl₄ exposure led to a decline in key antioxidant enzymes, including peroxidase (POD), catalase (CAT), superoxide dismutase (SOD), glutathione peroxidase (GPx), glutathione reductase (GR), glutathione-S-transferase (GST), and glutathione (GSH), while increasing nitrite, lipoperoxide (TBARS), and H₂O₂ levels. Additionally, testosterone levels were significantly reduced. Treatment with JDEE in combination with silymarin (200–400 mg/kg) counteracted these toxic effects, enhancing serum testosterone levels and improving primary germ layer thickness in testes (Shah & Khan, 2017).

Conclusion

J. dolomiaea is a valuable medicinal plant of the northwest Himalayan alpine region. Its tuberous roots and leaves have been traditionally used to treat various ailments. Phytochemicals extracted from *J. dolomiaea* have demonstrated therapeutic potential, particularly in antibacterial, antileishmanial, anticancer, hepatoprotective, and antioxidant applications. The enhanced pharmacological activities observed in AgNPs derived from *J. dolomiaea* highlight their potential as antimicrobial and anticancer agents. Further research is warranted to explore its full pharmaceutical potential.

Table 1.

Botanical description of *Jurinea dolomiaea*.

Plant parts	Botanical descriptions	References
Herb	Perennial	Kasana <i>et al.</i> , 2021
Roots	Long tuberous roots	Shah <i>et al.</i> , 2014b
Leaves	Leaves are elliptic, 20–30 cm long with petioles, lobes are pinnatifid and denticulate margins, its leaves are densely wooly, beneath and hairy on the upper surface	Kasana <i>et al.</i> , 2021
Flower (capitulum)	3-15 in number, attached directly to base with or without a stalk Multilayered involucre bracts and purple in color, Flower filaments are smooth; anther bases bear caudate bandages, and lacerate tails, Flowering and fruiting time is July to September	

Table 2.

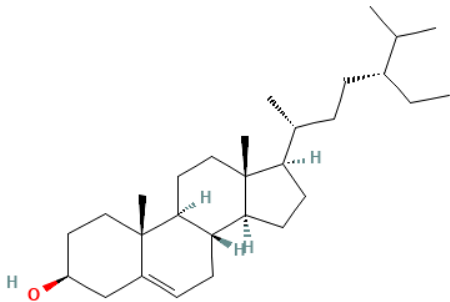
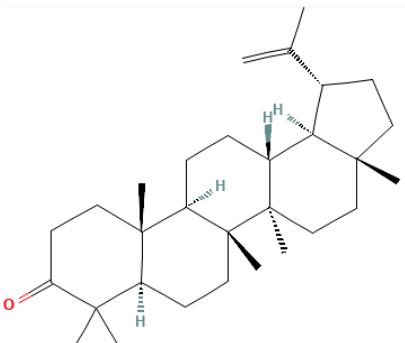
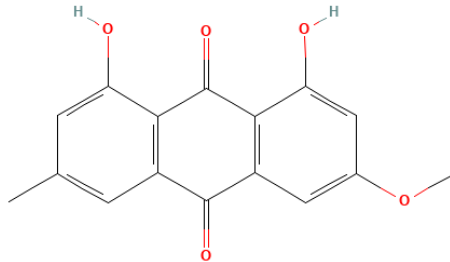
Traditional medicinal uses of *Jurinea dolomiaea*.

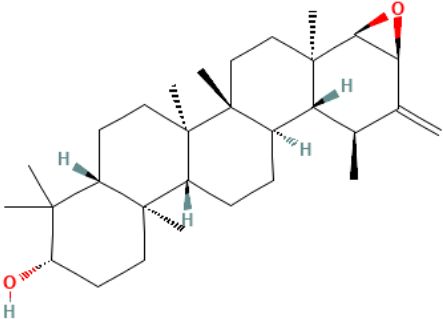
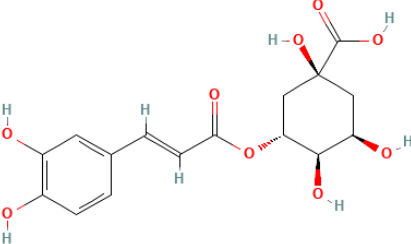
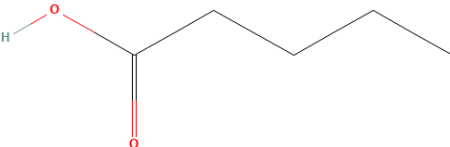
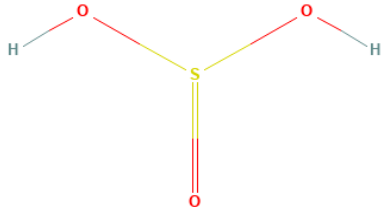
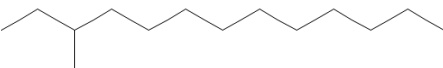
S. No.	Diseases	Part used	Formulations	References
1	Antiseptic	Root and bark	Roots and bark are used as antiseptic	Bisht <i>et al.</i> , 2013; Haq <i>et al.</i> , 2021
2	Arthritis	Root	Roots were boiled and the extract was mixed with ghee and wheat flour to make a halwa that's considered energetic and consumed before bedtime	Lone & Bhardwaj, 2013
3	Aphrodisiac	-	-	Sekar & Srivastava, 2005
4	Body pain	Roots and leaves	-	Ahmed & Akhtar, 2016
5	Breathing trouble	Whole plant	Incense of plant is used to cure breathing trouble	Rawat <i>et al.</i> , 2013
6	Cough, cold and headache	Roots and leaves	Juice of fresh roots given orally, Roots powder tea is consumed	Lone & Bhardwaj, 2013; Lone <i>et al.</i> , 2015; Puri & Saha, 2020
7	Colic	Roots and leaves	Roots decoction was consumed to cure colic, Leaves juice taken orally	Sharma <i>et al.</i> , 2010; Sarver <i>et al.</i> , 2013; Bano <i>et al.</i> , 2014
8	Demon repellent	Roots	Dried roots are burnt to produce smoke	Lone & Bhardwaj, 2013
9	Diabetes/ Sugar	Roots	Powdered roots are taken empty stomach with water	Haq <i>et al.</i> , 2023a
10	Diarrhea	Roots	Root paste consumed during diarrhea	Dovydaitis, 2017
11	Eye infection	-	-	Kumar <i>et al.</i> , 2009
12	Fever/ Fever after child birth	Roots	Stimulant roots were given in fever after child birth Root juice used for fever, Root poultice applied topically on forehead, Roots are considered to be stimulant & used to cure fever	Singh & Rawat, 2011; Lone & Bhardwaj, 2013; Sarver <i>et al.</i> , 2013; Sharma <i>et al.</i> , 2010; Bhat & Gulfishan, 2015; Jain & Khare., 2015; Bano <i>et al.</i> , 2014; Verma & Tewari, 2016

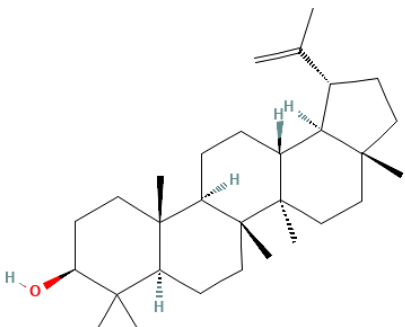
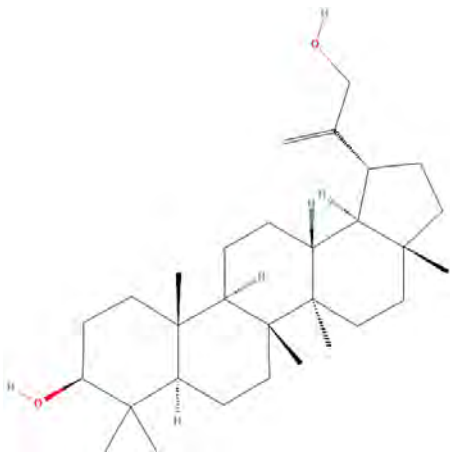
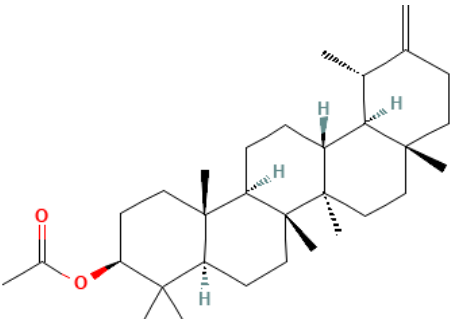
S. No.	Diseases	Part used	Formulations	References
13	Foot & mouth disease	Roots	Juice of fresh Roots given orally	Puri & Saha, 2020
14	Gout & rheumatism	Roots	Leaves and roots are used against rheumatic pains	Singh and Attri, 2014; Ishtiyak & Hussain, 2017; Verma & Tewari, 2016; Surmal <i>et al.</i> , 2021; Haq <i>et al.</i> , 2021
15	Gynic problems	Roots	-	Rana & Rawat, 2019
16	Incense	Roots	Roots are aromatic and used to form a main ingredient of dhoop industry	Manandhar, 2002; Singh & Rawat, 2011; Gupta <i>et al.</i> , 2013; Sarver <i>et al.</i> , 2013; Ishtiyak & Hussain, 2017; Devkota <i>et al.</i> , 2017
17	Nervous convulsion	Roots	Root decoction	Ahmed & Akhtar, 2016
18	Skin diseases, eruptions/ burns	Roots and leaves	Root powder is applied on cuts and skin eruptions, Juice of fresh Roots given orally, Roots powder was mixed with common salt and oil and applied as a paste on wounds for its quick healing and on boils that makes them burst	Ishtiyak & Hussain, 2017; Lone & Bhardwaj, 2013; Bano <i>et al.</i> , 2014; Bhat & Gulfishan, 2015; Lone & Rather, 2020; Abdullah & Andrabi, 2021; Ji <i>et al.</i> , 2023; Haq <i>et al.</i> , 2023b
19	Stomachache	Roots	Root juice is used	Kunwar <i>et al.</i> , 2006; Shah and Khan, 2017
20	Thirst & whitening of tongue	Roots and leaves	Roots powder tea consumed	Lone & Bhardwaj, 2013; Lone <i>et al.</i> , 2015
21	Tooth cleaning	Roots	Raw roots used for tooth cleaning	Haq <i>et al.</i> , 2023a
22	Weakness of bones and Internal fractures	Roots	Roots cooked with maize flour and consumed for internal fractures, Roots extract is consumed as tonic for the recovery of bones weakness	Ahmad & Habib, 2014

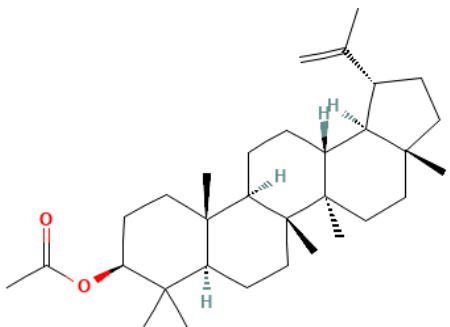
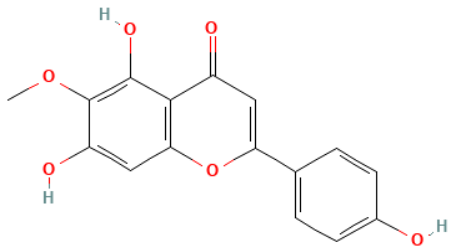
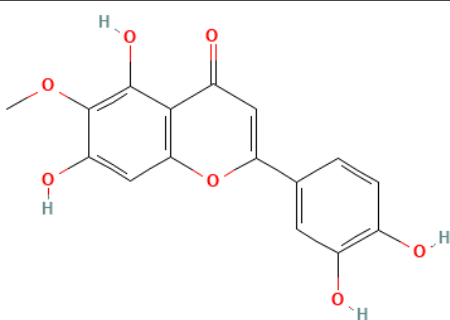
Table 3.

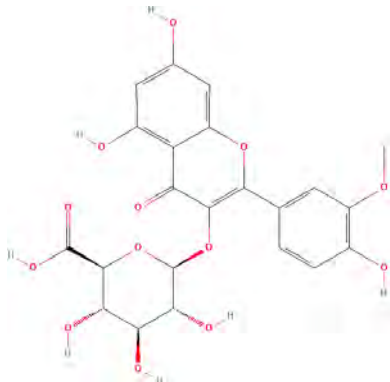
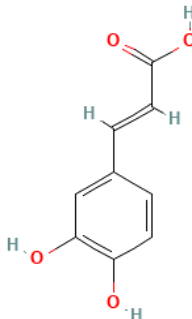
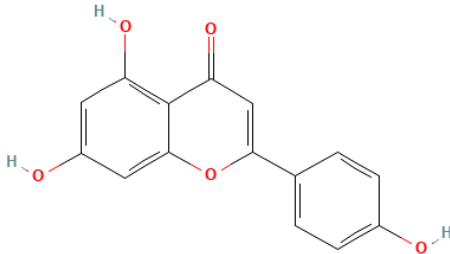
List of phytochemicals and their structures extracted from various parts of *J. dolomiaea*.

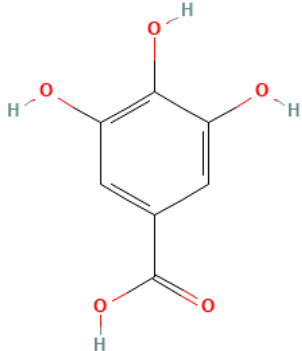
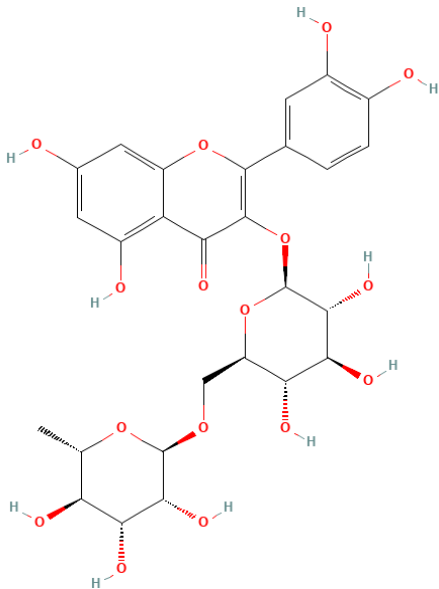
S. No	Compounds	Structures (Pubchem)	Plant part	Class	References
1	β -sitosterol		Root	Phytosterol (C ₂₉ H ₅₀ O)	Kumar & Agnihotri., 2020
2	Lupenone		Root	Terpene (C ₃₀ H ₄₈ O)	Kumar & Agnihotri., 2020
3	Physcion		Root	Anthraquinone (C ₁₆ H ₁₂ O ₅)	Kumar & Agnihotri., 2020

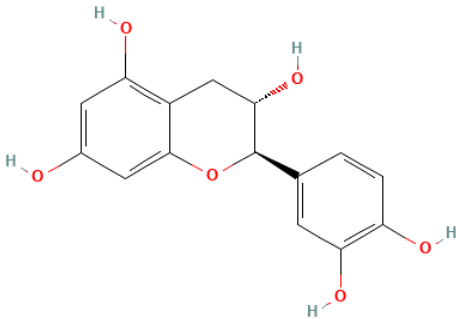
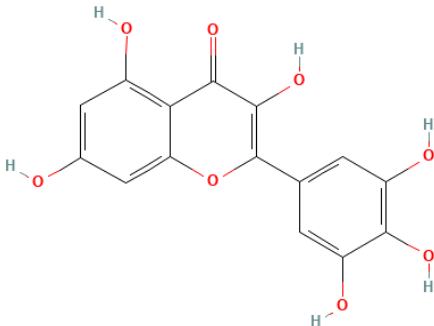
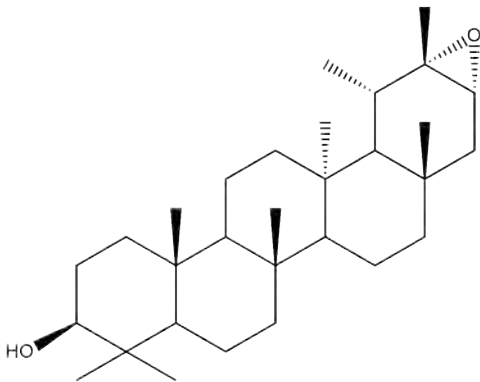
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4	Ptiloepoxide		Root	Ether (C ₃₀ H ₄₈ O ₂)	Kumar & Agnihotri., 2020
5	Chlorogenic acid		Root	Terpene (C ₁₆ H ₁₈ O ₉)	Kumar & Agnihotri., 2020
6	Pentanoic acid		Root	Triterpenoid (C ₅ H ₁₀ O ₂)	Bhat <i>et al.</i> , 2022c
7	Sulfurous acid		Root	Triterpenoid (H ₂ O ₃ S)	Bhat <i>et al.</i> , 2022c
8	Methyltridecane		Root	Triterpenoid (C ₁₄ H ₃₀)	Bhat <i>et al.</i> , 2022c

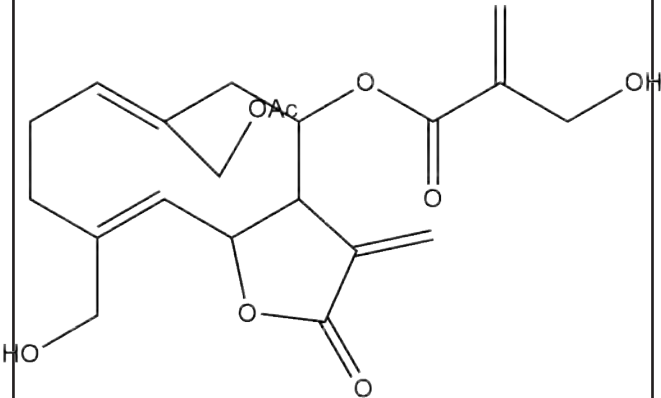
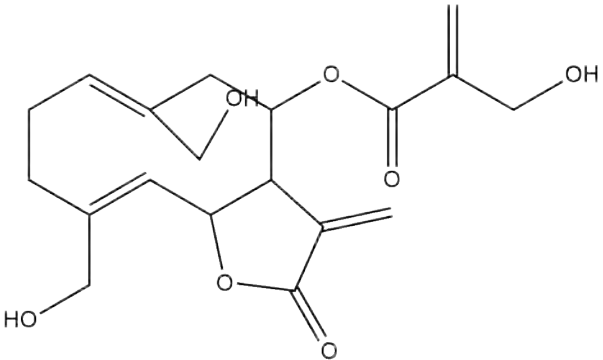
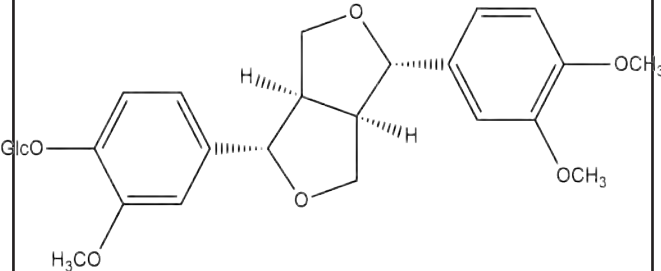
S. No	Compounds	Structures (Pubchem)	Plant part	Class	References
9	Lupeol		Root, AP	Triterpene (C ₃₀ H ₅₀ O)	Gürbüz <i>et al.</i> , 2022; Bhat <i>et al.</i> , 2022c
10	Hennadiol		AP	Triterpene (C ₃₀ H ₅₀ O ₂)	Gürbüz <i>et al.</i> , 2022
11	Taraxasterol acetate		AP	Triterpene (C ₃₂ H ₅₂ O ₂)	Gürbüz <i>et al.</i> , 2022

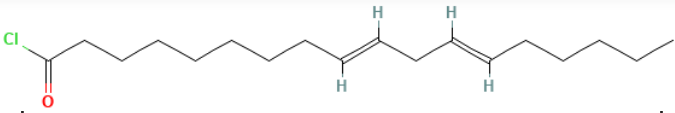
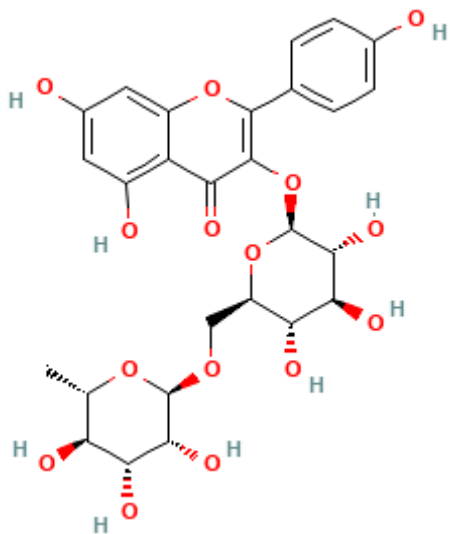
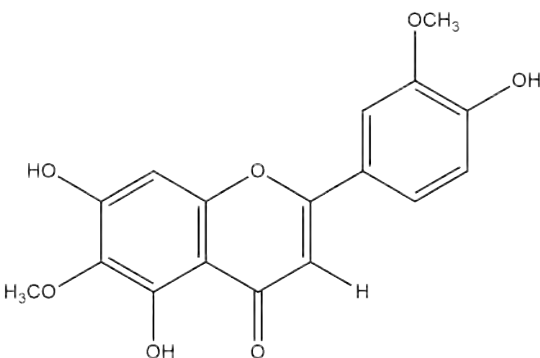
S. No	Compounds	Structures (Pubchem)	Plant part	Class	References
12	Lupeol acetate		AP	Triterpene (C ₃₂ H ₅₂ O ₂)	Gürbüz <i>et al.</i> , 2022
13	6-methoxyapi-genin		AP	Flavonoid (C ₁₆ H ₁₂ O ₆)	Gürbüz <i>et al.</i> , 2022
14	6-methoxylute-olin (Nepetin)		AP	Flavonoid (C ₁₆ H ₁₂ O ₇)	Gürbüz <i>et al.</i> , 2022

S. No	Compounds	Structures (Pubchem)	Plant part	Class	References
15	Isorhamnetin 3-O-glucuronide		AP	Flavonoid (C ₂₂ H ₂₀ O ₁₃)	Gürbüz <i>et al.</i> , 2022
16	Caffeic acid		Root	Phenol (C ₉ H ₈ O ₄)	Shah <i>et al.</i> , 2014b
17	Apigenin		Root, AP	Flavonoid (C ₁₅ H ₁₀ O ₅)	Shah <i>et al.</i> , 2014b; Gürbüz <i>et al.</i> , 2022

S. No	Compounds	Structures (Pubchem)	Plant part	Class	References
18	Gallic acid		Root	Phenolic acid (C ₇ H ₆ O ₅)	Shah <i>et al.</i> , 2014b
19	Rutin		Root	Flavonoid (C ₂₇ H ₃₀ O ₁₆)	Shah <i>et al.</i> , 2014b

S. No	Compounds	Structures (Pubchem)	Plant part	Class	References
20	Catechin		Root	Flavonoid (C ₁₅ H ₁₄ O ₆)	Shah <i>et al.</i> , 2014b
21	Myricetin		Root	Flavonoid (C ₁₅ H ₁₀ O ₈)	Shah <i>et al.</i> , 2014b
22	20,21α-epoxytaraxastan-3β-ol		Root	Terpene (C ₁₆ H ₁₈ O ₉)	Kumar and Agnihotri., 2020

S. No	Compounds	Structures (Pubchem)	Plant part	Class	References
23	Hydroxy-pectorolide-14-o-acetate		AP	Sesquiterpene lactones	Atabaki <i>et al.</i> , 2021
24	4-Hydroxy pectorolide		AP	Sesquiterpene lactone	Atabaki <i>et al.</i> , 2021
25	Pinoresinol monomethyl ether-β-D-glucoside		AP	Furofuran-type lignan	Atabaki <i>et al.</i> , 2021

S. No	Compounds	Structures (Pubchem)	Plant part	Class	References
26	(9E, 12E)-9,12-Octadecadien-oyl chloride (dienylchloride)		Root	Triterpenoid (C ₁₈ H ₃₁ C ₁₀)	Bhat <i>et al.</i> , 2022c
27	Kaempferol-3-O-rutinoside (Nicotiflorin)		AP	Flavonoid (C ₂₇ H ₃₀ O ₁₅)	Gürbüz <i>et al.</i> , 2022
28	6-methoxyluteolin 3'-methyl ether		AP	Flavonoid	Gürbüz <i>et al.</i> , 2022

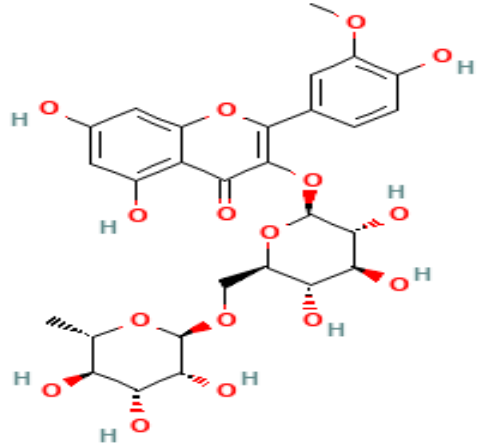
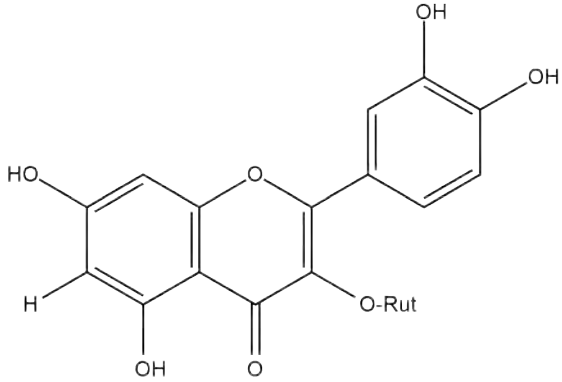
S. No	Compounds	Structures (Pubchem)	Plant part	Class	References
29	Isorhamnetin 3-O-β-rutino- side (Narcissin)		AP	Flavonoid(C ₂₈ H ₃₂ O ₁₆)	Gürbüz <i>et al.</i> , 2022
30	Quercetin 3-O-rutinoside		AP	Flavonoid	Gürbüz <i>et al.</i> , 2022

Table 4.

Biological activities of compounds extracted from *Jurinea dolomiaea*.

Sr. No	Compounds	Biological activities	References
1	β -sitosterol	Analgesic, antinociceptive, anxiolytic & sedative effects, anti-cancer, immunomodulatory, antimicrobial, lipid lowering effect, anti-inflammatory, hepatoprotective, wound healing, protective effect on respiratory diseases, anti-diabetic and antioxidant	Babu and Jayaraman, 2020
2	Lupenone	Liver protection, anti-inflammatory, anti-tumor, anti-Chagas disease, immune regulation and antiviral	Xu <i>et al.</i> , 2018
3	Physcion	Hepatoprotective, laxative, anti-inflammatory, anti-proliferative and anti-microbial	Pang <i>et al.</i> , 2016
4	Chlorogenic acid	Hepatoprotective, antioxidant, anti-diabetic, antimicrobial, anti-carcinogenic, anti-inflammatory, and anti-obesity	Kim and Park, 2019
5	Lupeol	Anticancer, antioxidant, anti-inflammatory, antimicrobial and antiprotozoal	Liu <i>et al.</i> , 2021
6	Taraxasterol acetate	Anti-inflammatory, anti-oxidative, anti-carcinogenic anti-viral, antimicrobial and anti-tubercular	Jiao <i>et al.</i> , 2022
7	Lupeol acetate	Anticancer, antiprotozoal and anti-inflammatory	Gallo <i>et al.</i> , 2009
8	Caffeic acid	Anti-inflammatory antioxidant and anticarcinogenic activity	Espíndola <i>et al.</i> , 2019
9	Apigenin	Muscle relaxing, sedative, antioxidant, anti-inflammatory, anti-amyloidogenic, neuroprotective, cognition-enhancing, anti-alzheimer	Salehi <i>et al.</i> , 2019
10	Gallic acid	Anti-inflammatory, antioxidant, antineoplastic properties, gastrointestinal, metabolic, cardiovascular disorders and neuropsychological activity.	Kahkeshani <i>et al.</i> , 2019
11	Rutin	Antioxidative, antimicrobial, antifungal, anti-allergic, antioxidant, antihypertensive and neuroprotective	Abdullah Al-Dhabi <i>et al.</i> , 2015
12	Catechin	Anti-diabetic, anti-inflammatory, anti-cancer, bactericidal, neuroprotective, memory enhancer, hepato-protective and anti-arthritis	Baranwal <i>et al.</i> , 2022
13	Myricetin	Anti-oxidant, anticancer, anti-inflammatory, analgesic, antitumor, hepatoprotective and antidiabetic	Semwal <i>et al.</i> , 2016
14	Pinoresinol Monomethyl Ether- β -D-Glucoside	Anticancer	Atabaki <i>et al.</i> , 2021
15	Kaempferol-3-O-rutinoside	Central nervous system (CNS) prevention, anticarcinogenic, anti-inflammatory, antifungal, antibacterial, antiprotozoal	Ma <i>et al.</i> , 2017; Periferakis <i>et al.</i> , 2022

Table 5.

Pharmacological activities of *Jurinea dolomiaea*

Part used	Extraction solvents	Pharmacological activities	Details	References
Leaves	Aqueous, MeOH, EtOH, ETAC and chloroform	Antibacterial activity (Zone of inhibition)	<i>E. coli</i> (10 mm Methanol, 8 mm chloroform)	Dwivedi <i>et al.</i> , 2014; Singh <i>et al.</i> , 2015; Riaz <i>et al.</i> , 2018
			<i>S. aureus</i> , (9 mm Methanol, 4 mm chloroform)	
			<i>X. vesicatoria</i> , (12 mm Methanol, 4 mm chloroform)	
			<i>R. solanacearum</i> , (12 mm Methanol, 4 mm chloroform).	
			Silver nanoparticles (inhibition zone of 11 mm) against <i>P. aeruginosa</i> and <i>E. coli</i>	
			Methanol extract (12 mm & 15 mm) against <i>S. aureus</i> and <i>E. coli</i> .	
			Ethyl acetate extract (10 mm & 13 mm) against <i>S. aureus</i> and <i>E. coli</i> respectively.	
			Both the extracts did not show any activity against <i>S. typhirium</i> and <i>K. pneumoniae</i> .	
		Antibacterial activity (Minimum inhibitory concentration)	MIC- <i>X. vesicatoria</i> , <i>R. solanacearum</i> - 0.25 to 4.0 mg/mL and <i>E. coli</i> , <i>S. aureus</i> - 0.35 to 4.0 mg/mL.	
Roots	Methanol, chloroform, n-hexane, ethyl acetate, water and n-butanol	Antileishmanial activity (IC ₅₀)	IC ₅₀ = 5.3 ± 0.2 µg/mL (Ethyl acetate fraction)	Shah <i>et al.</i> , 2014b
			IC ₅₀ value of 5.6 ± 0.25 µg/mL (Standard drug Glucantime)	
			R2 value: 0.81 to 0.91 IC50 = 10.9 ± 1.1 µg/mL (Methanol extract)	

Part used	Extraction solvents	Pharmaceutical activities	Details	References
Roots	Methanol, n-hexane, chloroform, ethyl-acetate, butanol and aqueous	Antioxidant activity	Ethyl acetate showed best fraction with IC ₅₀ (41.1 ± 1.0 µg/mL) via DPPH (RSA)	Shah <i>et al.</i> , 2014a; Riaz <i>et al.</i> , 2018; Singh <i>et al.</i> , 2015
			IC ₅₀ (42.2 ± 0.9 µg/mL) via Hydrogen peroxide (SA)	
			IC ₅₀ (3.3 ± 0.4 µg/mL) via Hydroxyl (RSA)	
			IC ₅₀ (46.7 ± 0.6 µg/mL) via ABTS (RSA),	
			Methanol-extract showed high antioxidant potency IC ₅₀ (0.494 µg/mL)	
		Anti lipid peroxidation activity	Ethyl acetate with IC ₅₀ (54.3 ± 1.6 µg/mL)	
			Ethyl acetate, butanol with IC ₅₀ (82.8 ± 0.6; 86.5 ± 1.1 µg/mL) respectively via β-carotene bleaching activity	
			Chloroform with IC ₅₀ (91.7 ± 1.3 µg/mL) via Superoxide anion (RSA)	
			Chloroform with IC ₅₀ (92.0 ± 1.0 µg/mL) via Nitric oxide (RSA)	
Roots	Ethanol	Antimalarial activity	Ethanol extract <i>in-vitro</i> IC ₅₀ (65.39±1.22 µg/mL)	Misra <i>et al.</i> , 1991
			Ethanol extract <i>in-vivo</i> IC ₅₀ (49.27±1.02 µg/mL)	
Root and leaf	Water	Anticancer activity	MIC: 12.5 µg/mL in root	Ahmed <i>et al.</i> , 2019; Bhat <i>et al.</i> , 2022a
			MIC: 50.0 µg/mL in leaf	
			Cell growth inhibition: 62.54±2.41% in leaf	
			Cell growth inhibition: 53.96±2.34% in root	
			Standard drug (Bleomycin) growth inhibition: 79.43±1.92%	
			Cervical cancer cell lines (HeLa) and breast cancer cell lines (MCF-7) with an IC ₅₀ value of 55±0.51µg/mL	
Root	Methanol, chloroform, n-hexan, ethyl acetate, aqueous and n-butanol	DNA protection activities	Chloroform+water+hexane fractions showed DNA protection only at high concentrations	Shah <i>et al.</i> , 2014a
			High dose of butanol showed degrading effect on plasmid DNA	

Part used	Extraction solvents	Pharmaceutical activities	Details	References
Root	Methanol, chloroform, n-hexan, ethyl acetate, water and n-butanol	Antitoxic activities	Methanol extract moderate toxicity LC_{50} : $733.0 \pm 15.1 \mu\text{g/mL}$	Shah <i>et al.</i> , 2014b
			Ethyl acetate fraction higher toxicity	
			Water fraction lowest toxicity	
			R ² : 0.92 to 1.0.	
Root	Water	Antiulcer activity	Exhibited in dose dependent pattern	Bhat <i>et al.</i> , 2022b
			Effects of the water extract of root at the dose of 50, 100 and 200 mg/kg with inhibitions of 67.7, 61.1 and 77.8% respectively	
			Doses of water extract of root were statistically significant ($p < 0.005$)	
			Famotidine also significantly reduced ethanol-induced gastric lesions for 34.4%.	
Root	Water	Analgesic effect	Exhibited in dose-dependent pattern	Bhat <i>et al.</i> , 2022b
			Inhibitory effects of WER at the dose of 50, 100 and 200 mg/kg with 62.1, 70.4 and 89.2% respectively.	
			Metamizol also significantly ($p < 0.01$) reduced acetic acid-induced writhing with 39.4%.	
Root	Hydroalcoholic	Hepato-protective activity	100 and 200 mg/kg of hydroalcoholic roots extract significantly reduced elevated marker enzymes (SGOT, SGPT, ALP) and total bilirubin levels induced by CCl_4	Bhat <i>et al.</i> , 2022b
Root	Ethyl acetate	Reproductive health	CCl_4 diminished the levels of POD, CAT, SOD, GST, GPx, GSH, GR and enhanced the levels of (TBARS), nitrite and H_2O_2 in (testes) sample of male rats	Shah & Khan, 2017
			JDEE altered (histopathological) changes induced by CCl_4 and inhibited CCl_4 induced toxicity in rats.	
			JDEE increased (GSH) level in testes and the quantity of testosterone in serum samples. It also increased the thickness of germinal layers in testes dose dependently.	

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EFFECT OF KINETIN-GRAPHENE OXIDE NANOENSEMBLE ON THE DEVELOPMENT AND ANTIOXIDANT SYSTEM OF COTTON

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Abstract. *The application of nanotechnology in agriculture is gaining increasing significance. The use of graphene oxide (GO)-based nanoensembles as stabilizers of functional groups or plant growth inducers, such as phytohormones, represents a promising direction for further research. This study aimed to conduct a comparative analysis and examine the effects of a GO-based nanoensemble with the phytohormone kinetin on the morphophysiological and biochemical parameters of *Gossypium hirsutum* L. Agdash-3 cultivar seedlings. Morphophysiological analysis revealed that treatment with kinetin + GO stimulated seed germination and increased stem length compared to the control and free kinetin treatment. Biochemical studies demonstrated an increase in polyphenol oxidase activity, the concentration of photosynthetic pigments (chlorophyll a and carotenoids), as well as proline content in leaf tissues upon nanoensemble treatment. In contrast, root length, catalase and guaiacol peroxidase activity, along with chlorophyll b and proline concentrations in roots, remained at levels comparable to those observed with kinetin alone, suggesting no additional effect of GO on these parameters.*

The obtained results indicate a synergistic effect of GO in combination with kinetin on specific morphophysiological and biochemical characteristics of cotton seedlings, highlighting potential avenues for further research.

Keywords: upland cotton, kinetin+ graphene oxide, nanotechnology, antioxidant system

Introduction

Cotton is a strategic agricultural crop that plays a key role in the economy not only Azerbaijan, but the whole world. In our country

cotton production is a traditional sector that contributes to regional development and employment while also serving as an important export commodity. This crop serves as a primary

raw material for the textile industry, and its by-products are widely utilized in the food, paper and other industries (Akin, 2024). Cottonseed oil ranks fourth in global vegetable oil production, while its fibers are increasingly valued due to the rising demand for natural materials (Özertan, 2014).

Cotton production faces numerous challenges that impact its development and sustainability. These challenges range from environmental stresses to economic and technological barriers. Climate change has intensified abiotic stresses like drought, which severely affect all plants, including cotton yield and fiber quality by disrupting photosynthesis and carbohydrate metabolism (Ul-Allah et al., 2021; Abdiyev & Jafarzade, 2024; Amrahov et al., 2023)). Additionally, poor soil health, water scarcity, and unpredictable weather patterns further threaten sustainable cotton production (Ghaffar et al., 2020).

Nanotechnology, as one of the most advanced and promising scientific fields, opens new avenues for research in biotechnology and agriculture (Wang et al., 2016; Shang et al., 2019; Hasanova et al., 2022)). In recent years, nanomaterials such as graphene oxide (GO) have been increasingly utilized for the efficient delivery of nutrients and agrochemicals to plants. These materials exhibit unique physicochemical properties, including a high specific surface area (approximately 2620 m²/g), exceptional resistance to chemical and thermal degradation, and an excellent capacity to adsorb micronutrients and agrochemicals (Zhang et al., 2020; Costa et al., 2021"ISSN":"0013-936X, 1520-5851","issue":"6","journalAbbreviation":"Environ.Sci.Technol.,"language":"en","license":"https://doi.org/10.15223/policy-029","page":"3181-3190","source":"DOI.org (Crossref). GO can be employed to transport various substances, including phytohormones, thereby enhancing nutrient availability to plants and minimizing losses caused by leaching, photolysis, and hydrolysis (He et al., 2018).

One such phytohormone is kinetin, a natural cytokinin that plays a crucial role in regulating plant growth, enhancing stress tolerance,

and stimulating antioxidant activity. Kinetin is widely used to promote cell division, improve seed germination, and increase plant resistance to various abiotic stresses (Koprna et al., 2016). However, its effectiveness is largely dependent on application conditions, such as concentration and the method of delivery to plants. The use of kinetin in combination with graphene oxide could offers new opportunities for improving plant growth, enhancing stress resistance, and increasing the efficiency of agricultural production.

This research aimed at an investigation of the effects of a newly synthesized kinetin-graphene oxide complex on the development and immune system components of the most significant species of cotton plant (*Gossypium hirsutum*), which accounts for 99% of the our country's production.

Materials and Methods

The experiments were carried out on cotton genotype, *Gossypium hirsutum* L. Agdash-3. The seeds of the plant were pre-treated with 0.3% potassium permanganate for 5 minutes, then were planted in 7 cm plastic cups containing perlite. The seedlings were grown in a phytotron (Taisite, GZX-300 E) at a temperature of 24–26 °C, a humidity of 65–75%, and a light intensity of 4800 lux. The day/night regime was 14/10 hours, respectively.

Graphene oxide nanolayers are synthesized by the modified Hummer method (Taghiyeva et al., 2024). For the synthesis of the kinetin-graphene oxide nanoensemble, 0.05 g of graphene oxide (GO) was taken and sonicated in 10 ml of glacial acetic acid for 15 minutes. Subsequently, 0.2 g of 6-furfurylaminopurine (kinetin), dissolved in 20 ml of glacial acetic acid, was slowly added to the GO dispersion, and the mixture was subjected to stirring for 1 day. The resulting solid mixture was filtered, washed with acetic acid, then with distilled water, and left to dry at room temperature. For use on plants, both compounds were first dissolved in 10 ml of ethanol at a concentration of 96 % and after ultrasonication were added to the

Steiner hydroponic solution, used as a nutrient medium. The kinetin (10 μ M) and kinetin-GO (10 μ M) were added during the entire period of growth, starting from the first days of seedling formation. Five-week-old plants were used for analyses.

Determination of enzymatic activity. Catalase activity was determined by the MOSHEVA gasometric method (Mosheva, 1982). First, 0.5 g of plant material was measured, which was homogenized with the gradual addition of 0.5 g of CaCO_3 and 20 ml of distilled water. Subsequently, the extract was transferred to a Landolt vessel (Erlenmeyer flask) with a neck on the side and catalase activity was measured. To start the reaction, 5 ml of 3% H_2O_2 was added to the extract and during the reaction, a Landolt vessel was stirred on a magnetic stirrer. The measurement was carried out after 3 minutes. The amount of oxygen released was read on the burette scale. The enzyme activity was expressed in ml/second/g (fresh sample).

The activity of **guaiacol peroxidase (GPX, EC 1.11.1.7)** was determined according to Chance and Maehly (Chance & Maehly, 1955). The reaction mixture contained 0.1 M Na-phosphate buffer, pH 7.2, 1mM EDTA, 30mM H_2O_2 , 50mM guaiacol, and 50 μ l of enzyme extract in the final volume of 1 ml. The formation of tetraguaiacol was detected at 440 nm. The concentration of tetraguaiacol was calculated using the extinction coefficient of tetraguaiacol (26.6mM⁻¹ cm⁻¹). GPX activity was expressed as $\Delta\text{A}590/\text{min}/\text{g}$ fresh weight.

Polyphenol oxidase (PPO) activity has been determined by the modified method Sharma (Sharma et al., 1994) and Ermakov (Ermakov et al., 1987). The PPO enzyme extract was prepared by the modified method as in the procedures described by Sharma (Sharma et al., 2001). One gram of cotton cotyledons, together with 5 ml of 100 mM phosphate buffer (pH 7.3) containing 10 mM of sodium ascorbate were homogenized in a cold mortar, filtered through four layers of gauze and centrifuged at 3,000 x g for 20 min. The final supernatant volume of the extract was made up to 25 ml with phosphate

buffer (pH 7.3) and was then centrifuged again at 15,000 x g for 20 min. The supernatant was used as an enzyme source. Polyphenol oxidase (PPO, EC 1.10.3.1) activity was determined by measuring the oxidation of 0.05 M catechol at 590 nm in 0.1 M potassium phosphate buffer (pH 7.2). Activity of enzyme were expressed as enzyme $\Delta\text{A}590 \text{ g}^{-1} \text{ min}^{-1}$.

Chlorophyll a, b and carotenoid content determination. The analysis and calculation of the concentration of chlorophyll a, b and carotenoids were carried out using the Wellburn method (Wellburn & Lichtenthaler, 1984). 1 gram of leaf tissue was taken, cut into small pieces and homogenized in a mortar in 20 ml of 80% acetone. Then the homogenate was passed through an F-grade filter paper and the optical density was measured in the resulting filtrate at wavelengths of 440, 644 and 662 nm. The results obtained were presented in mg/g of fresh sample.

Proline content determination. The amount of proline was measured by thin layer chromatography (NLX), which was based on the modified method proposed by Boctor et al. (Boctor, 1971). By using the ImageJ program, densitometric indicators of the proline-isatin complex as shown in the figure were obtained. The densitometric results were graphed and statistically analyzed using the Excel program.

Statistical analysis. The adsorption experiments were performed in triplicate and data was reported as mean $\pm$ SD. The regression coefficients (R^2) values of isotherms and kinetics models were calculated using statistical functions of Microsoft Excel (version Office 7, Microsoft Corporation, USA).

Results

The effect of a kinetin and kinetin-graphene oxide nanoensemble on the germination and development of cotton seedlings have been presented in Figure 1 and in table 1.

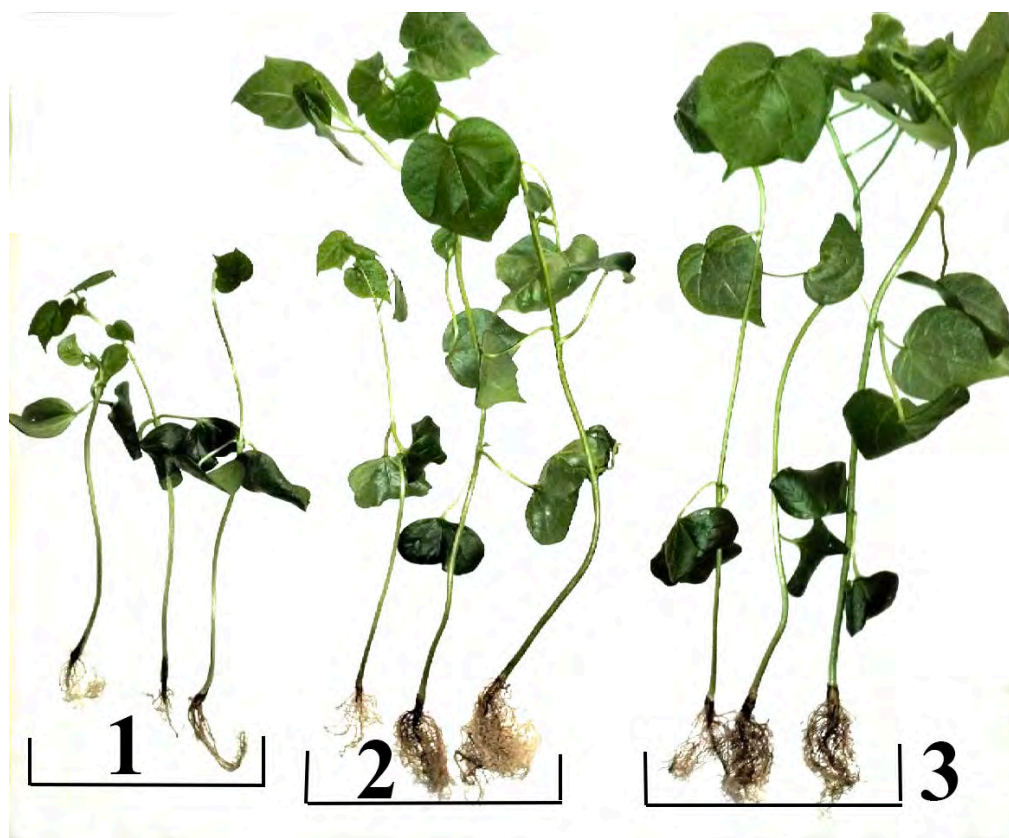


Figure 1. The development of 5 weeks-old of Agdash-3 cotton genotype under the influence of kinetin and kinetin-GO nanoensemble. 1. Control. 2. Kinetin-10 µM. 3. 10 µM kinetin-GO nanoensemble.

Table 1

**Germination percentage, root, and stem lengths of the *Gossypium hirsutum* L.
Agdash-3 variety exposed to kinetin and kinetin + graphene oxide**

Samples	Number of seedlings (total number of seeds - 60)	Germination percentage, %	Stem length (sm)	Root length (sm)
Agdash-3 - Control	48	80,0	22,5±2,01	7,17±0,62
Agdash-3 - 10 µM kinetin	47	78,3	38,3±0,94	6,4±0,46
Agdash-3 - 10 µM kinetin +GO	56	93,3	39,43±1,63	5,3±0,51

Kinetin had a slight negative impact on seed germination but its combination with graphene oxide increased the germination ability of seeds by 13.3 % compared to control group. So, kinetin-GO nanoensemble had an inductive effect on the germination process in Agdash-3 cotton genotype.

Both kinetin and kinetin-GO nanoensemble significantly increased the stem development of cotton seedlings. In the case of kinetin, the

increase of stem growth (relative to the length of the stem) was 1.70 times, while kinetin-GO complex induce stem length 1.75 times greater than in control samples. But the situation was different regarding development the main root length. Under the influence of both kinetin and nanoensemble, a decrease in root length was observed, although the development of lateral roots was stimulated to a greater extent than in control seedlings (Figure 1). Thus, the kinetin

nanoensemble with graphene oxide significantly enhances the germination capacity and stem length of Agdash-3 cotton genotype seeds.

Catalase is one of the important antioxidant enzymes that breaks down hydrogen peroxide into water and oxygen and plays an important role in cell detoxification by removing its excess. Both kinetin and kinetin-GO nanoensemble slightly induced catalase activity in the true leaves of *Gossypium hirsutum* Agdash-3

genotype compared to the control group (Figure 2). The difference between the experimental variants was insignificant. Apparently, kinetin and kinetin-GO nanoensemble do not significantly affect the catalase component of the protective system of *Gossypium hirsutum* cotton seedlings Agdash-3.

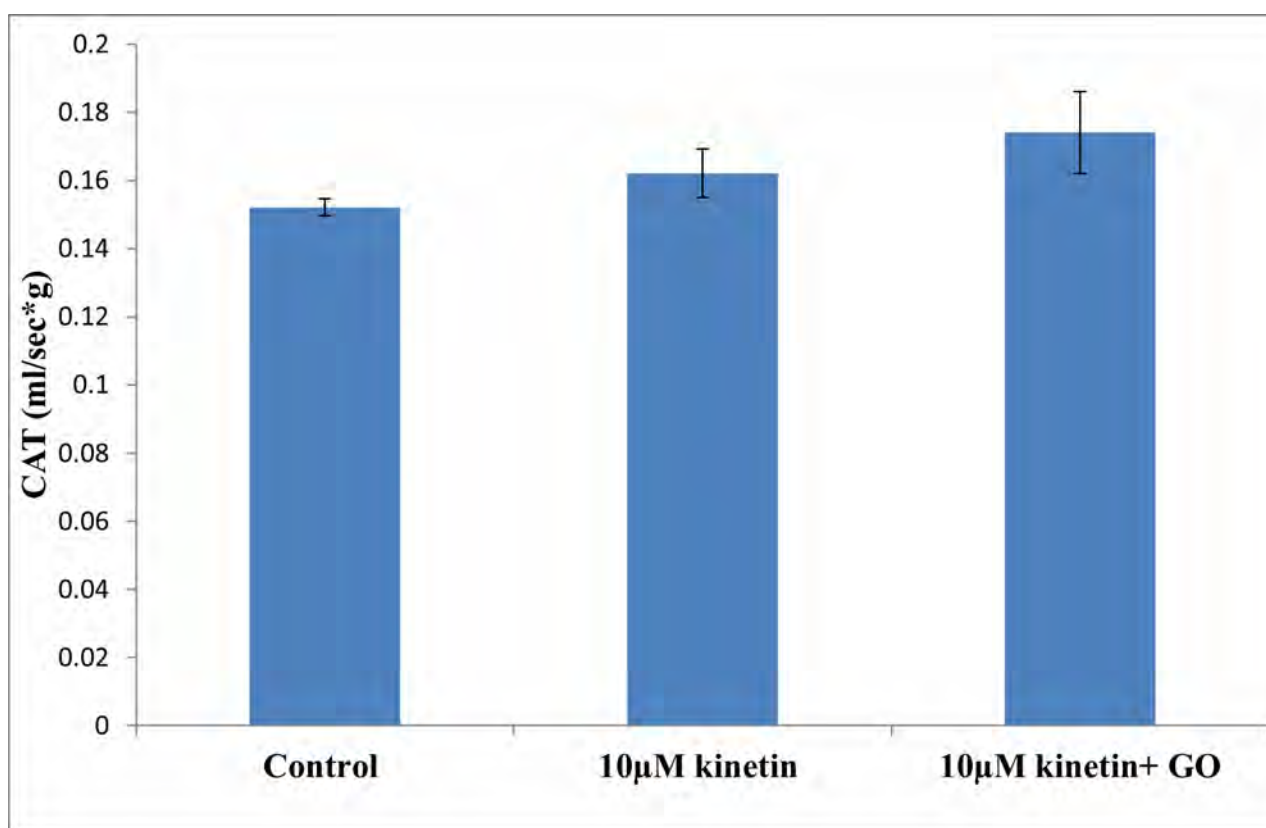


Figure 2. Catalase activity in the true leaves of *Gossypium hirsutum* Agdash-3 genotype treated by inductive concentration of kinetin and kinetin-GO nanoensemble.

The treatment of cotton seedlings with kinetin phytohormone lead to a negligible increase in GPX activity compared to the control (Figure 3). Approximately, the same stimulatory effect on the enzyme was observed during the application of the kinetin-graphene oxide

nanoensemble 8,5 % for former and 11% for latter results respectively. These data demonstrated that both kinetin and kinetin-graphene oxide nanoensemble exerted a stimulatory effect on this enzymatic component of antioxidant system of cotton plants.

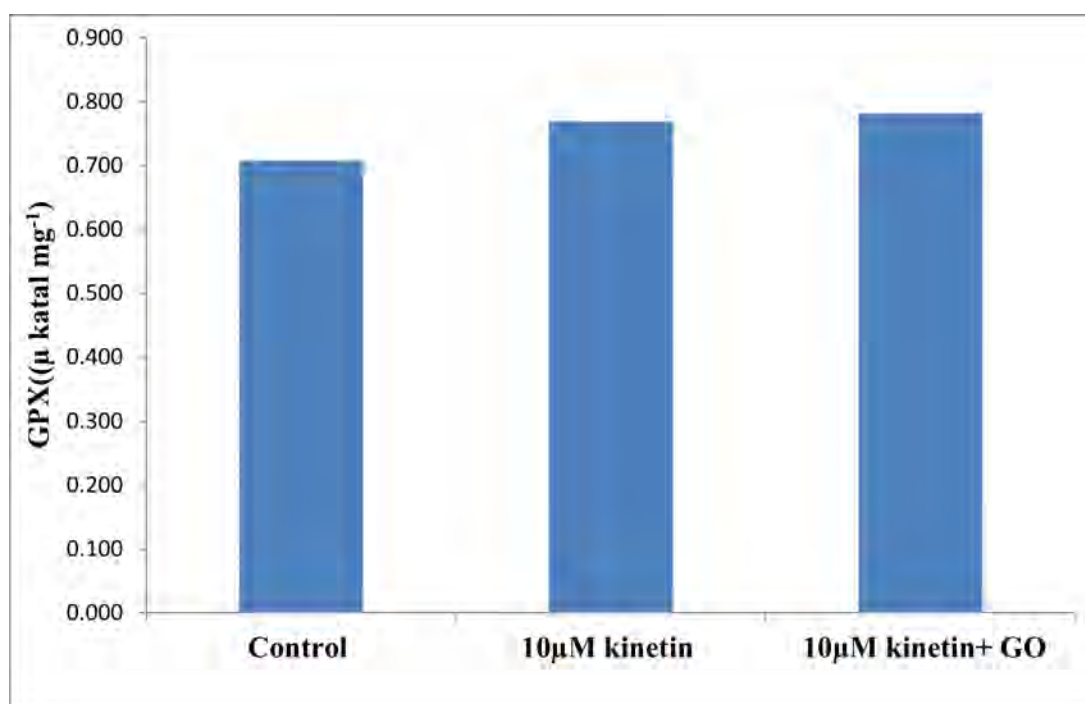


Figure 3. Guaiacol Peroxidase (GPX) activity in the true leaves of *Gossypium hirsutum* L. Agdash-3 genotype treated by inductive concentrations of kinetin and kinetin-GO nanoensemble.

The effect of kinetin and kinetin-GO nanoensemble on PPO activity of Agdash-3 cotton genotype was presented in Figure 4. Low concentration of kinetin caused a slight inhibitory effect in enzyme activity compared to the control group, while kinetin-GO nanoensemble had

no significant effect on PPO activity in compare with control. This results likely suggested that graphene oxide neutralizes the inhibitory effect of kinetin or stabilizes enzymatic activity at the control level.

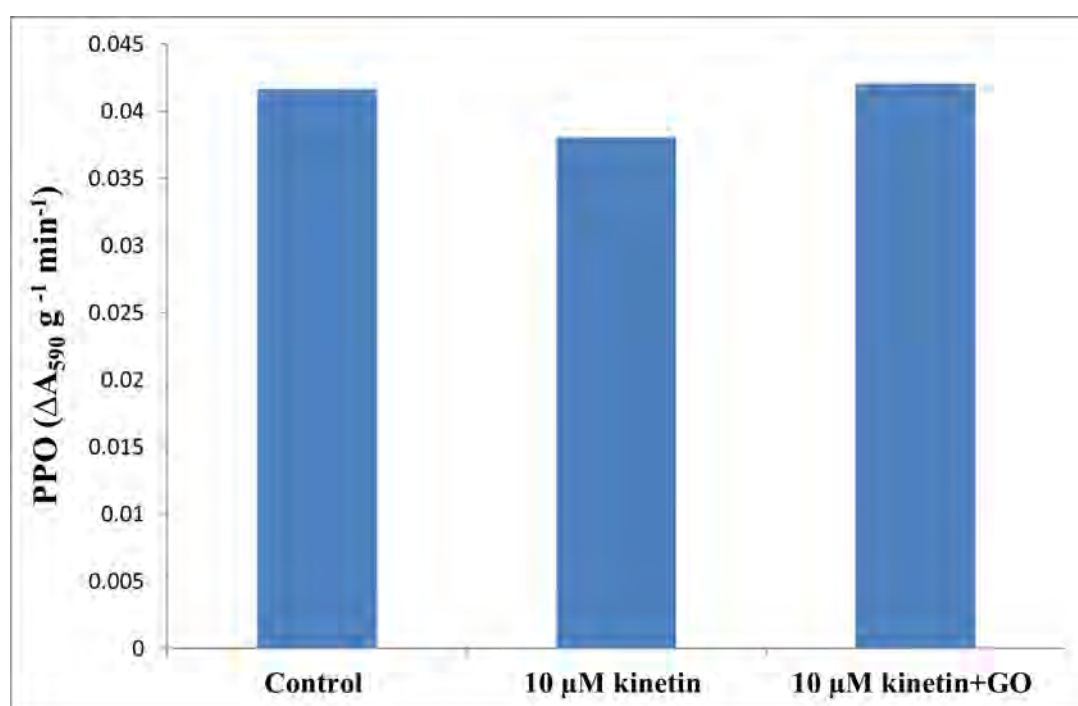


Figure 4. Polyphenol oxidase (PPO) activity in the true leaves of *Gossypium hirsutum* L. Agdash-3 genotype treated by inductive concentrations of kinetin and kinetin+GO nanoensemble

The analyses demonstrated that in the kinetin-treated samples, the amounts of chlorophyll a and chlorophyll b significantly increased compared to the control group — by 21% and 60%, respectively. These results suggest that kinetin has a stimulatory effect on the plant's photosynthetic apparatus, which manifests in the enhanced synthesis of key photosynthetic pigments. But the amount of carotenoids decreased by 10%, indicating that kinetin may have a differential effect on the pigment composition (Figure 5). The addition of kinetin-GO nanoensemble further increased the amount of

chlorophyll a by 36% and carotenoids by 13%. These results suggest that the combined effect of kinetin and GO leads to enhanced synthesis of chlorophyll a and carotenoids, while kinetin alone primarily stimulates the synthesis of chlorophyll a and b. These observations highlight the potential use of nanoensembles for regulating the photosynthetic activity of plants and underscore the need for further research to clarify the interaction mechanisms.

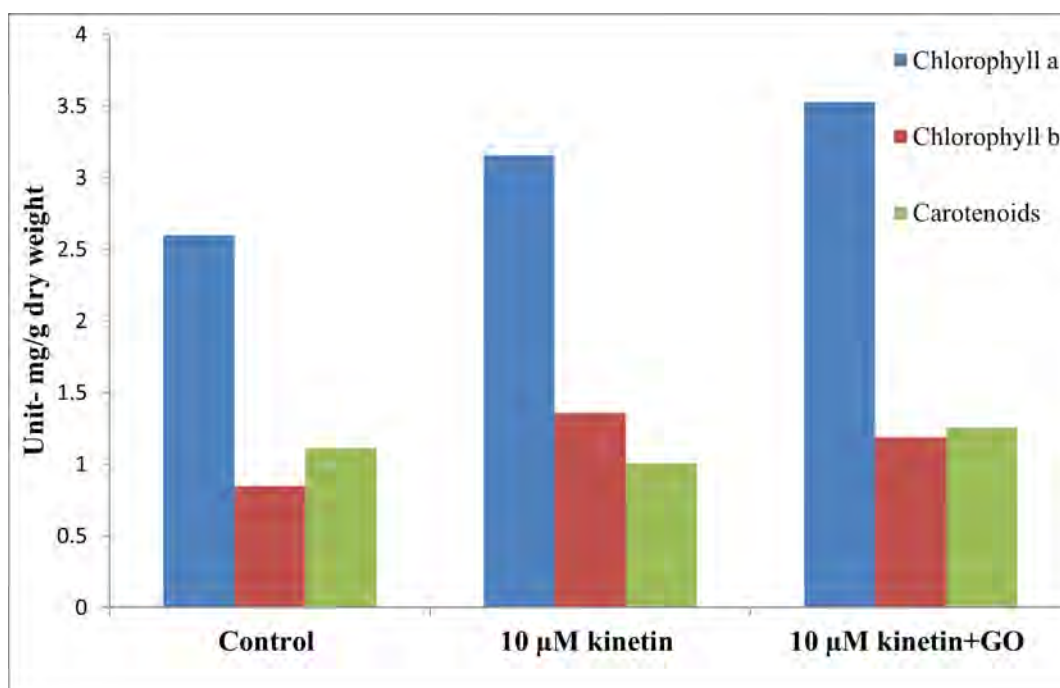


Figure 5. The effect of kinetin and kinetin-GO nanoensemble on the content of chlorophyll a, b, and carotenoids in the true leaves of *Gossypium hirsutum* L. Agdash-3 genotype.

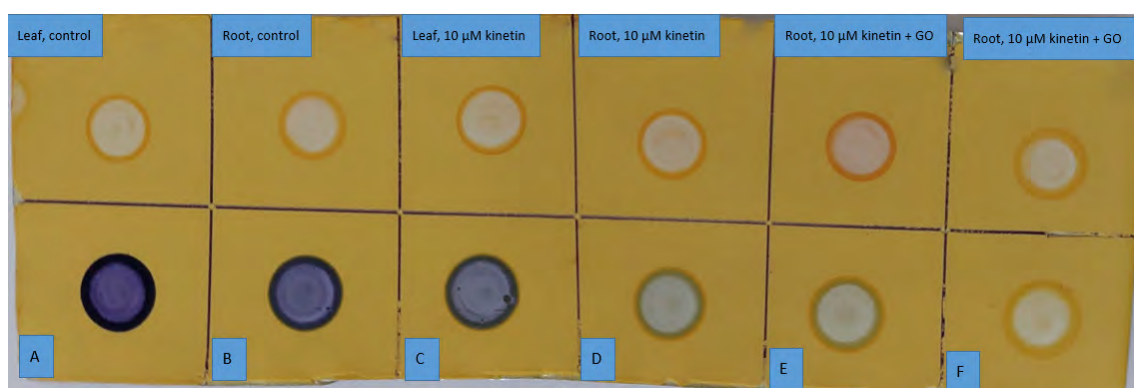


Figure 6. Proline analysis in *Gossypium hirsutum* Agdash-3 genotype exposed to inductive concentrations of kinetin and kinetin-GO nanoensemble in layer chromatography. Top line (left to right): Leaf, control; root, control; leaf, 10 µM kinetin; root, 10 µM kinetin; leaf, 10 µM kinetin-GO; root, 10 µM kinetin-GO. Bottom line (left to right): A, B, C, D, E, F - Control variants of proline in different concentrations (A-10 mM, B-2 mM, C-1 mM, D-0.2 mM, E-0.1 mM, F-0.02 mM).

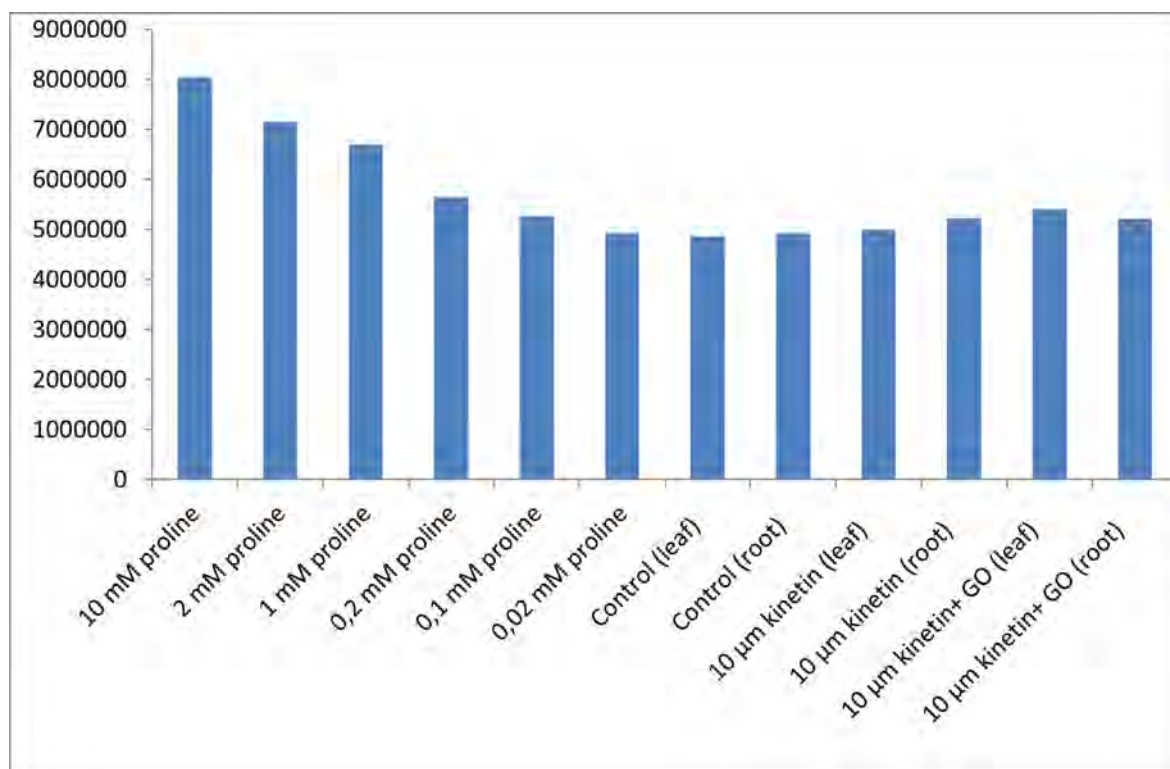


Figure 7. Results of densitometric analysis of proline determination in leaf and root samples of *Gossypium hirsutum* Agdash-3 genotype exposed to inductive concentrations of kinetin and kinetin+GO nanoensemble using ImageJ software.

The analysis results indicate that proline concentration significantly varies depending on the experimental conditions. In both the kinetin and kinetin+graphene oxide nanoensemble-treated experimental groups, an increase in proline concentration was observed in both root and leaf extracts.

In root extracts, proline levels increased similarly in both experimental groups, reaching similar values approximately 0.02-0.1 mM proline after treatment with either pure kinetin or its nanostructured derivative. This suggests that both treatment variants exert similar effects on proline synthesis in the root tissue.

In the case of leaf extracts, proline concentration increased in both the kinetin-treated group and the kinetin+graphene oxide-treated group. However, the addition of graphene oxide further enhanced proline synthesis, surpassing the values obtained in the kinetin-only treated group. These results suggest that graphene oxide may exert an additional stimulatory effect on proline synthesis.

Thus, the results indicate that kinetin and

its graphene oxide nanoensemble stimulate the synthesis of proline amino acid, which is indicative of its clear osmotic protective function. The increase in proline concentration in the graphene oxide variant is likely related to the direct effect of this nanoparticle on proline biosynthesis or its potential to partially stimulate osmotic stress.

Discussion

Kinetin, being a cytokinin, is a phytohormone known for its impact on various aspects of plant growth and development, including seed germination. Research conducted on *Arabidopsis* demonstrated significant growth and development of plants under the influence of cytokinins (Bozsó & Barna, 2021). It is interesting to note that in our studies, no seed germination induction was observed from free kinetin. Although earlier studies reported an inductive effect of kinetin on seed germination of the Egyptian cotton (*Gossypium barbadense*) at a concentration of 5 mg/L (Sawan et al., 2000). Despite the absence of an effect on seed germination, kinetin showed high activity in stem

growth, which was also observed in previous cotton research (Kassem et al., 2009).

Recently, nanoassemblies have shown significant influence in plant development, as evidenced by the use of carbon nanotubes, graphene, or graphene oxide (Fernández-Gómez et al., 2023). In our study, it was recorded that a nanoensemble based on graphene oxide, non-covalently bonded with kinetin, not only induced stem growth (likely related to the effect of kinetin in this compound) but also accelerated seed germination (by 13.3 %), which was a novel finding for this type of research.

The antioxidant system of plants protects cells from damage caused by stress, a condition in which reactive oxygen species (ROS), such as superoxide anion, hydrogen peroxide, and hydroxyl radicals, accumulate in cells. These compounds can damage lipids, proteins and DNA, disrupting cellular processes. The coordination between increased antioxidant enzyme activity and oxidative stress at the early stages of stressor exposure may have a direct correlation, related to the genetic regulation of these processes, as well as the redox homeostasis of the cell (Das et al., 2015). Kinetin at higher concentrations can provoke an increase in catalase activity, which ultimately leads to a reduction in cotton pest infestation (Al-Nuaimi & Ahmed, 2023). Modified graphene oxide can also induce catalase activity, as demonstrated in rice seedlings (Zhang et al., 2020"ISSN": "0013-936X, 1520-5851", "issue": "6", "journalAbbreviation": "Environ.Sci.Technol.", "language": "en", "license": "https://doi.org/10.15223/policy-029", "page": "3181-3190", "source": "DOI.org (Crossref). In our study, both kinetin and the kinetin-graphene oxide nanoensemble slightly enhanced catalase activity, which may suggest a possible synergistic effect of this nanoensemble on the antioxidant system.

Given that peroxidases, along with catalase, is involved in the antioxidant defense of cells, it was important to understand how activity of these enzymes was regulated in the presence of the nanoensemble. In our study, we found that the activity of guaiacol peroxidase undergone a slight stimulation and the effect of kinetin and its nanoensemble was identical. This effect may

be related to the inducing effect of low kinetin concentrations on the enzyme, as was shown in earlier researches with cotton plant (Lee, 1974). It should be noted that no additional effect of graphene oxide on the activity of this enzyme was found in our experiment, which may indicate the inertness of this nanocompound and the absence of any additional oxidative stress.

Polyphenols play a crucial role in plant defense system by forming more toxic compounds for pathogens, such as quinones, thanks to the catalytic activity of the PPO. In our study, neither the individual effect of kinetin nor its complex with graphene oxide induced PPO activity, which may indicated the absence of an effect of these compounds on this component of the defense system of *Gossypium hirsutum* Agdash-3 genotype cotton.

Chlorophyll *a* and *b*, being key components of photosynthesis, provide plants with organic compounds, which serve as the primary energy and carbon skeleton sources for plant cells. The increase in chlorophyll *a* content under the individual action of kinetin and the additional stimulus by its combination with GO may serve as evidence of enhanced photosynthetic processes. At the same time, the increase in carotenoids in the presence of kinetin-GO may indicate the strengthening of photoprotective reactions and antioxidant defense within the plastids (Bassi & Caffarri, 2000). Early studies with kinetin also indicated that this phytohormone could maintain a high level of chlorophylls and carotenoids in experiments with leaf discs, highlighting the role of the phytohormone in preserving pigments (Caspar & Xhaufflaire, 1968).

Proline serves as an indicator of abiotic stress conditions in plants, but it also plays a role in protective functions, such as antioxidant and osmoregulatory mechanisms in plant defense. The study showed that although kinetin at low concentration did not induce proline synthesis, the kinetin-GO nanoensemble stimulated the accumulation of proline in leaf tissue, which could be an indicator of enhanced protective responses in this tissue. Moreover, this proline concentration was not detrimental to the plant, as no negative morphophysiological changes were observed in the plants.

Conclusion

Summarizing the obtained results, it can be concluded that the GO + kinetin nanoensemble exerts a stimulatory effect on stem length, as well as on components of the photosynthetic apparatus and quinone synthesis. These findings provide a basis for an optimistic outlook

regarding the potential application of this nanoensemble in cotton cultivation.

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POTENTIAL STATUS OF PERSIMMON (*DIOSPYROS KAKI* L.) IN AZERBAIJAN

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Abstract. *Persimmon (Diospyros kaki) is a significant subtropical fruit crop extensively cultivated in Diospyros kaki (Oriental persimmon) is extensively cultivated in Azerbaijan, particularly in the Balakan, Zagatala, Sheki, and Gakh regions. Meanwhile, the native Diospyros lotus (Caucasian persimmon) thrives at elevations of 700–1200 m, predominantly in humid microhabitats near riverbanks, shaded slopes, and human settlements. As a subtropical crop, persimmon cultivation demands specific climatic and edaphic conditions. The establishment of the Balkhoorma processing facility in 2017 has significantly enhanced the persimmon industry, facilitating large-scale drying and export, primarily to Russia and European markets. Owing to its high sugar content, persimmon serves as a key raw material for dried fruit products, molasses, and bakery applications. Additionally, its bioactive compounds contribute to its pharmaceutical and nutraceutical significance. This study underscores Azerbaijan's growing role in global persimmon production, the economic impact of its export sector, and the necessity of adopting sustainable cultivation and post-harvest technologies to optimize fruit quality and market value.*

Keywords: *Diospyros kaki, Diospyros lotus, persimmon cultivation, Azerbaijan, export economy, post-harvest processing, Balkhoorma.*

Introduction

Persimmon belongs to the genus *Diospyros* (family Ebenaceae). Around 400 species grow in ecological conditions ranging from tropical to more temperate climates. The species *Diospyros lotus*, *Diospyros virginiana*, and *Diospyros oleifera* have been used as rootstocks in several countries. These species are also utilized in medicine, pharmacy, and the cosmetic industry as a source of tannins. *Diospyros kaki*, which originated in China and is the only commercial species, includes cultivars whose fruits are consumed fresh or processed (Besada et al., 2010). Oriental persimmon (*Diospyros kaki*) occupies a special place among subtropical fruit crops, being a global industrial crop. Oriental persimmon and other species of the genus *Diospyros* are valuable ornamental and most frost-resistant plants among all subtropical fruit crops

(Huseynov & Bakhshaliyeva, 2023; Ortiz et al., 2006; Pang et al., 2007).

Persimmon was introduced into the Mediterranean region by the end of the 19th century, first as an ornamental tree, and it was also appreciated for the quality of its wood. As a fruit tree, it was grown as isolated trees in gardens, family orchards, or in small plantings, and their fruits were locally consumed (Perucho, 2015; Mammadova, 2022, 2021, 2012). The species spreads along the Mediterranean coast and coexists with citrus, fig, and olive trees (Salvador et al., 2007). Despite the origin of *D. kaki* from the regions of East Asia, the modern area of cultivation covers almost all tropical and subtropical regions of the Earth.

The skin color of fruit varies according to cultivar, from light yellow-orange to dark orange-red. The color of the flesh also differs

among cultivars, as some persimmon cultivars depict a much richer orange-colored flesh upon commercial harvest than others. The pulp, consisting of a dense cellular structure, may have large almond-shaped seeds in the inner part of all approximately light-colored carpels, but the fruits develop parthenocarpically. The calyx is a green four-lobed structure surrounding the stem-end of the fruit. Gas exchange in persimmon fruits depends on the calyx, since there are no stomata or lenticels on the surface of the fruit, which are covered with a waxy cuticle (Woolf & Ben-Arie, 2011).

Persimmon fruit is a climacteric fruit, meaning that it is highly sensitive to exogenous ethylene and induces ripening through autocatalytic ethylene production when exposed to exogenous ethylene. They produce small but significant amounts of ethylene during ripening (Wills et al., 1998; Zheng et al., 2005). In the last decade, several molecular studies have demonstrated the involvement of the ethylene biosynthetic pathway and signal transduction in persimmon fruit ripening (Ortiz et al., 2006; Pang et al., 2007).

The external skin color of this fruit is the index currently used as the nondestructive index for harvesting persimmons. The color evolution displayed by persimmon cultivars comes from immature fruit that has a homogenous green skin to fruit with its characteristic orange or orange-reddish tones in the commercial maturity stage. The color changes that occur during the maturation process run in parallel to gradual flesh firmness loss. This softening of the fruit is associated with microstructural changes in the pulp. As the parenchyma matures, it gradually degrades, less swollen and more deformed cells are observed, and cell walls and membranes are destroyed (Salvador et al., 2007).

Thus, according to the FAO, the leading positions in the production of persimmons in the world are occupied by Asian countries—88.9% (5.1 million tons); Europe—7.9% (0.46 million tons); America—3.2% (0.18 million tons); Oceania—0.1% (0.03 million tons) (FAO, 2023). Nowadays, Spain, Azerbaijan, Italy, Uzbekistan, and Israel are the main Mediterranean producer countries, and Spain is the country with

the largest and most rapidly expanding crop. Regarding Azerbaijan and Uzbekistan, production is based mainly on local astringent varieties that are exported mostly to Russia. An estimated 200,000 tonnes of persimmon are exported to the Russian market every year from former Soviet countries.

Today in Azerbaijan, the persimmon-growing area is concentrated in the Balakan, Zagatala, Sheki, and Gakh regions. Eastern persimmon (*Diospyros kaki*) ranks first among plants growing in the Sheki-Zagatala region (Azizov et al., 2020). Up to 40% of sugar is collected from this plant in dried fruits, and molasses, dried products, and alcoholic beverages are made from its fruits. Dried fruits are crushed and added to flour in baking sweet bread (Asmy & Fitri, 2021).

Traditionally, most varieties were bred in China, Japan, and Korea. However, breeding work is also underway in Russia, Turkey, Spain, etc. Worldwide persimmon production is approximately 3 million metric tons. China, Korea, and Japan account for 90% of total production; minor producers include Italy, Israel, Turkey, New Zealand, and Spain. In Turkey, the major production areas are the Mediterranean, Black Sea, and Aegean regions, where total production has reached 18,000 metric tons, about 80% of which comes from the Mediterranean region (Celil et al., 2009).

In some Asian cultures, consumers are aware of the health claims associated with persimmons and their functional ingredients. The rich phytochemical composition of persimmon has opened up new opportunities for research in the field of dietary regimens for the treatment of various diseases. The health-promoting potential of persimmon includes its effectiveness against free radical formation, hypercholesterolemia, diabetes mellitus, cancer, skin diseases, hypertension, etc. This review is an attempt to elucidate the phytochemistry of persimmon and the importance of its bioactive molecules in the treatment of various diseases.

World selection of persimmons is aimed at obtaining new varieties with different periods of vegetation and flowering, lack of astringency in fruits, and their increased keeping quality, quality (with a high content of biologically active

substances), and yield. Breeding is also underway for resistance to biotic and abiotic environmental factors, optimal plant habit, and others. One of the important economically valuable traits in persimmon breeding is the lack of fruit astringency. Oriental persimmon (*Diospyros kaki*) fruits are round, dark red, yellow, or bluish black, waxy, with yellow, edible peel. Seeds are thinly sheathed, with a very hard endosperm; the embryo is flat or wedge-shaped and slightly curved (Gunduz et al., 2020).

The fruit should be eaten after it is fully ripe. In folk medicine, an alcoholic infusion of persimmon fruit is used to treat the thyroid gland; *bekmez* made from its fruit is used as a tonic for weakness, as a stimulant for diseases of the nervous system, as a means to suppress appetite, as a depressant for hypertension, as an anti-edema agent, and as a coughing agent in case of bronchitis. Fresh and dried persimmons are an important food product, high in sugars, as well as glucose and fructose as an energy source.

Important parameters for determining the quality of fresh and dried persimmons are the total dry matter content and moisture content, respectively. It is worth noting that total solids are important in the dewatering process. Most of the dry matter consists of simple sugars, mainly glucose and fructose, which are most represented in persimmon fruits. Persimmon is not widely distributed in Azerbaijan, and reproduction occurs generatively.

Materials and Methods

This study employed a combination of theoretical and statistical methods to ensure the accuracy and reliability of the findings. Theoretical approaches included **analysis, synthesis, and generalization**, which were used for refining theoretical and practical conclusions, as well as systematizing the results.

For statistical data processing, the following methods and software tools were utilized:

F-Fisher Test (ANOVA): Applied to assess the statistical significance of differences between multiple data sets.

Pearson's Chi-Squared Test: Used to determine the significance of differences in empirical

frequency distributions.

Microsoft Office Excel 2016 (Microsoft Corporation): Utilized for data organization, computation, and graphical representation (Serikova, 2019).

Results and Discussion

Persimmon is the most widely produced fruit in Balakan, with an annual yield of approximately 15,000 tons. The establishment of a modern processing facility has significantly addressed market challenges, ensuring the production of high-quality packaged products for both domestic and international markets. Contracts have been secured with several European countries, facilitating large-scale exports. The processing facility, which has a weekly production capacity of 20 tons, is equipped with automated technical systems that comply with international food safety standards. The persimmons used in this facility are sourced from private orchards, ensuring hygienic and ecologically clean production. Additionally, a cold storage complex with a capacity of 2,000 tons enables long-term storage, securing a steady supply of raw materials for the enterprise (Interfood, 2018).

The "Balkhoorma" enterprise has obtained the ISO 22000 international food safety certification, granting it access to global markets. International laboratory certifications further support its competitiveness in the global food industry (AzAgroInvest, 2021). The company has collaborated with international partners to develop dehydration technology for persimmon fruits, producing two types of dried products: semi-dried and fully dried khoorma. The enterprise has also introduced advanced packaging solutions, such as doypacks for dried persimmons and VIP boxes for semi-dried fruits, to meet market demands. These innovations have positioned Balkhoorma as a leading exporter of 100% Azerbaijani-grown persimmons (Figure 1).

Among Azerbaijan's economic regions, the Sheki-Zagatala zone holds a prominent place in persimmon production. In 2021, the Balakan district alone produced 15,680 tons of persimmons, marking an increase of 460 tons

compared to the previous year. The average yield per hectare was 205.1 quintals, reflecting an upward trend in persimmon cultivation due to its high export potential (APA, 2023).

In 2021, an additional 2 hectares of persimmon orchards were established in Balakan, bringing the total cultivated area to 764.5 hectares, of which 723.1 hectares are productive orchards (UNECE, 2023). Over the years, the Balkhoorma enterprise, a privately funded facility dedicated to dried persimmon production, has

expanded its operations. With an annual processing capacity of 2,000 tons, the enterprise primarily sources its fruit from local private farms, ensuring a steady supply of high-quality produce. The fully hygienic and ecologically clean persimmon products are sold domestically and exported internationally, strengthening Azerbaijan's position in the global persimmon trade (FAO, 2022).



Figure 1. Balkhoorma enterprise. Working process.

Once harvested, persimmon fruits must be handled with extreme care to prevent bruising, which can lead to unsightly marks as the fruit ripens. They should be placed in shallow containers with smooth or soft sides to minimize staining, as persimmons are particularly prone to discoloration. Special attention is required for pointed-topped varieties, such as Hachiya, to prevent them from damaging adjacent fruits.

Marketing standards necessitate polishing, grading, and packaging before distribution. While persimmons can be hand-polished with a cloth, this process is typically automated, using soft roller brushes in packaging lines. Unlike

some other fruits, persimmons are not waxed, making proper maintenance of roller brushes essential to preserve the fruit's natural wax coating. After polishing, persimmons are sorted by size and packaged manually, usually in single-layer trays.

Bruising during processing has a direct impact on persimmon quality and shelf life, leading to a faster loss of firmness, increased weight loss, and darkening of the skin under refrigeration (Lee et al., 2005; Valentini et al., 2009). Therefore, it is crucial to minimize fruit dropping during handling and reduce height transitions in processing lines. Foam rubber and other

protective materials should be used to cushion impacts, as persimmons are highly sensitive to mechanical damage.

Azerbaijan's non-oil exports in October 2023 saw a 15.4% increase, reaching 278.2 million USD (APA, 2023). Food product exports accounted for 90.6 million USD (a 24.1% increase), while non-food products contributed 187.7 million USD (an 11.6% rise). Among non-oil export

commodities, persimmons led with a 29.5 million USD export value, followed by electricity (17.7 million USD) and gold (16.9 million USD).

In October 2023, the Russian Federation emerged as the top importer of Azerbaijan's non-oil exports, purchasing 94.1 million USD worth of goods. Turkey ranked second (44.1 million USD), while Georgia stood third (26 million USD) (AzAgroInvest, 2021).

Table 1

Balkhoorma export list (2017-2025) of Oriental persimmon (*Diospyros kaki*) common in Sheki-Zagatala economic region

Season	Quantity (kg)	Amount (AZN)	Average price (AZN)
2017-2021	413.832	3.828.377	9,25
2021-2022	286.043	3.378.595	11,81
2022-2023	503.130	5.692.192	11,31
2023-2024	317.382	4.057.918	12,79

If you pay attention to the results presented in Table 1, you can see that the amount and price varies by years. In the list of export products from January to February 2022, persimmon products were the third product, with 27.9 US dollars in value. It should be noted that this number shows a nearly two-fold increase compared to the total value of persimmon exported in the corresponding period of 2020

Conclusions

Persimmon production plays a crucial role in Azerbaijan's non-oil export sector, contributing significantly to the country's agricultural economy due to its high profitability and strong export potential. The peak marketing season for fresh persimmons extends from September to December, during which demand in both domestic and international markets is at its highest.

However, yield fluctuations remain a key challenge in persimmon cultivation. Variations in annual fruit production are often linked to

inadequate pruning and thinning practices, which impact tree health and fruit quality. Implementing proper orchard management techniques, including regular pruning, thinning, and soil fertility management, is essential for ensuring consistent yields, improved fruit quality, and enhanced market competitiveness.

Future efforts should focus on sustainable cultivation practices, post-harvest handling improvements, and expanding export markets to further strengthen Azerbaijan's position in the global persimmon industry.

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**MORPHOLOGICAL, PALYNOLOGICAL AND ECOLOGICAL STUDIES OF MEDICINAL, ENDEMIC
GENTIANA BOISSIERI SCHOTT. KOTSCHY EX BOISS. (TURKIYE)**

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Abstract. *Gentiana boissieri* Schott. Kotschy ex Boiss. is an species local endemic with a narrow distribution to Turkey. The morphological, palynological and ecological properties of this species were investigated. When morphological measurements of investigated species are compared with Flora of Turkey, the some differences have determined. Eventually, full description of these species was given. Pollen morphology of *Gentiana boissieri* was studied using light microscopy (LM), scanning microscopy (SEM). The shape of the pollen grains was oblate-spheroidal. The apertures were 3-zonocolporate. Porus shape was oblate-spheroidal to spheroidal. The sculptural pattern of exine was striate-reticulate. Muri were usually thick long running parallel to the colpus, lumen usually deep, irregular in shape. In this study it was analysed that the plant prefers clayey textured soil, poor in calcium carbonate, being neutral and containing varying amounts of organic matter being very rich in nitrogen. This species grows on nonsaline soils.

Keywords: Ecology, Endemic, *Gentiana boissieri*, Morphology, Pollen

Introduction

The genus *Gentiana* L. is naturally distributed almost all over the World except for North Africa, Eastern Australia and low altitude tropical regions (Pringle, 2014). *Gentiana*, which is native to Asia, later spread to North America, Siberia, Anatolia and the Caucasus. This distribution eventually spread naturally in northern regions, especially in high-altitude areas (Kohlein, 1991).

In the Flora of Turkey, the *Gentiana* is represented by 12 species and 14 taxa (*G. aquatica* L., *G. asclepiadea* L., *G. boissieri* Schott Et Kotschy Ex Boiss., *G. brachyphylla* Vill. Subsp. *favratii* (Rittener) Tutin, *G. cruciata* L., *G. gelida* Bieb., *G. lutea* L. subsp. *lutea* L., *G. lutea* L. subsp. *symphyandra* (Murb.) Hayek, *G. nivalis* L., *G. olivieri* L., *G. pyrenaica* L., *G. septemfida* Pallas, *G. verna* L. subsp. *balcanica* Pritchard, *G. verna* L. subsp. *pontica* (Soltok.) Hayek). Of

these taxa, *G. nivalis* and *G. aquatica* are annual and the other taxa are perennial herbaceous. Among these 14 taxa distributed in Turkey, *G. boissieri* is the only taxon that is endemic. It is naturally distributed only in the Bolkar Mountains of Niğde in the World. *G. boissieri* was first collected by Aucher from Eastern Anatolia and later by Sintenis from Erzincan, Kuruçay and Hasanova in 1899 (Pritchard, 1978).

Due to their strong medicinal value, there are more pharmacological and chemical studies on *Gentiana* species (Hayashi&Yamagishi, 1988, Bachheti et al. 2022, Huang et al., 2023). However, there are also studies on pollen (Halbritter&Berger, 2018, Nilsson, 1967, 2002, Yankova et al., 2010), seed (Davitashvili&Karrer, 2006, 2010, Ömer& Quaser, 1995; Alçitepe et al., 2017) and, to a lesser extent, on its ecology (Akhan et al., 1999, Adams&Thompson, 2017, Razmjoue et al., 2015). In Turkey, different taxa

belonging to the genus *Gentiana* are named as; censiyan, cintiyane, cityane, cimdiyen, enzian, arap dede, güşad otu etc. (Öztürk, 1997, Akan et al., 1999).

With this study, it was aimed to reveal the morphological, previously unknown ecological and pollen characters of endemic *G. boissieri* in detail.

Materials and methods:

The area where *G. boissieri* naturally spreads: C5: NiğDE, Bolkar Mountain, Karagöl surroundings, alpine clearings, 2650 m., 16.08.2013.

Morphological measurements are given comparatively with Flora of Turkey (Pritchard, 1978). For LM, Pollen grains were prepared according to the acetolysis method as described by Erdtman (1960) and the terminology follows Erdtman (1969), and Faegri&Iversen (1964). For SEM, it was analyzed by covering them with golden. A JSM 5600 microscope was used to capture images at Selcuk University Advanced Technology Research and Application Centre. The morphological measurements of pollen grains based on 30 readings are given in Table 1. After air drying the soil samples taken from 0-20 cm depth, pH, total salt, CaCO₃, texture, nitrogen, phosphorus, potassium and organic matter values were determined by standard methods (Öztürk et al.1997). Total phosphorus, total potassium and organic nitrogen were also evaluated by standard methods (Kaçar, 1972,

Bayraklı, 1987, Allen et al., 1976). The threat categories of the species were also assessed (IUCN, 2001).

Results

Morphological Features

The structure resembles a smaller version of *G. septemfida*. The plant's body measures between 0.15 to 0.2 cm in diameter and 4 to 13.5 cm in length. It has a creeping growth habit and typically bears one flower. The leaves are ovate, semi-acute, and 3-veined, with sizes ranging from 3 to 6 mm in length and 4 to 10 mm in width.

The calyx measures 5 to 6 mm in diameter and 11 to 17 mm in length, becoming fragmented up to about one-third of its length. The lobes of the calyx are 1 to 2 mm wide and 3 to 8 mm long. The corolla may also be fragmented, up to about one-sixth, with dimensions of 15 to 20 mm in length and 27 to 37 mm in width. The lobes of the corolla are triangular, semi-acute, and vary in size from 4 to 6 mm in length and 3 to 7 mm in width. The subsidiary lobes are about half the size of the corolla lobes, measuring 2.5 to 4 mm, and have 3 to 4 teeth.

The number of internodes ranges from 6 to 15. The seeds are brown with a pale margin and are obovate and flattened, measuring 1.3 to 2.1 mm in length and 1.5 to 2.2 mm in width (see Figure 1 and Table 1).



Figure 1. General appearance of *G. boissieri* in natural habitat (Photo: Erken S. 2013)

Table 1

Morphological Measurements of *G. boissieri*

Character	Min. (μm)	Max. (μm)	M (Mean)	σ (Standard Deviation)
Stem				
- Width	1.5	2.0	1.75	±0.35
- Length	70	135	97.5	±21.7
Leaf				
- Width	3.0	6.0	4.5	±0.95
- Length	4.0	10.0	7.6	±1.79
Calyx				
- Width	5.0	6.0	5.4	±0.52
- Length	11.0	17.0	12.7	±2.00
Calyx Lobe				
- Width	1.0	3.0	1.48	±0.47
- Length	2.0	8.0	5.88	±1.73
Corolla				
- Width	15.0	20.0	17.3	±1.87
- Length	27.0	37.0	32.8	±2.75
Corolla Lobe				
- Width	4.0	6.0	5.25	±0.60
- Length	3.0	7.0	4.50	±1.08
Corolla Tube				
- Width	12.0	17.0	13.7	±1.98
- Length	22.0	32.0	27.3	±3.00
Subsidiary Lobe			3.0	±0.40
Number of Internodes	6.0	15.0	10.57	±2.93
Seed				
- Width	1.3	2.1	1.6	±0.23
- Length	1.5	2.2	1.8	±0.21

Note:

- All measurements are in μm.
- **M** stands for the arithmetic mean.
- **σ** stands for the standard deviation.
- The measurements are based on various plant parts such as stems, leaves, calyx, corolla, and seeds.

G. boissieri seeds were analyzed in terms of important features such as the shaping of the inner periclinal walls, seed shape, seed and testa cell, wing cell size, testa wall thickness and seed shape. this species is named as has shallowly reticulate type due to is isodiametric or reticulate due to polygonal cells with thickened

walls. Also secondary sculpture is also covered with structures that are called pits (Figure 2). *G. boissieri* has obovate flattened seed (1.3 - 2.1 x 1.5 - 2.2 mm), brown colored with lighter edges (Alçitepe et al., 2017).

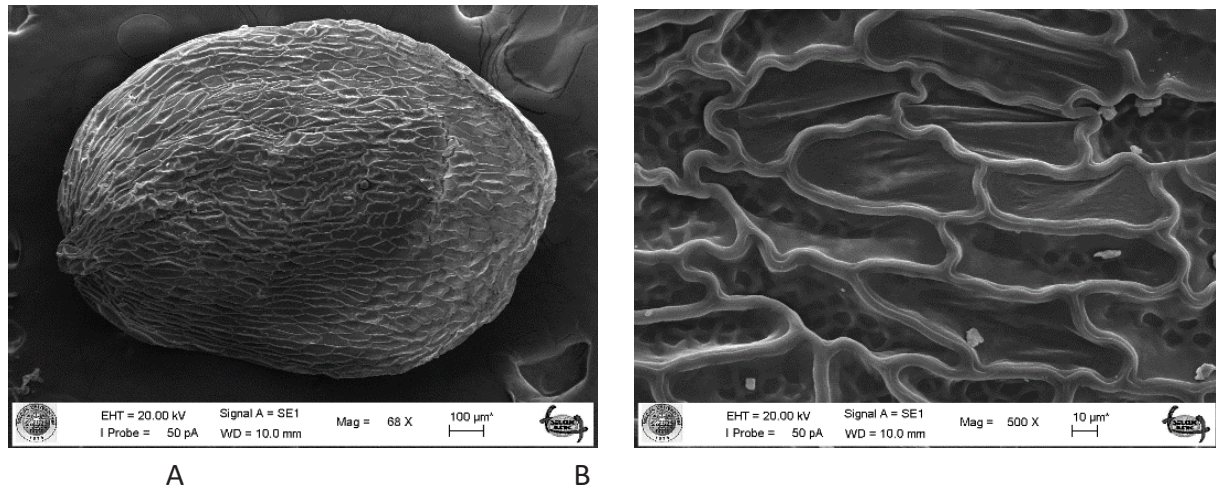


Figure 2. SEM of seed surface of *G. boissieri* at two different magnifications. (A-B) (Alçitepe et al., 2017).

Table 2

The Outer Periclinal Walls, Inner Periclinal Walls, Secondary Sculpture, and Borders of Testa Cell in *G. boissieri*

Species	The Outer Periclinal Walls	The Inner Periclinal Walls	Secondary Sculpture	Borders of Testa Cell
<i>G. boissieri</i>	Complete discoid wing	Shallowly reticulate	Pitted	Curved

Palynological Features

The fundamental shape of the pollen grains was suboblate and radially symmetrical. The apertures were 3-zonocolporate. Porus shape (plg/plt) was subprolate. The sculptural pattern of exine was striate-reticulate. Muri were

usually thick long running parallel to the colpus, lumen usually deep, irregular in shape. Lumina was 1µm or smaller in diameter (Figure 3). The main palynological features of this species are summarized in Table 3.

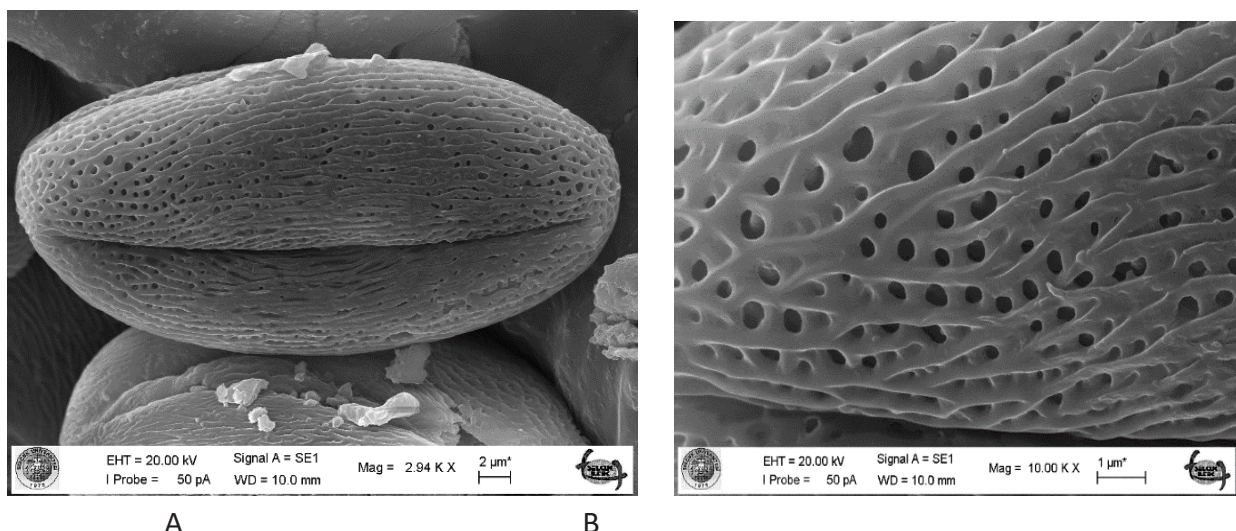


Figure 3. SEM of pollen surface of *G. boissieri* at two different magnifications. (A) equatorial view; (B) exine ornamentation.

Table 3

Palynological measurements of *G. boissieri* (W)

Characters	(μm) $M \pm \sigma$ (var.)
P	26.36 $\pm$ 3.59 (20.00-37.18)
E	30.25 $\pm$ 3.29 (26.14-43.20)
P/E	1.77 $\pm$ 0.17 (0.48-1.28)
Plg	8.77 $\pm$ 2.42 (5.36-11.30)
Plt	7.22 $\pm$ 2.45 (4.5-10.30)
Plg/Plt	1.29 $\pm$ 0.40 (0.93-2.05)
clg	28.08 $\pm$ 4.37 (12.34-38.0)
clt	6.97 $\pm$ 1.32 (3.17-10.60)
apocolpium	7.52-2.49 (4.40 $\pm$ 12.11)
mesocolpium	16.93 $\pm$ 3.92 (11.10-23.23)
Exine thickness	1.09 $\pm$ 0.10 (0.88-1.30)
Intine thickness	0.84 $\pm$ 0.09 (0.65-0.98)

Note: polar diameter (P), equatorial diameter (E), pollen shape (P/E), porus length (plg), porus width (plt), porus shape (plg/plt), colpus length (clg), colpus width (clt), M; arithmetic means, σ ; standard deviation, var.; variations, Marks are in μm .

Ecological Features

The water saturation rate of the soil sample in the natural distribution areas of *G. boissieri* was found to be 81% i $\ddot{s}$ ba. Accordingly, the soil in which the species grows has a clayey structure. The pH value of the soil sample was determined to be 7.1 (neutral). The total amount of CaCO_3 in the sample area was 0.4% (low calcareous).

The electrical conductivity (EC) of the soil was determined as 0.15 mS/cm (salt-free) and the average organic amount was 12.34% (with a lot of humus). The amount of potassium is 160% (medium), and it is low in phosphorus (6%) (Table 4).

Table 4

Physical and chemical analysis of the soil of *G. boissieri*

Character	Value
EC25 (1:2.5)	0.15 mmhos/cm
pH	7.1
Lime %	0.4
Organic Matter %	12.34
P (ppm)	6
K (ppm)	160

Discussion

Morphological, palynological, and ecological studies were conducted on *G. boissieri*, the only endemic species of its genus, which has a narrow distribution in Türkiye. According to the Flora of Turkey (1978), "*G. boissieri* may well be a local derivative of *G. septemfida*, restricted to the Tauros range and geographically isolated. It has a distinct appearance due to its crowded, densely leafy stems, and no intermediate forms or similar plants have been observed elsewhere."

The basal leaves of *G. boissieri* are cordate and oval-cordate. The attachment of the calyx is clear and relatively uncertain, appearing tooth-like. Additionally, the corolla has a broadly bell-shaped structure with five deeply divided parts, which is one of the distinguishing features mentioned in the Flora of Turkey. This study expands on the descriptive features of the species, adding many characteristics not previously detailed in the Flora of Turkey, along with measurements provided in Tables 5.

Table 5

Morphological characters of *G. boissieri* based on our data and Flora of Turkey

Characters (mm)	Our data	Flora of Turkey
Stem WidthxLength	15-20 x 70-135	40 - 100
Leaf WidthxLength	3-6 x 4-10	5 x 10
Calyx WidthxLength	5-6 x 11-17	15
Calyx lobe WidthxLength	1-2 x 3-8	1.5-2
Corolla WidthxLength	15 -20 x 27-37	25-30
Corolla tube WidthxLength	12-17 x 22-32	-----
Corolla lobe WidthxLength	4-6 x 3-7	-----
Subsidiary lobe length	2.5-4	-----
Number of internode	6-15	-----
Seed WidthxLength	1.3-2.1 x 1.5-2.2	-----

As a result of the study by Alçitepe et al. (2017), seed morphology (testa outer periclinal walls, inner periclinal walls, seed shape, seed and testa cell, wing cell size, testa wall thickness and seed shape) can be used together with morphological character in creating classifications in the samples examined for the genus *Gentiana*. According to the external periclinal walls of testa, *G. boissieri* is classified as complete discoid wing when compared to other species. It is a shallowly reticulate type matching to primary sculpting of seeds (sculpting of inner periclinal walls). According to Alçitepe et al. (2017), based on the limits of testa cells, they were observed that *G. boissieri*, *G. gelida* and *G. asclepiade* were curved, while *G. septemfida* was straight. *G. boissieri*, *G. gelida* species were assessed as complete discoid wing; *G. septemfida* has a chalazal wing and *G. asclepiade* has an incomplete discoid wing.

There are two different ecological studies on *G. lutea*. In the first of these, it was observed that it was clayey-loamy, slightly alkaline, slightly calcareous, moderately saline, moderately humus-rich and low in phosphate (Akan et al., 1999), and in the other, unlike this study, it was observed that the plant also grew in neutral and strong acid, salt-free and lime-free soils (Erken et al., 2012). According to the analysis results of the soil sample taken from the growing environment of *G. boissieri*, it is seen that it prefers clayey, neutral, salt-free, low-calcareous, organic matter-rich soils. Additionally, it was

determined that the soil was poor in phosphate and medium in potassium. When compared with *G. lutea*, it can be said that the common point of gentiana species is that it prefers clayey, lime-free, salt-free and organic matter-rich soils.

Since most of the *Gentiana* species have showy flowers and contain active components in the roots and aboveground parts, they have been removed by people for many years and great damage has occurred to their populations. *G. boissieri*, naturally distributed in Niğde and Adana, is included in the "Vulnerable (VU)" category of the IUCN (International Union for Conservation of Nature and Natural Resources) criteria (2001) and this category is declared as "under high threat in the medium-term future". The same conclusion was reached as a result of our field studies.

Conclusion

G. boissieri is the only endemic taxon, meaning it is restricted to the Tauros region and is geographically isolated. Preparations were made to conduct studies on this species, alongside other species in the genus, which included detailed examinations of pollen, seed coat, ecology, and more. A comprehensive description of *G. boissieri* was provided.

Results from pollen and soil analysis were evaluated. The pollen grains are suboblate, with three zonocolporate apertures. The exine sculptural pattern is striate-reticulate. This plant

prefers clayey soil low in calcium carbonate, which is neutral and contains varying amounts of organic matter, particularly rich in nitrogen. *G. boissieri* thrives on nonsaline soils and can be used as an ornamental plant.

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PRINCIPLE COMPONENT ANALYSES OF QUANTITATIVE TRAITS IN CULTIVATED FIG (*FICUS CARICA* L.) GENOTYPES

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Abstract. *This study provides a comprehensive morphological assessment of 90 fig varieties and forms, based on 19 quantitative traits. Significant variation in ripening times of the main crop was observed among the female fig varieties. The growth cycle of fruits and the presence of *Blastophaga psenes* wasps on caprifig trees were also documented. Among the 90 cultivated fig accessions, the most notable variations were observed in ostiole width, terminal bud ratio, fruit neck length, and fruit weight, which ranged from 7.4 g to 110 g. The ‘Adriatic’ variety exhibited the smallest fruit size, while ‘Dalmat’ produced the largest. Total soluble solids ranged from 11.9% to 32.4%, with ‘Bol Enjir’ displaying the highest value. Principal component analysis revealed that the first seven components explained more than 76.2% of the total variation. PC1, contributing 19.5% to the variation, was primarily associated with fruit traits, while PC2 (18.7%) was influenced by leaf traits. The biplot analysis further highlighted key traits, including leaf length, leaf area, leaf width, and fruit size, as major contributors to the observed variability. These findings emphasize the high diversity among fig genotypes, offering insights for future breeding programs, conservation strategies, and the selection of superior varieties with desirable traits.*

Keywords: *Ficus carica* L., phenology, morphological traits, PCA, biplot

Introduction

With over 800 species worldwide, *Ficus* is one of the largest genera of angiosperms. It belongs to the Moraceae family, which includes many edible species characterized by aggregated drupes or achenes as fruit and the presence of milky latex (Ayuso et al., 2022). The fig tree (*Ficus carica* L.), among the oldest cultivated fruit-bearing trees, is valued not only for its culinary significance but also for its therapeutic properties (Ramadan, 2023). *F. carica* is particularly appreciated for its fresh and dried fruits, which are rich in vitamins, carbohydrates,

minerals, sugars, phenolic compounds, organic acids, and cholesterol-lowering fats (Mahmoudi et al., 2018). The phytochemical composition of figs plays a crucial role in their health benefits, yet compared to other fruits, their medicinal properties remain underappreciated (Sandhu et al., 2-23). Figs have been traditionally used to prevent and manage various diseases, including endocrine disorders, respiratory conditions, digestive disorders, and infectious diseases (Badjugar et al., 2014).

Based on traits related to cropping and pollination, four types of figs are described (Mars

et al., 2015). Commercially, three varieties of figs are cultivated (Storey, 1976): 1) Common type, which develops fruit parthenocarpically and can produce two crops per year (breba and main crop); 2) Smyrna type, which require pollination with caprifig to set fruit; and 3) San-Pedro type, which produces a first crop parthenocarpically, but require pollination for the main crop. The fourth type, caprifigs (male trees), serves as a source of pollen for female trees. Caprifigs produce at least three generations of persistent syconia: mamoni, mamme, and profichi (Mars et al., 2015). Compared to unpollinated figs, pollinated figs are typically tend to be larger and develop a darker pulp color (Flaishman et al., 2008).

F. carica originates from Southwestern Asia and is widely cultivated both as an ornamental tree and for its edible fruit (Wirth et al., 2020). The leading producers of dried figs are Turkey (320.0 K metric tons), Spain (59.9 K metric tons), and the United States (27.1 K metric tons). Azerbaijan is renowned for its rich diversity of fruit-bearing plants and is home to a wide range of indigenous fruit tree varieties, such as pomegranate, hazelnut and fig trees (Garagurbanli et al., 2024; Hajiyeva et al., 2024). In Azerbaijan, approximately 12,334 tons of fresh and dried figs are produced annually (STAT.GOV.AZ, 2022). The country hosts around 300 local and introduced fig varieties and forms, including 'Buzovburnu,' 'Absheron Sari Enjiri,' 'Sari Enjir,' 'Goy Enjir,' and 'Qara Enjir' (Ahmadov, 2020). While fig cultivation is concentrated in the Absheron Peninsula, the specie is also widely distributed in the Shirvan zone, the western and southern regions, and along the Caspian coast (Hasanov, 2007).

Given the wide morphobiological variation in *Ficus carica*, this study aimed to assess the morphological diversity among Azerbaijani germplasm.

Materials and methods

The study included 90 fig accessions grown at the Absheron, Saray and Agdash Experimental Bases of the Genetic Resources Institute of ARSEM, comprising both local and introduced varieties. Phenological, morphological and

pomological traits were assessed following the international fig descriptor by Bioversity International (IPGRI and CIHEAM, 2003). Phenological observations were conducted throughout the year, tracking leaf and fruit development in female trees (breba and main crop), as well as the formation of 'profichi' and 'mamme' fruits in male trees. Nineteen quantitative traits were measured for each of the 90 fig accessions. Leaf and fruit attributes were recorded from 15 leaves and fruits per accession during the peak fruit-ripening phase. Descriptive statistics for quantitative traits were performed using IBM SPSS Statistics (Version 16.0) (SPSS Statistics, 2007), while principal component analysis (PCA) analysis was performed using XLSTAT software (XL STAT, 2024).

Result and discussion

Today, fig cultivation is widespread in hot, dry regions across the world (Sandhu et al., 2023). The extensive morphological diversity, compositional complexity, and unique properties of figs underscore the need for a comprehensive study of this species.

In this study, morphological assessment based on 19 quantitative traits was conducted on 90 fig varieties and forms from the Absheron, Saray, and Agdash experimental bases. Among the cultivated fig genotypes examined, 63 belonged to the Common type, 25 to the Smyrna type, and 2 to the Caprifig group, while no San-Pedro types were identified in the collection. Common fig plants have the potential to produce fruit three times during the growing season (breba, main crop, and late crop); however, only breba and main crop were observed among the studied varieties. The main crop ripened between late July (July 29) and August (August 10–28), while the breba crop matured in late June (June 26). The Common types included varieties such as Roland, Shalala, Chapla, Form No. 7, Bol Enjir, and Sari Absheron. All Smyrna type varieties in the collection were introduced cultivars, including Kalimirno, Smena, and Chakvin. The studied fig varieties exhibited differences in main crop ripening times. Most genotypes from the Absheron Experimental and Saray Base Stations reached full maturity

in mid-August, while a smaller subset ripened in early or late August. Notably, three genotypes (Lankaran Fragasi, Dalmat, and Fioletovi) achieved full ripeness earlier, by July 29.

In the Caprifig group, the *Sarı Tozlayiji* and *Ganja-1* trees produced three crops annually, forming the foundation of the *Blastophaga psenes* wasp's life cycle. During winter, the developmental stages of *mamme* fruits on male trees were observed, and images were captured showing blastophagous larvae overwintering inside the gall flowers (Figure 1). These

fruits were scarce and located at the highest parts of the trees. They contained numerous short-styled female flowers (galls) and a modest number of male flowers, but no long-styled female flowers were detected. From early spring to autumn, *profichi* fruits developed on caprifigs. Throughout the summer, *Blastophaga* wasps emerged from the *profichi* fruits to pollinate female flowers. The *profichi* fruits were abundant on caprifig trees and contained a high number of both male and gall flowers.

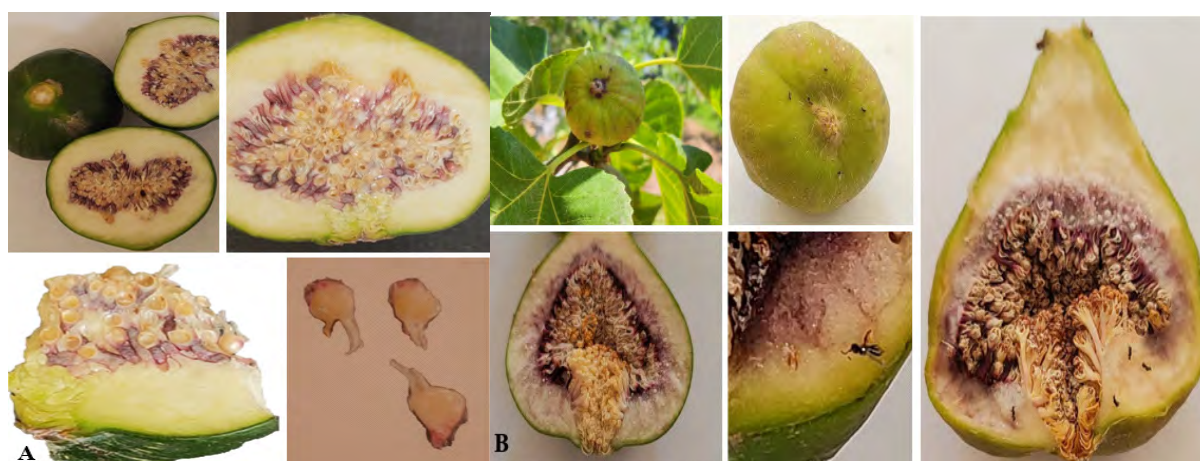


Figure 1. The growth cycle of fruits and *Blastophaga psenes* wasps in the *Sarı Tozlayiji* caprifig variety:
A - *Blastophaga* larvae overwintering inside short-styled female (gall) flowers within *mamme* fruits and individual gall flowers; B - ripened pollen and adult *Blastophaga* emerging from *profichi* fruits.

The statistical analysis was performed using the mean values of morphological and pomological data. Key parameters, including minimum and maximum values, mean, standard deviation (SD), and coefficient of variation (CV%), were calculated for the measured traits. The studied traits exhibited considerable variation among the genotypes, with some showing significant differences among accessions. Among the 90 cultivated fig accessions, the highest variations were observed in ostiole width (70.5%), terminal bud ratio (58.3%), fruit neck length (51.8%), and fruit weight (41.5%). Conversely, fruit shape index, leaf length, fruit width, and leaf width displayed the lowest variation, with CV values of 14.6%, 16.6%, 17.0%, and 18.4%,

respectively (Table 1).

Ostiole width ranged from 1 to 13 mm, with an average of 4.3 mm; most varieties had small ostioles. Since large ostioles allow infections and pests to enter, they are considered undesirable in fig production (Gündeşli, 2020). Fruit weight varied between 7.4 g and 110 g, aligning with findings by Çalışkan and Polat (2012), who reported an average main-crop fruit weight ranging from 12.3 g to 99.4 g. Fruit width ranged from 28 mm to 68 mm, with an average of 41.9 mm, while fruit length varied between 25 mm and 71 mm, averaging 41.5 mm. Within the collection, Adriatic had the smallest fruit size, whereas Dalmat produced the largest fruits.

Table 1

**Descriptive statistics of morphological and pomological traits
in the studied cultivated fig genotypes**

Traits	Min.	Max.	Mean	SD	CV %
Shoot characteristics					
Shoot length (ShL), cm	3	20	9.8 ±0.36	3.44	35.1
Shoot width (ShW), mm	5	19	10.6 ±0.33	3.10	29.2
Terminal bud length (TBL), mm	4	28	11.6 ±0.45	4.27	36.8
Terminal bud width (TBW), mm	3	14	5.7 ±0.22	2.1	36.8
Terminal bud ratio (TBL/TBW)	0.43	12.2	2.23 ±0.14	1.3	58.3
Leaf characteristics					
Leaf length (LL), cm	13	32	21.4 ±0.38	3.56	16.6
Leaf width (LW), cm	11	28	17.9 ±0.35	3.29	18.4
Leaf area (LA), cm ²	143	896	394.8 ±14.5	137.3	34.8
Length of leaf stalk/length of leaf (LS/LL)	0.13	0.75	0.35 ±0.01	0.10	28.6
Petiole thickness (PTh), mm	3	8	5.04 ±0.1	1.06	21
Fruit characteristics					
Fruit shape index (FSI)	0.74	1.46	1.03 ±0.02	0.15	14.6
Number of fruits per shoot (NFSH)	2	11	5 ±0.19	1.79	35.8
Fruit weight (FWe), g	7.4	110	39.3 ±1.72	16.3	41.5
Fruit width (FWi), mm	28	68	41.9 ±0.75	7.14	17
Fruit length (FL), mm	25	71	41.5 ±0.9	8.59	20.7
Fruit neck length (FNL), mm	3	16	5.1 ±0.28	2.64	51.8
Ostiole width (OW), mm	1	13	4.3 ±0.32	3.03	70.5
Fruit flesh thickness (FFTh), mm	24	66	37.6 ±0.8	7.9	21.0
Total soluble solids (TSS), %	11.9	32.4	19.2 ±0.39	3.72	19.4

Fruit neck length ranged from 3 mm to 16 mm, with an average of 5.1 mm. This was consistent with the findings of Çalışkan and Polat (2012), where the longest neck length was 13.0 mm. Total soluble solids (TSS) content varied from 11.9% to 32.4%, with Bol Enjir exhibiting the highest value. These results aligned with previous studies (Çalışkan & Polat, 2012; Gaa-liche et al., 2012). Among leaf traits, leaf area showed the highest variability (CV = 34.8%), with an average value of 394.8 cm² across the collection.

A principal component analysis (PCA) was performed to assess variation in fruit, leaf, and shoot traits (Table 2). Based on the eigenvalues, the first seven principal components (PCs) effectively captured the variability, explaining more than 76.2% of the total variation.

The first component (PC1) accounted for 19.5% of the total variation and was primarily associated with fruit traits, including fruit width (FWi), fruit length (FL), fruit neck length (FNL), ostiole width (OW), fruit flesh thickness (FFTh), and fruit weight (FWe).

Table 2

**Eigenvalues and contributions of the first seven principle component
(PCs) in the analyses in 90 fig accessions**

Traits	PC1	PC2	PC3	PC4	PC5	PC6	PC7
TBL	0.092	0.352	0.381	0.363	0.525	-0.147	0.185
TBW	-0.072	0.198	0.273	0.406	0.561	-0.149	-0.405
TBR	0.271	0.131	0.033	0.260	0.247	-0.156	0.763
ShL	-0.082	0.438	0.034	0.490	-0.330	0.181	0.031
ShW	-0.194	0.025	0.212	0.415	0.266	0.587	-0.201
NLSH	0.192	-0.109	0.336	0.541	-0.459	-0.070	-0.154
LL	-0.011	0.956	-0.116	-0.045	-0.043	-0.002	-0.076
LW	-0.107	0.933	-0.088	-0.147	-0.067	0.007	-0.038
LA	-0.075	0.962	-0.092	-0.104	-0.050	0.012	-0.030
LR	0.349	-0.024	0.776	-0.138	-0.165	0.072	0.203
PL	0.306	0.510	0.659	-0.175	-0.165	0.084	0.160
PTh	-0.088	0.683	0.079	-0.253	0.025	0.023	-0.100
FSI	-0.285	0.170	-0.675	0.180	-0.131	0.006	0.168
FWe	0.777	-0.075	-0.263	0.123	0.128	0.166	-0.008
FWi	0.834	0.132	-0.418	0.082	-0.027	-0.007	0.024
FL	0.915	0.010	0.130	-0.088	0.057	0.032	-0.095
FNL	0.587	-0.147	0.318	-0.340	-0.106	0.246	-0.132
OW	0.588	0.114	-0.282	0.135	0.098	0.120	-0.120
FFTh	0.832	0.113	-0.425	0.099	-0.003	0.004	-0.049
TSS	-0.298	-0.042	-0.131	0.118	-0.006	0.721	0.282
NFSh	0.058	0.042	0.113	0.656	-0.424	-0.219	-0.042
<i>Eigenvalue</i>	4.101	3.925	2.559	1.867	1.343	1.134	1.084
<i>Variability (%)</i>	19.526	18.690	12.185	8.891	6.396	5.401	5.160
<i>Cumulative %</i>	19.526	38.216	50.401	59.292	65.687	71.088	76.248

PC2 explained 18.7% of the variance and was predominantly influenced by leaf traits such as leaf length (L), leaf width (LW), leaf area (LA), petiole length (PL), and petiole thickness (PTh). PC3 accounted for 12.2% of the variation, with strong contributions from leaf ratio (LR) and petiole length (PL), which were negatively correlated with the fruit shape index (FSH). PC4

was mainly associated with shoot characteristics, including the number of leaves per shoot (NLSH), terminal bud width (TBW), shoot length (ShL), and shoot width (ShW). PC5 primarily reflected terminal bud traits, particularly terminal bud length (TBL) and terminal bud width (TBW). PC6 and PC7 were characterized by total soluble solids (0.721) and terminal bud ratio

(0.763), explaining 5.4% and 5.1% of the total variation, respectively.

There was more variety in samples that were farther from the center ('Form#4 Renaz', 'Agh Encir', 'Black Smyrna', 'Turkiye', 'Qala-1' and others) and less variation in samples that were farther from the center ('Chakvin', 'Kadota', 'Lankaran fraqasi', 'Suxofruktoviy 472' etc.). The figure showed that there was more variation in the leaf length (LL), leaf area (LA), and leaf width (LW) traits. According to leaf characteristics, samples such as 'Form#22', 'Form#4 Renaz', 'Sari Lob', 'Sari Tozlayici', and 'Bol encir' showed more diversity. Samples of 'Limonfig', 'Nikitskiy 4067', 'Nikitsky 486', 'Alisson Krupniy', 'Dalmat', 'Agalina' and other fruits displayed more diversity based on fruit attributes.

The biplot was generated by superimposing variables as vectors onto the plot, where the relative length of each vector represents the degree of variability in the corresponding trait. The analysis revealed substantial variation among the 90 genotypes and 19 measured parameters (Figure 2). Greater variability was observed in genotypes positioned farther from the center, such as 'Form#4 Renaz', 'Agh Encir', 'Black Smyrna', 'Turkiye', and 'Qala-1.' In contrast, genotypes like 'Chakvin', 'Kadota', 'Lankaran Fraqasi', and 'Suxofruktoviy 472' exhibited less variation.

The biplot further indicated that leaf-related traits, particularly leaf length (LL), leaf area (LA), and leaf width (LW), contributed significantly to the observed variation. Genotypes such as 'Form#22', 'Form#4 Renaz', 'Sari Lob', 'Sari Tozlayici', and 'Bol Encir' displayed greater diversity in leaf characteristics. Meanwhile, fruit-related traits were more diverse in accessions like 'Limonfig', 'Nikitskiy 4067', 'Nikitsky 486', 'Alisson Krupniy', 'Dalmat', and 'Agalina.'

Conclusion

This study provides a comprehensive analysis of the morphological and pomological traits of 90 local and introduced Azerbaijani fig varieties. The results of the principal component analysis (PCA) revealed significant variation among the accessions, particularly in terms of leaf and fruit characteristics. The PCA highlighted the contribution of key traits, such as leaf length, leaf area, leaf width, and fruit size, to the overall variation observed. These findings underscore the diversity present within the studied fig genotypes, offering valuable insights for future breeding programs, conservation efforts, and the identification of superior varieties with desirable traits. This detailed characterization lays the groundwork for further research into the ecological and agricultural potential of these fig varieties in Azerbaijan.

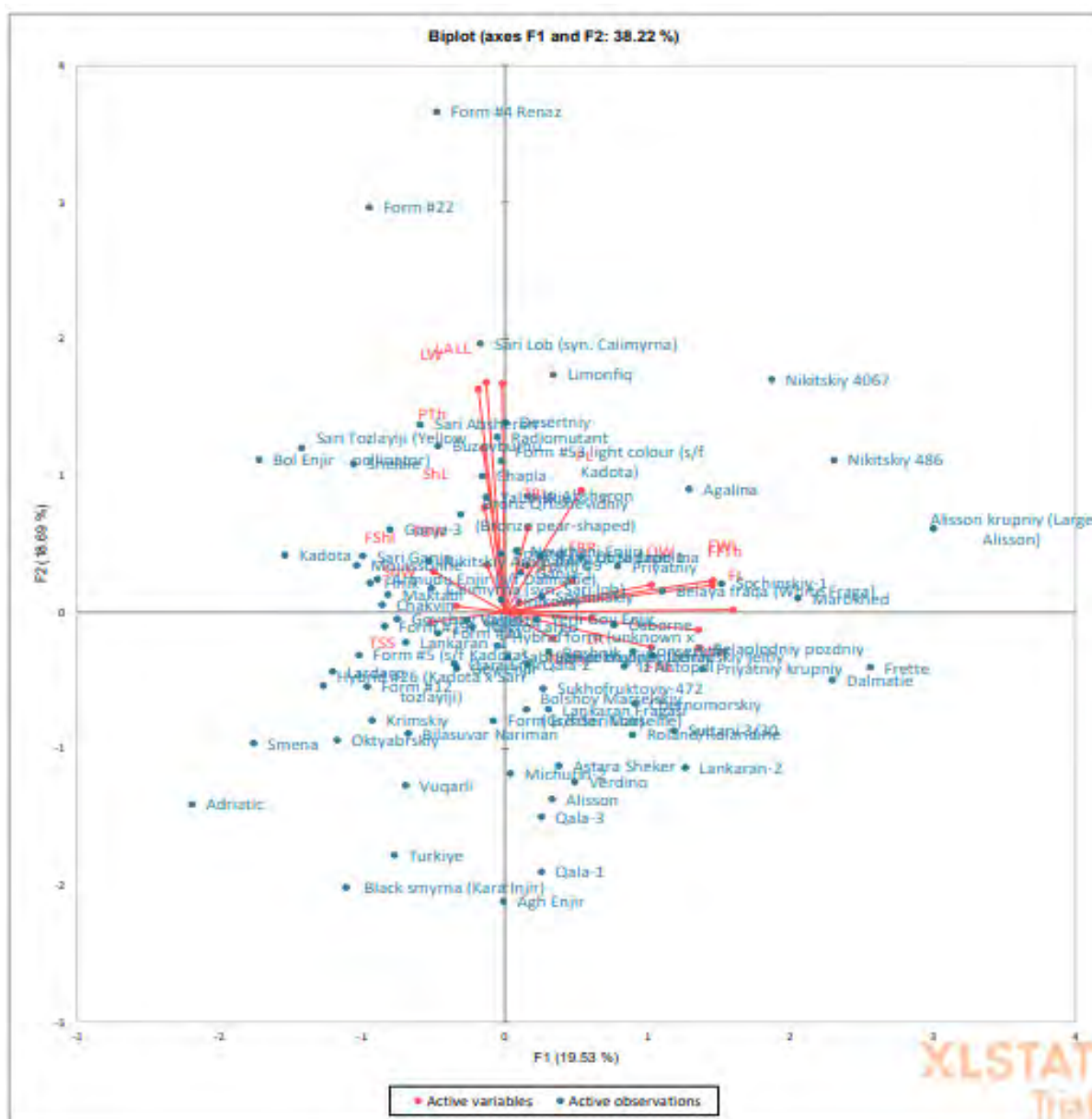


Figure 2. Biplot analysis of 90 fig germplasm based on the first seven principal components (PCs)

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**DISTRIBUTION, PHYTOCENOTIC CHARACTERISTICS AND ANTIMICROBIAL PROPERTIES OF SOME
MEDICINAL PLANTS OF THE HIGHLANDS OF THE GREATER CAUCASUS
(WITHIN AZERBAIJAN)**

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Abstract. Monitoring of forest and meadow phytocenoses in the Greater Caucasus regions was conducted. The phytocenotic association of *Lapsana communis*, *Leontodon hispidus*, *Pojarkovia pojarkovae*, *Tanacetum coccineum*, *Centaurea phrygia* subsp. *salicifolia*, *Aconitum nasutum* and *Lomelosia caucasica*, as well as the species composition and tiering of accompanying species were studied. These species are components of forest and meadow phytocenoses and actively participate in the formation of various plant communities. A total of 107 species belonging to 88 genera and 41 families were registered in forest areas. Among from them 16 are trees, 12 are shrubs and 79 are herbaceous plants. In meadow phytocenoses 101 species from 83 genera and 32 families were noted. Herbaceous plants were the most represented (95 species), while trees (2), shrubs (3) and sub-shrubs (1) were the least represented. Most of the studied species are representatives of the Asteraceae family (10 in forest and 22 in meadow phytocenoses), Lamiaceae (9 in each phytocenosis), Apiaceae (3 and 7, respectively), Fabaceae (7 and 6), Rosaceae (5 and 6) and Orchidaceae (5 species each). Additionally, the ontogenetic and demographic structure of coenopopulations (CP) of two Caucasus endemics - *Pojarkovia pojarkovae* and *Tanacetum coccineum* was studied. Four CPs of each species were identified and studied in different areas. The study revealed that all CPs were normal, but some were incomplected due to the absence of subsenile and senile individuals. Based on the Δ - ω indices, CP 1 of *P. pojarkovae* is a transitional type, while the remaining CPs are young. For *T. coccineum* CP 1-2 are transitional, CP 3 is maturing, and CP 4 is young. The study of the antimicrobial activity of aqueous-alcoholic and methanol extracts of the studied species was also examined. The extracts of *Centaurea phrygia* subsp. *salicifolia* flowers, *Leontodon hispidus* roots, *Aconitum nasutum* leaves and *Lapsana communis* aerial parts showed more effective effect on test cultures of *Staphylococcus aureus* (MSSA). Methicillin-resistant *Staphylococcus aureus* (MRSA), *Bacillus anthracoides*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae* and *Candida albicans*.

Key words: Greater Caucasus, medicinal plants, endemics, rare species, ontogenetic and demographic structure, antimicrobial activity

In recent years, there has been a significant increase in interest in the use of natural plant-based remedies in various areas of human life,

including medicine. This is primarily due to a wary attitude towards synthetic drugs, as well as the gentle action and greater safety of herbal

remedies.

Therefore, studying the experience of traditional medicine in the use of medicinal plants, searching for new sources of biologically active substances of plant origin and conducting resource studies in this area are quite relevant. In addition to the fact that such studies have a purely practical pharmacological significance, they also create the basis for organizing work on the rational use of plant resources and the conservation of biodiversity in general.

The aim of this study is investigating the distribution, phytocenotic features and antimicrobial activity of the most widespread, as well as rare and endemic species of medicinal plants of the highlands of the Greater Caucasus within Azerbaijan.

The objects of this study are 7 species (including 1 subspecies) of wild medicinal plants with empirically and experimentally confirmed medicinal properties, actively used in folk medicine (*Lapsana communis* L., *Leontodon hispidus* L., *Aconitum nasutum* Fisch.ex Reichenb., *Pojarkovia pojarkovae* (Schischk.) Greuter (= *Senecio pojarkovae* Schischk.), *Tanacetum coccineum* (Willd.) Grierson (= *Pyrethrum carneum* M.Bieb.) *Lomelosia caucasica* (M.Bieb.) Greuter & Burdet (= *Scabiosa caucasica* Bieb.), *Centaurea phrygia* subsp. *salicifolia* (M.Bieb. ex Willd.) Mikheev (= *C. salicifolia* M.Bieb.).

The aerial parts of *Leontodon hispidus* L. are used in folk medicine for gallbladder diseases, toothache, jaundice, digestive problems, and urinary tract infections. The leaves are used in salads (Plant resources of the USSR, 1993). In modern phytotherapy, it is used as a diuretic, as well as for liver diseases (<https://medicinalherbs>). Experimental studies by Ebrahimzadeh et al. (2010) established the antioxidant and antihemolytic activity of the aqueous-alcoholic extract of the aerial parts of this plant. Noha Mokhtar et al. (2024) revealed the anti-inflammatory and cytotoxic activity of hypocretenolide glycoside, first isolated from *L. hispidus*, in relation to malignant neoplasms of bone marrow stem cells CD34(+)5.

An aqueous infusion of the aerial parts of *Lapsana communis* L. is used in folk medicine as a mild laxative, externally in the form of

poultices - for rheumatic pains and inflammatory processes of the outer skin and tumors, and crushed leaves or powder of dry leaves as a wound-healing agent for purulent wounds. The leaves, like those of *L. hispidus*, are eaten as a vitamin salad (Makhlayuk, 1967). A decoction of the herb is used as an analgesic. Crushed grass in the form of poultices is used for cracked nipples in nursing mothers and mastitis, as well as in veterinary medicine for cracked nipples in cows. The juice of the leaves is an emollient, as well as for diabetes. It has been established that the flowers and fruits exhibit antibacterial activity (Plant resources of the USSR, 1993).

In folk medicine, an infusion of the above-ground parts of *Centaurea phrygia* subsp. *salicifolia* is used for diarrhea. Experimental studies have revealed antibacterial activity, as well as antiamebic and antitrichomonal properties of tincture from the above-ground parts of this plant (Plant resources of the USSR, 1993). The results of studies conducted by Turgut Sekerler et al. (2018) found that the chloroform extract of the above-ground parts of this plant exhibits high antioxidant, anticancer against hepatocellular cancer HepG2 cell line and anti-inflammatory activity.

Tanacetum coccineum is an official plant (Kiseleva & Smirnova, 2009). A decoction, tincture and extract of its inflorescences are used in folk medicine as an anthelmintic for pinworms, powder for pediculosis, as an insecticide for bedbugs, flies, fleas, cockroaches, and an extract for malaria mosquito larvae. An aqueous extract of the leaves exhibits antibacterial and bacteriostatic activity against gram-negative bacteria. It is used for digestive disorders and headaches (Plant resources of the USSR, 1993; Qambarli I.J et al., 2018).

The above-ground parts of *Pojarkovia pojarkovae* have a hemostatic effect (Plant resources of the USSR, 1993). In folk medicine, the above-ground parts of *Lomelosia caucasica* are used as an astringent (Alimbaeva et al., 1986).

Aconitum nasutum is a poisonous plant, a tincture of its tubers is used in folk medicine as an external irritant and distracting agent for rheumatism, radiculitis and neuralgia (Damirov et al., 1988). The above-ground parts of the

plant have an insecticidal, fungistatic and repellent effect. In an experiment, substances of the non-alkaloid fraction isolated from the tubers weaken the tone and slow down intestinal peristalsis, contract the smooth muscles of the uterus, and have a sympathomimetic, curare-like and hypertensive effect (Plant resources of the USSR, 1985, 1993).

Betula pendula is an official medicinal plant (Kiseleva, Smirnova, 2009). Water infusion and decoction, as well as alcohol tincture of buds and leaves are used as a choleric and diuretic. Alcohol tincture of buds is taken internally for rheumatism and aching joints, and is also used for rubbing as a pain reliever. In traditional medicine of medieval Azerbaijan, young leaves in the form of water infusion and syrup were used for scurvy, vitamin deficiency and hypovitaminosis (Aleksperov, 2001). Juice obtained from cuts on the trunk is drunk as a tonic and refreshing remedy for scurvy (Damirov et al., 1988). Tincture of staminate catkins is used for heart disease, tuberculosis, stomach ulcers, gastritis, eczema, boils and anemia (Plant resources of the USSR, 1985).

Materials and Methods

Field studies were carried out in the summer period of 2019–2024 in forest and meadow areas located in all botanical and geographical regions of the Greater Caucasus (GC) using the generally accepted methods of field geobotanical studies (*Field Geobotany*, 1964). When describing phytocenoses, we relied on the works of Mirkin et al. (2001) and Lebedeva et al. (2004). For this purpose, model plots with an area ranging from 100 to 1000 m² were laid out in places with the highest concentration of the studied species. The abundance of species was determined according to the Drude scale.

When studying the ontogenesis and demographic structure of cenopopulations of rare species, the principles and methods adopted in modern plant population biology were used, developed by Rabotnov (1976) and Uranov (1975) and their followers (*Plant Cenopopulations*, 1988; Zaugolnova et al., 1988; Zhukova, 1995). The list of endemics was compiled according to the *Flora of Azerbaijan*, supplemented and

clarified according to the *Red List of the Endemic Plants of the Caucasus Region* (Ali-zade et al., 2014). When identifying rare and protected species, the *Red Book of the Republic of Azerbaijan* (3rd edition; *Red Book of Azerbaijan*, 2023) was used. Latin names of species are given according to the *Flora of Azerbaijan* (1950–1961) in accordance with the new nomenclature of the WFO Plant List taxonomy database (<https://wfo.plantlist.org/taxon/wfo>).

The study of the antimicrobial activity of alcohol-water (30:70) extracts of *Leontodon hispidus*, *Lapsana communis*, *Centaurea phrygia* subsp. *salicifolia*, *Lomelosia caucasica*, *Aconitum nasutum* was conducted in the laboratory of the Department of Medical Microbiology and Immunology of the Azerbaijan Medical University. Laboratory strains stored in the “museum of cultures” of this department were used as test microorganisms. The effect of extracts obtained from the above-mentioned plants on the following was studied:

Gram-positive bacteria – methicillin-sensitive *Staphylococcus aureus* (MSSA); methicillin-resistant *Staphylococcus aureus* (MRSA) and *Bacillus anthracoides*

Opportunistic fungi – *Candida albicans*

Gram-negative bacteria – *Escherichia coli*, *Pseudomonas aeruginosa*, and *Klebsiella pneumoniae*.

The bacterial cultures were incubated on Müller-Hinton medium, and the *C. albicans* culture was incubated on Sabouraud dextrose agar for 24 hours at 37°C. The microbial suspensions used in the study were prepared in accordance with the 0.5 McFarland standard (1 ml contains 10⁸ cells).

The antimicrobial activity of methanol extracts of *Tanacetum coccineum*, *Pojarkovia pojarkovae*, and *Betula pendula* was studied in the same laboratory using the disk diffusion method. A sterile paper disk (6 mm in diameter) was soaked with 1 ml of the extract of the species and then placed on the surface of the nutrient medium inoculated with microbes. The results were recorded after 18–24 hours of incubation at 37°C. The diameter of the sterile zones around the disk, where no bacterial growth was observed, is indicated in millimeters (mm) and

shows the degree of impact of the test substances on microorganisms.

Results and Discussion

During expedition trips to the districts of the GC in the forest areas of Siyazan (Galaalty), Guba (near the villages of Gryzdahna; Balbulag); along the Shamakhi-Ismaily highway; Shamakhy (forest between the villages of Pirgulu and the village of Damirchi), Ismailly (territory of the Topchu forestry of the Ismailly branch of the Shahdag National Park) and Gabala (near the village of Yengidzha, as well as in the direction of the village of Laza) districts, we recorded places of the highest concentration of *Lapsana communis*, *Leontodon hispidus* and *Pojarkovia pojarkovae* (Asteraceae Giseke) (Figure 1).

Lapsana communis L. is an annual taproot plant (Figure 2a). Xeromesophyte. It is widespread in all areas of the GC and LC, as well as the Nakhchivan and Lenkoran mountainous regions. It grows from the lower to the subalpine belt. It is found in forests and shrubs, on mountain meadows forming small clumps of

5-8 individuals.

Leontodon hispidus L. is a perennial short-rhizome plant (Figure 2b). Xeromesophyte. It is widespread in all areas of the GC, as well as in the areas of LC north, LC center, Nakhchivan and Lenkoran mountain. It grows from the lower mountain to the subalpine and alpine belts (Alizade et al., 2019). It is found singly or in small groups of 2-5 individuals in forests and shrubs, as well as in mountain meadows.

Pojarkovia pojarkovae (Schischk.) Greuter (= *Senecio pojarkovae* Schischk.) - endemic to the Caucasus (Fora Az. and Red list) (Figure 2c). Perennial rhizomatous plant. Distributed in the regions of the GC east and GC west (Alizade et al., 2019). We discovered a new location (GC Guba) of this species on August 5, 2016, in a forest clearing near the village of Gryzdahna (Guba district) (Mehdiyeva & Mursal, 2023). It is found in the upper forest belt near waterfalls, in forest clearings and rocky screes, often forming small patches of about 20 individuals located at a remote distance.

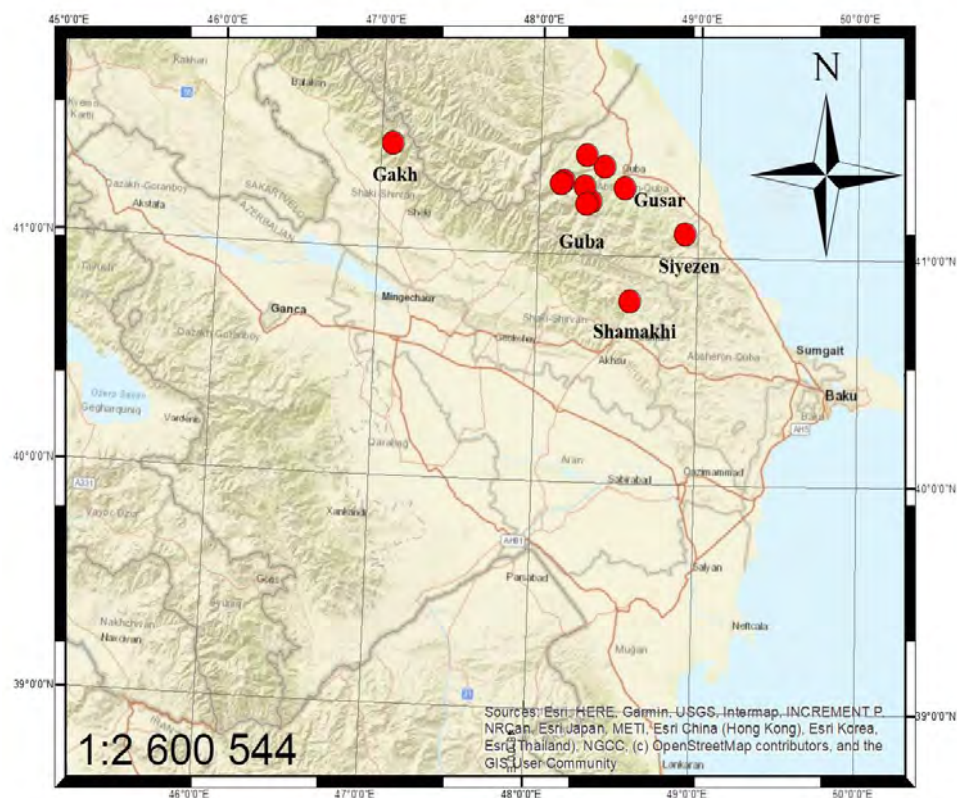


Figure 1. Places of the highest concentration of the studied species



Figure 2. a - *Lapsana communis* L., b - *Leontodon hispidus* L., c - *Pojarkovia pojarkovae* (Schischk.) Greuter

During the study, geobotanical descriptions of phytocenoses with the participation of *Lapsana communis*, *Leontodon hispidus* and *Pojarkovia pojarkovae* were carried out in each of the above-mentioned areas. As a result, more than 100 species were registered in forest areas. The main tree species in the tree-shrub layer of forest phytocenoses are *Fagus orientalis* Lipsky, *Carpinus betulus* L., *Fraxinus excelsior* L., *Quercus iberica* M.Bieb., *Acer campestre* L., *A. cappadocicum* Gled., *Alnus incana* (L.) Moench, *Juglans regia* L., *Taxus baccata* L., *Torminalis glaberrima* (Gand.) Sennikov & Kurtto (= *Sorbus torminalis* (L.) Grantz.), *Malus orientalis* Uglitzk, *Cerasus avium* (L.) Moench, *Prunus cerasifera* Ehrh., *Crataegus pentagyna* Waldst. & Kit. ex Willd., *C. kyrtostyla* Fingerh., *Cydonia oblonga* Mill. The shrubs represent the following species: *Rhamnus spathulifolia* Fisch. & C.A.Mey., *Euonymus europaea* L., *Salix caprea* L., *Corylus avellana* L., *Pyracantha coccinea* M.Roem., *Ligustrum vulgare* L., *Cornus mas* L., *Lonicera caucasica* Pall., *Rubus caesius* L., *R. idaeus* L., *Rubus ibericus* Juz. and *Hypericum androsaeum* L.

In the herbaceous layer we have identified 2 sub-layers: in the 1st sub-tier, which includes species over 50 cm in height, we have registered 45 species: *Achillea millefolium* L. (Sp-Cop¹), *Agrimonia eupatoria* L. (Cop¹-Cop²), *Anthemis dumetorum* Sosn. (Sp), *Arctium lappa* L. (Sp-Cop¹), *Artemisia absinthium* L. (Cop¹-Cop²), *Asparagus verticillatus* L. (Sp-Cop¹), *Bupleurum polyphyllum* Ledeb. (Sp), *Campanula bononiensis* L. (Sp-Cop¹), *Coronilla varia* L. (Cop¹-Cop²),

Cota melanoloma (Trautv.) Holub (= *Anthemis melanoloma* Trautv.) (Sp-Cop¹), *Dipsacus laciniatus* L. (Sp-Cop¹), *Epilobium angustifolium* L. (= *Chamaenerion angustifolium* (L.) (Sp), *Equisetum ramosissimum* Desf. (Cop¹-Cop²), *Erigeron annuus* (L.) Desf. (Cop¹), *Hypericum perforatum* L. (Sp-Cop¹), *Inula aspera* Poir. (Sp-Cop¹), *I. helenium* L. (Sp.), *Juncus effusus* L. (Sp), *Lathyrus sylvestris* L. (Cop¹), *Leonurus cardiaca* L. (Sp), *Lysimachia vulgaris* L. (Cop¹-Cop²), *L. verticillaris* Biehler (Sp.-Cop¹), *Lythrum salicaria* L. (Cop²-Cop³), *Malva sylvestris* L. (Cop²-Cop³), *Melilotus officinalis* (L.) Desr. (Cop¹), *Mentha aquatica* L. (Cop²-Cop³), *Oenothera odorata* Jacq. (Sp), *Orchis purpurea* Huds. (Sol-Sp), *Origanum vulgare* L. (Cop¹-Cop²), *Pimpinella affinis* Ledeb. (Cop²-Cop³), *Rumex crispus* L. (Cop²-Cop³), *R. obtusifolius* L. (Cop¹-Cop²), *Salvia glutinosa* L. (Cop¹-Cop²), *S. verticillata* L. (Cop²-Cop³), *Sambucus ebulus* L. (Soc), *Scabiosa columbaria* L. (Cop¹-Cop²), *Scrophularia nodosa* L. (Sp), *Silybum marianum* (L.) Gaertn. (Sp-Cop¹), *Sonchus arvensis* L. (Cop¹-Cop²), *Stachys sylvatica* L. (Sp-Cop¹), *S. byzantina* K.Koch, (Cop¹-Cop²), *Tanacetum parthenium* (L.) Sch.Bip. (Cop¹-Cop²), *Trifolium ambiguum* M.Bieb. (Cop²-Cop³), *Verbascum thapsus* L. (Sp-Cop¹), *Verbena officinalis* L. (Cop²-Cop³). As you can see from the list in the 2nd sub-tier, representing low-growing plants up to 50 cm in height, we noted a slightly smaller number of 34 species: *Acalypha australis* L. (Cop.¹), *Ajuga genevensis* L. (Sp), *Anacamptis pyramidalis* (L.) Rich. (Sp-Cop¹), *Anthriscus nemorosa* Spreng. (Cop¹-Cop²), *Carlina vulgaris* L. (Sp), *Centaurium pulchellum* L. (Sp),

Cephalanthera longifolia (L.) Fritsch. (Sp), *C. rubra* (L.) Rich. (Sp-Cop¹), *Convolvulus cantabrica* L. (Cop¹-Cop²), *Cruciata laevipes* Opiz (Sp-Cop¹), *Dactylorhiza romana* subsp. *georgica* (Klinge) Soó ex Renz & Taubenheim (Sp), *Epilobium lanceolatum* Sebast. & Mauri (Sp-Cop¹), *Erigeron orientalis* Boiss. (Sp), *Euphorbia condylocarpa* Bieb. (Sp-Cop¹), *Fragaria vesca* L. (Cop²-Cop³), *Galium odoratum* (L.) Scop. (Soc), *Geranium robertianum* L. (Cop¹-Cop²), *G. sanguineum* L. (Sp-Cop¹), *Geum urbanum* L. (Cop¹-Cop²), *Lotus herbaceus* (Vill.) Jauzein (= *Dorycnium intermedium* Ledeb.) (Cop²-Cop³), *L. tenuis* Waldst. et Kit. ex Willd. (Cop¹-Cop²), *Onobrychis petraea* (M.Bieb. ex Willd.) Fisch. (Cop¹-Cop²), *Cerintho minor* L. (Sp), *Ornithogalum pyrenaicum* L. (Cop¹), *Plantago major* L. (Cop²), *Primula veris* subsp. *macrocalyx* (Bunge) Lüdi (= *P. macrocalyx* Bunge) (Cop¹-Cop²), *P. vulgaris* subsp. *rubra* (Sm.) Arcang (= *P. woronowii* Losinsk.) (Cop²-Cop³), *Prunella laciniata* L. (Sp-Cop¹), *Thlaspi arvense* L. (Cop¹), *Trifolium pratense* L. (Soc), *Viola arvensis* Murr. (Sp), *V. hirta* L. (Cop¹-Cop²), *V. canina* L. (Cop¹), *Veronica crista-galli* Steven. (Soc).

As can be seen from the list, in forest phytocenoses, the majority of species of the herbaceous layer are represented by species belonging to the families *Asteraceae* Giseke (10), *Lamiaceae* Martinov (9), *Fabaceae* Juss. (7), *Orchidaceae* Juss. (5) and *Primulaceae* Batsch ex Borkh. (4), the remaining families include 1-3 species.

In the wet meadows of the mountain slopes of Shahdag in the vicinity of the villages of Laza, Suvar, Gidzhan and Sudur of the Gusar district, as well as in the vicinity of the villages of Susay, Jek and Budug of the Guba district, we recorded the places of the greatest distribution of *Centaurea phrygia* subsp. *salicifolia*, *Lomelosia caucasica*, *Tanacetum coccineum* and *Aconitum nasutum*.

Centaurea phrygia subsp. *salicifolia* (M. Bieb. ex Willd.) Mikheev (= *C. salicifolia* M.Bieb.) – a perennial short-rhizome plant (Figure 3). Xeromesophyte. Distributed in all areas of the GC, as well as in the areas of LC north, LC center,

Alaz.-Agrich. Distributes from the lower mountain to the subalpine belt in forests in clearings, along forest edges, among bushes, in mountain meadows (Flora of Azerbaijan, 1961), in the form of groups (5-8 individuals), located at a short distance from each other.

Tanacetum coccineum (Willd.) Grierson (= *Pyrerhrum carneum* M.Bieb.) - endemic to the Caucasus, a rare species included in the Pink List of the Red Book of the Republic of Azerbaijan (Alizade et al., 2014; Red Book of the Republic of Azerbaijan, 2023). Perennial short-rhizome plant (Figure 3). Xeromesophyte. Distributed in the areas of GC Guba, GC west, LC north, LC center and Nakhchivan (Flora of Azerbaijan, 1950-1961). Distributes in the subalpine belt in meadows singly or in small groups with 3-5 individuals.

Aconitum nasutum Fisch.ex Reichenb. - endemic to the Caucasus, a rare species included in the Pink List of the Red Book of the Republic of Azerbaijan (2023). A perennial tuberous plant up to 1 m height (Figure 3). Xeromesophyte. Distributed in the regions of GC Guba, GC west, LC north, LC center and Nakhchivan mountain. Grows in the middle and upper mountain belts. (Flora of Azerbaijan, 1953). Rarely found in subalpine meadows, along forest edges and in bushes with 1-2 individuals located at a considerable distance from each other.

Lomelosia caucasica (M.Bieb.) Greuter & Burdet - endemic to the Caucasus (Alizade et al., 2014). Perennial taproot plant (Figure 3). Xeromesophyte. Distributed in all areas of the Greater Caucasus and Lesser Caucasus. Grows in the subalpine and alpine belts, in meadows (Flora of Azerbaijan, 1961) often forms clumps (8-15 individuals).



Figure 3. a - *Centaurea phrygia* subsp. *salicifolia* (M.Bieb. ex Willd.) Mikheev, b - *Tanacetum coccineum* (Willd.) Grierson, c - *Aconitum nasutum* Fisch.ex Reichenb., d - *Lomelosia caucasica* (M.Bieb.) Greuter & Burdet

The total projective cover of grass stand in the studied meadows is 100%. The aspect of cenoses is variegated. The vertical structure is 3-tiered: the first tier (sparse) is formed by trees (*Betula pubescens* var. *litwinowii* Doluch.), shrubs (*Salix kuznetzowii* Laksch. ex Goerz, and dwarf shrubs (*Rosa azerbaijandica* Novopokr. & Rzazade);

The second tier is formed by components of tall grass communities. In this tier we have registered 11 species: *Doronicum macrophyllum* Fisch. (Cop²), *Senecio propinguus* Schischk. (Cop¹-Cop²), *Cephalaria gigantea* (Ledeb.) Bobr. (Cop¹), *Aconitum nasutum* Fisch.ex Reichenb. (Sp), *A. orientale* Mill. (Cop¹-Cop²), *Delphinium flexuosum* Bieb. (Cop¹), *Eleutherospermum cicutarium* Boiss. (Cop²-Cop³), *Arctium tomentosum* Mill. (Cop¹-Cop²), *Lactuca macrophylla* A.Gray (= *Cicerbita grandis* (K.Koch) Schchian) (Sp), *Filipendula ulmaria* (L.) Maxim. (Sp) и *Thalictrum simplex* L. (Cop¹).

III layer is the most dense, with mixed grasses. In this layer of meadow phytocenoses of the studied territories, we registered 75 species belonging to 64 genera, 23 families: *Achillea millefolium* L. (Cop¹-Cop²), *Aconitum confertiflorum* (D.C.) Voroschilov (Sp), *Alchemilla sericata* Rchb. ex Buser (Cop²-Cop³), *Allium ursinum* L. (Cop¹-Cop²), *Anemonastrum fasciculatum* (Sp-Cop¹), *Aquilegia olympica* Boiss. (Sol-Sp), *Aster alpinus* L. (Sol-Sp.), *A. amellus* subsp. *ibericus* Steven) Grierson (= *Aster ibericus* (Stev.) (Sp.), *Astrantia trifida* (Cop¹-Cop²), *Asyneuma campanuloides* (M.Bieb.) Bornm. (Sp.), *Campanula trautvetteri* (Sp), *Caucasalia parviflora* (M. Bieb.) B.Nord. (= *Senecio lamsanoides* DC. (Sp),

Chaerophyllum aureum (Cop¹-Cop²), *Dianthus caucaseus* Sims (= *D. discolor* Sims) (Sp-Cop¹), *Filipendula vulgaris* Moench (Cop²-Cop³), *Gentiana septemfida* (Cop¹-Cop²), *Linum austriacum* L. (Cop¹-Cop²), *L. catharticum* L. (Sp), *L. hypericifolium* Salisb. (Sp-Cop¹), *Lilium monadelphum* M.Bieb. (Sol.), *Centaurea cheiranthifolia* Willd. (Cop¹), *C. fischeri* Willd. (Cop¹), *C. phrygia* subsp. *salicifolia* (Cop¹-Cop²), *Clinopodium vulgare* L. (Sp.-Cop¹), *Coeglossum viride* (Sol.), *Coronilla varia* L. (Cop.²-Cop³), *Cota triumfetti* subs. *triumfetti* (Sol.) (= *Anthemis dumetorum* D.Sosn.) (Cop¹-Cop²), *Dactylorhiza euxina* (Nevski) Czerep. (Sp-Cop¹), *Dolichorrhiza caucasica* (M. Bieb.) Galushko (= *Senecio caucasicus* DC) (Sol.), *Galega officinalis* L. (Cop¹-Cop²), *Galium verum* L. (Cop¹-Cop²), *Gentiana cruciata* L. (Cop¹), *G. septemfida* Pall. (Sp-Cop¹), *Hesperis matronalis* L. (Sol.), *Hypericum linarioides* subsp. *linarioides* (= *Hypericum polygonifolium* Rupr.) (Sp), *Inula aspera* Poir. (Cop¹-Cop²), *Klasea radiata* (Waldst. & Kit.) Á.Löve & D. Löve (*Serratula radiata* M. Bieb.) (Sp.), *Lamium maculatum* (L.) L. (Cop¹), *Lomelosia caucasica* (M.Bieb.) Greuter & Burdet (= *Scabiosa caucasica* Bieb.) (Cop¹-Cop²), *Nonea echioides* Roem. & Schult. (= *Macrotomia echioides* (L.) Boiss.) (Cop¹), *Melampyrum arvense* L. (Cop¹-Cop²), *Myosotis sylvatica* Ehrh. ex Hoffm. (Cop¹-Cop²), *Nepeta nuda* subsp. *nuda* (= *Nepeta pannonica* L.) (Cop¹-Cop²), *N. mussinii* Spreng. (Sp), *Origanum vulgare* L. (Cop¹-Cop²), *Pastinaca armena* Fisch.et C.A.Mey. (Cop¹), *Pedicularis sibthorpii* Boiss. (Sp-Cop¹), *Pentanema orientale* (Lam.) D.Gut.Larr., Santos-Vicente, Anderb., E.Rico & .M.Mart.Ort. (= *Inula orientalis*) (Cop¹-Cop²), *Peucedanum ruthenicum*

M.Bieb. (Cop¹), *Phelypaea coccinea* (M.Bieb.) Poir. (Sol.), *Phlomis tuberosa* (L.) Moench (Sp), *Pimpinella rhodantha* (C-op¹-Cop²), *Polygala anatolica* (Cop¹), *P. alpicola* Rupr. (Sp), *Polygonatum glaberrimum* K.Koch (Cop¹-Cop²), *Polygonum carneum* K.Koch (Sp), *Primula ruprechtii* Kusnez. (Cop¹-Cop²), *Psephellus dealbatus* K.Koch (Cop¹), *Rhinanthus vernalis* (Cop¹-Cop²), *Rubus saxatilis* L. (Cop¹), *Scabiosa bipinnata* K.Koch (Cop¹ -Cop²), *S. owerinii* Boiss. (Cop¹-Cop²), *Scutellaria oreophila* Grossh. (Sp), *Senecio racemosus* (M.Bieb.) DC. (Sp.), *Seseli transcaucasicum* (Schischk.) Pimenov & Sdobnina (= *Libanotis transcaucasica* Schischk.) (Cop¹), *Stachys macrantha* (K.Koch) Stearn (Cop¹-Cop²), *S. spectabilis* Choisy ex DC. (Cop²-Cop³), *Symphytum asperum* Lepech. (Cop¹), *Tanacetum coccineum* (Willd.) Grierson (Sp), *T. parthenium* (L.) Sch.Bip. (= *Pyrethrum partheniifolium* Willd) (Cop¹), *Traunsteinera sphaerica* (M.Bieb.) Schltr. (= *Orchis sphaerica* M.Bieb.) (Sp), *Trifolium trichocephalum* M.Bieb. (Cop¹-Cop²), *Trisetum*

flavescens (L.) P.Beauv.(= *T. pratense* Pers.) (Cop¹-Cop²), *Valeriana alliariifolia* var. *tiliifolia* (Troicij) V.E.Avet. (= *V. tiliifolia* Troitzk.) (Sp), *Vicia abbreviata* Fisch. ex Spreng. (Cop¹-Cop²).

On the rocks located in the territory of the studied meadows we recorded 12 species from 11 genera of 9 families: *Artemisia chamaemelifolia* Vill. (Sp), *A. splendens* Willd. (Sp-Cop¹), *Campanula saxifraga* subsp. *meyeriana* (Rupr.) Ogan. (*C. meyeriana* Rupr.) (Sp), *Cotoneaster integerrimus* Medik. (Sp.-Cop¹), *Juniperus communis* var. *saxatilis* Pall. (Sp), *Minuartia circassica* (Albov) Woronow (= *Minuartia caucasica* Mattf. ex Asch. & Graebn.) (Cop¹), *Saxifraga cartilaginea* Willd. ex Sternb. (Cop¹), *Scrophularia olympica* Boiss. (Sp), *Phedimus spurius* (M.Bieb.) 't Hart (= *Sedum oppositifolium* Sims) (Sp-Cop¹), *Sorbus aucuparia* L. (Sp), *Thalictrum foetidum* L. (Cop¹), *Valeriana alliariifolia* var. *tiliifolia* (Troicij) V.E.Avet. (= *Valeriana tiliifolia* Troitzk.) (Sp) (Figure 4) and etc.

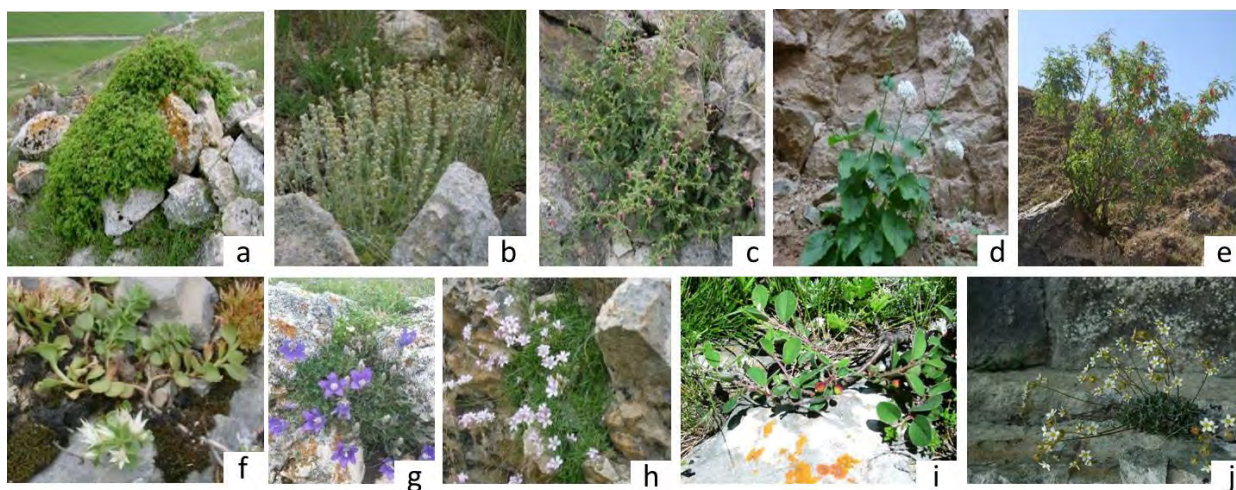


Figure 4. a - *Juniperus communis* var. *saxatilis* Pall, b – *Artemisia splendens* Willd., c – *Scrophularia olympica* Boiss., d - *Valeriana alliariifolia* var. *tiliifolia* (Troicij) V.E. Avet., e - *Sorbus aucuparia* L., f - *Phedimus spurius* (M.Bieb.) 't Hart, g - *Campanula saxifraga* subsp. *meyeriana* (Rupr.) Ogan., h - *Minuartia circassica* (Albov) Woronow, i - *Cotoneaster integerrimus* Medik., j - *Saxifraga cartilaginea* Willd. ex Sternb.

Thus, of the total number of species registered by us (101) in meadow phytocenoses, the largest number are representatives of the families Asteraceae (22), Lamiaceae (9), Apiaceae (7), Fabaceae, Rosaceae (6 each), Ranunculaceae (5), the remaining families are represented by

1-4 species.

Considering the beneficial properties of *Tanacetum coccineum* and *Pojarkovia pojarkovae*, as well as their poor study, we investigated the structure of the cenopopulations (CP) of these endemic plants.

Cenopopulations (CP) of the *Tanacetum coccineum* species were studied in subalpine meadows. CP1 - in moist meadows around the village of Cek in the Guba region, CP 2 - in meadows around the village of Susay, CP 3 - in meadows around the village of Sudur in the Gushar region, and CP 4 - in meadows in the Ismayilli region.

The study of the ontogenetic structure of *Tanacetum coccineum* cenopopulations in the study area revealed that all cenopopulations are normal. However, CP 3-4 is incomplete due to the absence of subsenile and senile individuals

(Figure 5).

It was found that in the 4 studied cenopopulations, the highest percentage of pregenerative individuals was in CP 4 (31%), and the lowest indicators were in CP 3 (25%), the highest percentage of generative individuals was in CP 1 (51%), and the lowest indicators were in CP 4 (28%). The maximum indicators of individuals in the postgenerative state were recorded in CP 1 (7%).

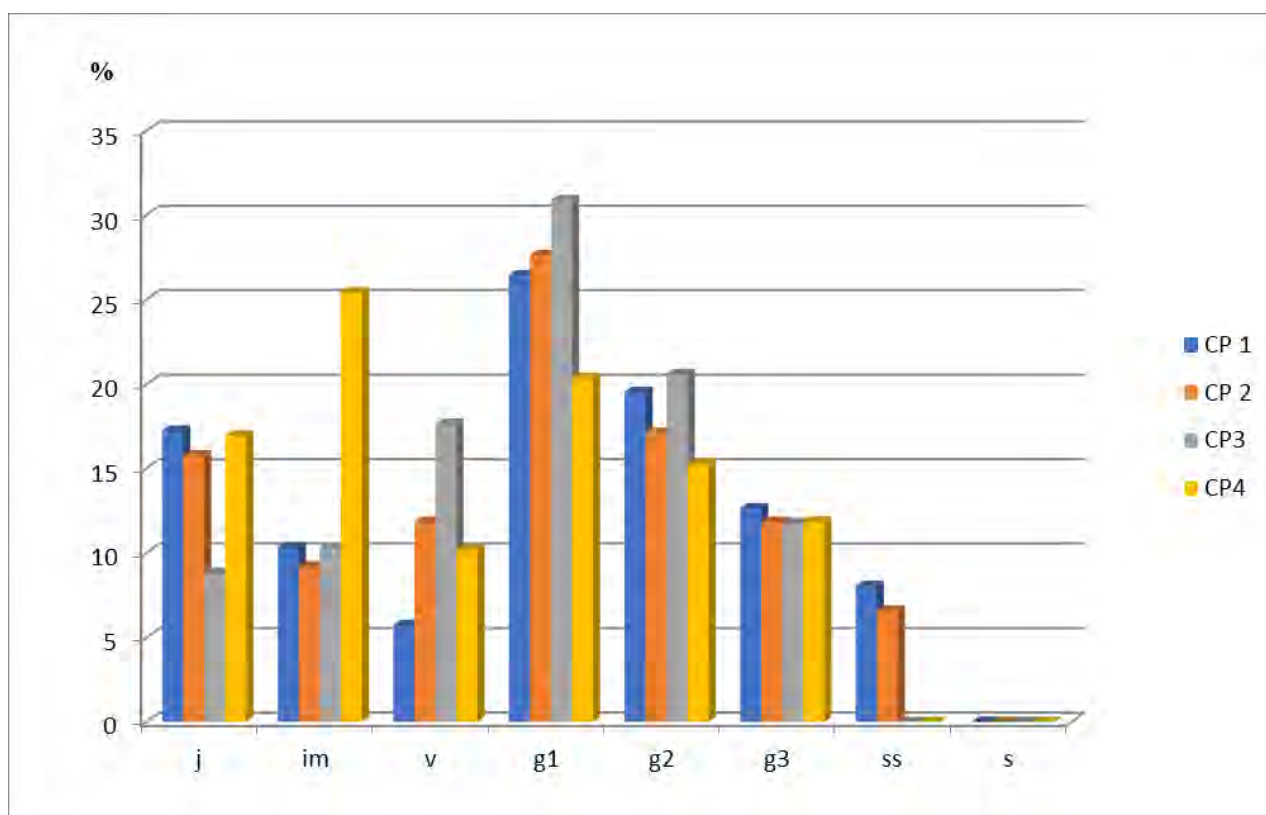


Figure 5. Ontogenetic spectrum of cenopopulations of *Tanacetum coccineum* (Willd.) Grierson

The number and average density of individuals were recorded at the highest level in CP 1 and the lowest in CP 4. The highest average density of pregenerative individuals was observed at CP 4, and generative and postgenerative

individuals at CP 1. The recovery and replacement index had the highest values at CP 2. Based on the Δ and ω indices, CP 1, CP 2, are transitional, CP 3 is maturing, and CP 4 is young (Table 1).

Table 1

**Spatial and demographic characteristics of cenopopulations of
Tanacetum coccineum (Willd.) Grierson**

No	n	X_a	X_{pre}	X_g	X_{post}	I_r	I_a	I_{rep}	Δ	ω	Type of CP
CP 1	87	5,8	1,9	3,4	0,5	0,568	0,081	0,5	0,416	0,591	transitional
CP 2	76	5,1	1,8	2,9	0,3	0,651	0,583	0,657	0,383	0,586	transitional
CP 3	68	4,5	1,6	2,9	0	0,582	0	0,582	0,327	0,641	maturing
CP 4	59	3,9	2,1	1,9	0	1,107	0	1,107	0,291	0,506	young

Note. n—number of individuals; X_a — total average density of plants. individuals /1 m²; X_{pre} —density of the pregenerative individuals. individuals/1m²; X_g —density of generative individuals/1m²; X_{post} —density of postgenerative individuals/1m²; I_r —recovery index; I_a — aging index, I_{rep} — replacement index; Δ —age index; ω —efficiency index.

Cenopopulations of the *Pojarkovia pojarkovae* species were studied in the forest massif around the village of Gryzdahne in the Guba region (CP1-2), the waterfall in the village of Ilisu of Gakh region (CP3), and the area around the waterfall in the Topchu forest reserve No. 1 in the Ismayilli region (CP4).

The study of the ontogenetic structure of the cenopopulations of *Pojarkovia pojarkovae* in the study area revealed that all cenopopulations are normal. However, CP 4 is incomplete due to the absence of subsenile and senile individuals

(Figure 6).

In the 4 studied cenopopulations, the highest percentage of pregenerative individuals was determined in CP 2 (38%), and the lowest indicators were determined in CP 3-4 (18%), the highest percentage of generative individuals was determined in CP 1 (78%), and the lowest indicators were determined in CP 4 (11%). The maximum indicators of individuals in the post-generative state were determined in CP 4 (14%).

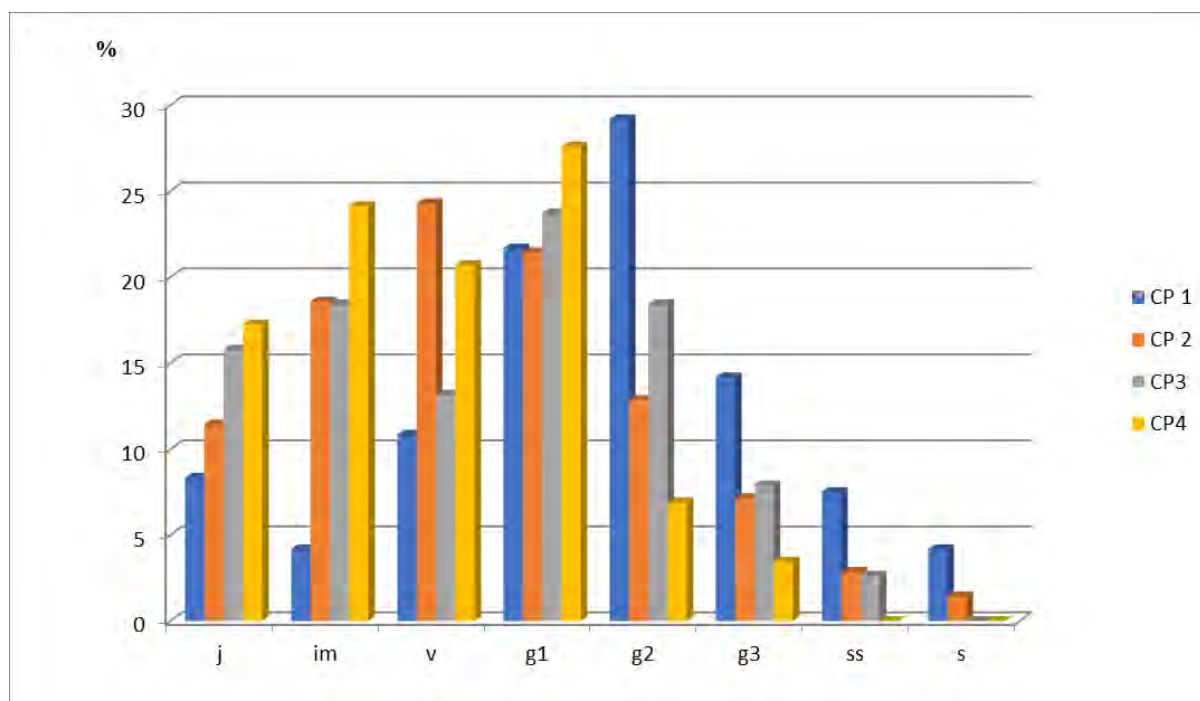


Figure 6. Ontogenetic spectrum of cenopopulations of *Pojarkovia pojarkovae* (Schischk.) Greuter

The number and average density of individuals were recorded at the highest in CP 1 and the lowest in CP 4. The highest average density of pregenerative individuals was observed at CP 2, and generative and postgenerative individuals

at CP 1. The recovery index and replacement index have the highest values at CP 4. Based on the Δ and ω indices, CP 1 is transitional, and the others are young type (Table 2).

Table 2.

Spatial and demographic characteristics of cenopopulations of *Pojarkovia pojarkovae* (Schischk.) Greuter

No	n	X_a	X_{pre}	X_g	X_{post}	I_r	I_a	I_{rep}	Δ	ω	Type of CP
CP 1	120	8	1,9	5,2	0,9	0,359	0,117	0,304	0,468	0,674	transitional
CP 2	70	4,7	2,5	1,9	0,2	1,310	0,043	1,187	0,284	0,512	young
CP 3	38	2,5	1,2	1,3	0,1	0,947	0,026	0,9	0,310	0,543	young
CP 4	29	1,9	1,2	0,7	0	1,636	0	1,636	0,205	0,455	young

Note. n—number of individuals; X_a — total average density of plants. individuals /1 m²; X_{pre} —density of the pregenerative individuals. individuals/1m²; X_g —density of generative individuals/1m²; X_{post} —density of postgenerative individuals/1m²; I_r —recovery index; I_a — aging index, I_{rep} — replacement index; Δ —age index; ω —efficiency index.

Taking into account the experience of traditional medicine and the experimental studies conducted by us, primary experiments were conducted to study the antimicrobial activity of 8 plant species. As a result, it was revealed that water-alcohol and methanol extracts of the studied plant species to a certain extent had an antimicrobial effect on the studied microorganisms

(*Staphylococcus aureus* (MSSA), (MRSA), *Bacillus anthracoides*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae* и *Candida albicans*), the exception is the extract of *Leontodon hispidus* flowers. The results of the antibacterial and antimycotic action of plant extracts are presented in Table 3.

Table 3

Antimicrobial action of hydroalcoholic plant extracts

Test cultures	Plant extracts									
	<i>Centaurea phrygia</i> subsp. <i>salicifolia</i> (flower)	<i>Centaurea phrygia</i> subsp. <i>salicifolia</i> (leaf)	<i>Centaurea phrygia</i> subsp. <i>salicifolia</i> (fruit)	<i>Leontodon hispidus</i> (flower)	<i>Leontodon hispidus</i> (root)	<i>Lomelosia caucasica</i> (flower)	<i>Lomelosia caucasica</i> (root, leaf, stem)	<i>Aconitum nasutum</i> (flower)	<i>Aconitum nasutum</i> (leaf)	<i>Lapsana communis</i> (aerial parts)
Gram-positive bacteria										
<i>Staphylococcus aureus</i> (MSSA)	+	-	-	-	+	+	-	-	+	+
<i>Staphylococcus aureus</i> (MRSA)	+	+	-	-	+	+	+	+	+	+
<i>Bacillus anthracoides</i>	+	+	+	-	-	-	-	-	-	-
Gram-negative bacteria										
<i>Escherichia coli</i>	+	-	-	-	+	+	-	-	+	+
<i>Pseudomonas aeruginosa</i>	-	-	-	-	+	-	-	-	+	+
<i>Klebsiella pneumoniae</i>	-	-	-	-	+	-	-	-	+	+
Opportunistic yeast-like fungus										
<i>Candida albicans</i>	+	-	-	-	+	-	-	-	+	+

Note: "+" - inhibits the growth of microorganisms. "-" - does not inhibit the growth of microorganisms.

As can be seen from Table 3, the extract obtained from the flowers of *Centaurea phrygia* subsp. *salicifolia* affected all gram-positive bacteria, as well as *Candida albicans* (7 mm) and *Escherichia coli* (7 mm). The extract of this plant had a more effective effect on methicillin-resistant *Staphylococcus aureus* (MSSA) and suppressed its development at a diameter of 14 mm. Whereas bactericidal action on strains of *Pseudomonas aeruginosa* and *Klebsiella pneumoniae* was not observed. The extract obtained from the leaves of the same plant affected only *Staphylococcus aureus* (MRSA) (9 mm) and *Bacillus anthracoides* (7 mm), and the extract of the fruits - only *B. anthracoides* (7 mm).

The extract obtained from the flowers of *Leontodon hispidus* showed no activity against the test cultures studied, whereas the extract from the roots inhibited the development of all microorganisms (except *Bacillus anthracoides*) in the 7 mm range, especially suppressing the development of the gram-positive bacteria *Pseudomonas aeruginosa* in the 9 mm range.

The extract obtained from the flowers of *Lomelosia caucasica* inhibited the development of gram-positive bacteria *Staphylococcus aureus* (MSSA) and *Staphylococcus aureus* (MRSA), and of the gram-negative bacteria only *Escherichia coli*. Whereas the extract of the root, leaves and stem of the same plant showed activity only against *Staphylococcus aureus* (MRSA). A similar effect was also exerted by the extract of *Aconitum nasutum* flowers. In both cases, in the range of 7 mm. However, the extract from the leaves of *A. nasutum* had a strong antimicrobial effect on the test cultures used (except for *Bacillus anthracoides*), especially against strains of *Staphylococcus aureus* (MSSA - 9 mm, MRSA - 10 mm) and *E. coli* (11 mm). The same antimicrobial activity was demonstrated by the extract of the aerial parts of *Lapsana communis* on the test cultures of *Staphylococcus aureus* (MSSA, MRSA, *Pseudomonas aeruginosa* and *Candida albicans* in the range of 7 mm), with the exception of *B. anthracoides*. Higher activity of this extract was observed especially against *Escherichia coli* and *Klebsiella pneumoniae* (10 and 8 mm, respectively).

Although extracts of flowers, roots, leaves

and stems of *Lomelosia caucasica*, as well as leaves of *Aconitum nasutum* and aerial parts of *Lapsana communis* did not have activity on the culture of *Bacillus anthracoides*, they weakened its growth in a fairly wide range - 16, 11, 22 and 20 mm in diameter, respectively.

The antimicrobial effect of methanol extracts of *Tanacetum coccineum*, *Betula pendula* and *Pojarkovia pojarkovae* was also studied (Table 4).

The extract obtained from the flowers of *Tanacetum coccineum* and their dilutions in the ratio of 1:2 and 1:4. has an effective effect on *Pseudomonas aeruginosa*, and the extract obtained from the leaves is effective against the test culture of *Bacillus anthracoides*, suppressing their development at a diameter of 14 mm and 20 mm, respectively. The antimicrobial effect of the extracts in dilutions of 1:2 and 1:4 on the studied test cultures was not observed.

The conducted studies have established that the extract of *Betula pendula* leaves exhibited antimicrobial activity only against *Bacillus anthracoides*.

Extracts obtained from the stems of *Pojarkovia pojarkovae* had a sufficiently high bactericidal effect on the test culture of *Staphylococcus aureus* and suppressed its development in the diameter of 12 mm and 10 mm, respectively. Although these extracts did not inhibit the growth of the *Bacillus anthracoides* culture, they sharply reduced its growth in the range of 21 mm and 14 mm, respectively. The extract of the stems did not inhibit the development of *Pseudomonas aeruginosa*, but reduced the diameter (10 mm), while the same extract in a dilution of 1:2 had a sufficient effect (8 mm). Antimicrobial activity of extracts of *Pojarkovia pojarkovae* flowers was not observed. Extracts obtained from the leaves of this plant showed activity only against the test culture of *Staphylococcus aureus*. Although these extracts had no effect on the development of *Bacillus anthracoides*, they significantly weakened its development (13 and 15 mm, respectively). The same can be said about the leaf extract (dilution 1:2), which to some extent weakened the development of the test culture *Pseudomonas aeruginosa* (8 mm).

Table 4

Antimicrobial activity of methanol extracts of different parts of *Betula pendula*, *Pojarkovia pojarkovae* and *Tanacetum coccineum*

Test cultures	<i>Betula pendula</i> leaf		<i>Pojarkovia pojarkovae</i> stem		<i>Pojarkovia pojarkovae</i> flowers		<i>Pojarkovia pojarkovae</i> leaf		<i>Tanacetum coccineum</i> flowers		<i>Tanacetum coccineum</i> leaf	
	1	1:2	1	1:2	1	1:2	1	1:2	1	1:2	1	1:2
Gram-positive bacteria												
Staphylococcus aureus	–	–	+	+	–	–	+	–	–	–	–	–
Basillus anthracoides	+	–	–	–	–	–	–	–	–	–	+	–
Gram-negative bacteria												
<i>Escherichia coli</i>	–	–	–	–	–	–	–	–	–	–	–	–
<i>Klebsiella pneumoniae</i>	–	–	–	–	–	–	–	–	–	–	–	–
<i>Pseudomonas aeruginosa</i>	–	–	–	+	–	–	–	–	+	–	–	–
Opportunistic yeast-like fungus												
<i>Candida albicans</i>	–	–	–	–	–	–	–	–	–	–	–	–

Note: “+” - inhibits the growth of microorganisms. “-” - does not inhibit the growth of microorganisms.

Conclusion

The results of monitoring forest and meadow phytocenoses conducted in the Greater Caucasus regions over the past few years have shown that the vegetation cover is rapidly degrading. Thus, the meadow areas in the vicinity of the villages of Sudur in Gusar and Dzhek in Guba districts, where grass previously occupied significant areas, now have significantly decreased. In forest areas, the appearance of representatives of marsh (*Phragmites australis* subsp. *australis*) and psammophyte-littoral vegetation (*Convolvulus persicus* L.), which are not typical for mountain forests, and the introduction of invasive species (*Acalypha australis* L., *Amaranthus spinosus* L., *Artemisia verlotiorum* Lamotte, *Erigeron annuus* (L.) Desf., *Oenothera odorata* Jacq. and others) is observed (Mehdiyeva, Geltman, 2015; Abdiyeva et al., 2020; Abdiyeva et al., 2021; Mehdiyeva et al., 2022; Mehdiyeva et al., 2024). If in previous years *Lapsana communis*, *Centaurea phrygia* subsp. *salicifolia*, *Lomelosia caucasica*, as well as *Achillea millefolium*, *Stachys macrantha*, *Doronicum macrophyllum*, *Senecio propinguus*, *Cephalaria gigantea* and others had significant reserves (Mehdiyeva, 2024), at present the number of these plants has significantly decreased. Many years of experience in expeditionary research shows that one of the main reasons for this situation is a significant increase in anthropogenic factors (road construction, expansion of tourist infrastructure, haymaking, grazing, etc.),

which negatively affect the vegetation cover and its biodiversity. The studied species, as well as most of the plants are part of phytocenoses, have medicinal properties and can further serve as a basis for the development of new effective drugs. In order to preserve the natural habitats of such plant species, it is necessary to regulate human economic activity and reduce the recreational load.

The impact of the identified changes in the habitat is evident in alterations to population parameters, community structure, and their dynamics. Our study of the ontogenetic and demographic structures of two endemic and vulnerable species from the Caucasus revealed that, while pregenerative individuals predominated in the population of *Pojarkovia pojarkovae*, young and middle-aged generative individuals were more prevalent in the population of *Tanacetum coccineum*. Nonetheless, both species are vulnerable to climate change and human activities

Primary studies of the antimicrobial activity of aqueous-alcoholic and methanol extracts obtained from various organs of the above plants have shown that most of them exhibit activity against various gram-positive, gram-negative bacteria and opportunistic yeast-like fungi. In order to study in depth the antimicrobial properties of the studied species, further work can be continued using a wider range of microorganism strains.

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ECOLOGICAL AND ANATOMICAL CHARACTERISTICS AND TOLERANCE OF *SALSOLA NODULOSA* ILJIN AND *ZYGOPHYLLUM FABAGO* L. SPECIES UNDER ENVIRONMENTAL PRESSURES IN ARID AND SALINE ECOSYSTEMS

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Abstract: *This study aimed to examine the anatomical structures of the plant species Salsola nodulosa and Zygophyllum fabago. Material from the vegetative organs of Salsola nodulosa and both vegetative and some generative organs of Zygophyllum fabago were used for the research. Cross-sections obtained from various organs were analyzed under a microscope, and the results, including photomicrographs, are presented in the main text of the article. The leaf blades of Salsola nodulosa, a succulent species, possess a specific elongated circular structure, with chloroplast-containing tissues concentrated in the peripheral zones. The positioning characteristics of its vascular bundles differ according to the anatomical structure of the leaf. The roots of the plant exhibit a distinct structure, with repeated xylem and phloem rings. In the generative organs of Zygophyllum fabago, specifically the petals, a significant accumulation of carotenoid chromoplasts is observed, which give the petals their specific coloration. The petiole and stem of the plant contain sclerenchyma tissue, which serve as structural support. Sclereids are found in the roots as mechanical tissue elements. Anatomical studies of plants distributed in various regions are crucial for understanding the specific characteristics of individual species and identifying the regularities of anatomical changes in plants adapted to different ecological conditions. The research primarily focuses on the structural adaptations of Salsola nodulosa and Zygophyllum fabago species in arid and saline ecosystems under conditions of ecological pressure.*

Keywords: *stoma, druse, mesocarp, metaxylem, water-storage parenchyma*

Introduction

Salsola nodulosa is a plant species belonging to the genus *Salsola* of the *Amaranthaceae* family (Figure 1). It is one of the plant species adapted to arid environments, and the signs of these adaptations are evident in its morphological and anatomical features (Asgarov, 2016). The leaves on the stem of the plant are small and slender, having anatomical features that allow them to collect and conserve water. The narrow leaves minimize water loss through transpiration, unlike broader leaves that have a larger surface area. These leaves lack petioles. The plant grows in a bush form and has deep-reaching roots. As the stem ages, it begins to lignify (Novruzov, 2010). The plant used in traditional medicine, has antioxidant and antibacterial

properties. It contains antioxidants, alkaloids, flavonoids, saponins, and more. Its dry mass consists of approximately 9% soda and 2.5 % potash (Ibadullayeva, 2023). *Zygophyllum fabago* is a plant species of the *Zygophyllum* genus in the *Zygophyllaceae* family (Figure 1). Adapted to dry areas, this plant has a well-developed and deep-reaching taproot system (Qurbanov, 2009b). It grows in a bush form, but its stems are renewed annually. The leaves of the plant consist of a petiole that connects to two leaflets at its apex. Anatomical changes have occurred in the leaflets to facilitate water storage and conservation. The plant is rich in alkaloids, flavonoids, saponins, coumarins, essential oils, vitamins C and K, triterpenoids, phenolic acids and more (Karimov et al., 2010).



Figure 1. The general appearance of plants belonging to species *Salsola nodulosa* and *Zygophyllum fabago*.
A-*Salsola nodulosa*, B-*Zygophyllum fabago*.



Figure 2. The area of Jabrayil district where the studied plants are naturally distributed.

Materials and Methods

Collection of Plant Samples:

The plants studied were collected from the Jabrayil region of the Republic of Azerbaijan (Figure 2). Samples from the leaves, stems, and roots of *Salsola nodulosa* and from the leaves, stems, roots, flowers, and fruits of *Zygophyllum fabago* were collected for the research.

Sample Processing and Analysis:

The collected materials were processed in laboratory conditions with special chemical agents to prepare them for sectioning. Cross-sections were made using a hand microtome, and the staining process was performed using safranin dye, which stains lignified tissues red. Permanent preparations were made (Tutayuy, 1967) (Humbatov, 2017). (Jana, 2003). Safranin dye stains lignin-containing tissues red, allowing lignified or woody elements such as

xylem vessels, libriform fibers, and sclerenchyma cells to be clearly visible in the anatomical cross-sections when analyzed under a microscope (Sardarova, 2022a).

To determine the anatomical structures in the sections, light microscopes from the German brands ZEISS and MOTIC were used. Micrographs of the individual sections were taken (Asgarov, 2011) (Humbatov, 2017). During the analysis, the identification of the epidermis, parenchyma, vascular elements, and other tissue types was carried out. The structural characteristics, spatial arrangement, and the relationship between structure and function were clarified.

Results and discussions

Anatomic characteristic of *Salsola nodulosa*: Leaf Blade

In cross-section, the leaf blade appears

rounded, with the central portion predominantly filled by large, irregularly shaped water-storage parenchyma cells. The primary vascular bundle is situated in the central region of the epidermis's subepidermal region largely consists of palisade mesophyll cells, with Kranz cells located further inside. The mesophyll cells are slender and densely packed, whereas the Kranz cells are more isodiametric and larger. These chloroplast-bearing tissues are positioned in two sections along the lower

surface of the organ, separated by a subepidermal zone containing a single layer formed by collenchyma-like cells, which merge with water-storage parenchyma (Ibrokhimova and Duschanova, 2024). Stomata are visible in the epidermis in contact with mesophyll cells (Figure 4). Peripheral vascular bundles, with a few spiral protoxylem and phloem elements, are interspersed along the Kranz cell layer. Within the water-storage parenchyma, a large central vascular bundle is flanked on both sides by smaller

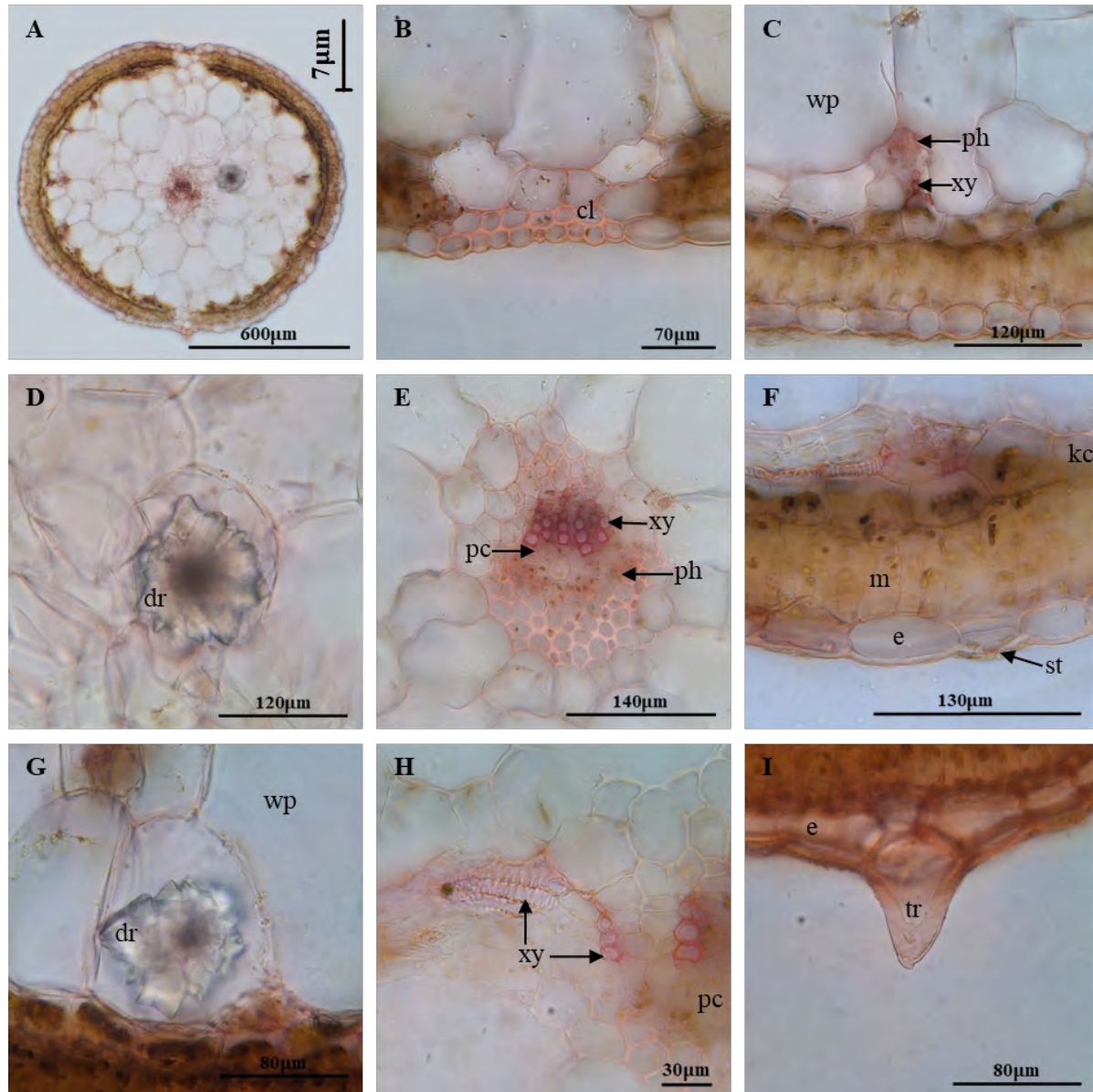


Figure 3. *Salsola nodulosa*. Leaf blade. **A**- General appearance of the cross-section of the leaf blade (10x), **B**-Subepidermal zone without chloroplast-containing tissue (40x), **C**- Chloroplast-containing tissue where the peripheral bundle is supported (40x), **D**-Druze crystals in water-storage tissue (40x), **E**- Central vascular bundle (40x), **F**- Chloroplast-containing tissue located in the subepidermal region (60x), **G**- Druze crystals (60x), **H**- Xylem of the central vascular bundle cut longitudinally (60x), **I** - Trichome formed on the epidermis (60x), **m**-mesophyll; **kc**-kranz cell; **ws**-water storage tissue; **e**-epidermis; **cl**-collenchyma; **xy**-xylem; **ph**-phloem; **pc**-procambium; **dr**-druze; **st**-stoma; **tr**-trichome.

lateral bundles near the edges of the leaf base, with occasional druse crystals within the parenchyma. The larger bundles contain protoxylem and few metaxylem vessels, procambial cells, and phloem elements.

Stem

In cross-section, a transitional arrangement between vascular and non-vascular stele

is observed in the stiffer part of the stem. Near the pith, collateral vascular bundles consist of protoxylem and metaxylem elements followed by phloem, oriented inward. At a certain developmental stage, the cambium layer becomes active, generating libriform fibers, which form a libriform ring. As seen in Figure 5, the cambium, composed of narrow meristematic cells, continues to produce new libriform fibers, identifiable

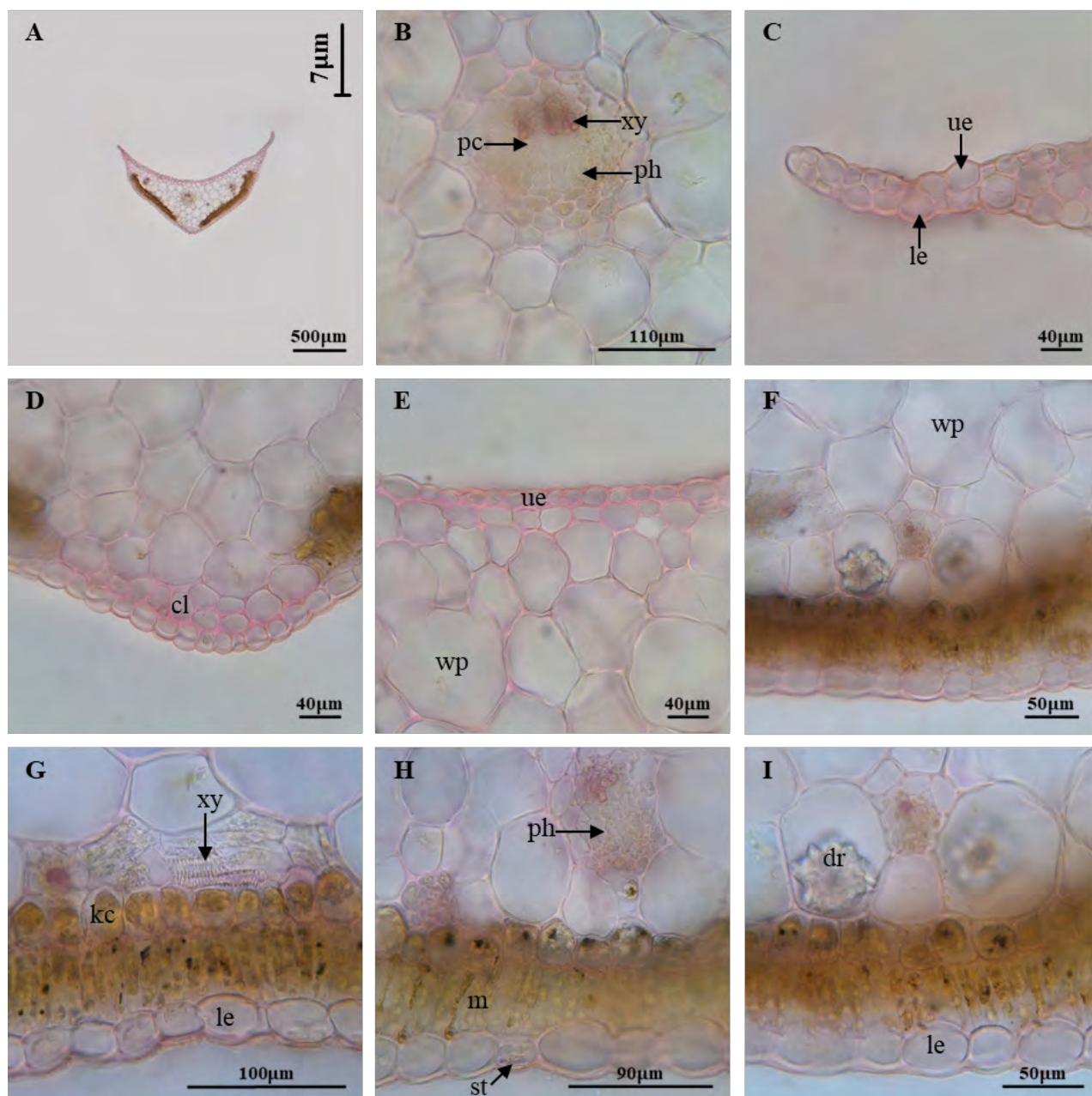


Figure 4. *Salsola nodulosa*. Leaf base. **A-** General appearance of the cross-section of the leaf base (x), **B-** Central vascular bundle (40x), **C-** Lateral extension of the leaf base (40x), **D-** Lower central area of the leaf base (40x), **E-** Upper area (40x), **F-** Subepidermal zone with druze (40x), **G-** Peripheral vascular bundle located in the subepidermal zone (60x), **H-** Epidermal area with stomata (60x), **I-** Subepidermal chloroplast region and druze crystals (60x), **m**-mesophyll; **kc**-kranz cell; **ws**-water storage tissue; **ue**-upper epidermis; **le**-lower epidermis; **cl**-collenchyma; **xy**-xylem; **ph**-phloem; **pc**-procambium; **dr**-druze; **st**-stoma.

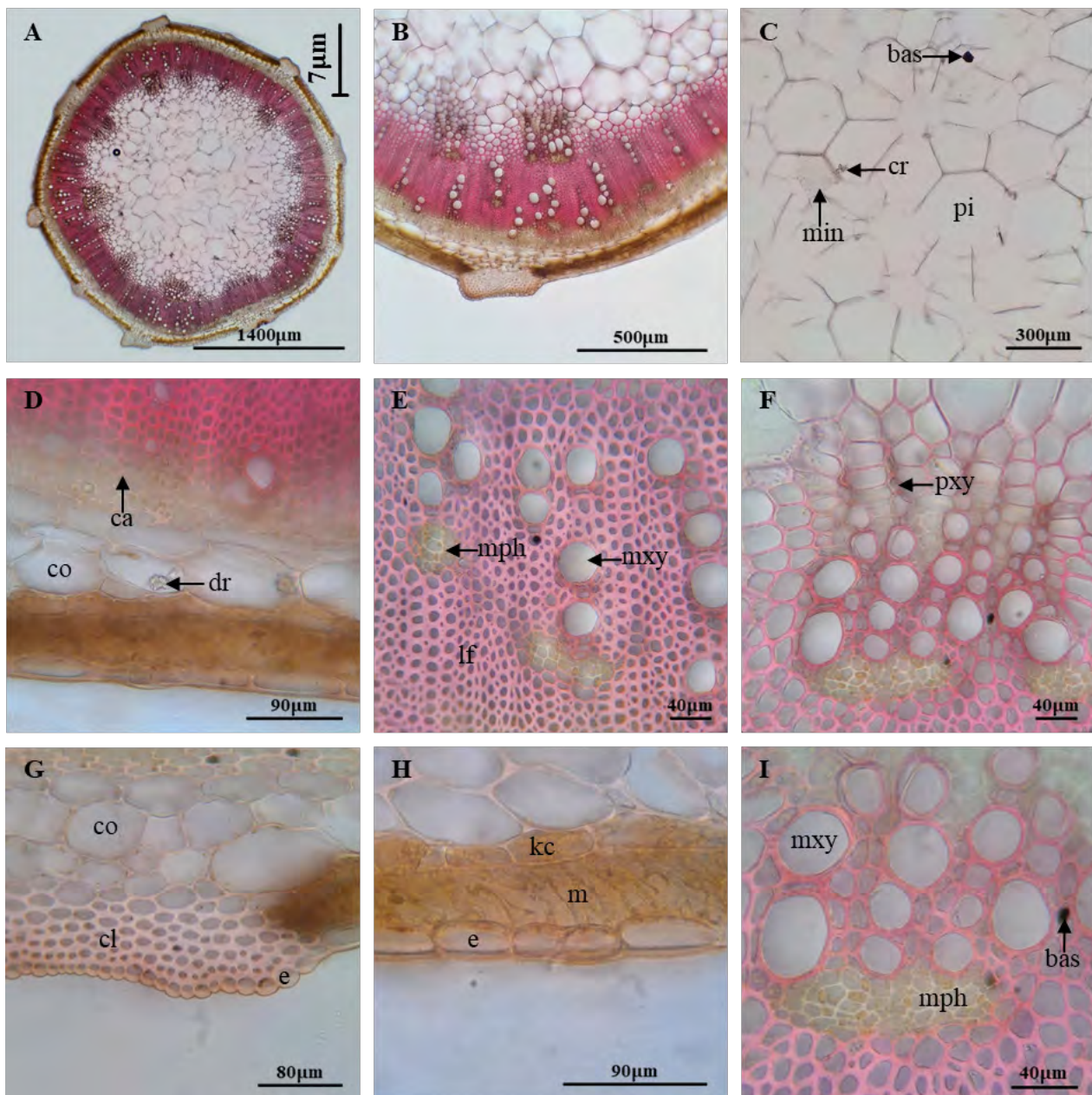


Figure 5. *Salsola nodulosa*. Stem. **A**- General appearance of the cross-section of the stem (4x), **B**- Lateral part of the stem (10x), **C**- Central part filled with pith parenchyma (10x), **D**- Peripheral area containing the cortex (40x), **E**- Xylem tissue (40x), **F**- Early stage vascular bundle formation (40x), **G**- Ridge region of the stem with collenchyma (40x), **H**- Subepidermal area with chloroplasts (60x), **I**- Early stage vascular bundle formation (60x), **m**-mesophyll; **kc**-kranz cell; **e**-epidermis; **cl**-collenchyma; **co**-cortex; **pi**-pith; **ca**-cambium; **lf**-libriform fibres; **dr**-druse; **bas**-biological active substances; **mxy**-metaxylem; **mph**-metaphloem; **pxy**-protoxylem; **min**-minerals; **cr**-crystals.

by their incomplete lignification. Within the libriform ring, radial clusters of metaxylem elements and dispersed phloem tissues are present. Additional phloem is found in the outer cambium layer, surrounded by cortical parenchyma. In ridge regions, cortical parenchyma interfaces with collenchyma, while in areas between the ridges, it contacts chloroplast-bearing tissue. Epidermal cells appear flattened in

cross-section and contain stomata where they contact chloroplast-bearing parenchyma. Kranz structure is evident, with chloroplast-bearing parenchyma consisting of elongated palisade mesophyll cells and Kranz cells. The pith is composed of large cells, and various material accumulations, including druse crystals, are found within the pith and vascular elements. The regions in the pith of the stem where minerals

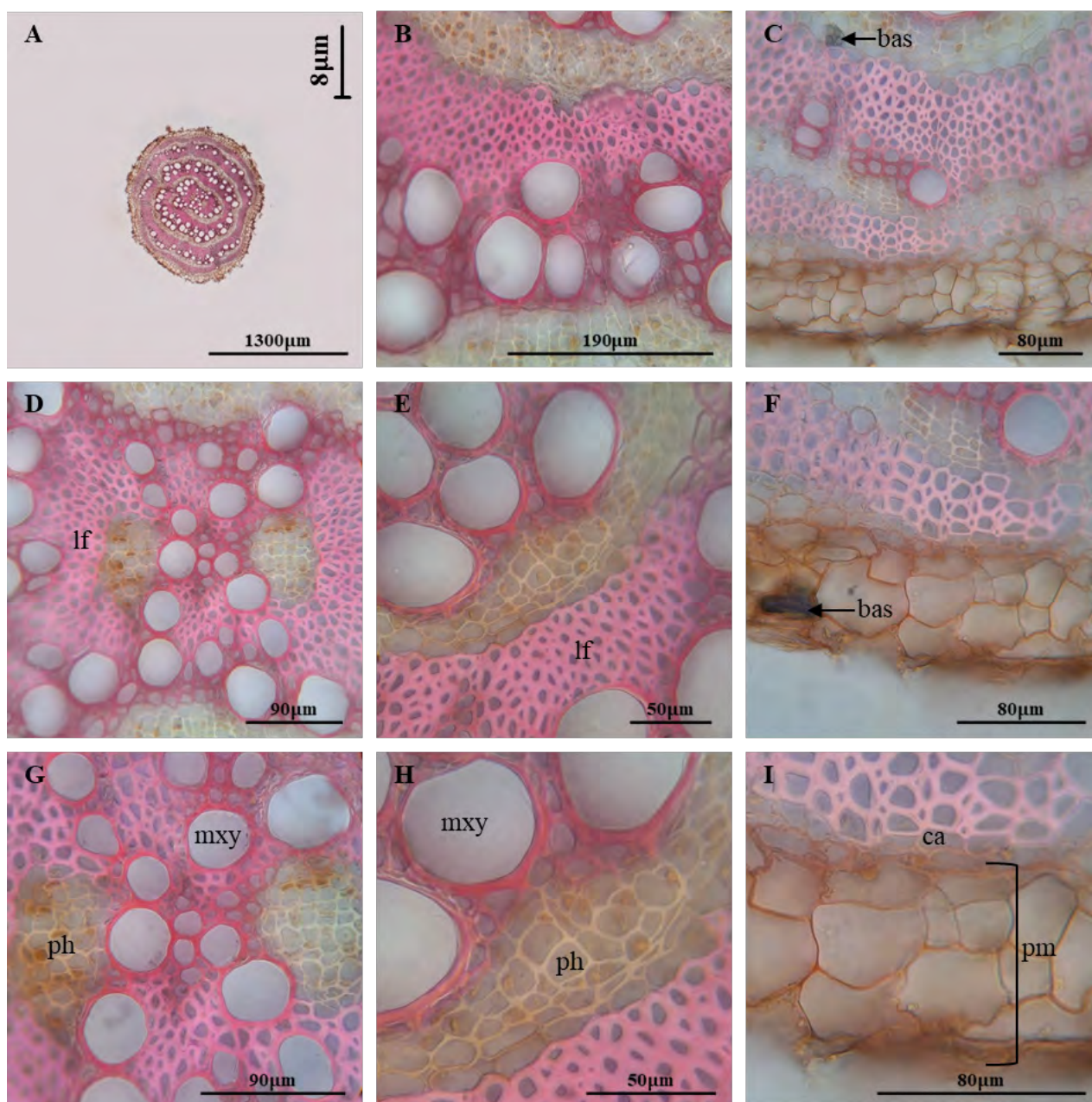


Figure 6. *Salsola nodulosa*. Primary root. **A**- General appearance of the cross-section of the primary root (4x), **B**- Xylem ring (40x), **C**- Lateral part of the root (40x), **D**- Central part of the root (40x), **E**- Phloem region between xylems (60x), **F**- Cortex area of the root and newly formed libriform fibers (60x), **G**- First formed xylem and phloem elements of the root (60x), **H**- Phloem structure (100x), **I**- Periderm structure (100x), **ph**-phloem; **mx**-metaxylem; **ca**-cambium; **pm**-periderm; **bas**-biological active substances.

such as sodium chloride and sodium sulfate accumulate are noticeable.

Primary Root

In the transverse section of the primary root, its distinct internal structure is visible. Xylem and phloem rings are repeated sequentially, with new rings continuing to form, as shown in Figure 6. Each xylem ring contains an inner area formed exclusively of libriform

fibers, appearing lighter stained, and an outer region where vessel elements and libriform fibers co-exist, showing a darker stain (Naz et al, 2022). Cambium cells align along the outer edge of each xylem ring, connecting with phloem that fills the space between successive xylem rings. Secondary metabolites and crystals are observed within the phloem. The root is covered externally by periderm.

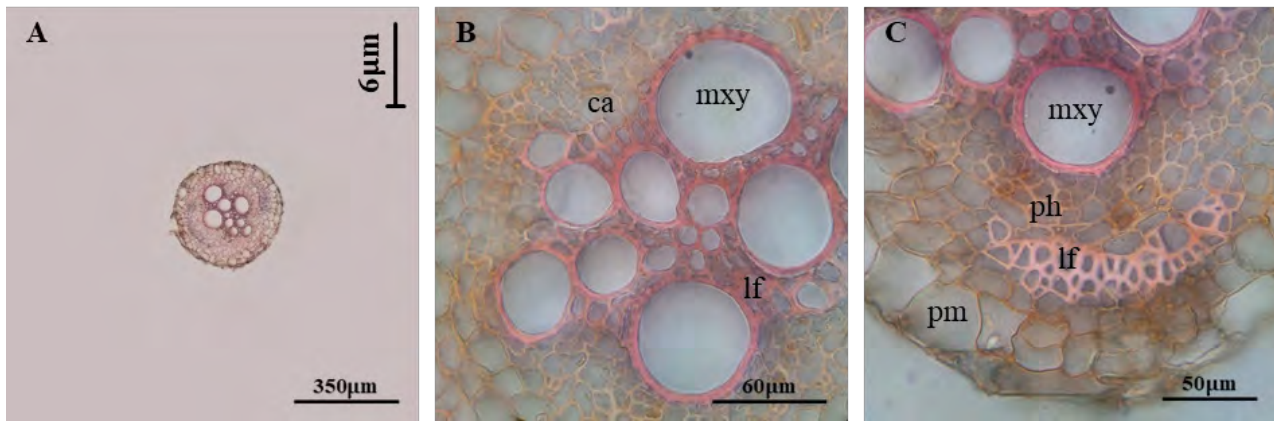


Figure 7. *Salsola nodulosa*. Tertiary root. **A**- General appearance of the cross-section of the tertiary root (10x), **B**- Central part of the root (60x), **C**- Lateral part of the root (60x), **ph**-phloem; **mxy**-metaxylem; **ca**-cambium; **pm**-periderm.

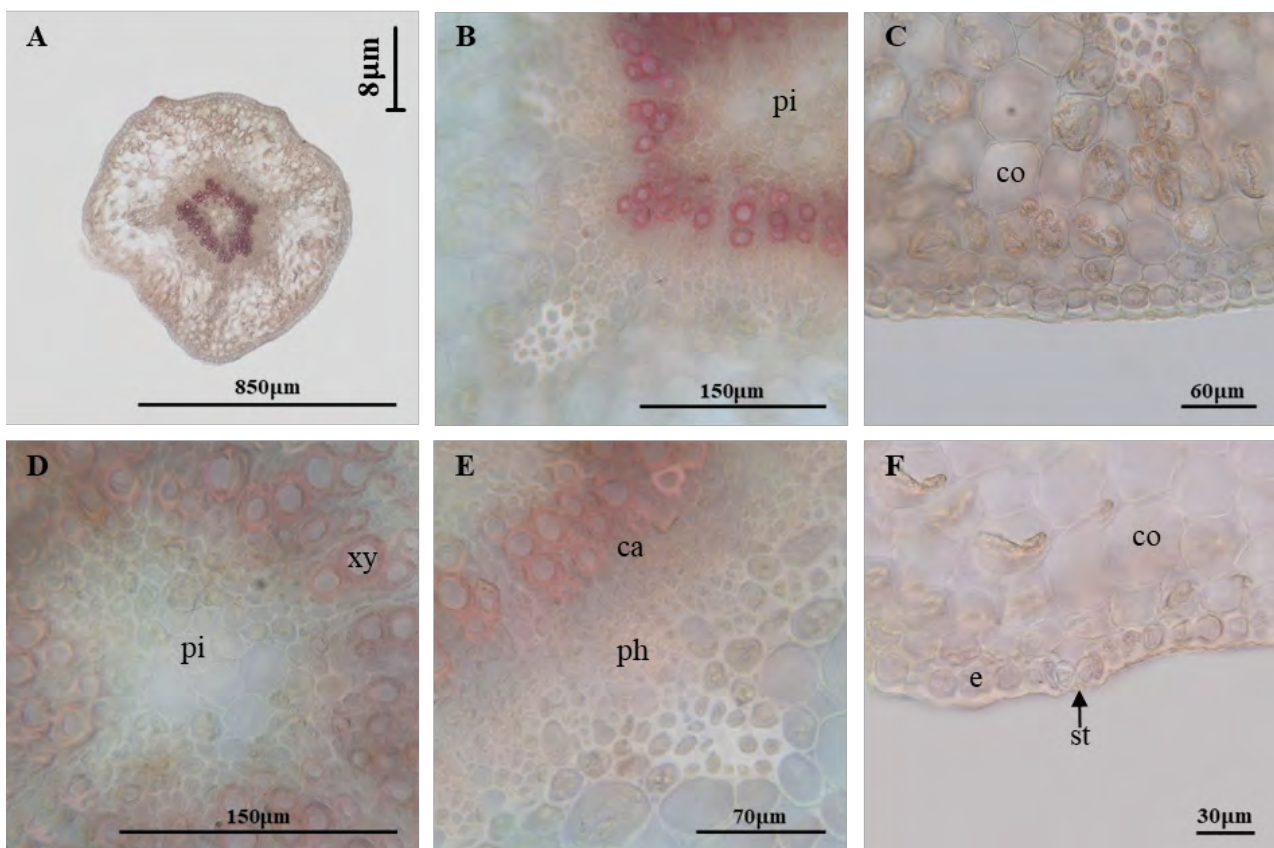


Figure 8. *Zygophyllum fabago*. Flower stalk. **A**- General appearance of the cross-section of the flower stalk (10x), **B**- Central cylinder (40x), **C**- Cortex filling the lateral parts of the flower stalk (40x), **D**- Pith holding the central part (60x), **E**- Peripheral part of the central cylinder (60x), **F**- Peripheral area of the cortex and the epidermis covering it (60x), **e**-epidermis; **co**-cortex; **pi**-pith; **xy**-xylem; **ph**-phloem; **ca**-cambium; **st**-stoma.

Tertiary Root

In the cross-section of a small tertiary root, metaxylem elements and libriform fibers are visible at the center, surrounded by metafloem. New xylem rings with libriform fibers and cambium are observed toward the root periphery.

The root is encased in periderm (Figure 7).

Anatomic characteristic of *Zygophyllum fabago*:

Flower Stalk

In the center of the flower stalk, several large

pith parenchyma cells are visible, surrounded by vessel elements of the xylem, which are separated by medullary rays in certain

Figure areas. Cambial elements on the outer side of the xylem, along with the phloem elements they produce, can be observed, and primary sclerenchyma clusters located in specific areas after the phloem are also seen. These are composed of cells with thick walls, although lignification has not yet occurred. The remaining section up to the epidermis is filled with ordinary parenchyma cells, some of which contain chloroplasts and some do not. In the stomata of the epidermis, guard cells, surrounding subsidiary cells, and the sub-stomatal cavity can be observed (Figure 8).

Sepal

In a cross-section of the sepal perpendicular to the vascular bundles, various tissues can be observed in detail. While the lower epidermis consists of relatively elongated cells arranged along the length of the sepal, the upper epidermis cells are more irregular in shape, and stomata are found here (Figure 9). The epidermises converge and join at the edges of the sepal. Inside the epidermis, chloroplast-containing tissue is located, with spherical-shaped cells that also surround the vascular bundles arranged along the central area. The xylem and phloem elements in the bundles are underdeveloped, and thick-walled primary sclerenchyma cells are located below the phloem.

Petal

As seen in the petal cross-section, the epidermis contains a large amount of carotenoid chromoplasts. Small, fine teeth are visible on the outer layer of the cuticle covering the epidermal cells. Inside the epidermis is parenchyma tissue, which surrounds the vascular elements running along the petal, and these parenchyma cells also contain chromoplasts (Figure 10). The xylem elements of the vascular bundles can be seen to have a spiral-like structure in longitudinal view.

Fruit Stalk

Structurally, the fruit stalk does not differ from the flower stalk. The protective tissue

covering the organ - the epidermis is covered with a cuticle and contains stomata. The guard cells and the surrounding subsidiary cells of the stomata are clearly visible. Beneath the epidermis, there are parenchyma and chlorenchyma cells that surround the central cylinder. The primary sclerenchyma elements located at intervals on the outside of the cylinder have not yet undergone lignification, similar to those found in the flower stalk. A ring of phloem encircles the xylem ring, which is primarily composed of vessel elements and is adjacent to a smaller-celled pith. Medullary rays extend radially along the xylem (Figure 11).

Fruit

The fruit is formed by five carpels, covered on the outside by the exocarp, which is cutinized and has stomata. The guard cells of the stomata are surrounded by two subsidiary cells on each side, and chloroplast-containing tissue is observed around the sub-stomatal cavity. Inside the exocarp is the thick mesocarp, ending with the endocarp that lines the inner surface of the locules. Each carpel contains one locule. Septa made up of mesocarp extend toward the center, where they connect with the central part - the placenta. Vascular elements are located at the junction of these structures. Vascular elements are also observed near the surface of the fruit within the mesocarp. Developing seeds are attached to the placenta along the locule cavities, and in some cross-sections, seed coats are visible (Figure 12).

Leaf

In a cross-section obtained perpendicular to the central vein of the leaf, dorsal and ventral ridge regions are observed in the central vein area, and the internal structure of the leaf appears thick, characteristic of succulent plants. The leaf is amphistomatous, meaning stomata are present on both the adaxial and abaxial epidermis, and both epidermises are covered with a cuticle. The mesophyll consists of two or three layers of palisade parenchyma under the upper epidermis and spongy parenchyma, which resembles palisade parenchyma cells in structure, below the lower epidermis. The large

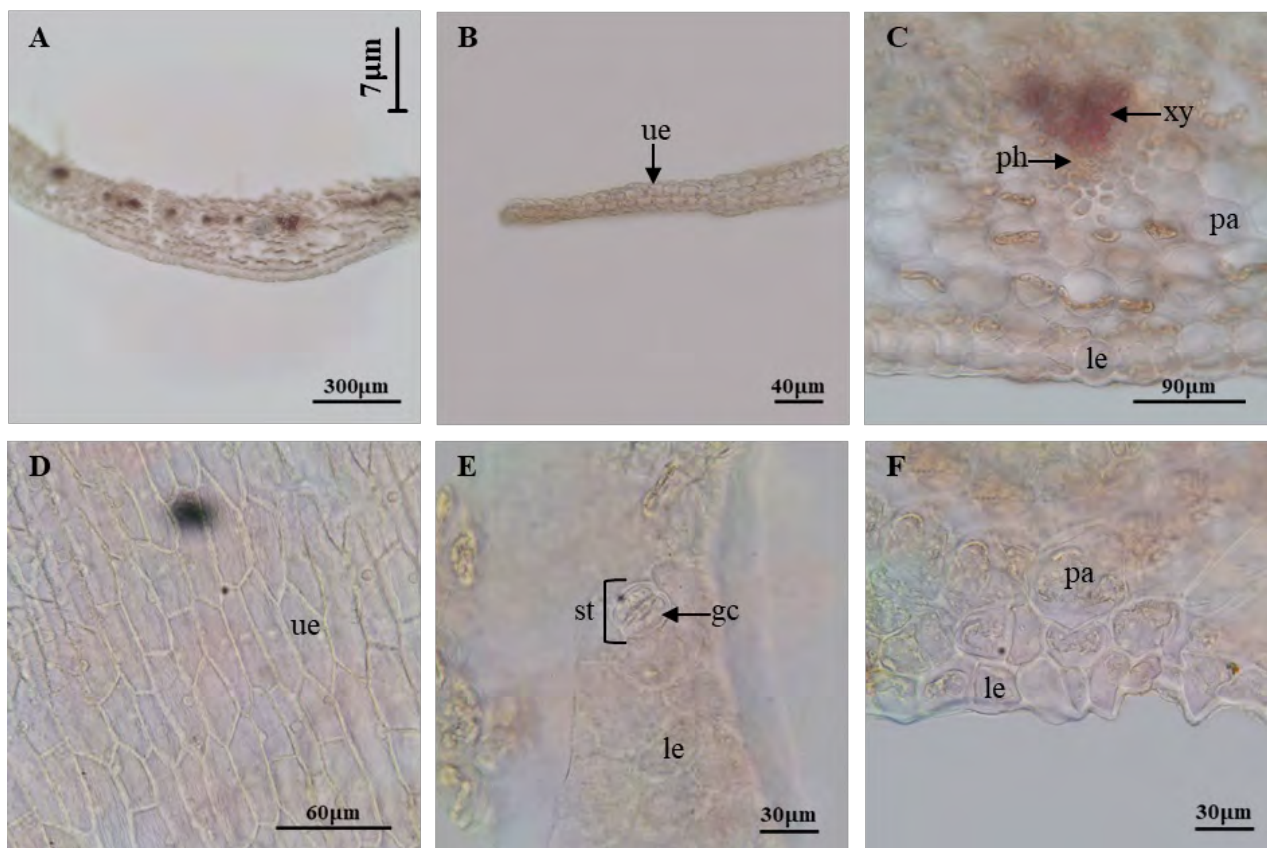


Figure 9. *Zygophyllum fabago*. Sepal. **A**- General appearance of the cross-section of the sepal (10x), **B**- Lateral tip of the sepal (40x), **C**- Central part (40x), **D**- Lower epidermis (60x), **E**- Upper epidermis (60x), **F**- Upper part of the mesophyll of the sepal (60x), **ue**-upper epidermis; **le**-lower epidermis; **xy**-xylem; **ph**-phloem; **st**-stoma; **gc**-guard cell.

number of mesophyll layers helps the leaf retain water, making the leaf blade thick, an adaptation to arid conditions (Sardarova, 2022b). CAM metabolism is present, as in other plants with similar characteristics, ensuring that photosynthesis, gas exchange, and transpiration follow specific patterns. Carbon dioxide uptake occurs at night when the stomata are open, preventing carbon shortage during the day when the stomata are closed. This allows photosynthesis to proceed efficiently without excessive water loss. In the mesophyll, the lateral bundles are arranged along the midline, with the phloem below and xylem above, while the central bundle resembles the structure in the stem, with non-thickened mechanical cells in the center, surrounded by xylem on the inside and phloem on the outside (Figure 13). Surrounding the bundle are primary sclerenchyma clusters located above, below, and at the sides.

Petiole

At the top of the petiole, there are periole wings extending to the sides, each containing lateral bundles that gradually narrow towards the tips. The structure of these wings corresponds to that of the leaf, with mesophyll composed of upper palisade and lower spongy parenchyma, transitioning towards central filling parenchyma. Stomata can be observed on the epidermis covering both the wings and the entire petiole. In the center of the petiole, there is a conductive region composed of xylem, arranged around mechanical elements and separated by procambium, with phloem surrounding it externally (Figure 14). Parenchyma rays extend inward from the phloem towards the xylem, formed by elongated cells arranged in a row (Wang et al, 2020). External to the phloem, a few clusters of sclerenchyma tissue are found. This tissue type is also observed in the lateral bundles.

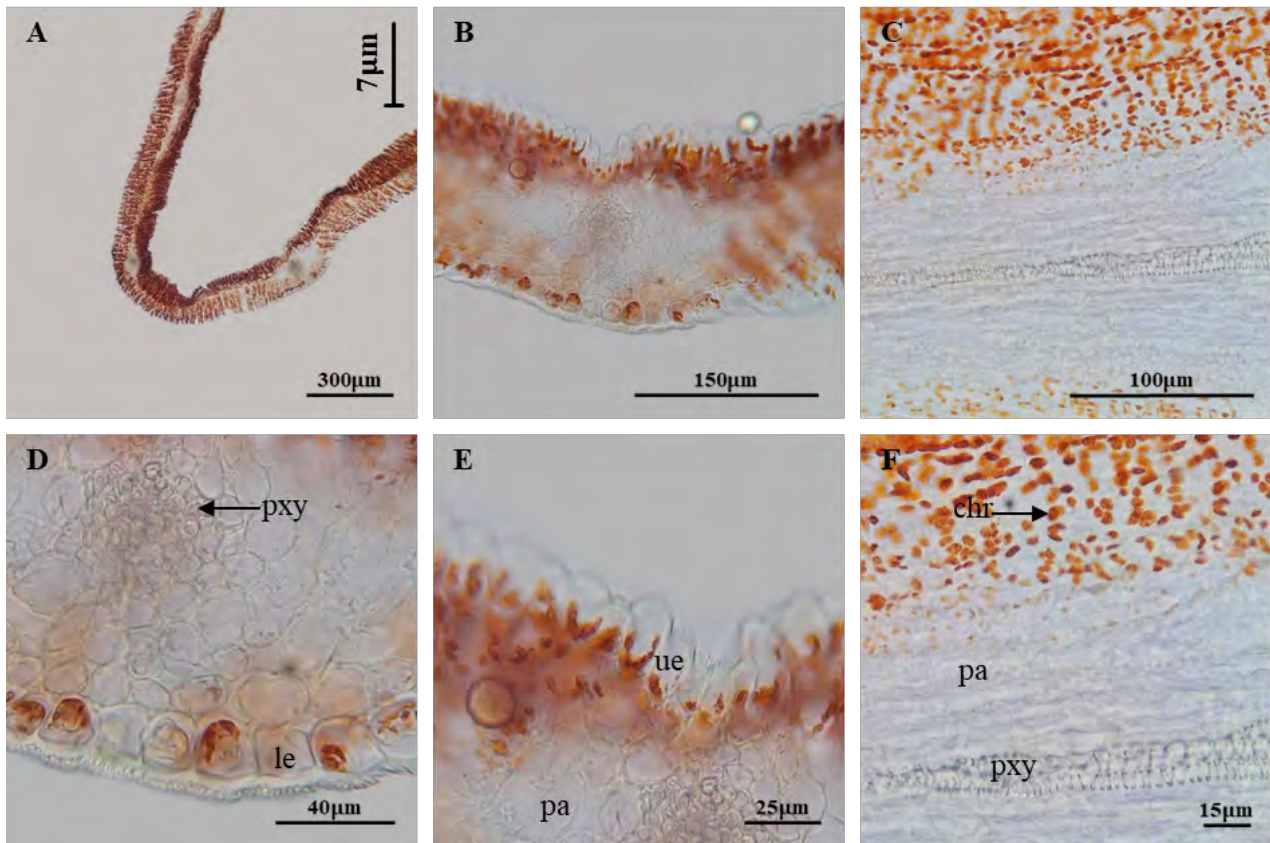


Figure 10. *Zygophyllum fabago*. Petal. **A-** General appearance of the cross-section of the petal (10x), **B-** Area where the central bundle is located (40x), **C-** Surrounding parenchyma of the bundle and the chromoplast-containing parenchyma around it (60x), **D-** Lower central part of the petal (100x), **E-** Upper central part of the petal (100x), **F-** Protoxylem element located longitudinally in the parenchyma (100x), **ue**-upper epidermis; **le**-lower epidermis; **pa**-parenchyma; **pxy**-protoxylem; **chr**-chromoplast.

Stem In the cross-section of the stem, a clear central pith parenchyma occupies the center, surrounded by xylem. Near the boundary with the pith, primary xylem elements from the initial structure remain. The vessel elements of the secondary xylem are larger and are surrounded by libriform fibers. These are elongated cells, thickened and lignified, which provide mechanical support and maintain the organ's straight form. Surrounding the xylem externally, phloem, located within the cortex parenchyma, contains sclerenchyma clusters serving the same fundamental support function (Elkharbotly, 2016). Cambium, situated between the xylem and phloem, divides to form their elements. The cortical parenchyma gradually transitions into a layer of cells with a few chloroplasts towards the subepidermal zone. Stomata are present on the epidermis covering the stem, with guard cells positioned close to the epidermis surface, covered on the upper and lower sides by a thick cuticle (Figure 15).

Primary Root

As seen in the cross-section, the xylem and phloem of the primary root have expanded significantly, with a thick, multi-layered cambium actively functioning between them. The xylem is composed of vessels and libriform fibers and contains numerous medullary rays. These rays extend through the cambium and phloem to the cortex parenchyma, consisting of relatively elongated living cells arranged radially (Abd El-halim et al, 2016). Starting from the outer part of the phloem and scattered throughout the cortex parenchyma, sclereid clusters are visible, each composed of one or more cells with excessively thickened walls (Figure 16). The cortex parenchyma is thick and covered externally by the periderm, the secondary protective tissue.

Tertiary Root

Despite its small size, the tertiary root has transitioned to a secondary structure, with primary xylem elements in the center surrounded

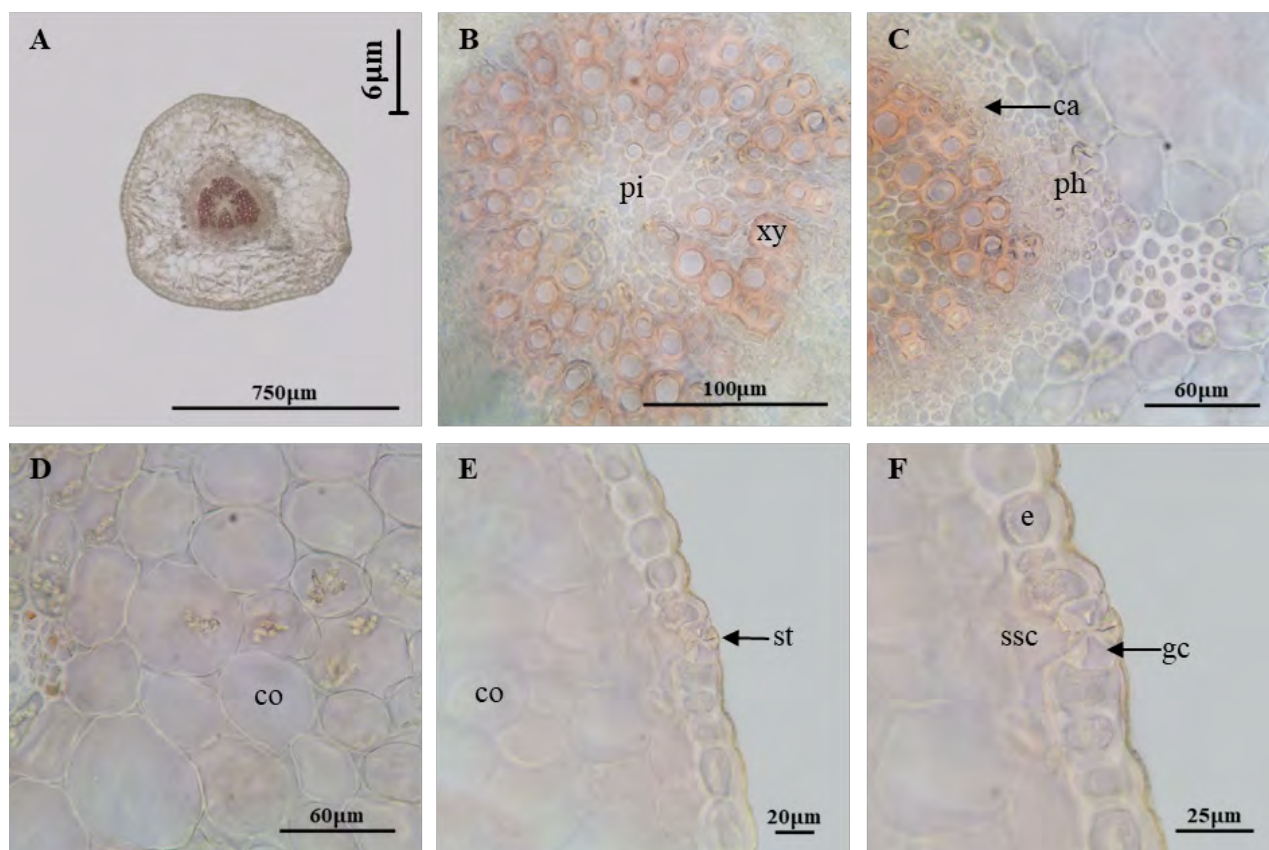


Figure 11. *Zygophyllum fabago*. Fruit stalk. **A**- General appearance of the cross-section of the fruit stalk (10x), **B**- Central cylinder (60x), **C**- Peripheral part of the central cylinder (60x), **D**- Cortex (60x), **E**- Lateral part of the fruit stalk (60x), **F**- Epidermal area containing stomata (100x), **e**-epidermis; **co**-cortex; **pi**-pith; **xy**-xylem; **ph**-phloem; **ca**-cambium; **st**-stoma; **ssc**-sub-stomatal cavity; **gc**-guard cell.

by secondary xylem vessels and libriform fibers, cambium around the xylem, and phloem. The cortex parenchyma is thin, with few sclereid elements present. In some parts of the cortex parenchyma, accumulations of secondary metabolites are observed. The periderm surrounding the root is composed of the phellem, phellogen, and phelloderm layers, which are clearly visible (Figure 17).

Conclusion

The results of the study can be summarized as follows:

The parenchyma tissue that has formed to store water in the leaves of both plant species indicates that similar ecological conditions lead to similar changes in different plant species.

The presence of large druse crystals in the leaves of *Salsola nodulosa* serves a defensive function and acts as a reservoir for accumulated excess minerals.

The formation of fully developed mechanical elements in the petiole of *Zygophyllum fabago*, and the lack of such development in the fruit stalk, ensures that the leaf remains erect while allowing the fruit stalk to be flexible and resistant to physical stress.

The roots of both species, even if small, are covered by a suberized, impermeable tissue, indicating that this structure serves as a mechanism to reduce water loss.

Ecological anatomical research revealed that the anatomical structure of the *Zygophyllum fabago* plant exhibits structural adaptations as a resilience mechanism against abiotic stress factors. These include a groups across all vegetative organs, and the optimized structure of vascular tissue and periderm in the root/

It was determined through ecological-anatomical studies that the synthesis of biologically active substances increased in species of *Zygophyllum fabago* and *Salsola nodulosa*

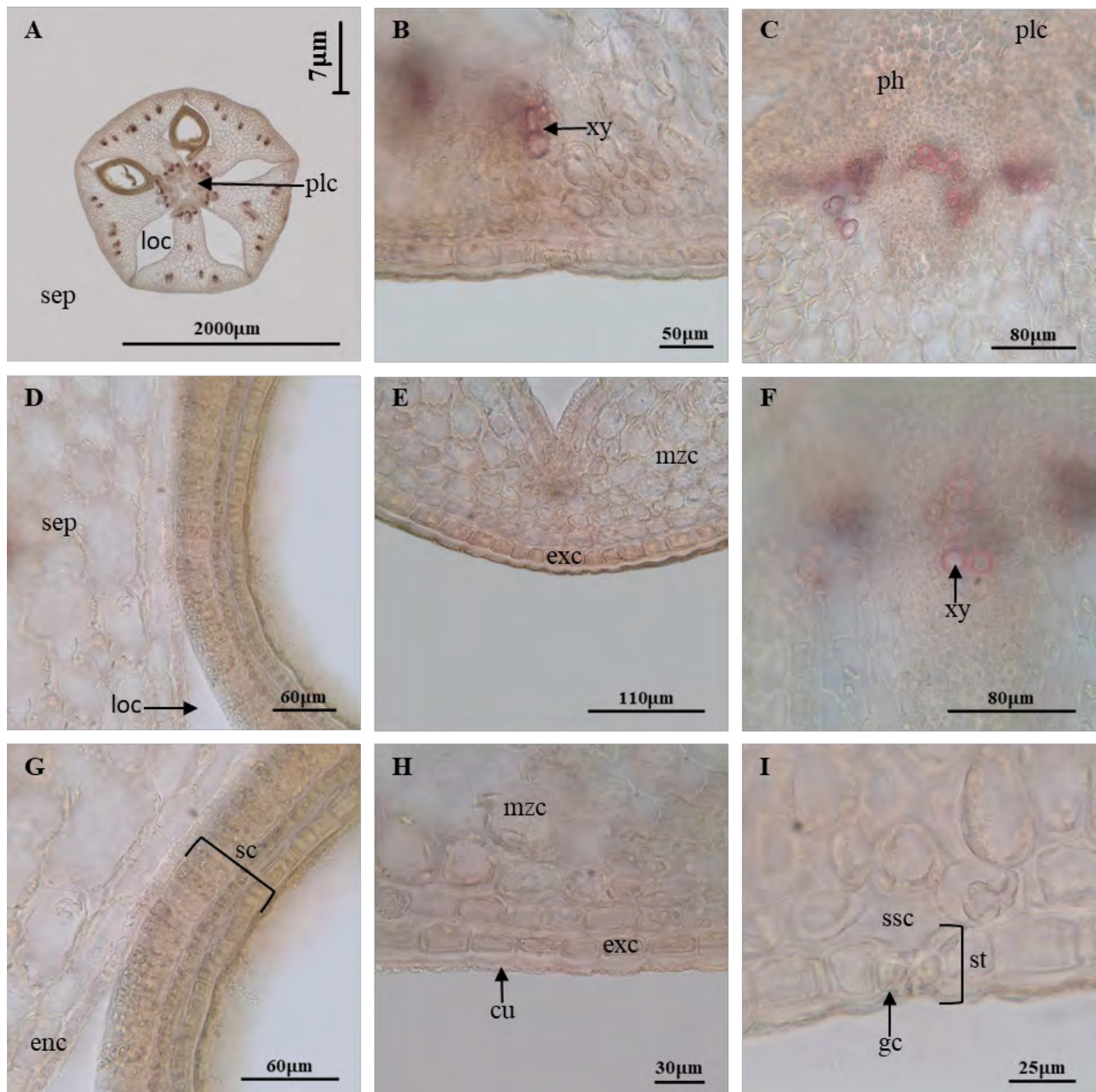


Figure 12. *Zygophyllum fabago*. Fruit. **A-** General appearance of the cross-section of the fruit (4x), **B-** Lateral area of the carpel where vascular bundles are located (x), **C-** Area where the septa join the placenta and the vascular bundles located here (40x), **D-** Septa and locule (40x), **E-** Peripheral end of the locule (40x), **F-** Vascular bundles surrounding the placenta (60x), **G-** Developing seed in the locule cavity (60x), **H-** Subepidermal area of the carpel (60x), **I-** Epidermal area containing stomata (100x), **cu**-cuticle; **xy**-xylem; **ph**-phloem; **st**-stoma; **ssc**-sub-stomatal cavity; **gc**-guard cell; **exc**-exocarp; **enc**-endocarp; **mzc**-mesocarp; **sc**-seed coat; **plc**-placenta; **loc**-locule; **sep**-septa.

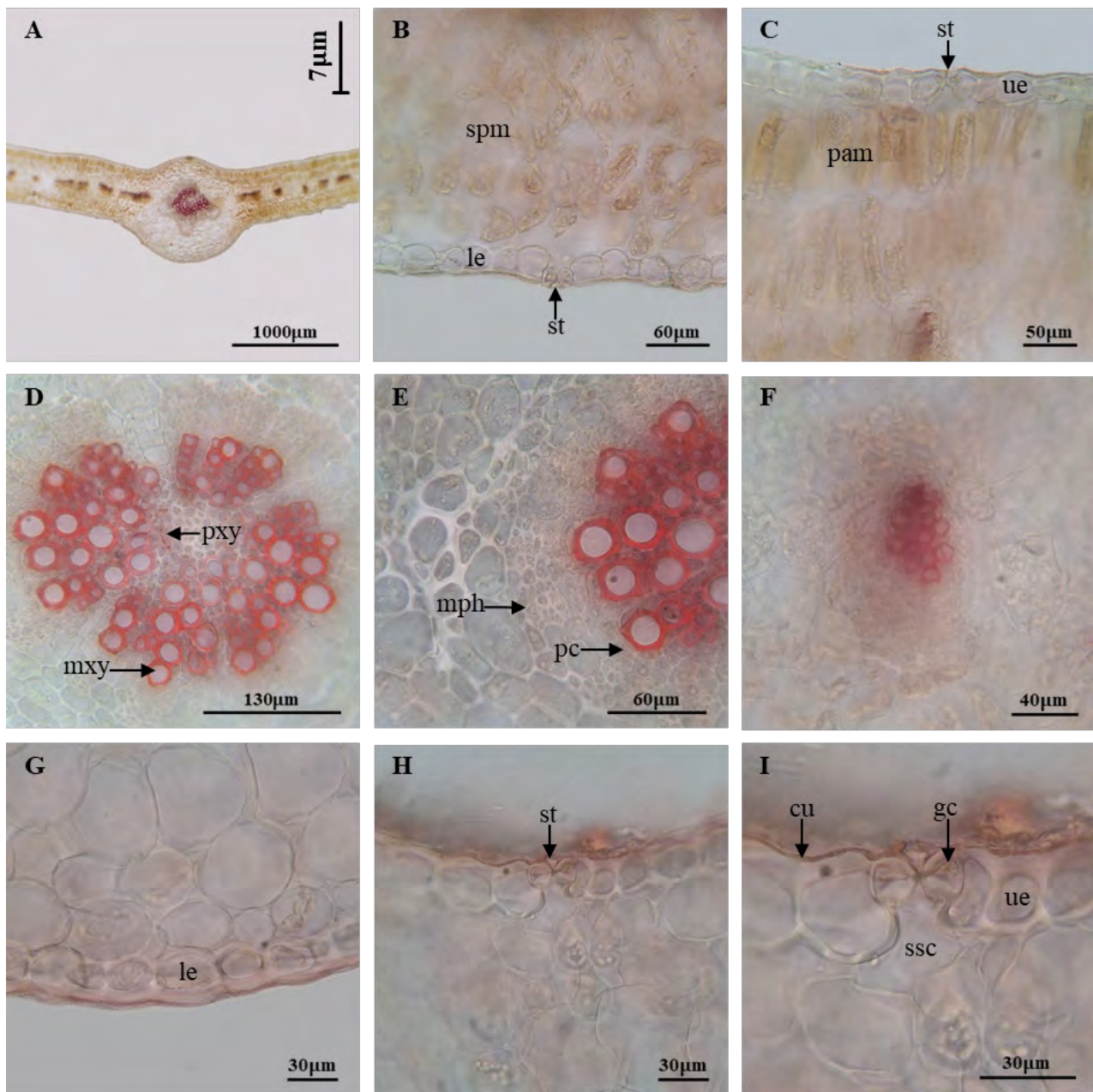


Figure 13. *Zygophyllum fabago*. Leaflet. **A-** General appearance of the cross-section of the leaflet (4x), **B-** Lower subepidermal zone (40x), **C-** Upper subepidermal zone (40x), **D-** Central vascular bundle (40x), **E-** Lateral part of the central vascular bundle (60x), **F-** Lateral bundle (60x), **G-** Lower part of the central vein (60x), **H-** Upper part of the central vein (60x), **I-** Epidermal area containing stomata (100x), **ue**- upper epidermis; **le**-lower epidermis; **cu**-cuticle; **pam**-palisade mesophyll; **spm**-spongy mesophyll; **pxy**- protoxylem; **mxy**-metaxylem; **mph**-metaphloem; **pc**-procambium; **st**-stoma; **ssc**-sub-stomatal cavity; **gc**-guard cell.

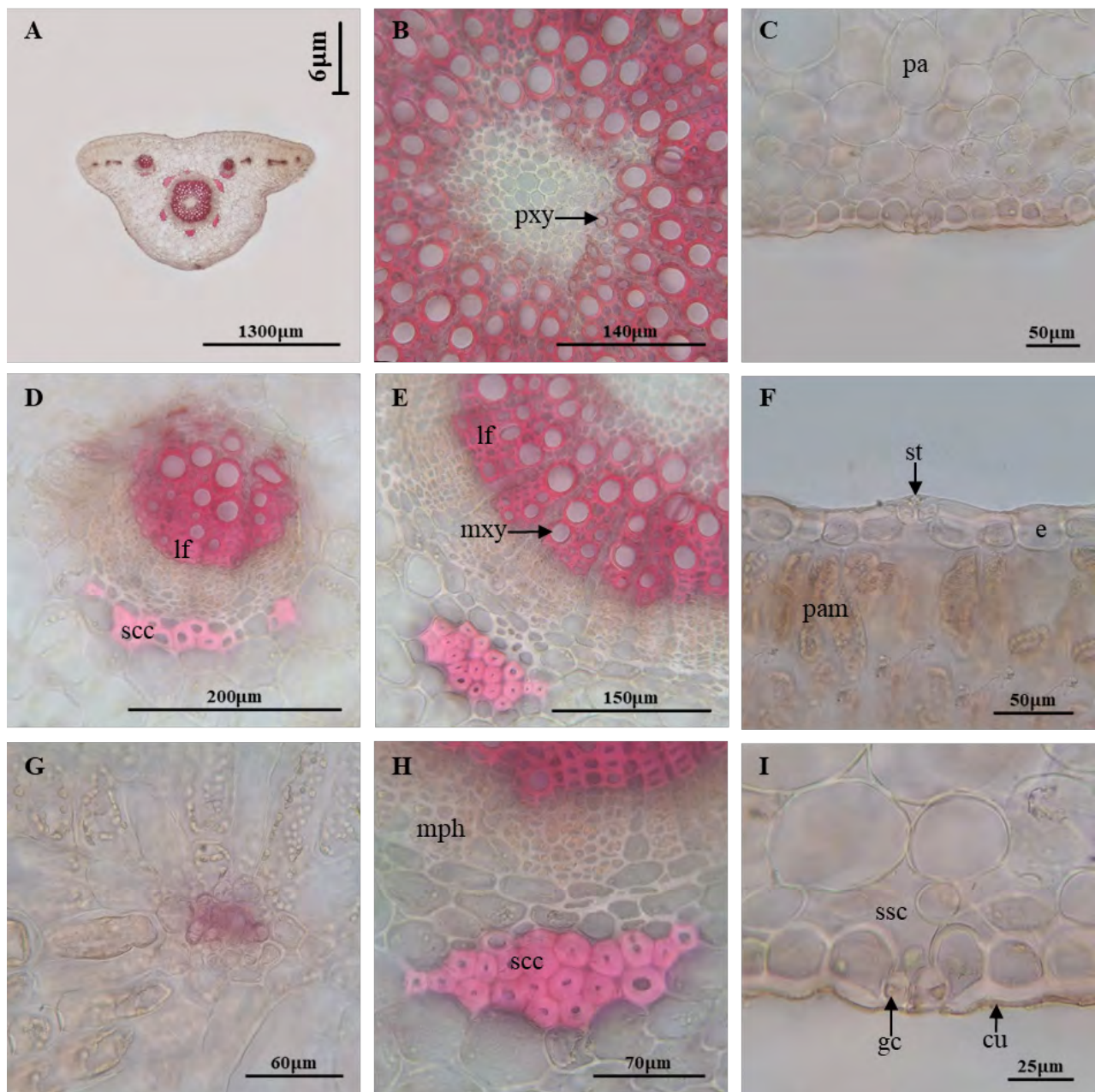


Figure 14. *Zygophyllum fabago*. Petiole. **A-** General appearance of the cross-section of the petiole (4x), **B-** Central part of the central vascular bundle (40x), **C-** Lower subepidermal zone (40x), **D-** Medium-sized lateral bundle (40x), **E-** Lateral part of the central vascular bundle (40x), **F-** Upper subepidermal zone (60x), **G-** Small-sized lateral bundle (60x), **H-** Sclerenchyma tissue surrounding the vascular bundles (60x), **I-** Epidermal area containing stomata (100x), **e-**epidermis; **cu-**cuticle; **pa-**parenchyma; **pam-**palisade mesophyll; **scc-**sclerenchyma; **pxy-**protoxylem; **mxy-**metaxylem; **mph-**metaphoem; **lf-**libriform fibres; **st-**stoma; **ssc-**sub-stomatal cavity; **gc-**guard cell.

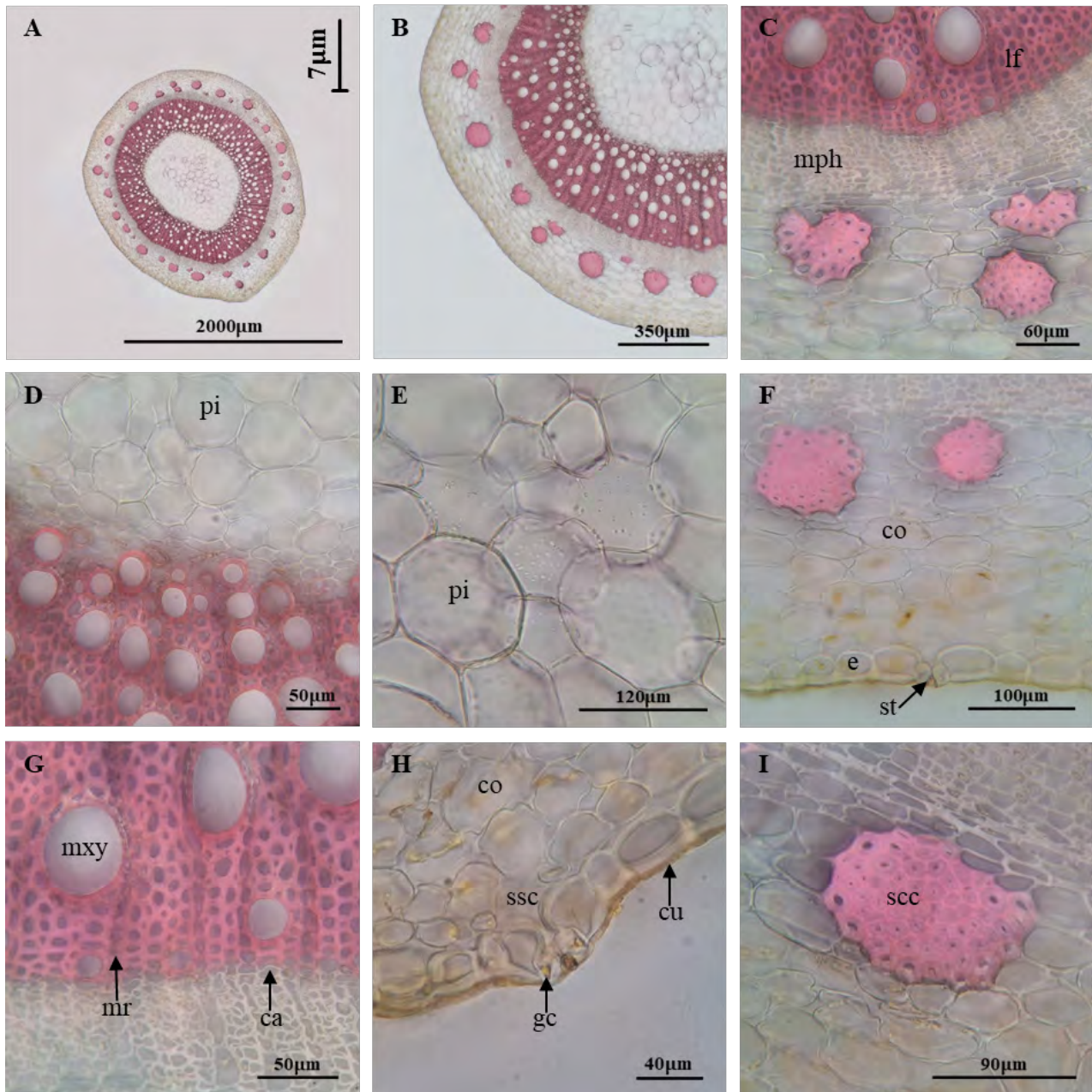


Figure 15. *Zygophyllum fabago*. Stem. **A-** General appearance of the cross-section of the stem (4x), **B-** Lateral part of the stem (10x), **C-** External part of the central cylinder, internal part of the cortex (40x), **D-** Inner part of the xylem ring leaning against the pith (40x), **E-** Pith (40x), **F-** Cortex area of the stem (40x), **G-** Area where xylem ring meets phloem (60x), **H-** Epidermal area containing stomata (60x), **I-** Sclerenchyma tissue in the external part of the phloem (60x), **e-**epidermis; **cu-**cuticle; **co-**cortex; **pi-**pith; **ssc-**sclerenchyma; **mxy-**metaxylem; **mph-**metaphoem; **ca-**cambium; **lf-**libriform fibres; **mr-**medullary ray; **st-**stoma; **ssc-**sub-stomatal cavity; **gc-**guard cell.

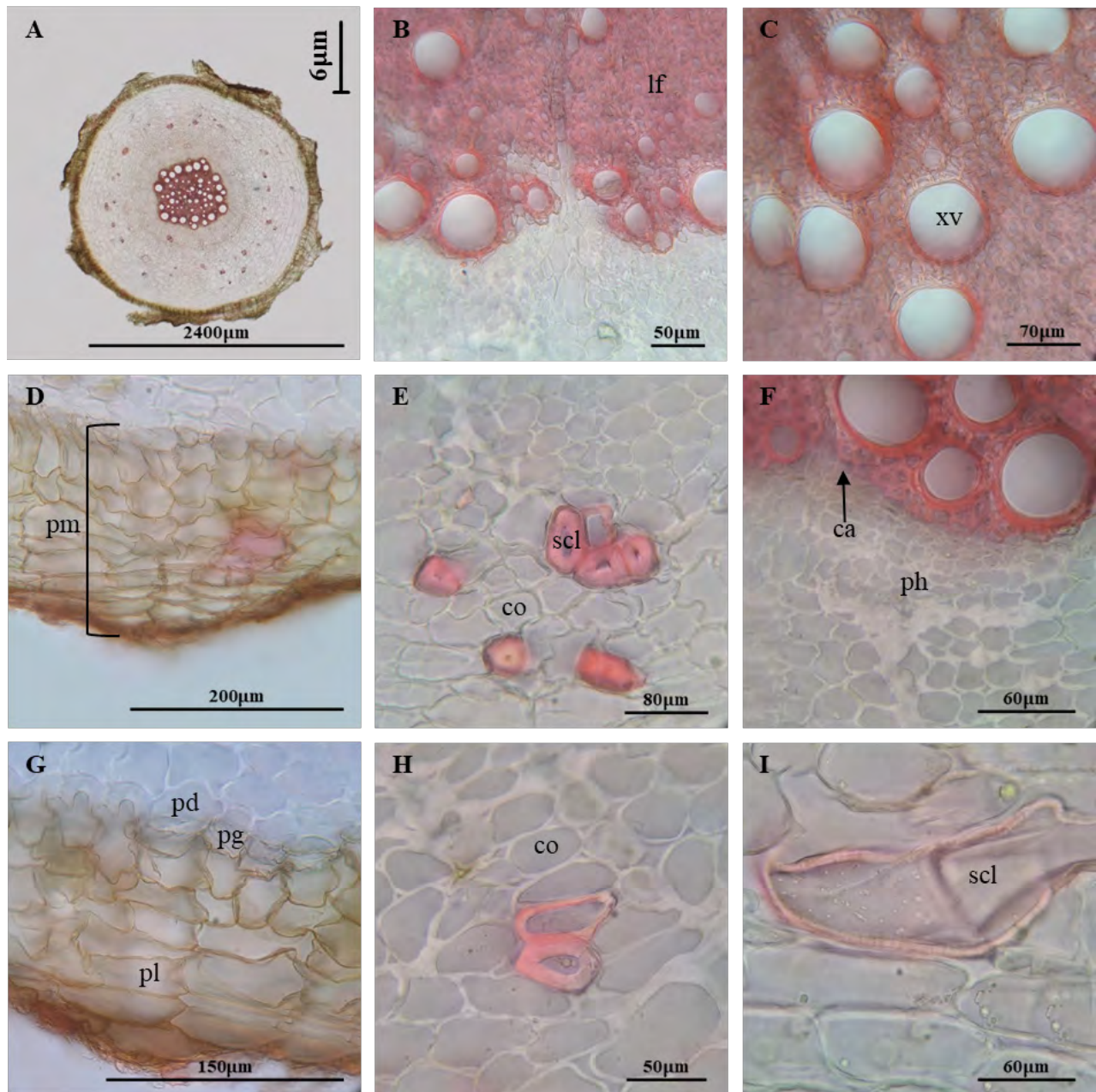


Figure 16. *Zygophyllum fabago*. Primary root. **A-** General appearance of the cross-section of the primary root (4x), **B-** Lateral part of the xylem (40x), **C-** Central part of the xylem (40x), **D-** Structure of the periderm (40x), **E-** Sclereid cells located within the cortex (40x), **F-** Junction of xylem with phloem (60x), **G-** Structure of the periderm (60x), **H-** Cortex and the sclereid cells located within it (60x), **I-** Developing sclereid (60x), **pm**-periderm; **pl**-phellem; **pg**-phellogen; **pd**-phelloderm; **co**-cortex; **scl**-sclereid; **ph**-phloem; **ca**-cambium; **xv**-xylem vessels; **lf**-libriform fibres.

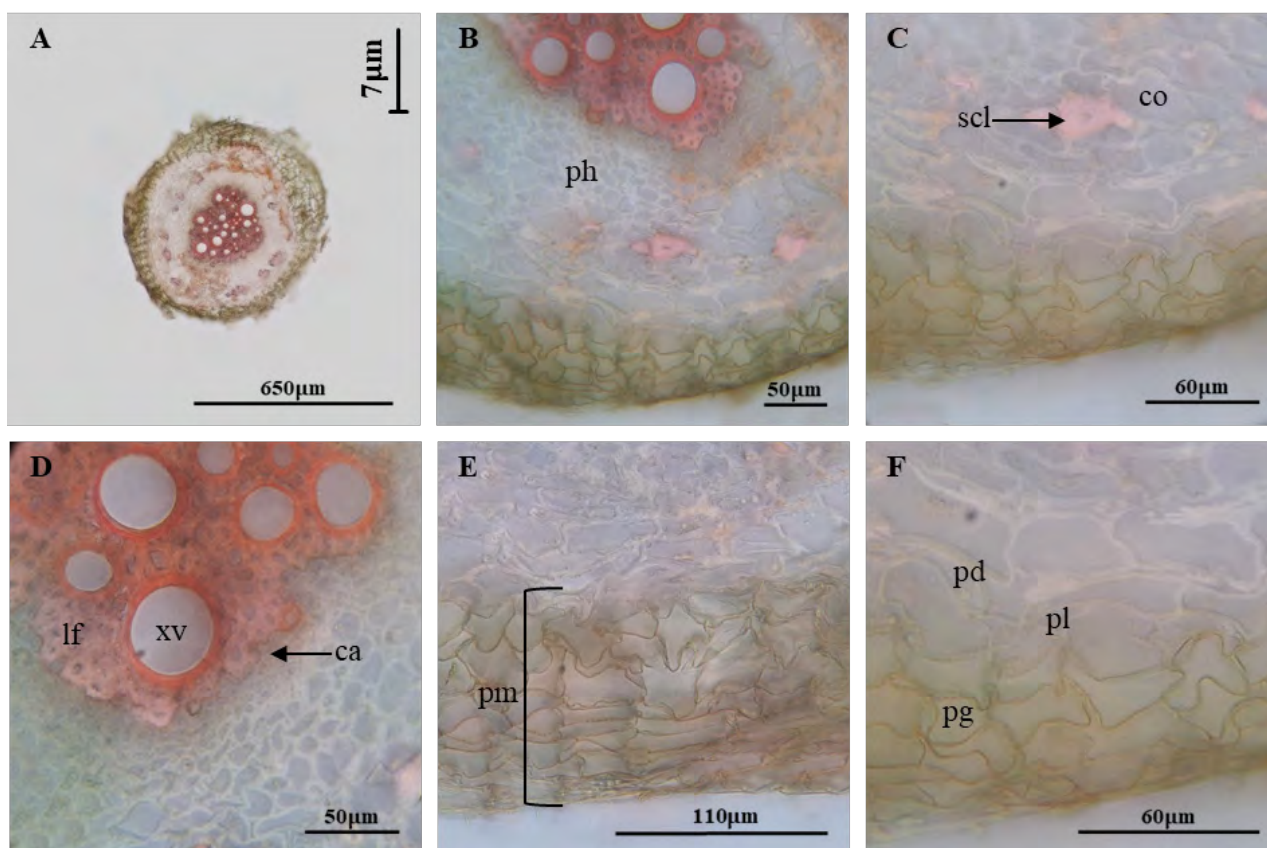


Figure 17. *Zygophyllum fabago*. Tertiary root. **A**- General appearance of the cross-section of the tertiary root (10x), **B**- Lateral part of the root (40x), **C**- Cortex and the periderm covering it (60x), **D**- Lateral part of the xylem (60x), **E**- Periderm covering the root (60x), **F**- Structure of the periderm (100x), **pm**-periderm; **pl**-phellem; **pg**-phellogen; **pd**-phelloderm; **co**-cortex; **scl**-sclereid; **ph**-phloem; **ca**-cambium; **xv**-xylem vessels; **lf**-libriform fibres.

under stress conditions. This significant finding can also be observed in micrographic images of the cross-section of *Salsola* leaves and the basal parts of the leaves, where large-sized, drupe-shaped oxalate crystal formations are evident.

Due to abiotic stress factors, the mechanical

tissue of the *Fabae* plant, specifically the well-developed sclerenchyma formed in a clustered manner. Additionally, the periderm tissue in the root developed strongly. These results are reflected in the experimental section through micrographic evidence.

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BIODIVERSITY AND ECOLOGICAL SIGNIFICANCE OF MANGROVES IN SOUTH EAST ASIA: A PICHAVARAM PERSPECTIVE

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Abstract. *The Pichavaram mangroves are characterized by an intricate network of tidal channels, small islands and dense mangrove vegetation. Mangrove forests are known for their high biodiversity including a variety of plants and animal species coexisting in a unique environment. This diversity can lead to the presence of various natural compounds and bioactive molecules with potential anti-pathogenic properties. The review represents the therapeutic significance of Pichavaram mangroves against pathogens affecting plants, animals, and humans. While there are studies based on the medicinal activities of mangrove plants, this review exclusively focuses on the mangroves distributed in the study area. Information was collected from various web-based search engines using different keywords related to this topic up until 2023 and detailed data about the mangrove flora and its biological activities were compiled. Mangroves are enriched with various therapeutic values and can treat various disorders such as diarrhea, stomach aches, fever, inflammation, toothaches, diabetes, skin infections and conjunctivitis. Many mangrove species are also recognized for their anti-cancer properties. This review provides a comprehensive insight into the medicinal significance of mangroves in Pichavaram highlighting their relevance in the search for innovative therapeutic agents.*

Keywords: *Anti-bacterial activity, Anti-cancer activity, anti-fungal activity, anti-plasmodial activity, anti-viral activity, antioxidant activity, Pichavaram*

Introduction

Pichavaram (11.4226° N, 79.7748° E) is situated on the Southern coast of Tamil Nadu

and the Pichavaram mangrove forest is known for a complex network of tidal waterways and dense mangrove vegetation. The Pichavaram

mangrove forest exists between the estuaries concerning Vellar and Coleroon. The forest sprawls on 51 islets that pertain to the Vellar and Coleroon estuaries and stretch in size from 10m² to 2km² (Kathiresan, 2000). Mangrove ecosystems have always attracted the attention of researchers due to their significant environmental impact (Bandaranayake, 2002). Mangroves are plant species that dwell along rivers, estuaries, and shorelines in tropical and subtropical regions and they are identifiable by tangled roots that emerge from the filthy soil (Friess et al., 2019). Mangroves significantly provide an array of ecosystem services that aid in the preservation of the environment, including livelihoods to people who rely on nature's glories (Sudhir et al., 2022). There are still over 147,000Km² of mangroves in the world, an area equal to that of Bangladesh, as per the ICRI 2022 assessment (Leal and Spalding, 2022). Mangroves act as an originator of energy on the coastal food chain and safeguard against various natural calamities such as cyclones and tsunamis. It also functions as natural nutrient filter as well as a recycler. They safeguard the coastal environment from seawater intervention and also help to mitigate floodwater (Arumugam and Panneerselvam, 2012). Despite their part in conserving the coastal ecosystem, mangroves are vanishing due to over-exploitation, pollution and land conversion (Marchand et al., 2016). Mangroves are one of the world's most efficaciously interpretable coastal ecosystems (UNEP, 2023). Mangroves are limitedly circumscribed to tropics and subtropics, which govern approximately 75% of the world's coastline between 25° N and 25° S and are appraised to cover an area of 1.7 to 2.0 × 105km² (Borges et al., 2003). Mangroves are biochemically distinct due to their high levels of polyphenols and tannins, that culminate in the production of novel natural compounds (Vinoth et al., 2019). This review summarizes the extensive biological activities associated with the mangrove plants particularly in Pichavaram Mangrove Forest.

Biological activities of mangroves

Plants hold historical significance and are essential sources of natural compounds for human

welfare and offer an enormous potential to synthesise novel medications (Abeysinghe, 2010). Mangrove species are utilised extensively in traditional folk medicine and indigenous people treat a variety of illnesses using various parts of these plants (Kalasuba et al., 2023; Sudhir et al., 2022; Subekti, 2019). Pharmacological studies of mangroves revealed the antioxidant, antimalarial, antibacterial, antiviral properties. Table 1 provides a list of the true mangroves found in the Pichavaram mangrove environment.

Antibacterial activity of mangroves

Mangroves are prevalent and promising resources for natural antibacterial drugs among the diverse wild medicinal plants (Sachithanandam et al., 2019; Audah et al., 2018). Table 2 summarized the true mangroves founds in Pichavaram that possessed antibacterial activity, highlighting the significant contribution of various species. The *Acanthus ilicifolius* leaf extract exhibited antibacterial properties and metabolomic profile revealed that the alkaloid and flavonoid components contributed to this action (Aisiah et al., 2022). Moreover, different solvent extracts prepared from leaves and roots of *Avicennia marina* demonstrated beneficial antibacterial effects (Okla et al., 2021), while leaf extracts were effectively used in traditional medicine for treating various tooth infections (Keerthi et al., 2022). *A. officinalis* leaves extract in ethyl acetate was used for the synthesis of therapeutic medications to treat bacterial infections (Lalitha et al., 2021). Bimba et al., 2010 reported inhibition zones for *S. aureus* and *E. coli* measuring 11 and 13 mm respectively. Additional findings indicated that both wet and dry *B. cylindrica* leaf extract displayed potent antibacterial activity against gram-positive bacteria (Audah et al., 2018). Furthermore, two di-terpenoids were found in the *C. decandra* fraction, which displayed broad range of antibacterial effectiveness and prospective uses in the pharmaceutical sector (Simlaiet al., 2016). *E. agallocha* leaf extract revealed outstanding antibacterial activity both *in-vitro* as well as *in-vivo* (Divya et al., 2022). Flavonoids such as quercetin, myricetin, quercetin glycosides, anthraquinone derivative emodin, and polyphenolic tannins,

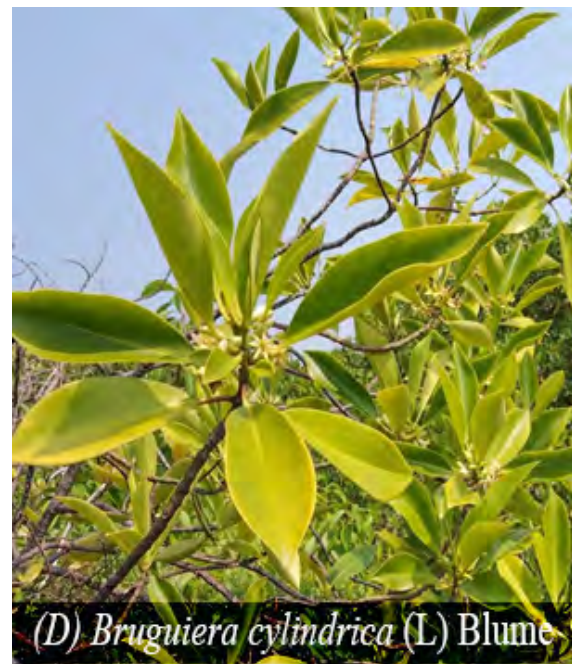


Figure.1 Showing true mangroves (A) *Acanthus ilicifolius* L. (B) *Avicennia officinalis* L. (C) *Excoecaria agallocha* L. and (D) *Bruguiera cylindrica* (L) Blume

particularly corilagin, were identified from extract of *L. racemosa*, which confers high antibacterial effectiveness against *Staphylococcus aureus* (Souza et al., 2010). Furthermore, silver nanoparticles prepared from extract of *R. apiculata* revealed antibacterial effectiveness against seven bacterial strains (Antony et al., 2011). The antibacterial activity of *R. mucronata* and *R. apiculata*, particularly against *S. agalactiae* and *A. hydrophila*, suggested their potential as effective drug sources (Vittaya et al., 2022).

Antifungal activities of mangroves

The phytochemical components identified from methanolic extract of *Acanthus ilicifolius* displayed antifungal activity against *Candida albicans* (Andriani et al., 2020). Furthermore, two antifungal compounds, Acornine 1 and Acornine 2, have been identified in the bark of *A. corniculatum* (Gupta et al., 2014). A marked reduction in the growth of *A. fumigatus*, *C. albicans* and *C. tropicalis* was observed upon treatment with the ethyl acetate fraction of *A.*

marina, yielding inhibition zones of 41, 40 and 25mm, respectively (Belhadj-Salah et al., 2022). The most effective and substantial zone of inhibition of 26mm was observed against *Fusarium oxysporum* upon treatment of methanolic extracts of *B. cylindrical* (Vadlapudi and Naidu, 2009). At 500mg/ml concentration, chloroform extracts of *C. decandra* leaves revealed potent antifungal activity against *Pythium aphanidermatum*, *Rhizoctonia solani*, *Pyricularia oryzae*, *Curvularia oryzae* and *Fusarium oxysporum* with zones of inhibition diameters of 29, 27, 28, 28, 28 and 28mm, respectively (Kumaret al., 2013). Aqueous, ethanol and chloroform extract of *Rhizophora apiculata* accounted inhibition against *Alternaria solani* (Mahalakshmi et al., 2020). Furthermore, Silver nanoparticles obtained from *R. mucronata* demonstrated enhanced antifungal activity when combined with standard antifungal agent against pathogenic fungi such as *Aspergillus fumigatus*, *Aspergillus flavus*, *Candida albicans*, and *Cryptococcus neoformans* (Singh et al., 2013). Detailed antifungal activity of true mangroves present in Pichavaram are listed in Table 3.

Anticancer activity of mangroves

The aqueous extract of *Acanthus ilicifolius* root exhibited an IC_{50} value of $39.76\mu\text{g/ml}$ against Hep G2 cancer cells (Paul and Ramasubbu, 2017). Additionally, new alkalyted benzoquinones isolated from *A. corniculatum* manifested cytotoxic actions against the A2780, BGC-823, HepG2, HL-60, NCI-H1650 and cell lines (Li et al., 2020). The ethanol extract of *A. marina* caused cell cycle arrest in breast cancer cell lines, but the ethyl acetate extract caused apoptotic processes in ovarian and cervical cancer cell lines. Methanolic leaves extract of *Avicennia officinalis* was examined for its ability to prevent cytotoxic effects in the treatment of Ehrlich Ascites Carcinoma cancer line at doses of 200 and 400mg/kg (Sumithra et al., 2011). Furthermore, biosynthesized *B. cylindrical* Ag-NPs was found to be cytotoxic to breast cancer cell lines (MCF-7) (Bhuvaneswari et al., 2015). The *E. agallocha* aqueous extract efficiently inhibited SiHa cervical cancer cell proliferation by inducing both autophagy and apoptosis, along with simultaneous activation of mitophagy and G2/M phase cell cycle arrest, with

Bergenin identified as the primary component orchestrating these diverse cellular responses (Sultana et al., 2022). The IC_{50} values for compounds extracted from *L. racemosa* against the HL-60 and HeL-299 cell lines were 0.15 ± 0.29 and $0.60\pm 0.16\mu\text{M}$, respectively (Thao et al., 2015). The hydrosol containing AgNPs from *R. apiculata* also reported to inhibit HEK-293 and HeLa cells. *R. apiculata* methanolic extract reduced the lung tumour sizes in mice (Prabhu and Guruvayoorappan, 2013). Quinizarin, isolated from *R. mucronata*, has also been employed in developing effective cancer treatments (Sachithanandam et al., 2022). Table 4 listed the anticancer activity of mangroves present in Pichavaram.

Antiviral Activity of Mangroves

The most effective antiviral activity has been reported in polarity-rich portion of the methanolic extract of *A. marina*, which suppressed HSV with IC_{50} and IC_{25} values of 3.5 and $0.75\mu\text{g/ml}$, respectively (Namazi et al., 2013). Additionally, The IC_{50} values for *Avicennia marina* leaf extract were recorded as $403.91\mu\text{g/ml}$ in the HBsAg binding assay, $489.39\mu\text{g/ml}$ HBV DNA Polymerase inhibitory assay and $372.09\mu\text{g/ml}$ in HIV-1 Reverse Transcriptase I Inhibition Test (Beula et al., 2012). The generation of dengue DEN-2 virus E protein in Vero cells was dramatically reduced and the expression of the DEN-2 E gene was downregulated after a single low-dosage treatment of silver nanoparticles of *B. cylindrical* (Murugan et al., 2015). Moreover, the EC_{50} value of *B. cylindrical* leaf extract against Encephalomyocarditis virus was found to be $21\mu\text{g/ml}$. The bark of *L. racemosa* and the leaves of *C. decandra* had EC_{50} values of 18.12 and 48.1mg/ml , respectively against Vaccinia virus (Premanathan et al., 1999a). For anti-HIV efficacy, the acid polysaccharide found in the leaves and bark of *R. apiculata* and *R. mucronata* inhibited the capacity of the virus to adhere to cells (Premanathan et al., 1999b). MT-4 cells infected with HIV-1 and peripheral blood mononuclear cells treated with *R. apiculata* polysaccharide had 50% effective concentrations (EC_{50}) of 10.7 and $25.9\mu\text{g/ml}$, respectively. Additionally, polysaccharide stopped the MT-4 cells from expressing the HIV-1 antigen and stopped the peripheral blood mononuclear cells from producing the HIV-1 p24 antigen (Premanathan et al., 1999c).



Figure.2 Showing true mangroves (E) *Aegiceras corniculatum* (L.) Blanco (F) *Ceriops decandra* (Griff.) Ding Hou (G) *Lumnitzera racemosa* Willd



Figure.3 Showing true mangroves (H) *Avicennia marina* (Forssk.) Vierh (I) *Rhizophora mucronata* Lam. (J) *Rhizophora apiculata* Blume

Table 5 listed the antiviral properties of the mangroves found in Pichavaram.

2.5 Antioxidant activity of mangroves

Mangroves displayed significant antioxidant activity. The IC_{50} of the *A. ilicifolius* leaf extract in 70 percent ethanol was determined to be 550 µg/ml, scavenging the superoxide radicals ($O_2^{\cdot-}$) produced by the riboflavin photoreduction technique (Babu et al., 2001). The bark of *A. corniculatum* demonstrated antioxidant activity with an IC_{50} of 20.49 µg/ml in the DPPH experiment (Biswas et al., 2019). Further, acetone extract of *Avicennia marina* stem and the aqueous extract of pneumatophore exhibited the highest ABTS activity, with the lowest IC_{50} value of 40 µg/ml (Moteriya, 2015). Additionally, the fraction of *A. officinalis* fraction containing phenols and naphthoquinones, which enhanced the antioxidant activity, achieving a strong percentage inhibition of 83% and an IC_{50} value of 0.02 mg/ml (Assaw et al., 2020). In the DPPH assay, the *B. cylindrica* stem exhibited dose-dependent inhibition with an IC_{50} value of 162.5 µg/ml (Gawali and Jadhav, 2011). By quenching the DPPH radical with EC_{50} values of 2.1 ± 0.28 , *C. decandra* demonstrated a concentration-dependent antiradical activity (Krishnamoorthy et al., 2011). *E. agallocha* bark extract showed high antioxidant activity in DPPH, NO_2 , and H_2O_2 scavenging tests, with IC_{50} values of 179.16, 120.24, and 134.29 µg/ml, respectively (Subhan et al., 2008). The reducing power assay and DPPH test demonstrated that *L. racemosa* leaves exhibit higher antioxidant activity than stem (Quraishi et al., 2015). *R. apiculata* leaf extracts demonstrated significant antioxidant capability *in vitro*, scavenging over 84 percent of DPPH free radicals, 76 percent of H_2O_2 , 82 percent of hydroxyl radicals, and 80 percent of reducing power (Ramalingam and Rajaram, 2018). The leaves of *R. racemosa* are a rich source of antioxidants and have excellent promise as an anti-diabetic drug because they reduce hyperglycemia by acting as an antioxidant (Suret et al., 2015). Detailed antioxidant activity of mangroves of Pichavaram are listed in table 6.

Antimalarial activity of mangroves

corniculatum methanolic extract exhibited strong antimalarial activity (Sundaram et

al., 2012). *In vitro* antiplasmodial activity of polyherbal extracts, which included the sea weed *Chaetomorpha antennina* and the marine plant *A. corniculatum* resulted in highest inhibition of parasitaemia, 63.50 ± 0.408 percent at 1.5 mg/ml (Ravikumar et al., 2011c). Bark extracts from the mangrove plant *A. marina* had IC_{50} values of 69.0 µg/ml against the *P. falciparum*. Table 7 showed detailed list of plants that exhibited antimalarial capacity.

Conclusion

Mangroves play a vital role in reducing the adverse effects of waves, tidal surges and high winds during storms and cyclones, which can significantly reduce both the death toll and property damage. Additionally, mangrove plants and their soils retain a large amount of carbon. The salty, waterlogged conditions prohibit bacteria from decomposing organic matter, so they sequester carbon and store it away in the soils where it can stay for millennia. Because it grows in exceedingly stringent situations, it not only maintains society environmental sustainability but also includes abundant supplies of phytochemical components. Phytochemicals derived from mangroves play a critical role in the exploration and development of novel drugs, as they exhibit a wide range of biological activities. Mangroves are used for the green synthesis of nanoparticles because of the high content of polyphenols. This comprehensive review delves deeply into the specific mangrove flora within the research area, presenting a thorough examination of its various biological properties. Among these properties are noteworthy antibacterial, antifungal, antiviral, anti-plasmodial, anticancer and antioxidant capabilities. The extensive documentation of these diverse biological attributes underscores the significant potential of mangrove-derived compounds in advancing drug discovery and therapeutic interventions across multiple fields.

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Table 1

Important mangroves of Pichavaram area

S. No.	Scientific name of the Mangrove	Family	Common Name	Tamil Name	Fig.	Reference
1	<i>Acanthus ilicifolius</i> L.	Acanthaceae	Holy Mangrove	Kaludaimulli	Fig. 1A	(Bose and Bose, 2008)
2	<i>Aegiceras corniculatum</i> (L.) Blanco	Primulaceae	Goat Horn mangrove	Narikandal	Fig. 2E	(Zhang et al., 2005)
3	<i>Avicennia marina</i> (Forssk.) Vierh.	Acanthaceae	Grey mangrove	Venkandal	Fig. 3H	(Fauvel et al., 1993)
4.	<i>Avicennia officinalis</i> L.	Acanthaceae	Indian mangrove	Karungkandal	Fig. 1B	(Suganthi et al., 2009)
5.	<i>Bruguiera cylindrica</i> (L) Blume	Rhizophoraceae	Black mangrove	Pannukuchi	Fig. 1D	(Krishnamoorthy et al., 2011)
6.	<i>Ceriops decandra</i> (Griff.) Ding Hou	Rhizophoraceae	Yellow mangrove	Cirukandal	Fig. 2F	(Wang et al., 2013)
7.	<i>Excoecaria agallocha</i> L.	Euphorbiaceae	Blind-your-eye mangrove	Thillai	Fig. 1C	(Subhan et al., 2008)
8.	<i>Lumnitzera racemosa</i> Willd	Combretaceae	White-flowered black mangrove	Thipparathi	Fig. 2G	(Souza et al., 2010)
9.	<i>Rhizophora apiculata</i> Blume	Rhizophoraceae	Tall-stilt mangrove	Surapunnai	Fig. 3J	(Gao et al., 2011)
10.	<i>Rhizophora mucronata</i> Lam	Rhizophoraceae	Loop-root mangrove	Surapunnai	Fig. 3I	(Adhikari et al., 2016)

Table 2.

Antibacterial activity of true mangroves in Pichavaram

Plant name	Microbes used	Plant parts	Solvents	Max. Inhibition	Reference
<i>Acanthus ilicifolius</i> L.	<i>Aeromonas hydrophila</i>	Leaves	Ethanol	Disc diffusion method 300 mg/ml-9.78 ±0.19 mm Broth dilution method (Colony/ ml) 200mg/ml (3.15 × 10 ⁷ ± 1.71 × 10 ⁶)	(Aisiah et al., 2022)
	<i>Aspergillus fumigatus</i> , <i>Aspergillus niger</i> , <i>Bacillus subtilis</i> , <i>Candida albicans</i> , <i>Pseudomonas aeruginosa</i> , <i>Proteus vulgaris</i> <i>Staphylococcus aureus</i> ,	Leaves and Roots	95% alcohol, butanol and chloroform	Leaves (Chloroform) 10mg/ml <i>Candida albicans</i> -26 mm	(Bose and Bose, 2008)
	<i>Escherichia coli</i> , <i>Bacillus subtilis</i> , <i>Staphylococcus aureus</i> <i>Klebsiella pneumoniae</i> and <i>Streptococcus pneumoniae</i>	Twigs	Methanol, Water, and Chloroform	Disc diffusion method <i>E. coli</i> -22.9 mm in 50µg/ disc chloroform extracts of <i>A. ilicifolius</i>	(Pothiraj et al., 2021)
	<i>Bacillus subtilis</i> , <i>S.pyogenes</i> , <i>E.coli</i> , <i>Salmonella typhi</i> , <i>Klebsella pneumoniae</i> , <i>S.marcescens</i> , <i>Vibrio cholerae</i> and <i>Vibrio cholera</i>	Twigs	Petroleum ether, ethyl acetate and methanol	<i>K. pneumoniae</i> 18mm in 500µg/ disc Methanol extracts	(Poornaet al., 2011)
	<i>Bacillus cereus</i> , <i>Staphylococcus aureus</i> , <i>Pseudomonas aeruginosa</i> and <i>Escherichia coli</i>	Twigs	Silver nanoparticles	Aqueous extract of <i>A. ilicifolius</i> contained 20 mm of AgNPs at 5.39µg/ml, while <i>E. coli</i> and <i>P. aeruginosa</i> showed 14mm and 20mm of AgNPs.	(Mohamad et al., 2019)

Plant name	Microbes used	Plant parts	Solvents	Max. Inhibition	Reference
2. <i>Aegiceras corniculatum</i> Blanco	<i>Bipolaris bicolor</i> , <i>Candida albicans</i> , <i>Cladosporium herbarum</i> , <i>Curvularia lunata</i> , <i>Erwinia carotovora</i> , <i>Pseudomonas marginales</i> , <i>P. syringae</i> , <i>Staphylococcus aureus</i> , <i>Streptococcus gordonii</i> , <i>S. anginosus</i> , <i>S. salivarius</i> , <i>S. mitis</i> , <i>S. mutans</i> , <i>Ustilago maydis</i> and <i>Xanthomonas campestris</i>	Twigs	Hexane, Chloroform, Methanol and Water	100mg/ml of <i>A. corniculatum</i> Methanol Extracts-13mm in <i>U. maydis</i>	(Bobbarala, 2009)
	<i>B. subtilis</i> and <i>E. coli</i>	Leaves	Methanol	Nutrient Broth 5mg/ml <i>E. coli</i> - 79.86%	(Janmanchi et al., 2017)
3. <i>Avicennia marina</i> (Forssk.) Vierh	<i>Pseudomonas aeruginosa</i> , <i>Bacillus subtilis</i> , <i>Staphylococcus aureus</i> and <i>Escherichia coli</i>	Root, leaves, stems, fruits, and seeds	Chloroform, ethanol, petroleum ether, ethyl acetate, and water	Disc diffusion-10mg/ml MBC for ethyl acetate extract of AM leaves against <i>S. aureus</i> -14.2 $\pm$ 0.5 mg/mL. <i>coli</i> -12.5 $\pm$ 0.32 mg/mL	(Okla et al., 2021)
	<i>Streptococcus mutans</i> , <i>S. oralis</i> and <i>S. rattus</i>	Leaves	90% methanol	100 μ g/ml <i>S. rattus</i> -15mm	(Keerthi et al., 2022)
	<i>Pseudomonas aeruginosa</i> , <i>Salmonella typhimurium</i> , <i>Candida albicans</i> , <i>Staphylococcus aureus</i> , <i>Escherichia coli</i> and <i>Vibrio damsela</i>	Entire plant	80% Ethanol	50 μ l of extract <i>Candida albicans</i> -25.0mm	(Yassien et al., 2021)
	<i>Bacillus anthracis</i> , <i>Pseudomonas aeruginosa</i> , <i>Staphylococcus aureus</i> , <i>S. epidermidis</i> , <i>Enterococcus faecalis</i> , <i>Escherichia coli</i> and <i>Bacillus subtilis</i>	Aerial parts	Petroleum ether, ethyl acetate, butanol, and methanol	Disc diffusion-50mg/ml <i>Escherichia coli</i> -MBC 25mg/ml	(Belhadj-Salah et al., 2022)
4. <i>Avicennia officinalis</i> L.	<i>Streptococcus mutans</i> , <i>Pseudomonas aeruginosa</i> , <i>Bacillus subtilis</i> , <i>Klebsiella pneumoniae</i> , <i>Enterobacter aerogenes</i>	Leaves	Ethyl acetate	250 μ g/ml- <i>S. mutans</i> -22 mm	(Lalitha et al., 2021)
	<i>Escherichia coli</i> , <i>Staphylococcus aureus</i>	Leaves	Ethanol, Petroleum ether, Ethyl acetate, Acetone and Methanol	15 μ l- <i>E. coli</i> -13mm	(Bhimba et al., 2010)

Plant name	Microbes used	Plant parts	Solvents	Max. Inhibition	Reference
5. <i>Bruguiera cylindrica</i> (L.) Blume	<i>Escherichia coli</i> , <i>Staphylococcus aureus</i> and <i>Staphylococcus epidermidis</i> .	Leaves	Water, Ethanol, and n-hexane	100% ethanol Wet extracts- <i>S.aureus</i> -14.30mm	(Audah et al., 2018)
6. <i>Ceriops decandra</i> (Griff.) Ding Hou	<i>Bacillus subtilis</i> , <i>B. coagulans</i> , <i>B.cereus</i> , <i>B. polymyxa</i> , <i>B. pumilus</i> , <i>Micrococcus luteus</i> , <i>Staphylococcus aureus</i> , <i>Shigella sonnei</i> , <i>Klebsiella pneumoniae</i> , <i>Bordetella bronchiseptica</i> , <i>Pseudomonas aeruginosa</i> , <i>Providencia spp.</i> , <i>Salmonella choleraesuis</i> , <i>S. typhimurium</i>	Wood	Hexane, Benzene and chloroform	<i>Bacillus coagulans</i> 2mg/disc- 12.41 ± 0.38mm	(Simlai et al., 2016)
7. <i>Excoecaria agallocha</i> L.	MTCC <i>Bacillus cereus</i> , <i>Micrococcus luteus</i> , <i>Staphylococcus aureus</i> , <i>Streptococcus mutans</i> , <i>Aeromonas hydrophila</i> , <i>Shigella flexneri</i> , <i>Escherichia coli</i> , <i>Klebsiella pneumoniae</i> , <i>Pseudomonas aeruginosa</i> Clinical isolates <i>Proteus vulgaris</i> , <i>Citrobacter freundii</i> , <i>Pseudomonas spp.</i> <i>S. aureus</i> , <i>Klebsiella spp.</i> and <i>E. coli</i> .	Leaves	Chloroform, dichloromethane, ethyl acetate, methanol, water	5 mg/ml Ethyl acetate: <i>S. aureus</i> (23.5 ±1.3mm)	(Sabu et al., 2022)
	<i>Klebsiella pneumonia</i> , <i>Pseudomonas aureginosa</i> , <i>Staphylococcus aureus</i> and <i>Bacillus thuringiensis</i>	Leaves	Acetone, Diethyl Ether, Petroleum Ether and Water	40µl <i>Pseudomonas aeruginosa</i> Petroleum Ether extract- 3.1±0.09 mm	(Divya et al., 2022)
	<i>Pseudomonas aeruginosa</i> <i>Staphylococcus aureus</i> , <i>Salmonella typhi</i> , <i>Bacillus cereus</i> ,	Leaves	Silver nanoparticles	<i>Salmonella typhi</i> and <i>Pseudomonas aeruginosa</i>	(Bhuvaneshwari et al., 2017)

Plant name	Microbes used	Plant parts	Solvents	Max. Inhibition	Reference
8. <i>Lumnitzera racemose</i> Wild.	<i>Proteus mirabilis</i> , <i>Escherichia coli</i> , <i>Vibrio cholera</i> , <i>Salmonella typhi</i> , <i>Pseudomonas aeruginosa</i> , <i>Klebsiella pneumoniae</i> , <i>Shigella flexneri</i> and <i>Staphylococcus aureus</i> .	Twigs	90% Methanol	Methanolic extract and n-butanol fraction at 500µg/ml and 50µg/ml	(Souza et al., 2010)
	<i>Staphylococcus aureus</i> and <i>Proteus vulgaris</i>	Leaves and Bark	Chloroform, Petroleum ether, Ethanol Ethyl acetate, and Sterilized water	Ethanol extract <i>L. racemose</i> barkin <i>Staphylococcus aureus</i> -12mm	(Abeyasinghe, 2010)
9. <i>Rhizophora apiculata</i> Blume	<i>Pseudomonas aeruginosa</i> , <i>Salmonella typhi</i> , <i>Bacillus cereus</i> , <i>Escherichia coli</i> , <i>Proteus mirabilis</i> , <i>Klebsiella pneumoniae</i> , and <i>Staphylococcus aureus</i>	Leaves	Silver nanoparticles	50µL AgNps 14mm= <i>Escherichia coli</i> , <i>Klebsiella pneumoniae</i> , <i>Proteus mirabilis</i> , <i>Pseudomonas aeruginosa</i> , <i>Staphylococcus aureus</i>	(Antony et al., 2011)
	<i>Streptococcus sp.</i> , <i>Staphylococcus aureus</i> , <i>Salmonella typhi</i> , <i>Proteus vulgaris</i> and <i>P. mirabilis</i>	Leaves	Ethanol	62.5mg/disc <i>S. aureus</i> (16mm)	(Sahoo et al., 2012)
10. <i>Rhizophora mucronata</i> Lam.	<i>Aeromonas hydrophila</i> , <i>Streptococcus agalactiae</i> , <i>Vibrio harveyi</i> and <i>V. parahemolyticus</i>	Leaf, twig, Pod, and bark	Methanol	Pod and bark of <i>R. mucronata</i> MIC value of 0.39mg/ml against <i>A. hydrophila</i> and <i>S. agalactiae</i>	(Vittaya et al., 2022)

Table 3.

Antifungal activity of true mangroves present in Pichavaram

Plant name	Fungal strains used	Plant parts	Solvents	Max. Inhibition	Reference
1. <i>Acanthus ilicifolius</i> L.	<i>Candida albicans</i>	Leaves	Methanol	20%-75.69±7.26	(Andriani et al., 2020)
2. <i>Aegiceras corniculatum</i> Blanco	<i>Candida albicans</i> <i>Termitomyces clypeatus</i> <i>Saccharomyces cerevisiae</i> <i>Trichophyton mentagrophytes</i> <i>T. rubrum</i>	Bark	Hexane, Benzene and Chloroform	Acornine 2 <i>T. clypeatus</i> 75150MIC (µg/disc)	(Gupta et al., 2014)
3. <i>Avicennia marina</i> (Forssk.) Vierh	<i>Aspergillus niger</i> , <i>Aspergillus flavus</i> , <i>A. fumigata</i> , <i>Candida albicans</i> , <i>C. tropicalis</i>	Aerial parts	Petroleum ether, Ethyl acetate, Butanol, and Methanol	50µl of Ethyl acetate extracts <i>C. tropicalis</i> - 41mm	(Belhadj-Salah et al., 2022)
4. <i>Bruguiera cylindrica</i> (L.) Blume	<i>Alternaria alternata</i> , <i>Acremonium strictum</i> , <i>Aspergillus flavus</i> , <i>Aspergillus niger</i> , <i>Bipolaris bicolor</i> , <i>Cladosporium herbarum</i> , <i>Curvularia lunata</i> , <i>Erwinia carotovora</i> , <i>Fusarium oxysporum</i> , <i>Macrophoma phaseolina</i> , <i>Penicillium expansum</i> , <i>Pseudomonas syringae</i> , <i>P. marginales</i> , <i>Rhizoctonia solani</i> , <i>Tiarospora phaseolina</i> , <i>Ustilago maydis</i> , <i>Xanthomonas campestris</i>	Leaves	Methanol	15mg/ml <i>P. syringae</i> 26mm	(Vadlapudi and Naidu, 2009)
5. <i>Ceriops decandra</i> (Griff.) Ding Hou	<i>Fusarium oxysporum</i> Pythium <i>aphanidermatum</i> <i>Pyricularia oryzae</i> <i>Rhizoctonia solani</i> <i>Curvularia oryzae</i>	Leaves	Chloroform, Methanol and Ethanol	Chloroform extracts <i>P. aphanidermatum</i> -29 mm at 500mg/ml	(Kumar et al., 2013)
6. <i>Excoecaria agallocha</i> L.	<i>Candida albicans</i> <i>Candida tropicalis</i>	Leaves	Chloroform, Dichloromethane, Ethyl acetate and Methanol	5mg/ml of Chloroform extract- <i>Candida albicans</i> -11.9±0.85mm	(Sabu et al., 2022)

Plant name	Fungal strains used	Plant parts	Solvents	Max. Inhibition	Reference
7. <i>Rhizophora apiculata</i> Blume	<i>Alternaria solani</i>	Leaves	Acetone, Chloroform, Ethanol, Ethyl acetate and Methanol	15% Ethanol leaf extract 95.54% inhibition	(Mahalakshmi et al., 2020)
	<i>Aspergillus niger</i> , <i>Aspergillus flavus</i> , <i>Trichoderma</i> sp <i>Rhizopus</i> sp	Bark, Roots, Leaves	Methanol, Ethanol, Hexane and Aqueous 1:4	1mg/mlMethanolic root extracts <i>A. niger</i> 24mm	(Seepana et al., 2016)
8. <i>Rhizophora mucronata</i> Lam.	<i>Candida albicans</i> , <i>Aspergillus flavus</i> , <i>A. fumigatus</i> , <i>Cryptococcus neoformans</i>	Leaves	Silver nanoparticles	20µl <i>C. albicans</i> - 26mm	(Singh et al., 2013)

Table 4.

Anticancer activity of true mangroves in Pichavaram

Plant name	Cell lines	Plant parts	Solvents	Max. Inhibition	Reference
1. <i>Acanthus ilicifolius</i> L.	HCT-116	Twigs	Petroleum ether, Ethyl acetate and Methanol	50µg of PE1- 58% 10µg of EA2-52% and M3-53%	(Poornaet al., 2011)
	Invivo study by Male Swiss albino mice. Cell lines: DLA, EAC and L-929	Leaves	Ethanol	50% proliferation of L-929 cells- 18±0.05 (g/ml)	(Babu et al., 2002)
	Hep G2 cancer cells	Root	Aqueous	IC ₅₀ value-39.76µg/ml	(Paul and Ramasubbu, 2017)
2. <i>Aegiceras corniculatum</i> Blanco	HepG2, HL-60, A2780 and BGC-823.	Stems and Twigs	Petroleum ether, n-bu- tanoland Ethyl acetate	HL-60 and BGC-823 IC ₅₀ values ranging from 7.6 to 10.6µM	(Li et al., 2020)
	HL-60, Bel7402, U937, and Hela	Stem and Twigs	Ethanol	50µg/ml IC ₅₀ values5-O-ethylembelin (2)1.3 - 3.9µg/ml 5-O-methylembelin (8) 1.5- 9.0µg/ ml	(Xu et al., 2004)
	MCF7, HCT116, B16F10, and A549	Leaves Ethyl acetate	Methanol	Sakurasosaponin methyl ester IC ₅₀ values- 2.89 ± 0.02 to 9.86 ± 0.21µM	(Vinh et al., 2019)
	HeLa, T47D and WiDr	Leaves	Methanol	IC ₅₀ value of HeLa cancer cells- 49.40 ± 5.85 T47D cancer cell- 78.12 ±11.38 and WiDr cancer cell- 45.60 ±7.35 µg/ml	(Arbiastutie et al., 2022)

Plant name	Cell lines	Plant parts	Solvents	Max. Inhibition	Reference
3. <i>Avicennia marina</i> (Forssk.) Vierh	MCF-7, OVCAR3, HeLa and VERO	Leaves	Ethanol and Ethyl acetate	CC ₅₀ values Ethanol extracts MCF-7 cells-70 µg/ml, OVCAR3 cells-1087µg/ml HeLa cells-189µg/ml Vero cells-382µg/ml Ethyl acetate extracts MCF-7 cells-102 µg/ml, OVCAR3 cells-272µg/ml, HeLa cells-67µg/ml, Vero cells-242µg/ml	(Afshar et al., 2022)
	AU565, NIH3T3, MDA-MB-231, Huh7 and HepG2	Leaves	Water, Ethanol, Methanol and Ethyl acetate	Ethyl acetate AU565-0.75µg/ml BT483-0.85µg/ml HepG2-0.79µg/ml Huh7- 5.6µg/ml	(Huang et al., 2016)
	HeLa	Leaves	Methanol	IC ₅₀ -321ppm	(Andriani et al., 2021)
4. <i>Avicennia officinalis</i> L.	EAC cells	Leaves	Methanol	ND	(Sumithra et al., 2011)
5. <i>Bruguiera cylindrica</i> (L.) Blume	MCF-7 cells	Leaves	Silver nano particles	50µg/ml AgNPs % of Death- 34.10±1.02	(Bhuvaneswari et al., 2015)
6. <i>Excoecaria agallocha</i> L.	SiHa HPV 16+	Leaves	Aqueous	Fraction III against SiHa cells IC ₅₀ values 15.538±0.577µg/ml	(Sultana et al., 2022)
	MCF-7	Leaves	Ethanol	Higher enzymatic antioxidant level-50µg/ml EEEA extract	(Reddy et al., 2023)

Plant name	Cell lines	Plant parts	Solvents	Max. Inhibition	Reference
7. <i>Lumnitzera racemosa</i> Willd.	HL-60 and Hel-299	Leaves	Methanol	HL-60-IC ₅₀ values of 0.15±0.29 and 0.60±0.16µM	(Thao et al., 2015)
	Hep G2 cancer cells	Leaves	Aqueous	IC ₅₀ value-26.05µg/ml	(Paul and Ramasubbu., 2017)
8. <i>Rhizophora apiculata</i> Blume	HEK-293 HeLa cells	Leaves	Aqueous extract Silvernanoparticle	HEK-293 cells at 2.5 µl/ml-100% cell death IC ₅₀ value-0.622µl/ml	(Liu et al., 2021)
	MG-63 cell line	Leaves	Aqueous	IC ₅₀ values: 0.655µl/ml	(Wen et al., 2020)
	<i>In vivo</i> - C57BL/6 mice Cell line- B16F10 melanoma cells	Whole plant	Methanol	<i>R.apiculata</i> extract administered (81±3.2) Survival % -107.6%	(Prabhu and Guruvayorappan, 2013)
	Invivo- Male BALB/c mice Cell line- B16F10 melanoma cells	Whole plant	Methanol	Hemoglobin levels Methanolic extract of <i>R. apiculata</i> (10 mg/kg) at Day 30-16.9 ± 0.7 g/dl	(Prabhu and Guruvayorappan, 2012)
9. <i>Rhizophora mucronata</i> Lam.	HeLa, MDA-MB231	Leaves	Methanol	HeLa- 4.60 ± 0.26mg/ml MDA-MB231- 3.89± 0.15mg/ml	(Sachithanandam et al., 2022)

Table 5.

Antiviral activity of true mangroves in Pichavaram

Plant name	Cell lines and Virus	Plant parts	Solvents	Max. Inhibition	Reference
1. <i>Acanthus ilicifolius</i> L.	Invivo- Guangxi shelducks Virus- Duck hepatitis B virus	Whole plants	Ethanol	No activity	(Wei et al., 2015)
	NDV	Roots	70% Ethanol	75-100% Activity	(Premnathan et al., 1992)
2. <i>Aegiceras corniculatum</i> Blanco	HTLV-1	Leaves	70% Ethanol	CC ₅₀ value- 48.31± 12.40µg/ml	(Premanathan et al., 1996)
3. <i>Avicennia marina</i> (Forssk.) Vierh	HSV-1 and polio virus	Leaves	10% Glycerin	IC ₅₀ values HSV-166µg/ml Poliovi- rus-145.7µg/ml	(Zandi et al., 2009)
	Cell lines- Vero, HEK293 Virus- SCR HIV-1 virions and KOS strain of HSV-1	Leaves	Methanol, Chloroform Ethanol, n-Hexane, and Water	IC ₅₀ of methanol extract for HSV- 9µg/ml HIV -15µg/ml	(Namazi et al., 2013)
	Invivo- Albino rats Virus- HIV-1	Leaves	95% Ethanol	IC ₅₀ value HBsAg- 489.39µg/ml, DNA polymerase inhibition assay 372.09µg/ml and RT inhibition assay 403.91µg/ml	(Beula et al., 2012)
4. <i>Avicennia officinalis</i> L.	Virus- EMCV	Bark and Leaves	70% Ethanol	1-24% activity	(Premnathan et al., 1992)
5. <i>Bruguiera cylindrica</i> (L.) Blume	Vector- Aedes aegypti and dengue virus DEN-2	Leaves	Aqueous and AgNps	AgNps - LC ₅₀ values ranged from 8.93ppm (larva I) to 30.69ppm (pupa)	(Murugan et al., 2015)
	Virus- NDV and HBV	Bark and Leaves	70% Ethanol	75 -100% Activity	Premnathan et al., 1992)
6. <i>Ceriops decandra</i> (Griff.) Ding Hou	HBV	Bark, Fruit and Leaves	70% Ethanol	75-100% Activity	Premnathan et al., 1992)
	HTLV-1	Leaves	70% Ethanol	40µg/ml 97.24%	(Premanathan et al., 1996)

Plant name	Cell lines and Virus	Plant parts	Solvents	Max. Inhibition	Reference
7. <i>Excoecaria agallocha</i> L.	HTLV-1	Leaves	70% Ethanol	40 µg/ml 98.92%	(Premanathan et al., 1996)
	EMCV	Fruit	70% Ethanol	75-100% activity	(Premanathan et al., 1999a)
	HCV	Twigs	Butanol	Excoeariphenols A–D (1–4) IC ₅₀ value- 3.45-9.03µM	(Li et al., 2012)
8. <i>Lumnitzera racemosa</i> Willd.	NDV	Bark	70% Ethanol	75-100% Activity	(Premanathan et al., 1999a)
9. <i>Rhizophora apiculata</i> Blume	HTLV-1	Leaves	70% Ethanol	435µg/ml- 95.64%	(Premanathan et al., 1996)
	HBV	Bark, Flower- and Fruit	70% Ethanol	75-100% Activity	Premnathan et al., 1992)
	HIV-1	Leaves	Ethanol	EC ₅₀ value- 10.7 and 25.9µg/ml	(Premanathan et al., 1999)
10. <i>Rhizophora mucronata</i> Lam.	HBV	Bark, Hypocotyl, Stilt Root	70% Ethanol	75-100% Activity	(Premanathan et al., 1999a)
	HTLV-1	Bark	70% Ethanol	30µg/ml- 98.92%	(Premanathan et al., 1996)
	HTLV-1	Bark	Ethanol	EC ₅₀ value- 97.73µg/ml	(Premanathan et al., 1999b)

Table 6.

Antioxidant activity of true mangroves in Pichavaram

Plant name	Method	Plant parts	Solvents	Max. Inhibition	Reference
1. <i>Acanthus ilicifolius</i> L.	Hydroxyl radical generation Superoxide radical production Lipid peroxide formation Nitric oxide radical formation	Leaves	70% Ethanol	IC ₅₀ values Superoxide radical 550µg/ml, Hydroxyl radical 2750µg/ml, Nitric oxide radical 670µg/ml and Lipid peroxide Fe ²⁺ /ascorbate system- 600µg/ml and Fe ³⁺ /ADP/ ascorbate 980µg/ml	(Babu et al., 2001)
2. <i>Aegiceras corniculatum</i> Blanco	DPPH free radical scavenging	Bark and Leaves	70% Ethanol	IC ₅₀ values of Bark- 20.49± 2.14µg/ml and Leaf - 33.51±1.60 µg/ml	(Biswas et al., 2019)
3. <i>Avicennia marina</i> (Forssk.) Vierh	1.DPPH radical cation scavenging activity 2. Superoxide anion radical scavenging assay 3. ABTS radical cation scavenging activity	Leaf, Stem and Pneumatophore)	Acetone, Hexane,- MethanolEthyl acetate and water	DPPH Acetone extract of stem-110µg/ml Pneu- matophore- 108µg/ml Methanol extract of the leaf- 127µg/ml Superoxide- Water extract of the leaf- 230µg/ml Water extract of stem-352µg/ml ABTS- Acetone extract of stem and water extract of pneumatophore -40µg/ml Methanol extract of leaf- 52µg/ml	(Moteriya, 2015)
4. <i>Avicennia officinalis</i> L.	DPPH radical scavenging assay	Twigs	-	F9 showed strong antioxidant activity IC ₅₀ value- 0.7mg/ml	(Assaw et al., 2020)
5. <i>Bruguiera cylindrica</i> (L.) Blume	DPPH radical scavenging activity	Stem and Leaves	80% Methanol	Stem- 162.5µg/ml and Leaves- 175µg/ml	(Gawali and Jadhav, 2011)

Plant name	Method	Plant parts	Solvents	Max. Inhibition	Reference
6. <i>Ceriops decandra</i> (Griff.) Ding Hou	1. DPPH· Quenching Activity 2. ABTS scavenging activity 3. OH· scavenging activity 4. Antihemolytic activity	Stem bark	Methanol	EC ₅₀ values- µg/ml DPPH- 2.1±0.28 ABTS- 13.5±0.02 OH- 9.5±0.24 Antihemolytic- 11.5 ± 0.24	(Krishnamoorthy et al., 2011)
7. <i>Excoecaria agallocha</i> L.	DPPH TBA Reducing power Nitric oxide Hydrogen peroxide	Bark	80% Ethanol	IC ₅₀ values-µg/ml DPPH- 179.16, NO- 120.24, H ₂ O ₂ -134.29 TBA- 189.27	(Subhanet al., 2008)
	DPPH method	Leaves	Methanol Ethyl acetate Chloroform Ethanol	Methanolic extract (IC ₅₀ -141.56µg/ml) in leaf	(Sofia and Teresa, 2016)
8. <i>Lumnitzera racemosa</i> Willd.	DPPH	Leaves and Stems	Methanol	IC ₅₀ values-µg/ml Leaves 23.31 Stems 111.5	(Quraishi et al., 2015)
9. <i>Rhizophora apiculata</i> Blume	DPPH H ₂ O ₂ scavenging activity Hydroxyl radical scavenging activity	Leaves	Ethanol, Methanol, Hexane, Butanol and Chloroform	DPPH- Butanol extract has 84% of activity H ₂ O ₂ - Butanol extract has 76% activity HRSA- Methanol extracts- 82%	(Ramalingam and Rajaram., 2018)
10. <i>Rhizophora mucronata</i> Lam.	DPPH Nitric oxide Superoxide ABTS	Leaves	Methanol (20-80%)	IC ₅₀ values of RH on DPPH-0.551µg/mg, Nitric oxide 0.360µg/mg, superoxide- 0.634µg/mg, HO-0.525µg/mg, ABTS- 0.149µg/mg.	(Sur et al., 2015)

Table 7.

Antimalarial activity of true mangroves in Pichavaram

Plant name	Strains used	Plant parts	Solvents	Max. Inhibition	Reference
1. <i>Acanthus ilicifolius</i> L.	Chloro-quine-sensitive strain (MRC-2) and Chloro-quine-resistant strain (RKL-9)	Leaves	Petroleum ether, Chloroform, and Methanol	Chloroform- Inhibition concentration 94% with anIC ₅₀ of 2.06µg/ml	(Hridya et al., 2021)
2. <i>Aegiceras corniculatum</i> Blanco	<i>P. falciparum</i>	Leaves	Acetone, Chloroform, Ethanol and Methanol	Methanolic extract IC ₅₀ 85.4612.76±µg/ml	(Sundaram et al., 2012)
	Invitro- <i>P. falciparum</i> Invivo- Swiss albino mice	Plant twigs	Methanol	Invitro – Ac+ Ca- 63.50±0.408% at 1.5mg/ml <i>In-vivo</i> antiplasmodial activity of Ac+ Ca in Swiss albino mice- 50.57±0.465 at 120mg/kg of bw	(Ravikumar et al., 2011c)
3. <i>Avicennia marina</i> (Forssk.) Vierh	<i>P. falciparum</i>	Bark	Ethanol: water (3:1)	IC ₅₀ value- 49.63µg/ml	(Ravikumar et al., 2011b)
Leaf extract of <i>A. marina</i> IC ₅₀ value- 69.0µg/ml					
4. <i>Avicennia officinalis</i> L.		Leaves	Methanol	% Parasitaemia for 150µg/ml is 40.202.16±mg/ml	(Sundaram et al., 2012)
5. <i>Bruguiera cylindrica</i> (L.) Blume		Hypocotyl	Ethanol and water mixture (3:1)	IC ₅₀ value- 74.8µg/ml	(Ravikumar et al., 2011b)
		Leaves	Methanol	% Parasitaemia for150µg/ml is 40.801.65±µg/ml	(Sundaram et al., 2012)
6. <i>Ceriops decandra</i> (Griff.) Ding Hou		Leaves	Methanol	% Parasitaemia for150µg/ml is 21.902.73±µg/ml	
		Hypocotyl	Ethanol and water mixture (3:1)	IC ₅₀ value- 123.25µg/ml	
				Leaves	IC ₅₀ value-150.3µg/ml
7. <i>Excoecaria agallocha</i> L.		Leaves	Methanol	% Parasitaemia for150µg/ml is 28.503.46±µg/ml	(Sundaram et al., 2012)
	Leaves	Ethanol and water mixture (3:1)	IC ₅₀ value- 89.34 µg/ml	(Ravikumar et al., 2011b)	

Plant name	Strains used	Plant parts	Solvents	Max. Inhibition	Reference
8. <i>Lumnitzera racemosa</i> Willd.	Chloroquine-sensitive (MRC-2) and Chloroquine-resistant (RKL-9)	Leaves	Petroleum ether, Chloroform, and Methanol	Chloroform extract Inhibition concentration 92% with IC_{50} value 4.51 μ g/ml	(Hridya et al., 2021)
9. <i>Rhizophora apiculata</i> Blume	P. falciparum	Leaves	Methanol	% Parasitaemia for 150 μ g/mL is 29.903.73 $\pm$ μ g/ml	(Sundaram et al., 2012)
			Ethanol and water mixture (3:1)	IC_{50} value - 110.93 μ g/ml	(Ravikumar et al., 2011a)
		Leaves	Methanol	% Parasitaemia for 150 μ g/ml 41.503.59 $\pm$	(Ravikumar et al., 2012)
10. <i>Rhizophora mucronata</i> Lam.	P. falciparum	Bark	Ethanol and water mixture (3:1)	IC_{50} value - 62.18 μ g/ml	(Ravikumar et al., 2011a)
		Stilt roots		IC_{50} value - 119.37 μ g/ml	
		Collar		IC_{50} value - 132.50 μ g/ml	
		Leaves	Methanol	% Parasitaemia for 150 μ g/ml is 75.001.40 $\pm$ μ g/ml	(Sundaram et al., 2012)
		Flower	Ethanol and water mixture (3:1)	IC_{50} value - 92.25 μ g/ml	(Ravikumar et al., 2011b)

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TAXUS BACCATA L. IN THE MIDDLE MOUNTAINS OF THE TEREK CAUCASUS (CHECHNYA)

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Abstract. *The article describes the current state of the *Taxus baccata* L. population in the mid-mountain landscapes (Wooded Range) of the Chechen Republic (Terek Caucasus) in the area between the Gekhi and Roshnya rivers. Regional populations of this species according to the standard of the International Union for Conservation of Nature (IUCN) belong to the category of rarity “Endangered”. We previously published a note about an unknown population of this species in the study area, but the authors provide a detailed description of these forest communities for the first time. The composition and structure of plant communities with the participation of *T. baccata* were studied, and data on the ecological and phytocenotic characteristics of its populations were obtained. The tract contains 20 species of trees and shrubs and more than 30 species of herbaceous plants. The first locus is small in number and is located under the dense canopy of *Fagus orientalis* Lipsky, *Carpinus betulus* L. and *Tilia caucasica* Rupr. The age structure of *T. baccata* cenopopulations is characterized as normal, complete, average dynamic with a predominance of immature individuals that gravitate to the periphery of the locus. The second locus of *T. baccata* is a more numerous and larger population in the forest edge. Here, the “edge” forms of *T. baccata* look prosperous, their vital condition is high. Despite the apparent well-being, in general, the state of the studied communities due to increased anthropogenic pressure (including the active development of the tourism cluster) is assessed as threatened. In order to preserve the population, it is necessary: constant monitoring of the state of the studied population, protection of the habitat, prohibition of forestry activities on the site and adjacent plots, and the territory itself is subject to conservation and the organization of a natural reserve on its basis.*

Key words: Chechnya, Terek Caucasus, *Taxus baccata*, locus, coenopopulation.

Introduction

Taxus baccata L. is a vulnerable, declining Western European species. The Caucasus Mountains are the eastern border of its range. *Taxus baccata* is a relic of the Tertiary period, protected on the territory of the Russian

Federation (Litvinskaya, 2024).

In the North Caucasus it grows in mountain forest areas from the Krasnodar Territory to Dagestan. It is found in shady forests of the lower and middle zones of the Western (Rezchikova, 2009, 2017), certain regions of the Central,

Terek Caucasus (Galushko, 1978) and Dagestan (Omarova, Asadulaev, 2012), as well as in the Crimea (Mytsyk et al., 2024). Quite rare everywhere. This is due to natural-historical reasons: general climatic, arealological, as well as phytocenotic and biological characteristics of the species.

More widely distributed in the Northwestern Caucasus; in the central part of the Caucasus - a small species, in the Eastern Caucasus (Chechnya, Ingushetia, Dagestan) - very rare. On the territory of Dagestan - periodically throughout almost the entire foothill strip of beech-hornbeam forests (Omarova, 2023). The species is protected everywhere.

In Chechnya and Ingushetia it is found in the belt of beech-hornbeam forests (Wooded ridge, mid-mountain belt) along the river Assa, in the basins of the rivers Fortanga (Achkhoy-Martan region), Gekhi (Galushko, 1975), Argun, Bassa, Hulkhulau, Aksaya, and in the upper reaches of the river Netkhoy (Dakieva, 2007; Umarov, 2020).

Material and methods

The main factual material for this report was the data collected by the authors during an expeditionary survey (08/10/2023) of a forest area within the watershed ridge of the adjacent Gekhi and Roshnya river basins. This is a territory in the Urus-Martan region of the Chechen Republic, south of the village of Roshni-Chu. Coordinates 42.975036 N; 45.400517 E. Altitude above sea level - 1040-1050 m.

We carried out our research to the east of the famous yew berry grove (Slepykh et al., 2019) in the valley of the river. Netkhoy. The drainage basins of the Shalazha and Valerik rivers are adjacent to the west.

During field research, a floristic survey technique was used. The choice of routes was carried out taking into account the completeness of coverage of various relief elements and the diversity of plant communities. Coenotic studies, collection and processing of field materials were carried out using traditional methods of geobotanical description and phytocenotic study of plants.

The participation of the species on the

survey sites in the composition of communities was assessed by its cover: r - the species was found on the site with insignificant cover; + - individuals of the species cover less than 1% of the site; 1 - individuals cover 1 - 5%; 2 - 5-25%; 3 - 25-50% of the accounting area.

Results and Discussion

The terrain is complicated by erosional hollow-gully dissection of the mesorelief. Yew is represented in two areas adjacent to each other. They are not isolated; the boundary between them is partly arbitrary. Meanwhile, the range of differing conditions of the ecological and phytocenotic environment determined the nature of the use of habitat resources and unequal conditions for the growth and development of *T.baccata*.

The first small forest cenotic locus (FCL) of the *T. baccata* population occupies transit positions in the landscape on the northern shadow microslope (its upper part, slope 30-40°) of a deep erosion-gully depression of the marginal part of the ridge. Its bottom is formed by erosion, transit and accumulation of sediment. The landscape is transeluvial, complicated by the biogeochemistry of its elements. Soil and atmospheric humidity are high. The area of the coenopopulation is insignificant.

T. baccata plants in this FCL grow as part of the lower tree and shrub layer of shady habitats under a dense canopy of beech-hornbeam communities with the participation of *Tilia caucasica*. Tree stand completeness 0.9-1.0. The height of the main forest-forming species is 20-22 m.

The undergrowth is quite pronounced (Total Projective Cover 5-7%, hereinafter referred to as TPC). The shrub layer itself is represented by single *Sambucus nigra*, *Rubus caesius*, *Euonymus europaeus*, *Viburnum opulus*, *Frangula alnus* (in descending order of species abundance).

The ground layer is rather poorly developed. In the shade of trees, the grass cover is sparse (TPC 20-30%), strengthened by nemoral shade-tolerant and shade-loving species (Table 1). Tree shoots are sporadic. Dead wood accounts for 2-3%. Indicators of damp conditions of constant moisture are individual

representatives of mycobiota (*Fomes fomentarius*, *Geastrum triplex* s.l., *Boletus subtomentosus*), incl. decomposers living on dead wood. Large ferns *Athyrium filix-femina*, *Dryopteris*

filix-mas, *Polystichum braunii* are prominently represented in the grass cover. The moss cover is pronounced.

Table 1

Plant species found within loci

No	Plant name	FCL	ECL
Wood forms			
1.	<i>Acer laetum</i> C.A. Mey.	+	1
2.	<i>A. platanoides</i> L.	+	–
3.	<i>A. pseudoplatanus</i> L.	r	+
4.	<i>Carpinus betulus</i> L.	2	–
5.	<i>Cerasus avium</i> (L.) Moench	r	–
6.	<i>Euonymus europaeus</i> L.	1	–
7.	<i>E. latifolius</i> (L.) Mill.	r	1
8.	<i>Fagus orientalis</i> Lipsky	3	–
9.	<i>Frangula alnus</i> Mill.	–	+
10.	<i>Fraxinus excelsior</i> L.	+	r
11.	<i>Quercus robur</i> L.	+	+
12.	<i>Lonicera steveniana</i> Fisch. ex Pojark.	r	–
13.	<i>Rhododendron luteum</i> Sweet	–	+
14.	<i>Rubus caesius</i> L.	+	+
15.	<i>Salix caprea</i> L.	–	+
16.	<i>Sambucus nigra</i> L.	1	–
17.	<i>Taxus baccata</i> L.	1	3
18.	<i>Tilia begoniifolia</i> Steven Tilia caucasica Rupr.	1	–
19.	<i>Ulmus glabra</i> Huds.	+	r
20.	<i>Viburnum opulus</i> L.	+	–
Herbs			
21.	<i>Actaea spicata</i> L.	+	–
22.	<i>Allium victorialis</i> L.	2	–
23.	<i>Athyrium filix-femina</i> (L.) Roth	1	–
24.	<i>Carex sylvatica</i> Maxim.	+	–
25.	<i>Cephalanthera damasonium</i> (Mill.) Druce	r	–
26.	<i>C. longifolia</i> (L.) Fritsch	r	–
27.	<i>Circaea lutetiana</i> L.	+	–
28.	<i>Epipactis helleborine</i> (L.) Crantz	r	–
29.	<i>Dryopteris filix-mas</i> (L.) Schott	2	–
30.	<i>Festuca altissima</i> All.	+	–
31.	<i>F. drymeja</i> Mert. & W.D.J. Koch	+	–
32.	<i>Fragaria vesca</i> L.	+	r

No	Plant name	FCL	ECL
33.	<i>Gadellia lactiflora</i> (M. Bieb.) Schulkina	–	+
34.	<i>Galium odoratum</i> (L.) Scop.	1	–
35.	<i>Gentiana asclepiadea</i> L.	r	–
36.	<i>Geranium robertianum</i> L.	+	–
37.	<i>Lamium album</i> L.	1	+
38.	<i>Listera ovata</i> (L.) R. Br.	r	–
39.	<i>Myosotis amoena</i> (Rupr.) Boiss.	+	–
40.	<i>Paris incompleta</i> M. Bieb.	+	–
41.	<i>Pachyphragma macrophyllum</i> (Hoffm.) N. Busch	1	–
42.	<i>Petasites hybridus</i> (L.) Gaertn. B. Mey. & Scherb.	+	–
43.	<i>Phyllitis scolopendrium</i> (L.) Newman	+	–
44.	<i>Poa nemoralis</i> L.	r	+
45.	<i>Polygonatum glaberrimum</i> K. Koch	1	–
46.	<i>Polypodium vulgare</i> L.	+	–
47.	<i>Polystichum braunii</i> (Spenn.) Fee	1	–
48.	<i>Prenanthes petiolata</i> (K.Koch) Sennikov	+	–
49.	<i>Primula macrocalyx</i> Bunge	–	+
50.	<i>Prunella laciniata</i> (L.) L.	–	+
51.	<i>Salvia glutinosa</i> L.	+	+
52.	<i>Stachys sylvatica</i> L.	r	+
53.	<i>Tussilago farfara</i> L.		
54.	<i>Tamus communis</i> L.	r	–
55.	<i>Urtica dioica</i> L.	+	+
56.	<i>Vincetoxicum scandens</i> Sommier & Levier	r	r
57.	<i>Viola odorata</i> L.	1	1
58.	<i>V. reichenbachiana</i> Jord. ex Boreau	r	–

The soils are gray forest, podzolized, carbonate, underlain by limestone rocks, transit, fresh, loose with forest litter as litter. The trophicity of the ecotope is high.

The distribution of *T. baccata* over the area is random, in single trees, and occasionally in small groups. In total, 49 yew individuals of different ages were encountered, their density on average being 4.8 plants per 100 m².

Measurement data by age (average height/stem circumference, cm) – juvenile (13/1.5); immature – (80/4.4); virginal – (300/17.3); generative 1 – (490/26.6); generative 2 – (920/42.8); generative 3 – (1170/77).

Analysis of the age structure of the cenopopulation under study allows us to characterize its

type as normal, full-membered, medium-dynamic with a predominance of immature individuals. Moreover, the latter are most often observed only on the periphery of the locus, adjacent to the ecotone cluster, with balanced possibilities. Natural seed regeneration here is carried out due to the influx of diaspores carried by birds from edge habitats. The share of individuals in the pregenerative age state in the cenopopulation is 58%.

The ratio of their number to generative plants is as follows – (j+im+v) / (g1:g2: g3) = 1.4/1.0.

In general, FCL yew plants seem to us to be depressed, with weak capabilities and development prospects. We associate this observation

primarily with the absence of seeds on trees of reproductive age located in the subcanopy space.

Meanwhile, we have noted cases of rooting of the lower branches of *T. baccata* when they are covered with soil. In low light conditions, many yew individuals are depressed due to the maximum intensity of photosynthesis.

The second yew locus is a large plantation in the ecotone (edge) forest zone (Ecological-Cenotic Locus – ECL). It is adjacent to the upper part of a steep slope of limestone rock and the side of a forest road, and is quite well lit. The soil is clastic, shingle-talus, caused by the destruction of rock during the filling of the road surface. The area of the site is partially occupied by fragments of gray forest soil and areas of mountain chernozem soils with undeveloped profiles, formed when underlying rocks emerge close to the surface. The boundaries of the yew coenopopulation here appear to be strictly fixed, with a narrow radius of activity.

Under conditions of excellent insolation, the ECL phytopopulation is highly saturated with yew plants. The general tree stand is reduced, sparse, edge type, with single participation of *Euonymus latifolius*, *Quercus robur*, *Acer laetum*, *Frangula alnus*, *Cerasus avium*. In the grass and shrub cover, edge-forest species are common, and occasionally *Rhododendron luteum*.

Here, in the transition zone between adjacent landscape-floristic complexes, the “edge” forms of *Taxus baccata* look prosperous, their vital condition is high. Adult individuals are characterized by high visible indicators of annual stable strong growth, intensive fruiting, and

a certain mechanism of stability. A certain number of individuals are multi-stemmed.

Limiting factors and threats. Low reproductive capabilities, slow growth in the first years of life. Isolation of the population in the landscape, low numbers and weak competitiveness.

Protection measures taken in the region. The species is included in the Red Data Books of Chechnya (Umarov, 2020) and Ingushetia (Dakieva, 2007). The gene pool of the yew berry is protected within the boundaries of the Specially Protected Natural Territory “Netkhoy Yew Grove” (Achkhoy-Martan district of the Chechen Republic).

Conclusion

Communities with the participation of *T. baccata* within the studied territory are characterized by different composition, structure, availability of water and sunlight, and, as a result, different capabilities of *T. baccata* phytopopulations for self-sustainment. Which emphasizes their specificity.

Assessing the environmental status of the cenopopulations of the surveyed areas, we can conclude that it is generally endangered. Increased anthropogenic pressure (forestry work, habitat destruction) and other extreme factors will inevitably lead to the death of *T. baccata*.

In the future, constant monitoring of the state of the studied population is necessary, protection of the habitat, prohibition of forestry activities on the site and adjacent plots, and the territory itself is subject to conservation and the organization of a natural reserve on its basis.



Photo 1. Beech-hornbeam large fern community with *Taxus baccata* L.

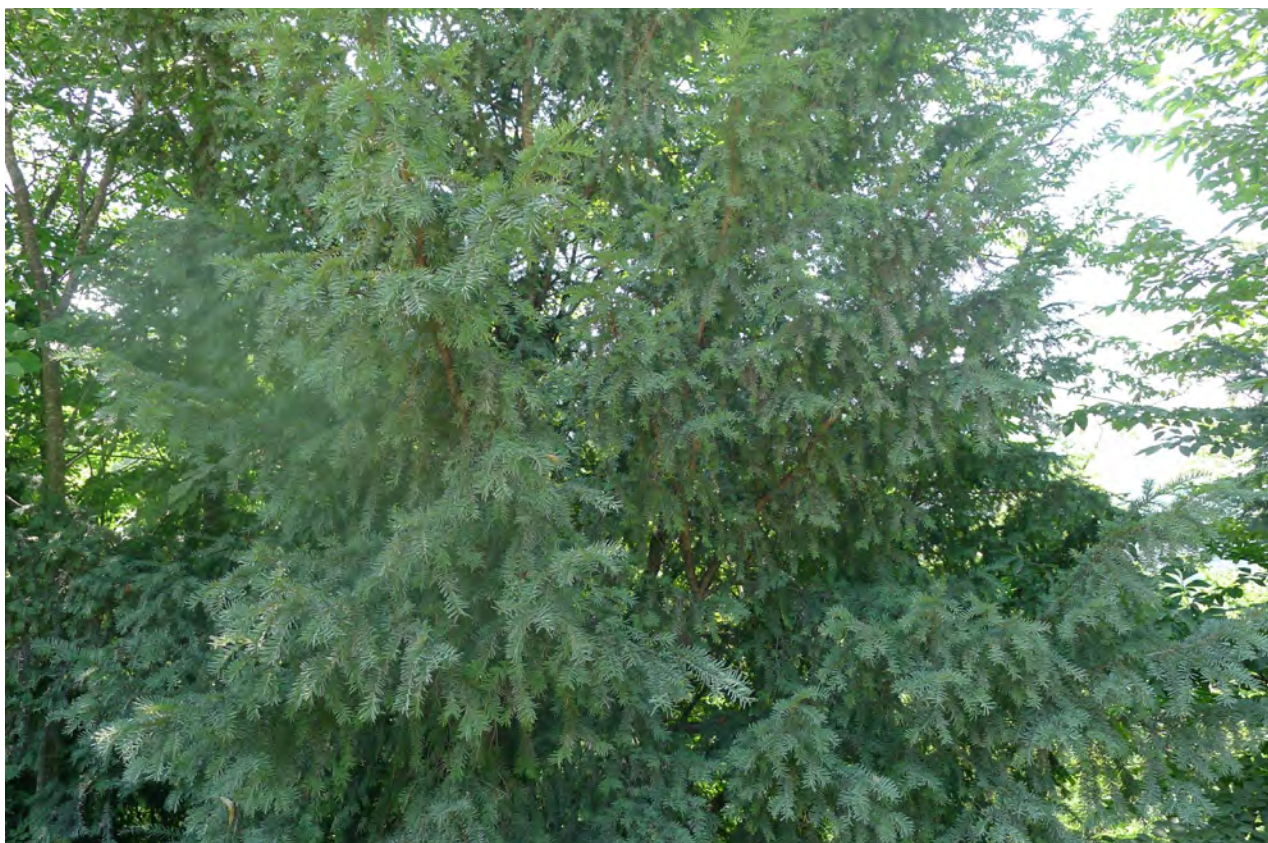


Photo 2. *Taxus baccata* L. in the conditions of an ecotone phytocenotic locus

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