



ISSN 2959-1864 (Online)
ISSN 2958-0536 (Print)
Volume 3, Number 3
December 2024

Acta Botanica Caucasica

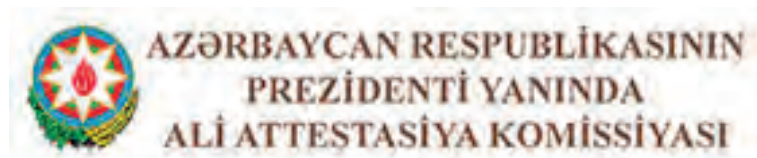
ISSN 2959-1864 (Online)
ISSN 2958-0536 (Print)

MINISTRY OF SCIENCE AND EDUCATION REPUBLIC OF AZERBAIJAN
BAKU STATE UNIVERSITY



Acta Botanica Caucasica

Volume 3, Number 3
December 2024



© It is necessary to use reference while using the journal materials.
© www.botanic.az/en
© info@botanic.az

The purpose of the journal is to stimulate the development of botanical science. The issues posed by the Journal are the publication of the results of research that are relevant for professional botanists.

The journal "Acta Botanica Caucasica" publishes the results of researches in various fields of fundamental Botany: Systematics, phylogeny, floristics, geobotany, morphology, structural Botany, Plant Physiology; articles on protection of the plant world, as well as the study of vegetation in the Caucasus; chronic materials on scientific events (symposiums, conferences); important botanical innovations; articles on the history of Botany. In the journal "Acta Botanica Caucasica" the Articles of Caucasian and foreign authors are published in English. Articles should include the latest, previously unpublished factual information and theoretical considerations.

EDITOR-IN-CHIEF:	ELSHAD GURBANOV Baku State University, Department of Botany and Plant Physiology
ASSOCIATE EDITOR:	SAYYARA IBADULLAYEVA Ministry of Science and Education of the Republic of Azerbaijan. Institute of Botany
RESPONSIBLE SECRETARY:	HUMIRA HUSEYNOVA Baku State University, Department of Botany and Plant Physiology

EDITORIAL BOARD:

IRADA HUSEYNOVA	Institute of Molecular Biology and Biotechnologies, ANAS Baku, Azerbaijan
TARIEL TALIBOV	Bioresources Institute, Nakhchivan Division of Azerbaijan National Academy of Sciences, Nakhchivan, Azerbaijan
VAGIF NOVRUZOV	Department of Botany, Ganja State University, Ganja, Azerbaijan
AFAT MAMMADOVA	Faculty of Biology, Baku State University, Baku, Azerbaijan
AYDIN ASGAROV	Institute of Botany, Ministry of Science and Education, Department of Systematics and Biodiversity, Baku, Azerbaijan
MEHRAC ABBASOV	Genetic Resources Institute, Ministry of Science and Education, Baku, Azerbaijan
ISMAT AHMEDOV	Leading Researcher, Nanoresearch Laboratory, Baku State University, Baku, Azerbaijan
TAHIR SULEYMANOV	Department of Pharmaceutical Chemistry, Azerbaijan Medical University, Baku, Azerbaijan
VILAYAT ABDIYEV	Department of Botany and Plant Physiology, Baku State University, Baku, Azerbaijan
ZULFIYYA MAMMADOVA	Department of Botany and Plant Physiology, Baku State University, Baku, Azerbaijan
İSMAIL TURKAN	Yaşar University, Faculty of Agricultural Sciences and Technologies Izmir, Turkey
ERSIN YUCEL	Faculty of Natural Sciences, Department of Botany, Eskisehir Technical University, Eskisehir, Turkey
MUNIR OZTURK	Department of Botany, Ege University, Izmir, Turkey
AYDIN TUFEKCHIOGLU	Department of Earth Science and Ecology, Artvin Coruh University, Artvin, Turkey
SHAHINA GHAZANFAR	Royal Botanic Gardens, Kew, London, United Kingdom
MIRZA HASANUZZAMAN	Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh
NAFEES KHAN	Department of Botany, Aligarh Muslim University, Aligarh, India
SARVAJEET SINGH GILL	Centre for Biotechnology, Maharshi Dayanand University, Rohtak, India
OLEXANDER PAKHOMOV	Department of Zoology and Ecology, Oles Honchar Dnipro National University, Dnipro, Ukraine
IVAN MOISEENKO	Department of Botany, Kherson State University, Kherson, Ukraine
NAZIM MAMMADOV	Department of Plant and Soil Sciences, University of Massachusetts, Amherst, USA
VAGIF ATAMOV	Department of Biology, Recep Tayyip Erdogan University, Rize, Turkey
JESUS GONZALEZ-LOPEZ	University of Granada, Granada, Spain
KHABIBJON KUSHIEV	Laboratory of Experimental Biology, Gulistan State University, Gulistan, Uzbekistan
NASIBAKHON NARALIYEVA	Department of Ecology and Botany of Andijan State University Andijan, Uzbekistan
ALEXANDER ZERNOV	Department of Higher Plants, Moscow State University Lomonosov, Moscow, Russia
MUHAMMAD ZAFAR	Quaid-I-Azam University, Plant sciences Islamabad, Pakistan

THE CURRENT STATE OF *JUNIPERUS FOETIDISSIMA* WILLD. CENOPOPULATIONS IN AZERBAIJANElshad Gurbanov¹ | ORCID: 0000-0003-4627-3760Afaq Rzayeva² | ORCID: 0000-0002-0395-2301¹ Department of Biology, Baku State University, Baku, Azerbaijan² Department of Biology, Baku Engineering University, Baku, Azerbaijan¹ Correspondence: elshadgurbanov@bsu.edu.az**Article Info:**DOI: <https://doi.org/10.30546/abc.2024.3.3.501>

Pages: 4–9

Received: April 20, 2024 | Revised: May 13, 2024 | Accepted: September 28, 2024

Abstract. The ontogenetic and bioecological evaluation of senescent populations of rare and endangered plant species in the Republic is of significant importance for the conservation of wild flora. This article is dedicated to an in-depth examination of the bioecology of *Juniperus foetidissima* Willd. This particular species is noteworthy, as it has been included in the Red Book of Azerbaijan due to its threatened status.

The study encompasses various aspects of the species' life cycle, habitat requirements, reproductive patterns, and interactions with the surrounding ecosystem. By understanding these factors, we aim to promote effective conservation strategies and raise awareness about the importance of protecting this rare species in its native environment. Additionally, this research could provide insights that are applicable to other endangered species within the region, ensuring a broader impact on biodiversity conservation efforts. The *Juniperus foetidissima* Willd. is an important part of the arid sparse forests in Azerbaijan, characterized by their unique dual nature. Some groups of plants in these forests rely on the essential qualities of the tree layer, while others form independent associations.

Key words: *Juniperus foetidissima* Willd, cenopopulation, wild flora, ontogenetic spectrum, climate change

Introduction

The *Juniperus foetidissima* Willd. serves as a crucial component of the arid sparse forests in Azerbaijan, which are defined by their distinct dual nature. Certain plant groups in these forests depend on the vital properties of the tree layer, while others exist as independent associations. A significant characteristic of the plant communities formed by *Juniperus foetidissima* Willd. is their low crown coverage, which consistently measures at a minimum of 0.3. It is essential to recognize that this value fluctuates based on variables such as plant species, stages of succession, and biological age. Furthermore, the incomplete mutual coverage of the crowns actively influences coenogenetic processes,

shaping the composition of plant communities and the ecological conditions of the lower layers.

The complete life cycle of plants undeniably includes all stages of development, beginning with fertilization, and it is divided into four distinct periods:

Latent Period: This critical phase follows fertilization, during which the seed is formed, and its morphological characteristics are established. Research on the latent periods of various plants clearly demonstrates that, after fertilization, the embryo develops alongside other structural elements that are vital for seed formation. Among these elements is the endosperm, a multicellular tissue that serves as

a nutrient reservoir essential for the embryo's growth. In *Juniperus* species, the endosperm is predominantly peripheral, while the embryo is positioned centrally. Furthermore, it is important to note that juniper species exhibit multi-lobed structures based on the number of cotyledons they possess.

1. **Virginal Period:** This stage includes the growth and development changes in plants as they age, encompassing cones, juveniles, and young plants. In other words, it includes the period leading up to seed formation.
2. **Reproductive Period:** This phase includes the generative stage of young, middle-aged, and old plants. It consists of three stages:
 - a. The plant has cones that do not produce seeds.
 - b. The plant has cones that do not produce fully viable seeds.
 - c. The plant produces fully viable seeds.
3. **Senile Period:** This period involves the changes that occur during the later years of a plant's life.

The ecological monitoring and assessment of cenopopulations of rare and endangered species play a vital role in the enrichment and

protection of wild flora. With this in mind, we directed our efforts toward a detailed evaluation of the cenopopulations of *Juniperus foetidissima* Willd., a species recognized in the Red Book of Azerbaijan for its conservation importance (Gurbanov et al., 2017; Rzayeva, 2021).

In our study, we meticulously documented the key botanical and ecological characteristics of the cenopopulations. These findings are comprehensively detailed in the accompanying table, which outlines the altitudes at which the juniper populations are found, their degree of isolation, the diverse soil types present in the regions, the associated plant communities, and the overall percentage of vegetation cover. Our assessment aims to contribute to effective conservation strategies for this endangered species and its unique habitats.

The first CP1 cenopopulation was observed in the Nakhchivanchay basin at an altitude of 600 to 1,000 meters above sea level. The region receives annual rainfall of 250 to 300 mm and is primarily covered by semi-desert and desert vegetation. This cenopopulation is highly isolated, and the vegetation density in the area is low.

Table 1.

Main characteristics of the studied cenopopulations of *Juniperus foetidissima* Willd.

Recorded Cenopopulation	CP1	CP2	CP3	CP4	CP5
Height	600–1000	300–350	400–420	450–500	400–650
Isolation level	High	Fair	Fair	Medium	High
Soil	Fertile black soil	Fertile black soil	Fertile black soil	Sandy	Clay
Plant associations	SAB-03B <i>Juniperion excelso-foetidissimae</i> Em.ex Matevski et al., 2010	<i>Junipero-Crataegnosum</i>	SAB-03B <i>Juniperion excelso-foetidissimae</i> Em.ex Matevski et al., 2010	RHA-01I <i>Brachypodio pinnati-Juniperion communis</i> Mucina all. nov. hoc loco	SAB-03B <i>Juniperion excelso-foetidissimae</i> Em.ex Matevski et al., 2010
Population types distinguished by the delta–omega criterion	Transitional	Transitional	Transitional	Transitional	Transitional
CP density (ind./m ²)	5	10	6	2	2
Cover	40%	75%	45%	20%	35%



Figure 1. *Juniperus foetidissima* Willd. in Turianchai state reserve (From CP 5).

CP2 is found in the Lesser Caucasus region, specifically in the northwest part of the Republic of Azerbaijan. This region is characterized by significant anthropogenic pressure, primarily due to agricultural activities and land development (Gurbanov & Rzayeva, 2019; Huseynova, 2023). As a result, the ecosystem has been altered, impacting its biodiversity. The annual precipitation in this area ranges from approximately 300 to 350 mm, influencing both the flora and fauna present, as well as the region's overall climate.

CP3 occupies well-isolated areas on mountain Dubrar, a location known for its breathtaking landscapes and unique geological features. Here, the influence of human activity is moderate; while tourism brings visitors to the area each year, the local wild vegetation has been largely preserved in the more remote highland regions. The balance between tourist management and conservation has allowed for the maintenance of the native plant species, contributing to the ecological richness of the mountaintop environment.

CP4 is situated in Gobustan, an area notable for its ancient rock carvings and cultural significance, positioned at an elevation of 450 to 500 meters above sea level. This small region faces intense anthropogenic pressure, largely due to its popularity as a tourist destination and its proximity to urban development. The soil in CP4 contains very few nutrients, which presents challenges for maintaining diverse plant life and affects the overall health of the ecosystem.

CP5 encompasses the territory of the Turyanchay State Nature Reserve, which was established in 1958 with the primary goal of protecting the rare pistachio-juniper arid forests that are indigenous to the area. This reserve is characterized by a high degree of isolation, which helps preserve its unique biodiversity. The density of vegetation is notably high, providing habitat for various species that thrive in this environment. The soil is predominantly clayey, which affects drainage and vegetation types. Furthermore, the region receives low levels of precipitation, making water conservation crucial for the sustainability of its ecosystems.

Overall, CP5 plays a vital role in the conservation of the region's natural heritage and biodiversity.

Materials and Methods

In the study of the ontogenetic spectrum of juniper cenopopulations, a comprehensive methodology was employed to categorize the various ontogenetic stages of trees. This methodology, proposed by researchers such as Zlobin and Uranov, allows for an in-depth understanding of tree development throughout their life cycles.

Furthermore, the classification of the cenopopulation types was carried out using the delta-omega (Δ - ω) system, which was developed by Uranov (Zhivotovsky, 2001). This system facilitates the evaluation of population dynamics and structure based on age distributions. The age index of the cenopopulations was subsequently assessed, helping to provide insights into the reproductive status and longevity of the plant populations in question.

$$\Delta = \frac{\sum k_i \cdot n_i}{N},$$

Where

k_i – is the coefficient of the ontogenetic stage

n_i – is the number of individuals at the

ontogenetic stage

N – is the total number of individuals in the cenopopulation

And ω – efficiency coefficient proposed by Zhivotovsky

$$\omega = \sum n_i e_i / \sum n_i, \text{ or } \omega = \sum p_i e_i,$$

ω – efficiency index presented by L. A. Zhivotovsky

e_i – efficiency coefficients of ontogenetic stages

n_i – is the number of individuals at the ontogenetic stage

Results and Discussion

To thoroughly evaluate the ecological and ontogenetic status of the species *Juniperus foetidissima* Willd. (Huseynova, 2022; Mammadova, 2020), which has a restricted distribution across only a few regions in the Republic, we conducted a detailed study that established an ontogenetic spectrum represented in a comprehensive table. This spectrum categorizes (Table 2) the species into various age groups, enabling us to analyze the number of individuals within each category.

Table 2.

Number of individuals belonging to different ontogenetic stages, calculation of age and efficiency index of cenopopulations

Ontogenetic stages									Δ	Ω
CP	J	im	V	g1	g2	g3	Ss	S		
CP1	4	6	3	6	8	6	4	1	0.38	0.47
CP2	2	4	2	6	6	9	2	3	0.47	0.55
CP3	2	5	4	5	4	4	2	5	0.42	0.41
CP4	0	2	11	1	3	13	1	2	0.42	0.59
CP5	6	11	8	4	4	6	8	5	0.49	0.52

We calculated critical parameters, including the age (Δ) and efficiency index (ω) of the cenopopulation, which serve as indicator of its sustainability. By applying the delta-omega model,

we assessed the ecological status of the cenopopulation, yielding insights into its overall vitality and resilience. Our findings reveal that all of cenopopulations exhibit a transitional type;

This rejuvenation process can be attributed to recent developments, such as the introduction of natural gas infrastructure to rural areas, which has improved living conditions. Additionally, the local residents have become more proactive in conserving their environment, leading to a significant reduction in deforestation activities. These factors together suggest a positive trajectory for the ecological health of *Juniperus foetidissima* in the region.

Conclusion

This study provides a comprehensive ontogenetic and bioecological evaluation of the endangered *Juniperus foetidissima* Willd., highlighting its ecological, reproductive, and habitat characteristics in the Republic of Azerbaijan. The results indicate that the studied cenopopulations exhibit transitional characteristics, and their sustainability was assessed based on age dynamics and efficiency indices. The application of the delta-omega model facilitated a detailed understanding of the ecological status and regeneration potential of these populations. Furthermore, improvements in rural infrastructure, such as the introduction of natural gas supply, along with increased environmental conservation efforts, have contributed positively to the rejuvenation of these populations.

References

- Gurbanov, E., & Aslanova, S. (2024). AVERAGE ANNUAL PRODUCTIVITY OF THE THYMUS-ETALUM-FESTUCOSUM FORMATION, DISTRIBUTED IN SUMMER PASTURE FIELD NO. 8" TURKESOBABA"(AZERBAIJAN). Norwegian Journal of Development of the International Science, 126.
- Kurbanov, E., Aslanova, S., & Ibragimov, S. (2023). Types of Hole-Meadow and Wetlands Vegetation in Oil-contaminated Soils Siyazan District (Azerbaijan). Bulletin of Science and Practice.
- Gurbanov, E. M., Mamedova, Z. C., & Rzaeva, A. A. (2017). *Juniperus polycarpos* K. Koch (Turkestan Juniper) Species in Turianchai Preserve (Azerbaijan Republic). *Journal of Food Science and Engineering*, 458–460.
- Gurbanov, E. M., & Rzaeva, A. A. (2019). A Taxonomic Revision and Distribution of the Genus *Juniperus* (Cupressaceae) in Azerbaijan. *Journal of Food Science and Engineering*, 9(4), 139–141. <https://doi.org/10.17265/2159-5828/2019.04.003>
- Gurbanov, E. M., & Rzaeva, A. A. (2022). Evaluation of Decorative Properties of Some Coniferous Plants Introduced to Absheron Peninsula. *Acta Botanica Caucasica*. <https://doi.org/10.30546/abc.2022.1.2.3>
- Gurbanov, E. M., & Rzaeva, A. A. (2017). Biomorphological Analysis and Identification of Subspecies of *Juniperus communis* in Azerbaijan. *Asian Journal of Plant Science and Research*, 7(3), 14–16.
- Hassanpanah, D., Gurbanov, E., Gadimov, A., & Shahriari, R. (2007). Reduction of nitrate accumulation in potato by use of potassium humate for human safety. *Iranian Biomedical Journal*,

Significant ecological variability was observed among the different cenopopulations studied. The **CP5 cenopopulation in the Turianchai State Nature Reserve** stands out due to its high isolation and rich biodiversity, maintaining a well-preserved ecosystem. However, cenopopulations such as CP2 and CP4, which are more exposed to anthropogenic pressures, demonstrate higher vulnerability, emphasizing the necessity for targeted conservation strategies.

The findings underscore the importance of *Juniperus foetidissima* Willd. as a key species in the ecological stability of Azerbaijan's arid sparse forests. Understanding the bioecological characteristics of this rare species is crucial for the development of effective management and conservation plans. Moreover, the methodology and results of this study provide a valuable framework for evaluating and conserving other rare and endangered species in the region, contributing to broader biodiversity conservation efforts. This research highlights the significance of integrating scientific insights into practical conservation strategies, ensuring the sustainability of unique ecosystems and their biodiversity.

11(1), 461.

- Gurbanov, E. M., & Rzaeva, A. A. (2019). Comparative Analysis of *Juniperus communis* L. (Cupressaceae) Berry Oils in Azerbaijan. *International Conference "Chemical Science and Education, Problems and Prospects of Development,"* Dedicated to the International Year of the Periodic Table of Chemical Elements, Makhachkala, 150–153.
- Huseynova, H. Z. (2023). New Distribution Areas of Some Species of Plants on the Southern Part of the Caspian Coast. *Biosystems Diversity Oles Honchar Dnipro National University Ukraine*, 31(1), 123–130.
- Huseynova, H. Z. (2022). Vegetation of the Southern Part of the Caspian Coast and Its Nutritional Value. *Biosystems Diversity Oles Honchar Dnipro National University Ukraine*, 31(3), 205–212.
- Iskender, E., Jafarzadeh, S., & Muradova, B. (2024). MORPHOLOGY DESCRIPTION AND TAXONOMY OF PYRUS L. SPECIES OF NORTH-EASTERN PART OF THE GREAT CAUCASUS. *Acta Botanica Caucasica* Volume, 3(2), 30-39.
- Mammadova, Z. J. (2020). Seed Productivity of Some Leguminous Plants Studied at the Level of Cenopopulation in Azerbaijan. *Bulletin of Science and Practice*, 6, 58–65.
- Rzayeva, A. A. (2021). Seed Propagation of *Juniperus foetidissima* Willd. in Absheron. *Bulletin of Science and Practice*, 1, 55–58.
- Seed Propagation of *Juniperus foetidissima* Willd. in Absheron. (2021). *Bulletin of Science and Practice*, 1, 55–58. <https://doi.org/10.33619/2414-2948/62/05>
- Zhivotovsky, L. A. (2001). Ontogenetic States, Effective Density, and Classification of Plant Populations. *Russian Journal of Ecology*, 32(1), 1–5.

ECO-FLUORESCENT CHARACTERISTICS OF THE FLORA OF THE GANGA RIVER BASIN

Vagif Novruzov¹ | ORCID: 0009-0007-5093-6914

Aynur Bayramova^{1*} | ORCID: 0009-0007-1441-5265

Elanura Cavadova¹ | ORCID: 0000-0000-0000-0000

¹ Ganja State University, Ganja, Azerbaijan

^{1*} Correspondence: abayramova@rambler.ru

Article Info:

DOI: <https://doi.org/10.30546/abc.2024.3.3.505>

Pages: 10–16

Received: August 10, 2024 | Revised: September 5, 2024 | Accepted: September 25, 2024

Abstract: *The Ganja River basin, characterized by a wide range of elevations and climatic gradients, constitutes a unique ecological matrix distinguished by its diverse vegetation assemblages. Rigorous investigations, encompassing over 100 phytosociological descriptions and the collection of 300 herbarium specimens, have elucidated 20 distinct types of fluorescent vegetation, classified based on phytochrome composition and their dominant edificers. For the first time, a comprehensive and contemporary phytocenological framework at the association level has been developed, delineating vegetation distribution across ecological zones, including forests, meadows, swamps, and wetlands. Utilizing I.G. Serebryakov's classification system, the research reveals a nuanced stratification of life forms into vegetative, restorative, and irruptive species types, which are further categorized into ecological groups such as mesoxerophytes, xeromesophytes, halomesophytes, and saprophytes. The study critically examines the drivers of soil erosion and the diminished productivity of natural fodder areas, proposing targeted phytomelioration strategies aimed at restoring ecological equilibrium and reinforcing the stability of coastal slopes. These findings significantly advance the discourse on sustainable resource management and emphasize the imperative of safeguarding the ecological integrity of the Ganja River basin.*

Keywords: *vegetation association, mesoxerophytes, xeromesophytes, halomesophytes, saprophytes.*

Introduction

Nature protection and the efficient use of natural resources are among the most critical challenges facing humanity today. Addressing this issue requires the implementation of comprehensive measures for environmental protection, proper utilization of natural resources, and their restoration. To safeguard and use the vegetation in any given region effectively, it is essential to conduct a thorough study of its flora and vegetation, identifying plants that hold national economic significance. In this context, regional floristic data plays a crucial role in our efforts (Askerov, 2011; Mammadova, 2018; Noruzov & Javadova, 2023).

The length of the Ganja River is 99 km, and the total area of the basin is 752 km². The river

takes its source at an altitude of 2814 m above sea level and flows into the Kura River at an altitude of 720 m. Five of the nine tributaries of the river are right, and four are left. The basin ranges from high-precipitation alpine meadows in the south to low-precipitation desert and semi-desert steppes in the north. From south to north, the river basin is elongated and wide. It borders the Tartar River along the Murov mountain ridge, the Kurek River basin from the east, and the Goshgar River basin from the west. The average width of the river basin is 7.6 km, and the average height is 119 m. The total fall of the river is 2744 m, the average slope of the river is 27.7%, and the density of the river network is 0.64 km/km² (Huseynov, 1959; Malikov, 1984; Novruzov & Bayramova, 2010).

Materials and Methods

Research Materials

The study utilized various materials, including herbarium specimens collected from different elevations of the Ganja River basin, ranging from 250 to 3,800 meters above sea level. A total of nearly 300 herbarium samples were collected, representing diverse ecological groups and life forms (Guliyeva, 2022; Mehdiyeva, 2011). The phytosociological descriptions and survey data served as foundational materials for analysis.

The Ganja River basin's diverse terrains-ranging from mountain rocks and ravines to eroded rock outcrops-were explored during the research process. These terrains provided rich material for studying the flora and vegetation's ecological and morphological characteristics (Hatamov, 1981; Guliyeva, 2020).

Research Methods

Surveys were conducted throughout the basin to examine the flora and vegetation comprehensively. Key methods included floristic, floristic-systematic, areological, botanical-geographic, phytosociological, and statistical techniques. These approaches enabled the detailed classification and analysis of plant species and ecological groups (Mammadova, 2018; Noruzov & Javadova, 2023).

The botanical-geographic and phytosociological techniques were particularly significant in analyzing the spatial distribution and ecological relationships of plant communities. Statistical tools were applied to interpret data, ensuring reliability and precision in findings (Mehdiyeva, 2011).

Herbarium collections were curated and analyzed to document species diversity and morphological traits. The specimens were identified and cross-referenced with taxonomic literature, providing a basis for the ecological classification of species within the basin.

Relevance of the topic: One of the most important approaches of Flora is to give an analysis of life forms. Flora consists of the sum of different life forms. The flora of the Ganja River basin is divided into different life forms (according to I.G. Serebriyakov) with certain changes:

1. Trees and shrubs, semi-shrubs;

2. Autotrophic herbaceous plants, dense grasses, soft grasses, rhizomes, tuberous roots, creeping and climbing stems;
3. Autotrophic monocarp herbaceous plants: perennials, biennials and annuals.

In the spectrum of life forms, perennial, biennial and annual grasses, dense grasses, rhizomatous herbs and monocarpic plants (especially annuals) do not play a large role in forest groups (Serebriyakov, 1962; Raunkier, 1934).

Many classification systems and schemes have emerged, based on which life forms have been studied. The classification of K. Raunkier and I. G. Serebryskov is widely used in the study of the analysis of life forms. The classification system is based on ecological-morphological, biological and phytocenological features (Raunkier, 1934; Danilov, 1954).

According to the system of I.G. Serebryakova, the life forms of the vegetation of the Ganja River basin are vegetative type (annuals and biennials that do not cover a large area, each time forming in different areas), restorative type (perennial species in the process of renewal) and irruptive types (perennials that develop vegetative reproductive organs, not only renewal). The composition of the flora is characterized by a large number of ecological groups in the area.

All types of flora are divided according to ecological cenotic groups. The natural flora of the basin is divided into 7 ecological groups: forest, meadow, swamp, water bank, weed, forest-meadow, and water-wetland (Serebriyakov, 1962; Poplavskaya, 1983).

In addition to the above, in the analysis of the flora, the length of life of the species is analyzed, according to Serebriyakov (annual, biennial and perennial). Also according to Raunkier (phanerophytes, chamaephyte, emifritophytes, geophytes, therophytes), according to A.H. Danilov (psammophytes, psychrophytes, etc.); according to the composition of elements (mesoxerophytes, xeromesophytes, halomesophytes, sarophytes, mesophytes, hydromesophytes, mesohydrophytes, hygrophytes); divided according to the method of seed and fruit propagation (anemochores, autochores, zoochores, ballists, agestochores, etc.) (Danilov,

1954; Poplavskaya, 1983) (Table 1 & Figure 1).

According to the data of G.I. Poplavskaya, among psychrophytes, the leaf openings are slightly open during the day, and some are

open all day or most of the day (Poplavskaya, 1983).

Table 1.

Analysis of flora of Ganja River basin according to ecological groups

Ecological Groups	Number of Species	Percentage (%)
Mesophytes	360	49.0
Xerophytes	151	20.6
Mesoxerophytes	121	16.5
Hydrophytes	57	7.8
Halophytes	45	6.1
Total	734	100

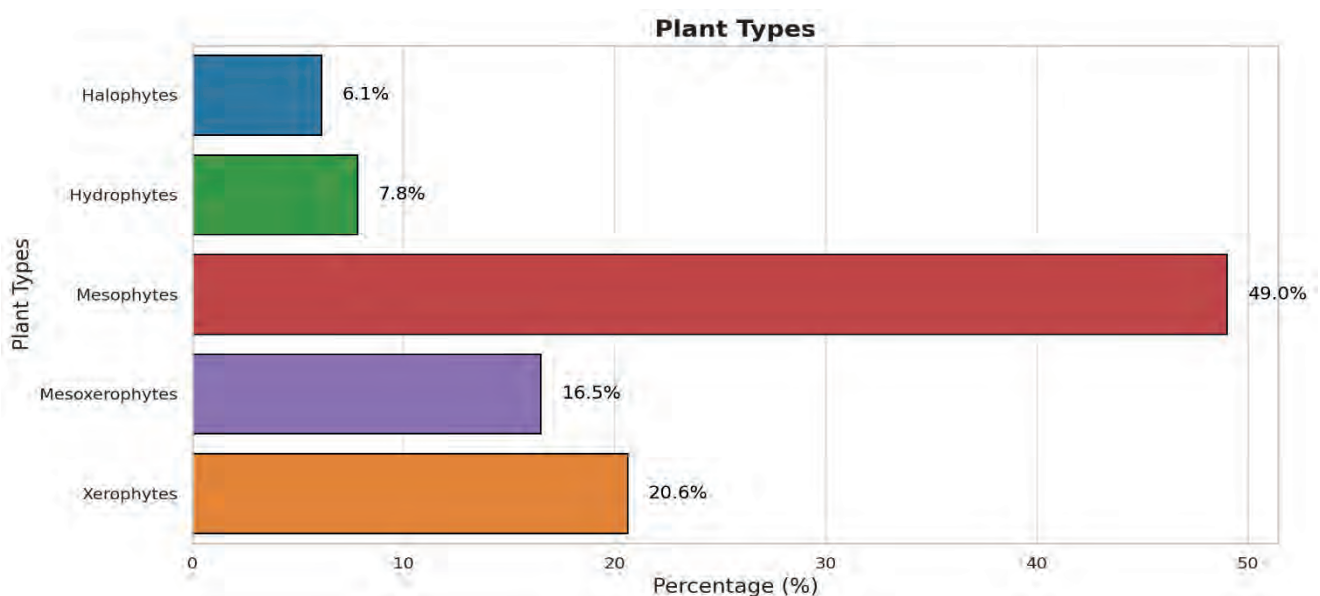


Figure 1. Distribution of Plant Types in the Flora of the Ganja River Basin Based on Ecological Groups

The modern flora and vegetation of the Ganja River basin have been formed under various anthropogenic influences as a result of the active economic activity of man. Therefore, the analysis of the flora of the Ganja River basin cannot be carried out without analyzing its anthropophilic elements. It should be pointed out that the separation of anthropophilic species and the identification of synanthropic flora is a very difficult process and, in most cases, it is done conventionally. In our research, anthropophilic flora is considered as the flora of areas disturbed by anthropogenic influences. Species and phylogenetic composition of the basin include species formed as a result of direct and indirect effects of human economic activity. This flora includes village surroundings, surroundings of

large and small enterprises, central roads, international gas pipelines, meadows, pastures, steppes, and water basins (Mammadova, 2018; Noruzov & Javadova, 2023).

Adventitious flora is the most important indicator of anthropogenic load. The economic use of the territory, and the increase of anthropogenic load, disrupt the natural balance of vegetation in natural landscapes, including plant groups. Disruption of habitats leads to apophytes and anthropites of the synanthropic flora (Nikiti, 1983). Apophytes, as representatives of the local flora, do not affect the change in the general composition of the flora. Anthropites do not initially affect the natural flora. Because of this, often the alien species are not included in the natural flora. The amount of adventitious

plants in the flora is influenced by the severity and periodicity of anthropogenic impacts (Pyak, 1994).

Adventitious flora is mostly found around the Ganja and Goranboy cities of the Ganja River Basin. Eighty-one adventive species belonging to 18 families and 60 genera are observed. **Caryophyllaceae**, **Cucurbitaceae**, **Malvaceae**, **Solanaceae**, and **Brassicaceae** species are predominant here. Non-native species mainly include **Asteraceae** (11 species), **Brassicaceae** (7 species), **Caryophyllaceae** (8 species), and **Poaceae** (13 species). **Solanaceae** includes 2 species, and the remaining families are represented by only one species.

Non-native species are classified by migration and degree of wilding:

By Migration:

1. **Xenophytes** - species that accidentally enter the area.
2. **Ergaziophytes** - wild cultivated plants.
3. **Xenoergasiophytes** - both non-native and cultivated plants (Hajiyev, 2004).

By Degree of Wilding:

1. **Epigophytes** - species that become wild and actively move to anthropogenic areas.
2. **Colonyphytes** - wild species that cannot spread very widely.
3. **Ephemirites** - non-native species that cannot reproduce effectively (Pyak, 1994).

These classifications reflect the ecological and anthropogenic dynamics of the Ganja River Basin's flora, emphasizing the significant impact of human activities on its natural composition and balance.

Table 2.

The spectrum of florosenotic complexes of the flora of the Ganja River basin

№	Florosenotic Complex	Amount of Species	Amount of Species (%)
1	Forest vegetation		
	1.1 Low mountain forests	15	2.0
	1.2 Medium mountain forests	24	3.2
	1.3 Upper mountain forests	18	2.4
	1.4 Tugai forests	12	1.6
2	Grass vegetation		
	2.1 Tall grassland after the forest	35	4.7
	2.2 Subalpine meadows	100	13.6
	2.3 Alpine meadows	75	10.2
3	Swamp vegetation	40	5.4
4	Aquatic coastal vegetation	35	4.7
5	Weed and ruderal vegetation	56	7.6

There are 56 species of plants that accidentally migrated into the Ganja River basin. Four species are periodically cultivated plants (e.g., *Malva*, *Medicago orbicularis*). Seven species are categorized as both wild and accidental arrivals. The last two groups include a total of 12 species (Mammadova, 2018; Noruzov & Javadova, 2023), (Table 2).

To provide an ecological and genetic characterization of species persistence, five types of

plant groups were assigned based on five florocenotic complexes.

Each species complex within the group is characterized by its specific habitat or plant grouping. Each florocenotic complex is conventionally divided into **euritopes**, which represent species occurring in various variants of their termination sites (Hajiyev, 2004; Pyak, 1994).

Table 3

Indicators according to the number of main families, genera and species in the flora of the Ganja River basin

№	Families	Genera		Species	
		Number	In % by number	Number	In % by number
1	<i>Asteraceae</i> Giseke.	44	11,1	80	11
2	<i>Poaceae</i> Barnhart.	25	6,3	51	7
3	<i>Lamiaceae</i> Martinov.	22	5.5	38	5.2
4	<i>Rosaceae</i> Juss.	20	5	41	5.6
5	<i>Boraginaceae</i> Juss.	17	4.3	28	3
6	<i>Fabaceae</i> Juss.	16	4	51	7
7	<i>Ranunculaceae</i> Juss.	16	4	32	4.4
8	<i>Brassicaceae</i> Burnett.	15	3.8	16	2.2
9	<i>Caryophyllaceae</i> Juss.	14	3.5	27	3.7
10	<i>Apiaceae</i> Lindl.	12	3	16	2,2
11	<i>Scrophulariaceae</i> Juss.	10	2.5	36	5
12	<i>Chenopodiaceae</i> Vent.	9	2.3	14	2
13	<i>Solanaceae</i> Juss.	8	2	10	1,4
14	<i>Papaveraceae</i> Juss.	6	1.5	14	2
15	<i>Orchidaceae</i> Juss.	6	1.5	10	1.4
1	<i>Cyperaceae</i> Juss.	5	1.3	12	1.6
17	<i>Campanulaceae</i> Juss.	4	1	10	1.4
18	<i>Polygonaceae</i> Juss.	4	1	10	1.4
19	<i>Rubiaceae</i> Juss.	4	1	13	1,8
Main families		257	64.6	509	69,3
Families represented by 10-1 species		141	35.4	225	30,7
Total:		398	100	734	100

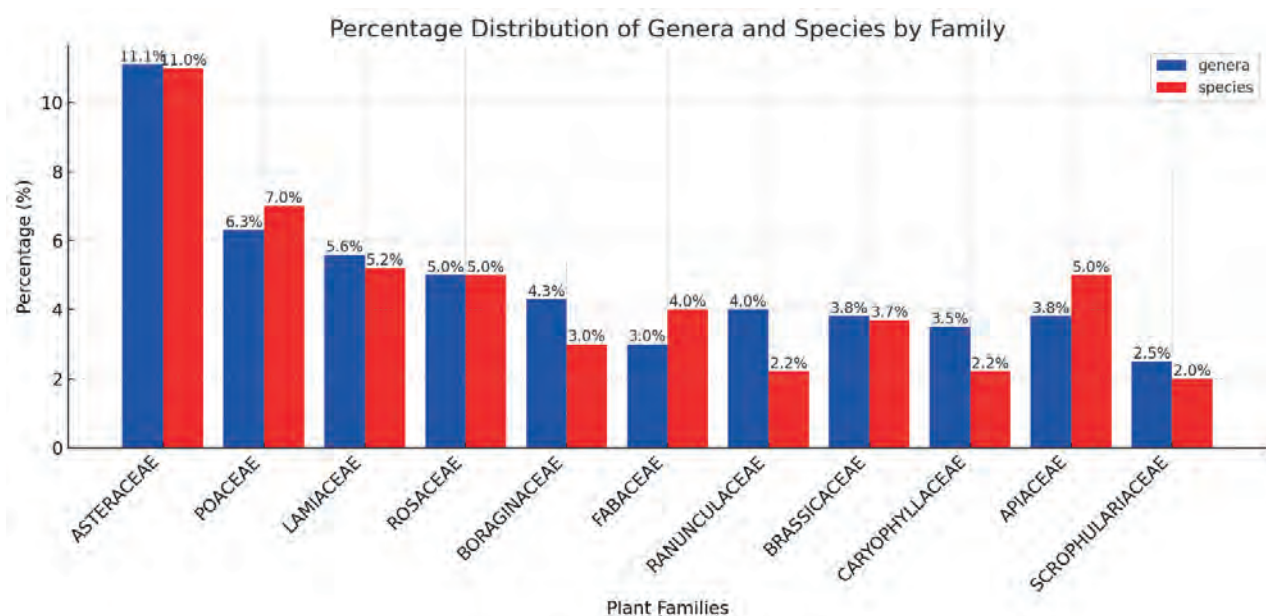


Figure 2. Percentage distribution of genera and species by family

Results and Discussion

The flora of the Ganja River basin is characterized by its ecological and taxonomic diversity, shaped by a combination of geographical and anthropogenic factors. The study identified 734 species distributed across 398 genera and 73 families, with the largest contributions from *Asteraceae* Giseke (80 species), *Poaceae* Barnhart (47 species), *Fabaceae* Juss. (51 species), *Rosaceae* Juss. (41 species), and *Lamiaceae* Martinov (38 species). These families account for a significant proportion of the basin's floral composition, reflecting the adaptation of these species to diverse ecological conditions (Mammadova, 2018), (Table 3).

Ecological Analysis

The ecological spectrum of the flora reveals dominance of mesophytes (49%) and xerophytes (20.6%), indicating the prevalence of plants adapted to moderate and arid conditions. This aligns with the varied climatic zones of the basin, ranging from humid alpine meadows to semi-arid steppes (Figure 2). Adventitious flora, primarily comprising 81 species from 18 families, was most prominent around urbanized and industrial zones such as Ganja and Goranboy. This suggests significant anthropogenic influence, leading to habitat disturbances and the

introduction of non-native species (Nikiti, 1983; Pyak, 1994).

Life form distribution

The analysis of life forms based on Raunkiaer's classification highlights the dominance of therophytes (annuals) at 35%, followed by hemicryptophytes (perennials) at 32%, and geophytes (underground perennials) at 20%. This spectrum reflects the basin's dynamic environmental gradients and human-induced changes (Serebryakova, 1964).

Conclusion

The Ganja River basin supports a diverse range of plant species, with its flora heavily influenced by both natural and anthropogenic factors. The prevalence of mesophytes and xerophytes underscores the region's climatic diversity, while the presence of adventitious species highlights the impact of human activities on local ecosystems. This study emphasizes the importance of conserving the native flora and mitigating the effects of anthropogenic pressures to preserve the ecological integrity of the basin. Future research should focus on the long-term monitoring of floral changes and the implementation of sustainable management practices.

References

- Abbasov, M., Rustamov, Kh., Rahimova, O., Rasulova, L., & Babayeva, S. (2024). Studying the gene pool of the wild ancestor of barley in Azerbaijan. *Acta Botanica Caucasica*, 3(1), 21–25.
- Askerov, A.M. (2011). *Synopsis of the Flora of Azerbaijan*. Baku: Science, 202 p.
- Danilov, A.H. (1954). *Classification of Life Forms and Ecological Groups*. Moscow: Biological Research Press.
- Guliyeva, G.M. (2020). Cryophilic Meadows as the Main Vegetation Type of High Mountains. *International Scientific Conference on Current Problems of Modern Natural and Economic Sciences*, Ganja, pp. 69–71.
- Guliyeva, S.H. (2022). *Ecobiological and Phytocenological Study of Species Belonging to the Lamiaceae Family in the North-Eastern Part of the Lesser Caucasus*. PhD Abstract, Baku, 26 pp.
- Hajiyev, V.C. (2004). *The Ecosystem of Highland Vegetation of Azerbaijan*. Baku, 130 p.
- Gurbanov, E., & Aslanova, S. (2024). AVERAGE ANNUAL PRODUCTIVITY OF THE THYMUSETA-VICAE-TUM-FESTUCOSUM FORMATION, DISTRIBUTED IN SUMMER PASTURE FIELD NO. 8" TURKESOBABA"(AZERBAIJAN). *Norwegian Journal of Development of the International Science*, 126.
- Gurbanov, E., & Rzayeva, A. (2022). Evaluation of decorative properties of some coniferous plants introduced to Absheron Peninsula. *Acta Botanica Caucasica*, 1(2), 3–7.
- Kurbanov, E., Aslanova, S., & Ibragimov, S. (2023). Types of Hole-Meadow and Wetlands Vegetation in Oil-contaminated Soils Siyazan District (Azerbaijan). *Bulletin of Science and Practice*.
- Hatamov, V.V. (1981). Ways of Increasing the Productivity of Some Steppe Phytocenoses of

Gobustan. BINITI, No. 2968, 82 p.

Hassanpanah, D., Gurbanov, E., Gadimov, A., & Shahriari, R. (2007). Reduction of nitrate accumulation in potato by use of potassium humate for human safety. *Iranian Biomedical Journal*, 11(1), 461.

Hassanpanah D., Gurbanov E., Gadimov A., Shahrairi R. Effect of potassium humate on advanced potato cultivars for water deficit tolerance in Ardabil region, Iran. In: *From Molecular Understanding to Innovative Applications of Humic Substances*; 2008, vol. 2, pp. 647-650.

Huseynova, H.Z. (2021) The classification of desert and semi-desert vegetation of the Caspian coast (Azerbaijan). *Bulletin of Science and Practise* 7/11: 43–50. <https://doi.org/10.33619/2414-2948/72/05>

Iskender, E., Jafarzadeh, S., & Muradova, B. (2024). MORPHOLOGY DESCRIPTION AND TAXONOMY OF PYRUS L. SPECIES OF NORTH-EASTERN PART OF THE GREAT CAUCASUS. *Acta Botanica Caucasica* Volume, 3(2), 30-39.

Ismayilova, L., Ahmadov, İ., Gasimov, E., Rzayev, F., Sultanova, J. and Ahmadova, H. Effect of nanoparticles on the Golden Delicious apple flower fertilization process and accumulation in the fruit. *Acta Botanica Caucasica*, 1(2), 46–56 (2022).

Malikov, R.K. (1984). Chemical Composition and Nutrition of Some Dominant Species of Semi-Desert Phytocenoses of Shirvan. *News of the Academy of Sciences of the Azerbaijan SSR, Series of Biological Sciences*, No. 1, pp. 22–26.

Mammadova, D.B. (2018). *Flora and Vegetation of the Sumgayit River Basin: Current State, Anthropogenic Effects, and Protection Methods*. PhD Abstract, Baku, 23 p.

Mehdiyeva, N.P. (2011). *Biodiversity of Medicinal Flora of Azerbaijan*. Baku: Letterpress, 186 p.

Nikiti, G. (1983). *Synanthropic Flora Studies*. Leningrad: Botanical Institute of the USSR Academy of Sciences.

Noruzov, V.S., & Javadova, E.F. (2023). The Problem of Flora Biodiversity and Protection of the Ganja River Basin. *Conference Proceedings, Baku*, p. 44.

Poplavskaya, G.I. (1983). Plant Adaptations in Psychrophyte Environments. *Biological Journal*, 34(2), pp. 150–162.

Pyak, A.I. (1994). *The Influence of Anthropogenic Impacts on Flora*. Moscow: Science Press.

Raunkier, K. (1934). *Life Forms and Statistical Plant Geography*. Oxford: Clarendon Press.

Serebryakov, I.G. (1962). *Life Forms of Plants and Their Study*. Moscow: Nauka Publishing.

Novruzov, V.S., & Bayramova, A.A. (2010). Protection and Efficient Use of Biological Diversity in Azerbaijan. *International Conference Materials, Baku*, pp. 105–106.

ASSESSMENT OF GENETIC VARIATION IN AZERBAIJANI HAZELNUT (*CORYLUS AVELLANA* L.) GENOTYPES THROUGH ISSR MARKERS

Ilham Garagurbanli¹ | ORCID: 0000-0003-2679-3806

Aytaj Asgarova¹ | ORCID: 0009-0007-4808-8960

Sevda Babayeva² | ORCID: 0000-0002-0888-4539

Elnara Ahmadova¹ | ORCID: 0009-0008-9567-9031

Nargiz Abdullayeva¹ | ORCID: 0009-0006-6749-617X

Vusala Izzatullayeva² | ORCID: 0000-0002-2168-745X

Zamina Sarhadova¹ | ORCID: 0000-0002-9007-7882

Sevil Suleymanova¹ | ORCID: 0000-0003-3130-443X

Mehraj Abbasov^{1,2*} | ORCID: 0000-0002-2564-3411

¹ Scientific Research Institute of Fruit and Tea Growing, Ministry of Agriculture, Guba, Azerbaijan

² Genetic Resources Institute, Ministry of Science and Education, Azadliq Ave 155, AZ1106, Baku, Azerbaijan

^{1,2*} Correspondence: mehraj_genetic@yahoo.com

Article Info:

DOI: <https://doi.org/10.30546/abc.2024.3.3.510>

Pages: 17–26

Received: August 3, 2024 | Revised: September 17, 2024 | Accepted: October 5, 2024

Abstract. The genetic diversity of 11 local hazelnut varieties (*Corylus avellana* L.) from Azerbaijan was assessed using 8 ISSR markers. A total of 48 fragments were amplified from these varieties, 15 of which were polymorphic. Among the primers, UBC 818 exhibited the highest polymorphism (55.6%), while UBC 812 showed the lowest (10%). Overall, the average polymorphism across the markers was 32%. Genetic diversity analysis revealed high diversity for UBC 818 primer, while UBC 812 displayed the lowest diversity. The mean GDI for the entire collection was 0.44. The Jaccard genetic distance index ranged from 0.14 to 0.86. The greatest value was observed between the Mirzebeyli and Galib, while the Ata-baba and Azeri, as well as the Barli and Azeri, showed the closest genetic relationships. The dendrogram analysis identified three main clusters. Principal Coordinate Analysis supported these findings, grouping the varieties into three distinct groups, with Mirzebeyli being the most genetically distinct. Additionally, molecular fingerprinting revealed unique genetic profiles for each variety, which can facilitate their identification. The use of more polymorphic primers could further enhance the accuracy and reliability of these genetic profiles. These results offer valuable insights for hazelnut breeding programs and contribute to the conservation of these local varieties.

Keywords: hazelnut, genetic diversity, variety, *Corylus avellana* L., ISSR

Introduction

The European hazelnut (*Corylus avellana* L.) is a shrub cultivated since ancient times for its oil-rich kernels, which are consumed whole, ground, or in paste form, and are prized for their unique flavor in various confectionery products (Ferreira et al., 2010). Evidence suggests that hazelnuts were domesticated and

cultivated in the western and eastern Mediterranean regions at least 2000 years ago (Frery, 2019). In recent years, the growing interest in hazelnut farming has led to a significant expansion in global cultivation. Despite this increase, global production remains reliant on a limited number of cultivars, most of which are highly adapted to the specific environments where

they were originally selected. Although hazelnuts rank among the most valuable tree nuts worldwide, genetic resources for their improvement are relatively scarce (Helmstetter et al., 2020). Moreover, identifying domestication syndromes in clonally propagated species such as hazelnut presents unique challenges. These plants are relatively understudied compared to seed-propagated species (McKey et al., 2010).

Recent advances in molecular markers and next-generation sequencing technologies have facilitated numerous analyses aimed at exploring the genetic structure of *C. avellana*. Studies on the genetic diversity of this species have employed various types of DNA markers (Leinemann et al., 2013; Martins et al., 2015; Brown et al., 2016; Colburn et al., 2017).

Hazelnuts have been cultivated in Azerbaijan since ancient times, with numerous selection studies contributing to the development of new varieties through traditional and scientific breeding methods. According to the International Trade Centre (ITC), Azerbaijan ranked as the fourth-largest exporter of hazelnuts globally in 2023. The country's main export destinations include Russia, Germany, Italy, and Switzerland (English News, 2024). The hazelnut industry in Azerbaijan is predominantly supported by small-scale producers, with 99% of production attributed to individual entrepreneurs, farmers, and household businesses.

Currently, approximately 150 local and introduced hazelnut varieties and forms are maintained at the Zagatala Experimental Station of the Scientific Research Institute of Fruit and Tea Growing. While these varieties have been studied for their morphobiological and kernel traits to meet market demands, no genetic analyses have been conducted by local researchers. Moreover, only a limited number of Azerbaijani hazelnut varieties are represented in foreign collections (Gürçan et al., 2010). Conducting a comprehensive evaluation of these varieties could enhance their utilization in future breeding programs.

The success of breeding programs largely depends on the careful selection of initial materials and the appropriate combination of parental forms. The genetic similarity between

parental forms plays a crucial role in generating genetically diverse recombinants. Unlike morphological traits, molecular markers provide a faster and more precise reflection of the genetic structure of samples, independent of environmental influences. Over the years, numerous molecular markers, including RAPD, SSR, AFLP, and ISSR, have been developed for hazelnut plants (Ferreira et al., 2010; Gökirmak et al., 2009). Among these, ISSR markers are particularly advantageous as they offer rapid insights into the genetic structure of samples without requiring prior knowledge of the genome sequence. This information significantly enhances breeding programs, enabling the development of new varieties with desirable traits more efficiently than traditional methods.

The primary goal of this research is to evaluate the genetic diversity and fingerprint local hazelnut varieties cultivated in Azerbaijan based on ISSR markers.

Materials and methods

Eleven local hazelnut varieties preserved at the Zagatala Experimental Station of the Scientific Research Institute of Fruit and Tea Growing were used as the research material (Figure 1). Hazelnut nuclear DNA was extracted in the Molecular Genetics and Genomics Department of the Genetic Resources Institute using the Doyle and Doyle (1987) method.

In this study, 10 ISSR primers were initially screened for their effectiveness in amplifying polymorphic regions across the hazelnut genome. Based on their performance, six primers demonstrating consistent and reliable amplification were selected for further analysis (Table 1). Polymerase chain reaction (PCR) was performed using these six effective primers, and the resulting amplification products were resolved through electrophoresis on a 1.5% agarose gel, following the optimized protocol (Babayeva et al., 2018). The genetic diversity index (GDI) was calculated following the methodology described by Weir (1990). To evaluate genetic relationships among the hazelnut genotypes, ISSR marker data were compiled into a binary matrix, and the Jaccard genetic distance index was calculated using DarWin 6.0 software (Perrier & Jacquemoud-Collet, 2006). This index

was used to construct a Neighbor-Joining (NJ) dendrogram through cluster analysis and to perform Principal Coordinate Analysis (PCoA).

Results and discussion: A thorough understanding of genetic diversity in both cultivated plants and their wild relatives is vital for enhancing breeding programs (Zamir, 2001; Abbasov et al., 2023; Abbasov et al., 2024), strengthening disease resistance (Zhu et al., 2000), and evaluating the impact of domestication (Wright, 2005). Genetic diversity forms the foundation for developing ecologically adaptable hazelnut varieties capable of producing stable, high-quality yields, particularly in the

face of climate change.

This study examines the genetic diversity and relationships among 12 local hazelnut (*Corylus avellana* L.) varieties using six intermicrosatellite (ISSR) loci. No results were obtained for the variety El Bari; therefore, it was excluded from the study, and the research continued with 11 accessions. The study also includes genetic identification of these varieties.

To achieve this, up to 10 ISSR markers were initially tested, and six primers (UBC 818, UBC 834, UBC 810, UBC 812, UBC 823, and UBC 835) were selected for evaluating the genetic diversity of the hazelnut collection.

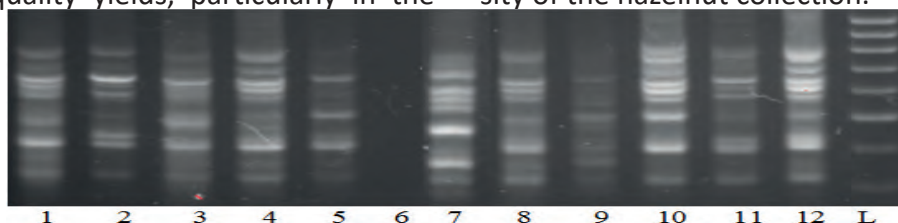


Figure 1. Amplification products in 11 local hazelnut varieties with UBC 818 primer. 1- Galib, 2- Dash Findiq, 3- Ata-baba, 4- Azeri, 5- Tala, 6- El Bari, 7- Topgara, 8- Sachakhli, 9- Firavan, 10- Nesimi, 11- Mirzebeyli, 12- Barli, L- ladder

A total of 48 fragments were successfully amplified from 11 local hazelnut varieties, of which 15 were polymorphic. The amplicon sizes ranged from 0.3 to 1.1 kb. The number of common fragments per primer varied between 7 and 10, while polymorphic fragments ranged from 1 to 5, with averages of 8 and 2.5,

respectively (Table 1). Among the primers tested, UBC 812 produced the highest number of fragments. These findings align with previous studies. For instance, Ferreira et al. (2010) reported 66 polymorphic bands using 11 ISSR primers in a hazelnut collection from Spain.

Table 1

Genetic diversity parameters in local hazelnut varieties based on ISSR markers

Primers	Sequence 5'~3'	Number of total bands	Number of polymorphic bands	Polymorphism, %	Genetic diversity index
UBC 818	(CA) ₈ G	9	5	55.6	0.85
UBC 834	(AG) ₈ YT	7	3	42.8	0.44
UBC 810	(GA) ₈ T	8	2	25.0	0.66
UBC 812	(GA) ₈ C	10	1	10.0	0.18
UBC 823	(TC) ₈ C	7	2	28.6	0.23
UBC 835	(AG) ₈ YC	7	2	28.6	0.26
Total		48	15	-	-
Mean		8	2.5	32	0.44

Among the six primers tested, the highest polymorphism (55.6%) was observed with the UBC 818 primer, while the lowest (10%) was recorded for the UBC 812 primer. On average,

the percentage of polymorphism in the local hazelnut collection was 32%. Besides UBC 818, the UBC 834 primer also exhibited a high level of polymorphism (Figure 2). In comparison,

Ferreira et al. (2010) reported a polymorphism rate of 61.6% using ISSR markers in a hazelnut collection comprising 90 trees. This difference

could be attributed to the smaller number of accessions included in our study.

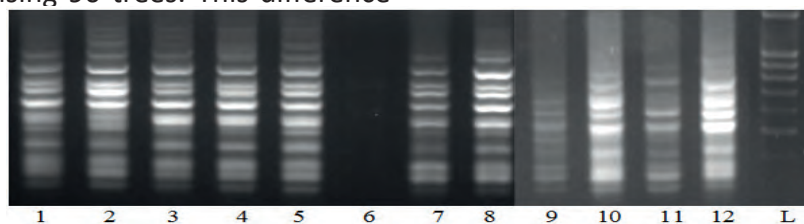


Figure 2. Amplification products in 11 local hazelnut varieties with UBC 834 primer. 1- Galib, 2- Dash Findiq, 3- Ata-baba, 4- Azeri, 5- Tala, 6- El Bari, 7- Topgara, 8- Sachakhli, 9- Firavan, 10- Nesimi, 11- Mirzebeyli, 12- Barli, L- ladder

Using the UBC 818 primer, eight distinct patterns were identified in the hazelnut collection, five of which were unique. In contrast, the UBC 834 primer produced three patterns, with the first being the most frequent (0.72), while the second pattern was exclusive to the Mirzebeyli variety. The UBC 810 primer detected three patterns, two with a frequency of 0.36 and one with a frequency of 0.27 (Figure 3). The remaining three primers revealed 2–3 patterns, characterized by high major allele frequencies and, consequently, low diversity (Table 1).

The genetic diversity index (GDI), calculated based on the frequency of ISSR profiles, varied across the primers. Among the six primers tested, three exhibited high genetic diversity indices (0.44–0.85), while the other three showed low diversity values. The highest diversity was observed with the UBC 818 primer, which features the (CA)₈G dinucleotide motif, whereas the UBC 812 primer, with the (GA)₈C motif, showed the lowest diversity. Notably, the UBC 810 primer also demonstrated high genetic diversity, with a GDI of 0.66.

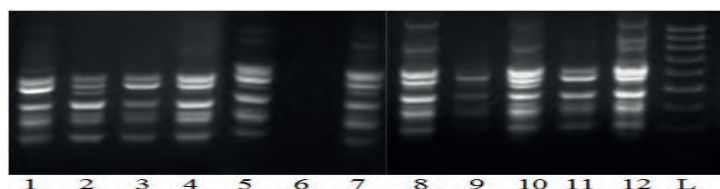


Figure 3. Amplification products in 11 local hazelnut varieties with UBC 810 primer. 1- Galib, 2- Dash Findiq, 3- Ata-baba, 4- Azeri, 5- Tala, 6- El Bari, 7- Topgara, 8- Sachakhli, 9- Firavan, 10- Nesimi, 11- Mirzebeyli, 12- Barli, L- ladder

Although cultivated varieties are typically expected to exhibit lower genetic diversity due to the bottleneck effect of domestication (Tanksley & McCouch, 1997), several studies have reported comparable levels of heterozygosity in both wild and cultivated hazelnut collections. This suggests that domestication has a relatively minimal impact on genetic diversity in hazelnut, as is also observed in many other perennial fruit trees (Miller & Gross, 2011; Cornille et al., 2012). In our study, the average Genetic Diversity Index (GDI) across all primers was 0.44. Previous research has examined genetic diversity in hazelnut varieties cultivated in the South Caucasus and Black Sea regions,

including Turkey, Georgia, and Azerbaijan, using SSR markers (Gürçan et al., 2010). These studies revealed the presence of synonyms and homonyms within the collections. For instance, some varieties shared identical names despite being phenotypically and/or genotypically distinct, while others, though clonally propagated, were assigned different names.

The results indicate a moderate genetic diversity among local hazelnut varieties, with a certain degree of compatibility with other collections. Among the ISSR primers utilized, UBC 818 and UBC 834 proved to be the most effective for assessing genetic diversity in hazelnut samples.

The Jaccard genetic distance indices among genotype pairs ranged from 0.14 to 0.86, with an average value of 0.51 (Table 2). The greatest genetic distance was observed between the Mirzebeyli and Galib varieties, followed by the

Firavan - Galib and Firavan - Dash Findig pairs. Conversely, the Ata-baba and Azeri varieties, as well as the Barli and Azeri varieties, displayed the closest genetic relationships.

Table 2

Jaccard genetic distance index among local hazelnut varieties

N	1	2	3	4	5	6	7	8	9	10
2	0.57									
3	0.17	0.63								
4	0.29	0.50	0.14							
5	0.63	0.17	0.50	0.38						
6	0.71	0.50	0.57	0.63	0.33					
7	0.67	0.67	0.50	0.57	0.50	0.60				
8	0.83	0.83	0.67	0.71	0.67	0.50	0.33			
9	0.57	0.33	0.43	0.50	0.17	0.20	0.40	0.60		
10	0.86	0.67	0.71	0.57	0.50	0.83	0.50	0.75	0.67	
11	0.43	0.43	0.29	0.14	0.29	0.57	0.50	0.67	0.43	0.50

Note: 1- Galib, 2- Dash Findiq, 3- Ata-baba, 4- Azeri, 5- Tala, 6- Topgara, 7- Sachakhli, 8- Firavan, 9- Nesimi, 10- Mirzebeyli, 11- Barli

The dendrogram revealed three main clusters, representing the genetic affinity among the local hazelnut varieties (Figure 4).

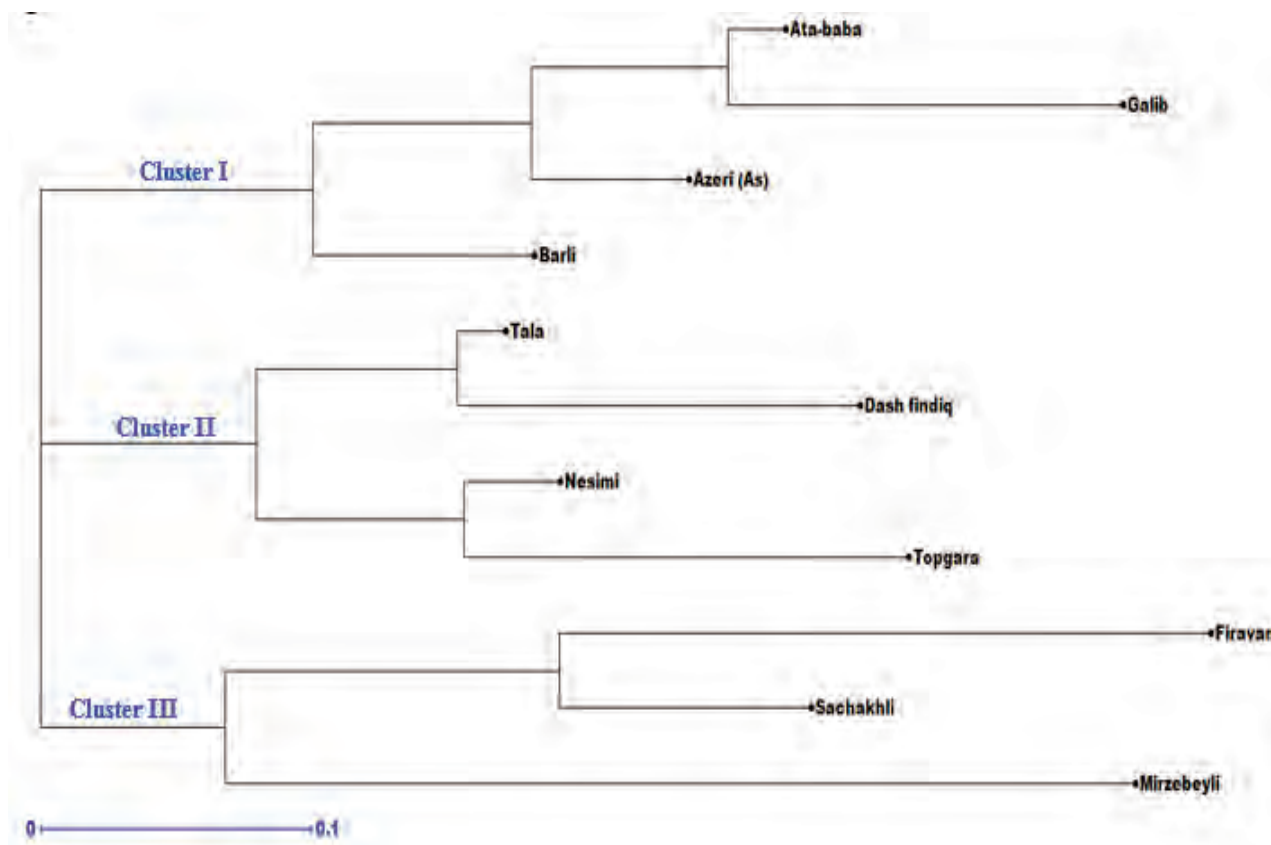


Figure 4. NJ dendrogram showing genetic relationships among 11 local hazelnut cultivars

Cluster I included four varieties: Ata-baba, Galib, Azeri, and Barli, with Ata-baba and Galib exhibiting the highest genetic similarity. Cluster II comprised the Tala, Dash Findiq, Nesimi, and Topgara varieties, with genetic distance indices ranging from 0.17 to 0.33 within the cluster. The remaining three varieties formed Cluster III, with shared alleles, though the genetic distance between them varied from 0.60 to 0.75, indicating considerable divergence among these varieties (Firavan, Sachakhli, and Mirzebeyli).

Among these, Mirzebeyli was the most genetically distinct, with a genetic distance index ranging from 0.50 to 0.86 when compared to the other varieties.

The results from the Principal Coordinate Analysis (PCoA) corroborated the findings from the NJ dendrogram, grouping the accessions into three distinct groups (Figure 5). The first two axes of the PCoA explained 59.5% of the total variation.

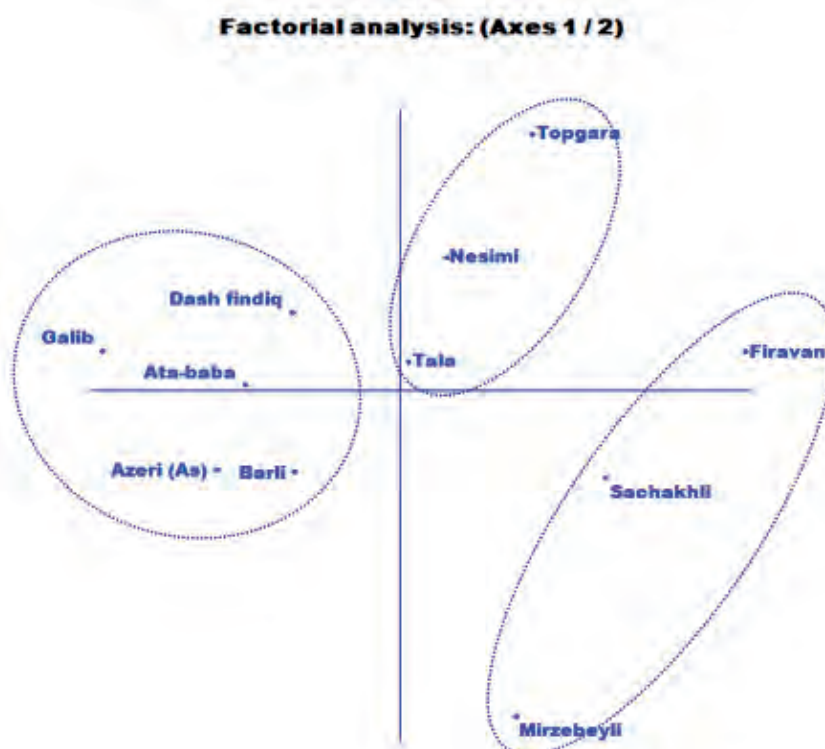


Figure 5. Distribution of local hazelnut varieties on the PCo plot

Genotypes from Cluster I are located in the left quadrants, while varieties from Clusters II and III are positioned in the right quadrants. The main distinction is that the Dash Findiq variety from Cluster II is situated closer to the varieties in Cluster I. Consistent with the dendrogram, the Mirzebeyli variety is positioned at the far end of the negative PCoA Y-axis, distinctly separate from the other varieties in Cluster III. In a similar study, Ferreira et al. (2010) identified two groups - one corresponding to reference varieties and the other to local varieties - during UPGMA clustering and PCA analysis of 90 hazelnut plants.

The insights gained from analyzing the

genetic relatedness and divergence of hazelnut varieties provide valuable information for guiding hazelnut breeding programs, aiding in the selection of appropriate parental forms.

Fingerprinting using molecular markers is critical in intellectual property rights applications. These markers play a significant role in patenting, breeder's/authors' rights, material exchange agreements, and farmers' rights. Genetic fingerprinting involves identifying unique combinations of sequences for each variety using primers that have high discriminatory potential and polymorphism. Several studies have compiled such "digital codes" for variety identification (Pharmawati et al., 2005; Liu et

al., 2012).

In our study, fingerprinting of 11 hazelnut varieties was performed using 8 loci, focusing on the unique and rare fragments and patterns generated with primers UBC 818, UBC 834, and UBC 810 (Table 3). The digital codes generated for the 11 varieties were distinct and did not match any variety in the collection, ensuring

their uniqueness. These codes can be used to differentiate the studied hazelnut varieties. However, for more precise variety identification, it may be beneficial to consider both morphological markers and specific markers such as SSR.

Table 3

Digital identification code of local hazelnut varieties

Varieties	Digital identification code	UBC818 700 bp	UBC818 500 bp	UBC818 480 bp	UBC818 410 bp	UBC834 600 bp	UBC834 900 bp	UBC810 550 bp	UBC 810 680 bp
Galib	10101101	1	0	1	0	1	1	0	1
Dash Findiq	10011110	1	0	0	1	1	1	1	0
Ata-baba	11101101	1	1	1	0	1	1	0	1
Azeri	11111101	1	1	1	1	1	1	0	1
Tala	11011110	1	1	0	1	1	1	1	0
Topqara	11001010	1	1	0	0	1	0	1	0
Sachakhli	01001100	0	1	0	0	1	1	0	0
Firavan	01001000	0	1	0	0	1	0	0	0
Nesimi	11001110	1	1	0	0	1	1	1	0
Mirzebeyli	01010100	0	1	0	1	0	1	0	0
Barli	11011101	1	1	0	1	1	1	0	1

A simultaneous comparative analysis using more polymorphic primers (loci) capable of distinguishing a greater number of varieties and accessions would enhance the reliability of the genetic code. The genetic information derived from such an approach would provide a more accurate and dependable basis for the conservation of local hazelnut varieties.

To conclude, the significant genetic diversity is present among the 11 local hazelnut varieties from Azerbaijan, with certain varieties displaying notable genetic divergence. The results provide valuable insights for hazelnut breeding programs and contribute to the conservation of these local varieties.

Conclusion

This study provides the first detailed genetic diversity analysis of 11 local hazelnut varieties (*Corylus avellana* L.) from Azerbaijan using ISSR markers. The results revealed a moderate level

of genetic diversity, with an average polymorphism rate of 32% across the tested primers. Among the primers, UBC 818 demonstrated the highest polymorphism (55.6%) and genetic diversity index (GDI = 0.85), making it the most effective marker for diversity assessment. Conversely, UBC 812 showed the lowest polymorphism (10%) and genetic diversity (GDI = 0.18).

Jaccard's genetic distance index ranged from 0.14 to 0.86, with the closest relationships observed between Ata-baba and Azeri, as well as Barli and Azeri. Mirzebeyli exhibited the greatest genetic distance, highlighting its genetic distinctiveness. Cluster analysis grouped the varieties into three distinct clusters, a result further supported by Principal Coordinate Analysis (PCoA). Mirzebeyli consistently emerged as the most genetically divergent variety.

Unique genetic fingerprints were generated for each variety, ensuring their precise identification and differentiation. These genetic

profiles have practical applications in breeding programs, variety protection, and conservation efforts. However, the inclusion of more polymorphic primers and morphological data in future studies would enhance the reliability and precision of these genetic profiles.

The results highlight the genetic diversity within local hazelnut varieties and provide valuable insights for breeding programs, particularly in the selection of genetically distinct parental lines to enhance heterozygosity in offspring. The identification of unique varieties, such as Mirzebeyli, offers potential for the development of new hazelnut cultivars with desirable traits.

This study establishes a foundation for the

conservation and sustainable utilization of Azerbaijan's hazelnut genetic resources. The findings support the preservation of genetic diversity as a critical component of hazelnut breeding, ensuring resilience to environmental challenges and market demands. These results contribute significantly to the global understanding of hazelnut genetic resources, emphasizing the need for ongoing genetic characterization and conservation efforts.

Acknowledgment

This work was supported by the Azerbaijan Science Foundation – Grant № AEF-MGC-2024-2(50)-16/08/3-M-08

References

- Abbasov, M., Babayeva, S., Rustamov, Kh., Rasulova, L., Rahimova, O., Mammadova, A., Izzatullayeva, V., Hajiyev, E., Aliyev, R., & Akparov, Z. (2023). Exploring genetic diversity in Azerbaijani barley collection through amplicon sequencing. *Acta Botanica Caucasica*, 2(1), <https://doi.org/10.30546/abc.2023.2.1.10.43> pp.38–44.
- Abbasov, M., Rustamov, Kh., Rahimova, O., Rasulova, L., & Babayeva, S. (2024). Studying the gene pool of the wild ancestor of barley in Azerbaijan. *Acta Botanica Caucasica*, 3(1), 21–25.
- Babayeva, S. M., Nasibova, J. A., Akparov, Z. I., Shikhaliyeva, K. B., Mammadova, A. D., Izzatullayeva, V. I., & Abbasov, M. A. (2018). Application of DNA markers in determination of Fusarium resistance and genetic diversity in chickpea. *Legume Research-An International Journal*, 41(4), 537–542. <https://doi.org/10.18805/LR-3993>
- Brown, J. A., Beatty, G. E., Montgomery, W. I., & Provan, J. (2016). Broad-scale genetic homogeneity in natural populations of common hazel (*Corylus avellana*) in Ireland. *Tree Genetics & Genomes*, 12(1), 1–15. <https://doi.org/10.1007/s11295-015-0969-8>
- Colburn, B. C., Mehlenbacher, S. A., & Sathuvalli, V. R. (2017). Development and mapping of microsatellite markers from transcriptome sequences of European hazelnut (*Corylus avellana* L.) and use for germplasm characterization. *Molecular Breeding*, 37(1), 1–14. <https://doi.org/10.1007/s11032-017-0698-5>
- Cornille, A., Gladieux, P., Smulders, M. J., Roldán-Ruiz, I., Laurens, F., Le Cam, B., & Giraud, T. (2012). New insight into the history of domesticated apple: secondary contribution of the European wild apple to the genome of cultivated varieties. *PLOS Genetics*, 8(5), e1002703. <https://doi.org/10.1371/journal.pgen.1002703>
- Doyle, J. J., & Doyle, J. L. (1987). A rapid DNA isolation procedure for small quantities of fresh leaf tissue. *Phytochemical Bulletin*, 19(1), 11–15.
- English News. (2024, August 27). Azerbaijan ranked as the fourth-largest exporter of hazelnuts globally. Retrieved from <https://english.news.cn/20240827/678e6e9521874950acec38c0b8205a55/c.htm>
- Ferreira, J. J., García-González, C., Tous, J., & Rovira, M. (2010). Genetic diversity revealed by morphological traits and ISSR markers in hazelnut germplasm from northern Spain. *Plant Breeding*, 129(4), 435–441. <https://doi.org/10.1111/j.1439-0523.2009.01697.x>
- Frery, A., Öztürk, S. C., Balık, H. I., Balık, S. K., Kızılcı, G., Doğanlar, S., & Frery, A. (2019). Analysis of European hazelnut (*Corylus avellana*) reveals loci for cultivar improvement and the effects

- of domestication and selection on nut and kernel traits. *Molecular Genetics and Genomics*, 294(3), 519–527. <https://doi.org/10.1007/s00438-019-01561-y>
- Gökirmak, T., Mehlenbacher, S. A., & Bassil, N. V. (2009). Characterization of European hazelnut (*Corylus avellana*) cultivars using SSR markers. *Genetic Resources and Crop Evolution*, 56(1), 147–172. <https://doi.org/10.1007/s10722-008-9350-5>
- Gurcan, K., Mehlenbacher, S. A., & Erdoğan, V. (2010). Genetic diversity in hazelnut (*Corylus avellana* L.) cultivars from Black Sea countries assessed using SSR markers. *Plant Breeding*, 129(4), 422–434. <https://doi.org/10.1111/j.1439-0523.2009.01753.x>
- Gurbanov, E., & Aslanova, S. (2024). AVERAGE ANNUAL PRODUCTIVITY OF THE THYMUS-ETAL-UM-FESTUCOSUM FORMATION, DISTRIBUTED IN SUMMER PASTURE FIELD NO. 8" TURKESOBABA"(AZERBAIJAN). *Norwegian Journal of Development of the International Science*, 126.
- Gurbanov, E., & Rzaeva, A. A. (2017). Biomorphological Analysis and Identification of Subspecies of *Juniperus communis* in Azerbaijan. *Asian Journal of Plant Science and Research*, 7(3), 14-6.
- Gurbanov, E., & Rzaeva, A. (2022). Evaluation of decorative properties of some coniferous plants introduced to Absheron Peninsula. *Acta Botanica Caucasica*, 1(2), 3–7.
- Hassanpanah, D., Gurbanov, E., Gadimov, A., & Shahriari, R. (2007). Reduction of nitrate accumulation in potato by use of potassium humate for human safety. *Iranian Biomedical Journal*, 11(1), 461.
- Hassanpanah D., Gurbanov E., Gadimov A., Shahriari R. Effect of potassium humate on advanced potato cultivars for water deficit tolerance in Ardabil region, Iran. In: *From Molecular Understanding to Innovative Applications of Humic Substances*; 2008, vol. 2, pp. 647-650.
- Huseynova, H.Z. (2021) The classification of desert and semi-desert vegetation of the Caspian coast (Azerbaijan). *Bulletin of Science and Practise* 7/11: 43–50. <https://doi.org/10.33619/2414-2948/72/05>
- Helmstetter, A. J., Oztolan-Erol, N., Lucas, S. J., & Buggs, R. J. (2020). Genetic diversity and domestication of hazelnut (*Corylus avellana* L.) in Turkey. *Plants, People, Planet*, 2(4), 326–339. <https://doi.org/10.1002/ppp3.10114>
- Kurbanov, E., Aslanova, S., & Ibragimov, S. (2023). Types of Hole-Meadow and Wetlands Vegetation in Oil-contaminated Soils Siyazan District (Azerbaijan). *Bulletin of Science and Practice*.
- Iskender, E., Jafarzadeh, S., & Muradova, B. (2024). MORPHOLOGY DESCRIPTION AND TAXONOMY OF PYRUS L. SPECIES OF NORTH-EASTERN PART OF THE GREAT CAUCASUS. *Acta Botanica Caucasica* Volume, 3(2), 30-39.
- Ismayilova, L., Ahmadov, İ., Gasimov, E., Rzaev, F., Sultanova, J. and Ahmadova, H. Effect of nanoparticles on the Golden Delicious apple flower fertilization process and accumulation in the fruit. *Acta Botanica Caucasica*, 1(2), 46–56 (2022).
- Leinemann, L., Steiner, W., Hosius, B., Kuchma, O., Arenhövel, W., Fussi, B., & Finkeldey, R. (2013). Genetic variation of chloroplast and nuclear markers in natural populations of hazelnut (*Corylus avellana* L.) in Germany. *Plant Systematics and Evolution*, 299(2), 369–378. <https://doi.org/10.1007/s00606-012-0738-4>
- Liu, Q., Cheng, D., Yang, L., Luo, C., Kong, F., & Wu, Y. (2012). Construction of digital fingerprinting and cluster analysis using ISSR markers for sugar beet cultivars (lines). *Transactions of the Chinese Society of Agricultural Engineering*, 28(1), 280–284.
- Martins, S., Simões, F., Mendonça, D., Matos, J., Silva, A. P., & Carnide, V. (2015). Western European wild and landraces hazelnuts evaluated by SSR markers. *Plant Molecular Biology Reporter*, 33(6), 1712–1720. <https://doi.org/10.1007/s11105-015-0890-2>
- McKey, D., Elias, M., Pujol, B., & Duputié, A. (2010). The evolutionary ecology of clonally propagated domesticated plants. *New Phytologist*, 186(2), 318–332. <https://doi.org/10.1111/j.1469-8137.2010.03210.x>
- Miller, A. J., & Gross, B. L. (2011). From forest to field: perennial fruit crop domestication. *American*

- Journal of Botany, 98(9), 1389–1414. <https://doi.org/10.3732/ajb.1000522>
- Perrier, X., & Jacquemoud-Collet, J. P. (2006). DARwin software. Retrieved from <http://darwin.cirad.fr/darwin>
- Pharmawati, M., Yan, G., & Finnegan, P. M. (2005). Molecular variation and fingerprinting of Leuca-dendron cultivars (Proteaceae) by ISSR markers. *Annals of Botany*, 95(7), 1163–1170. <https://doi.org/10.1093/aob/mci128>
- Tanksley, S. D., & McCouch, S. R. (1997). Seed banks and molecular maps: unlocking genet-ic potential from the wild. *Science*, 277(5329), 1063–1066. <https://doi.org/10.1126/science.277.5329.1063>
- Weir, B. S. (1990). *Genetic Data Analysis: Methods for Discrete Population Genetic Data*. Sunder-land: Sinauer Associates.
- Wright, S. I., Bi, I. V., Schroeder, S. G., Yamasaki, M., Doebley, J. F., McMullen, M. D., & Gaut, B. S. (2005). The effects of artificial selection on the maize genome. *Science*, 308(5726), 1310–1314. <https://doi.org/10.1126/science.1107891>
- Zamir, D. (2001). Improving plant breeding with exotic genetic libraries. *Nature Reviews Genetics*, 2(12), 983–989. <https://doi.org/10.1038/35103590>
- Zhu, Y., Chen, H., Fan, J., Wang, Y., Li, Y., Chen, J., ... & Mundt, C. C. (2000). Genetic diversity and disease control in rice. *Nature*, 406(6797), 718–722. <https://doi.org/10.1038/35021046>

FLORA OF MUD VOLCANO IN THE EASTERN PART OF THE GREATER CAUCASUS (AZERBAIJAN)**Shabnam Isayeva^{1*} | ORCID: 0009-0006-0571-8144****Shakir Gasimov¹ | ORCID: 0009-0002-8815-687X**

¹ Institute of Botany, Ministry of Science and Education of the Republic of Azerbaijan,
Baku, AZ 1004, A. Abbaszadeh Str. 128

^{1*} Correspondence: isayeva.shabnam@outlook.com

Article Info:DOI: <https://doi.org/10.30546/abc.2024.3.3.512>

Pages: 27–35

Received: September 2, 2024 | Revised: September 23, 2024 | Accepted: October 2, 2024

Abstract. *Mud volcanoes are widespread across many countries worldwide, yet the vegetation associated with these formations in Azerbaijan remains insufficiently studied. The dynamic processes occurring on mud volcanoes significantly influence their vegetation, highlighting the need for detailed floristic and geobotanical research. The study of mud volcanism in relation to vegetation is currently highly specialized and fragmented.*

For the first time in Azerbaijan, the species composition of the Gyzmeidan mud volcano, situated in the eastern part of the Greater Caucasus botanical and geographical area, has been thoroughly analyzed. Research conducted between 2018 and 2023 identified 90 species from 81 genera and 33 families. The most represented families were Asteraceae (Giseke) with 14 species (16%) and Poaceae (Barnhart) with 8 species (9%). Three rare species were documented: Ophrys oestriifera M. Bieb., Pyrus salicifolia Pall., and Rosa pulverulenta M. Bieb.

The study revealed that the vegetation cover becomes more abundant and diverse with increasing distance from the eruptive center of the volcano. Life form analysis indicated that 44 species are perennial herbaceous plants, while 31 are annuals. Ombrophytes, characterized by shallow root systems that utilize precipitation, dominate with 64 species, while phreatophytes and trichohydrophytes account for 10 and 16 species, respectively. These findings provide essential insights into the ecological dynamics of mud volcano flora.

Keywords: *Gyzmeidan, mud volcano, flora, ephemerae, eruptive center*

Introduction

The territory of Azerbaijan is a unique region of mud volcanism. By the number of volcanoes, their diversity, and intensity, Azerbaijan takes the first place in the world (Khain & Khalilov, 2009). Out of 800 mud volcanoes existing in the world, about 400 are located within the South Caspian oil and gas basin, and more than 300 of them are located onshore in East Azerbaijan and the adjacent water area of the Caspian Sea. In Azerbaijan, the phenomenon of mud volcanism is observed in Shamakhi-Gobustan and the Lower Kura depression, on the Absheron peninsula, and in the areas of Baku and the Absheron archipelagos. Flora and vegetation of

mud volcanoes of Azerbaijan, and their peculiarities of formation in conditions of volcanic activity, have not been studied so far. There is only fragmentary data on the growth of particular plants when describing the geological and landscape features of volcanoes. The largest generalizations in this regard were the works of K. A. Korznikov (Korznikov, 2015), T. M. Ting and A. D. Poulsen, who studied the diversity of plants surrounding the mud volcanoes of Tabin and Lipad (Ting & Poulsen, 2009).

Studies on the flora and vegetation of the volcano have not been conducted in Azerbaijan before. Preliminary research in this area has been conducted since 2016–2017 (Isayeva &

Mehdiyeva, 2017). However, despite the geological and geographical studies of the mud volcano in the Shamakhi region, investigation of the flora and vegetation cover of this volcano has not yet been studied. In this regard, the aim of the investigation was to study the flora, as well as plant communities and plant aggregation of the mud volcano Gyzmeidan.

Materials and Methods

Description of the territory. According to the botanical and geographical zoning of Azerbaijan (Prilipko, 1970), the territory under study belongs to the eastern part of the Greater Caucasus. There are 121 mud volcanoes in the Shamakhi-Gobustan region (Aliyev et al., 2015). Climatically, the areas where the Gyzmeidan mud volcano is located are characterized by a moderately warm climate with dry summers. The average annual precipitation is 400–600

mm, the absolute maximum air temperature is +38°C, and the absolute minimum is –23°C. The annual solar radiation duration is 2000–2200 hours, with a total distribution of 124–128 kcal/cm² (Mamedov et al., 2010).

The relief of mud volcanoes is significantly shaped by erosion processes, leading to the formation of barrancos. These depressions, located in the lower parts of the volcano, gradually widen and deepen, eventually transforming into deep gorges (Aliyev et al., 2019).

The Gyzmeidan volcano is located 4–5 km northwest of the village of the same name in the Shamakhi district (40°30′07.0″ N, 49°16′2.73″ E) (Figure 1). It is a slightly convex mud volcanic field, approximately 1 km in diameter, resembling a hummock with a relative height of 20 m, dissected by gorges and scours.



Figure 1. Site localization of Gyzmeidan mud volcano

It is located upon the upper Cretaceous sediments and is confined to the northern slope of the anticline bearing the same name, which is complicated by two longitudinal thrust-type dislocations. The mud volcanic breccia area covers 345 hectares, with an average thickness

of 25 m (Abbasov et al., 2015) (Figure 2). Over the last 200 years, the Gyzmeidan mud volcano has erupted twice, in 1987 and 2011 (Aliyev et al., 2019).



Figure 2. Terrain of the study area

The Methods of Research

Geobotanical descriptions were conducted from April to September during 2018–2023 using the linear transect method. Life forms were classified based on ecological and morphological characteristics according to I.G. Serebryakov and C. Raunkiaer (Raunkiaer, 1937). The ecological analysis of plants followed the methodology of A.P. Shennikov (1964). Plant groups were categorized by root system depth as described by I.N. Beidaman (1954).

The new taxonomic status of species was determined using nomenclature provided by the WFO Plant List database. The coordinates of test plots, transects, and altitudes were recorded using a GPS Garmin III Plus device. Distribution maps of the research objects were created using the ArcGIS 10.5 software.

Results and Discussion

The flora of vascular plants on the Gyzmeidan mud volcano consists of 33 families, 81 genera, and 90 species of higher plants (Table 1). Among all studied mud volcanoes, Gyzmeidan exhibits the highest plant species diversity, attributed to its favorable climatic conditions (Isayeva, 2022; Isayeva et al., 2022).

The largest representation among plant families is observed in *Asteraceae* (Giseke) with 14 species (16%), followed by *Poaceae* (Barnhart) with 8 species (9%), *Rosaceae* (Juss.) with 7 species (8%), and *Fabaceae* (Juss.) with 6 species (7%). Notably, three rare species were identified: *Pyrus salicifolia* Pall., *Ophrys oestrifera* M. Bieb., and *Rosa pulverulenta* M. Bieb.

The condition of these rare plant species was evaluated at the population-ontogenetic level (Isayeva, 2022).

Table 1

List of species distributed in the area adjacent to the Gyzmeidan volcano

№	Name of genera	Name of species	Life forms	Ecological group
1	2	3	4	5
I. <i>Amaryllidaceae</i> Juss.				
1	<i>Allium</i> L.	<i>A. rubellum</i> M. Bieb.	Perennial/Cr	mezophyte/ombrophyte
II. <i>Apiaceae</i> Lindl.				
2	<i>Carum</i> L.	<i>C. carvi</i> L.	Biennial/Hcr	mezophyte/ombrophyte
3	<i>Turgenia</i> Hoffm.	<i>T. latifolia</i> Hoffm.	Annual/T	mezophyte/ombrophyte
III. <i>Asparagaceae</i> Juss.				
4	<i>Muscari</i> Miller	<i>M. neglectum</i> Guss. ex Ten.	Perennial/Cr	mezophyte/ trichohydrophyte
5	<i>Ornithogalum</i> L.	<i>O. pyrenaicum</i> L.	Perennial/Cr	mezophyte/ trichohydrophyte
		<i>O. sintenisii</i> Freyn	Perennial/Cr	mezophyte/ trichohydrophyte
IV. <i>Asteraceae</i> Giseke				
6	<i>Achillea</i> L.	<i>A. millefolium</i> L.	Perennial/Cr	xeromezophyte/ombrophyte
7	<i>Anthemis</i> L.	<i>A. candidissima</i> Willd. ex Spreng.	Annual/T	mezophyte/ombrophyte
		<i>A. fruticulosa</i> M. Bieb.	Perennial/Hcr	mezophyte/ombrophyte
8	<i>Artemisia</i> L.	<i>A. alpina</i> Pall.ex Willd.	Perennial/Hcr	xerophyte /phreatophyte
9	<i>Carthamus</i> L.	<i>C. oxyacantha</i> M. Bieb.	Annual/T	xeromezophyte/ombrophyte
10	<i>Centaurea</i> L.	<i>C. solstitialis</i> L.	Annual/T	xeromezophyte/ombrophyte
11	Filago Loefl. ex L.	<i>F. arvensis</i> L.	Annual/T	mezophyte/ombrophyte
12	<i>Inula</i> L.	<i>I. aspera</i> Poir.	Perennial/Cr	mezophyte/ombrophyte
13	<i>Jurinea</i> Cass.	<i>J. arachnoidea</i> Bunge	Perennial/Hcr	mezophyte/ trichohydrophyte

No	Name of genera	Name of species	Life forms	Ecological group
14	<i>Pilosella</i> Hill	<i>Pilosella bauhينيا</i> (Schult.) Arv. -Touv	Annual/T	mezophyte/ombrophyte
15	<i>Psephellus</i> L.	<i>P. hymenolepis</i> (Trautv.) Boiss.	Perennial/Hcr	mezophyte/ trichohydrophyte
16	<i>Tragopogon</i> L.	<i>T. graminifolius</i> DC.	Perennial/Hcr	mezophyte/ombrophyte
		<i>T. pusillus</i> M. Bieb.	Perennial/Hcr	mezophyte/ombrophyte
17	<i>Xeranthemum</i> L.	<i>X. cylindraceum</i> Sm.	Annual/T	mezophyte/ombrophyte
V. Berberidaceae Juss.				
18	<i>Berberis</i> L.	<i>B. vulgaris</i> L.	Shrub/Ph	mezophyte/phreatophyte
VI. Boraginaceae Juss.				
19	<i>Lappula</i> Moench	<i>L. barbata</i> Gürke	Annual/T	mezophyte/ombrophyte
20	<i>Myosotis</i> L.	<i>M. arvensis</i> Hill	Annual/T	mezophyte/ombrophyte
21	<i>Arabis</i> L.	<i>A. hirsuta</i> (L.) Scop.	Biennial/Hcr	mezophyte/ombrophyte
22	<i>Capsella</i> Medik.	<i>C. bursa-pastoris</i> Medik.	Annual/T	mezophyte/ombrophyte
VII. Brassicaceae Burnett				
23	<i>Lepidium</i> L.	<i>L. campestre</i> (L.) W.T.Aiton	Annual/T	xeromezophyte/ ombrophyte
		<i>L. draba</i> L.	Perennial/Hcr	xeromezophyte/ trichohydrophyte
		<i>L. perfoliatum</i> L.	Annual/T	xeromezophyte/ ombrophyte
24	<i>Noccaea</i> Moench	<i>N. perfoliate</i> (L.) Al-Shehbaz	Annual/T	mezophyte/ombrophyte
25	<i>Rapistrum</i> Crantz	<i>R. rugosum</i> (L.) All.	Annual/T	xeromezophyte/ ombrophyte
VIII. Campanulaceae Juss.				
26	<i>Campanula</i> L.	<i>C. sibirica</i> L.	Biennial/Hcr	mezophyte/ombrophyte
IX. Caprifoliaceae Juss.				
27	<i>Lonicera</i> L.	<i>L. iberica</i> M. Bieb.	Shrub/Ph	xeromezophyte/ phreatophyte
28	<i>Scabiosa</i> L.	<i>S. columbaria</i> L.	Perennial/Cr	mezophyte/ombrophyte
X. Caryophyllaceae Juss.				
29	<i>Cerastium</i> L.	<i>C. pumilum</i> Curtis	Annual/T	mezophyte/ombrophyte
30	<i>Petrorhagia</i> Link	<i>P. prolifera</i> (L.) P.W.Ball & Heywood	Annual/T	mezophyte/ombrophyte
31	<i>Silene</i> L.	<i>S. conica</i> L.	Annual/T	mezophyte/ombrophyte
XI. Cistaceae Juss.				
32	<i>Fumana</i> Spach	<i>F. procumbens</i> Gren. & Godr.	Semishrub/Ch	mezophyte/ombrophyte
33	<i>Helianthemum</i> Mill.	<i>H. salicifolium</i> (L.) Mill.	Annual/T	mezophyte/ombrophyte
XII. Colchicaceae DC.				
34	<i>Colchicum</i> L.	<i>C. trigynum</i> (Adams) Stearn	Perennial/Cr	mezophyte/ trichohydrophyte
XIII. Convolvulaceae Juss.				
35	<i>Convolvulus</i> L.	<i>C. lineatus</i> L.	Perennial/Cr	mezoxerophyte/ ombrophyte
XIV. Cupressaceae Gray				
36	<i>Juniperus</i> L.	<i>J. communis</i> var. <i>saxatilis</i> Pall.	Shrub/Ph	mezoxerophyte/ phreatophyte

XV. <i>Euphorbiaceae</i> Juss.				
37	<i>Euphorbia</i> L.	<i>E. seguieriana</i> Neck.	Perennial/Hcr	mezoxerophyte/ trichohydrophyte
XVI. <i>Fabaceae</i> Juss.				
38	<i>Astragalus</i> L.	<i>A. bungeanus</i> Boiss	Perennial/Hcr	xeromezophyte/ trichohydrophyte
		<i>A. caucasicus</i> Pall.	Shrub/Ph	xeromezophyte/ phreatophyte
39	<i>Hedysarum</i> L.	<i>H. sericatum</i> Kitam.	Perennial/Hcr	mezophyte/ombrophyte
40	<i>Lotus</i> L.	<i>L. tenuis</i> Waldst.& Kit.	Perennial/Cr	mezophyte/ombrophyte
41	<i>Medicago</i> L.	<i>M. minima</i> (L.) L.	Annual/T	mezophyte/ombrophyte
42	<i>Onobrychis</i> Mill.	<i>O. viciifolia</i> Scop.	Perennial/Hcr	mezophyte/ trichohydrophyte
XVII. <i>Geraniaceae</i> Juss.				
43	<i>Erodium</i> L'Hér.	<i>E. cicutarium</i> (L.) L'Hér.	Annual/T	mezophyte/ombrophyte
XVIII. <i>Hypericaceae</i> Juss.				
44	<i>Hypericum</i> Tourn. ex L.	<i>H. linarioides</i> Bosse	Perennial/Hcr	mezophyte/ombrophyte
XIX. <i>Juncaceae</i> Juss.				
45	<i>Juncus</i> L.	<i>J. articulatus</i> L.	Perennial/Cr	xeromezophyte/ ombrophyte
XX. <i>Lamiaceae</i> Martinov				
45	<i>Ajuga</i> L.	<i>A. genevensis</i> L.	Perennial/Hcr	xeromezophyte/ ombrophyte
46	<i>Lamium</i> L.	<i>L. amplexicaule</i> L.	Annual/T	mezophyte/ombrophyte
47	<i>Salvia</i> L.	<i>S. verbascifolia</i> M.Bieb.	Perennial/Hcr	xeromezophyte/ ombrophyte
48	<i>Scutellaria</i> L.	<i>S. orientalis</i> L.	Dw. semishrub/ Ch	xeromezophyte/ ombrophyte
49	<i>Teucrium</i> L.	<i>T. polium</i> L.	Perennial/Hcr	mezophyte/ trichohydrophyte
50	<i>Thymus</i> L.	<i>T. praecox</i> subs. <i>caucasicus</i> (Ron.) Jalas	Dw. semishrub/ Ch	xeromezophyte/ ombrophyte
XXI. <i>Linaceae</i> DC. ex Perleb				
51	<i>Linum</i> L.	<i>L. austriacum</i> L.	Annual/T	mezophyte/ombrophyte
		<i>L. corymbulosum</i> Rchb.	Annual/T	mezophyte/ombrophyte
		<i>L. tenuifolium</i> L.	Perennial/Cr	mezophyte/ombrophyte
XXII. <i>Orchidaceae</i> Juss.				
52	<i>Anacamptis</i> Rich.	<i>A. pyramidalis</i> (L.) Rich.	Perennial/Cr	mezophyte/ trichohydrophyte
53	<i>Ophrys</i> L.	<i>O. oestrifera</i> M. Bieb.	Perennial/Cr	mezophyte/ trichohydrophyte
XXIII. <i>Orobanchaceae</i> Vent.				
54	<i>Pedicularis</i> L.	<i>P. condensate</i> M. Bieb.	Perennial/Hcr	xeromezophyte/ trichohydrophyte
XXIV. <i>Papaveraceae</i> Juss.				
55	<i>Fumaria</i> L.	<i>F. parviflora</i> Lam.	Annual/T	xeromezophyte/ ombrophyte

№	Name of genera	Name of species	Life forms	Ecological group
56	<i>Papaver</i> L.	<i>P. macrostomum</i> Boiss. & A.Huet.	Annual/T	mezophyte/ombrophyte
XXV. Plantaginaceae Juss.				
57	<i>Veronica</i> L.	<i>V. polita</i> Fr.	Annual/T	mezophyte/ombrophyte
XXVI. Poaceae Barnhart				
58	<i>Briza</i> L.	<i>B. media</i> L.	Perennial/Hcr	mezophyte/ombrophyte
59	<i>Bromus</i> L.	<i>B. japonicus</i> Houtt.	Annual/T	mezophyte/ombrophyte
60	<i>Dactylis</i> L.	<i>D. glomerata</i> L.	Perennial/Cr	xeromezophyte/ ombrophyte
61	<i>Festuca</i> L.	<i>F. ovina</i> L.	Perennial/Hcr	xeromezophyte/ ombrophyte
62	<i>Hordeum</i> L.	<i>H. brevisubulatum</i> (Trin.) Link	Perennial/Hcr	xeromezophyte/ ombrophyte
63	<i>Lolium</i> L.	<i>L. rigidum</i> Gaudin	Annual/T	xeromezophyte/ ombrophyte
64	<i>Poa</i> L.	<i>P. bulbosa</i> L.	Perennial/Hcr	mezophyte/ombrophyte
65	<i>Stipa</i> L.	<i>S. pulcherrima</i> K. Koch	Perennial/Hcr	xeromezophyte/ ombrophyte
XXVII. Polygalaceae Hoffmanns. & Link				
66	<i>Polygala</i> L.	<i>P. anatolica</i> Boiss. & Heldr.	Perennial/Hcr	mezophyte/ombrophyte
XXVIII. Primulaceae Batsch ex Borkh.				
67	<i>Primula</i> L.	<i>P. veris</i> L.	Perennial/Hcr	mezophyte/ombrophyte
XXIX. Ranunculaceae Juss.				
68	<i>Adonis</i> L.	<i>A. aestivalis</i> L.	Annual/T	mezophyte/ombrophyte
69	<i>Delphinium</i> L.	<i>D. ajacis</i> L.	Annual/T	mezophyte/ombrophyte
70	<i>Ranunculus</i> L.	<i>R. repens</i> L.	Perennial/Cr	mezophyte/ombrophyte
71	<i>Thalictrum</i> L.	<i>Th. simplex</i> L.	Perennial/Hcr	mezophyte/ombrophyte
XXX. Rosaceae Juss.				
72	<i>Cotoneaster</i> Medik.	<i>C. integerrimus</i> Medik.	Shrub/Ph	xeromezophyte/ phreatophyte
73	<i>Filipendula</i> Mill.	<i>F. vulgaris</i> Moench	Perennial/Cr	mezophyte/ombrophyte
74	<i>Potentilla</i> L.	<i>P. recta</i> L.	Perennial/Cr	mezophyte/ trichohydrophyte
75	<i>Pyrus</i> L.	<i>P. caucasica</i> Fed.	Tree/Ph	xeromezophyte/ phreatophyte
		<i>P. salicifolia</i> Pall.	Tree/Ph	xeromezophyte/ phreatophyte
76	<i>Rosa</i> L.	<i>R. pulverulenta</i> M.Bieb.	Dw. shrub/Ch	xeromezophyte/ phreatophyte
77	<i>Sanguisorba</i> L.	<i>S. officinalis</i> L.	Perennial/Hcr	mezophyte/ trichohydrophyte
XXXI. Rubiaceae Juss.				
78	<i>Galium</i> L.	<i>G. verum</i> L.	Perennial/Hcr	mezophyte/ombrophyte
XXXII. Thymelaeaceae Juss.				
79	<i>Daphne</i> L.	<i>D. caucasica</i> Pall.	Shrub/Ph	xeromezophyte/ phreatophyte
XXXIII. Violaceae Batsch.				
80	<i>Viola</i> L.	<i>V. arvensis</i> Murray	Annual/T	mezophyte/ombrophyte

Note: Dw. – dwarf, Ch – chamaephytes, Ph – phanerophytes, T – therophytes, Hcr – hemicryptophytes, Cr – cryptophytes

The results of the analysis of life forms (Table 1) showed that annual herbaceous plants accounted for 31 species, perennial plants for 44 species, biennials for 3 species, shrubs for 6 species, and semi-shrubs for 1 species. Trees were represented by two species, while dwarf shrubs and dwarf semi-shrubs were represented by one and two species, respectively.

According to Raunkiaer's system of

classification, the flora of the Gyzmeidan mud volcano includes 31 species (35%) of therophytes, 29 species (32%) of hemicryptophytes, and 18 species (20%) of cryptophytes. The proportion of perennial woody species (phanerophytes) recorded in the Gyzmeidan mud volcano is 8 species (9%), while chamaephytes account for 4 species (4%) (Figure 3).

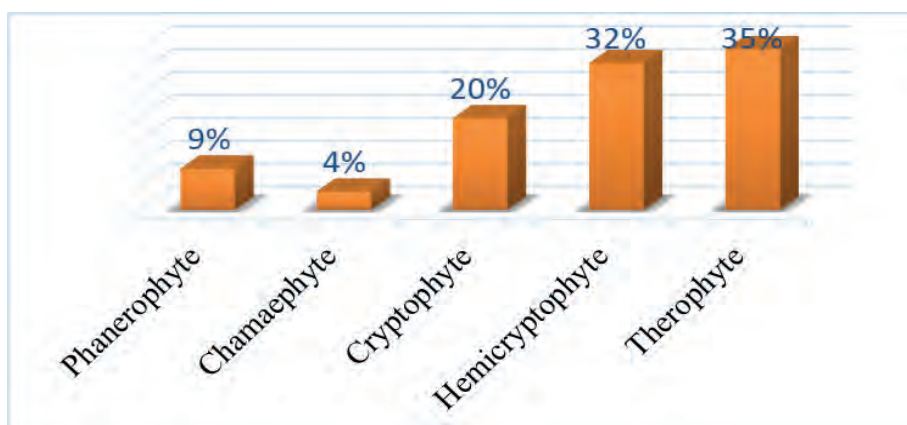


Figure 3. Biomorphological spectrum of life forms in the flora of the Gyzmeidan mud volcano based on C. Raunkiaer's classification.

Bioecological analysis of the conformity of plants concerning their impact on the moisture regime showed that the mesophyte group is primarily distributed and dominates the flora of the Gyzmeidan mud volcano, accounting for 59 species (more than 60%) (Figure 4). The

spectrum of ecological groups indicates that xeromesophytes are represented by 27 species, mesoxerophytes by 3 species, and xerophytes by 1 species.

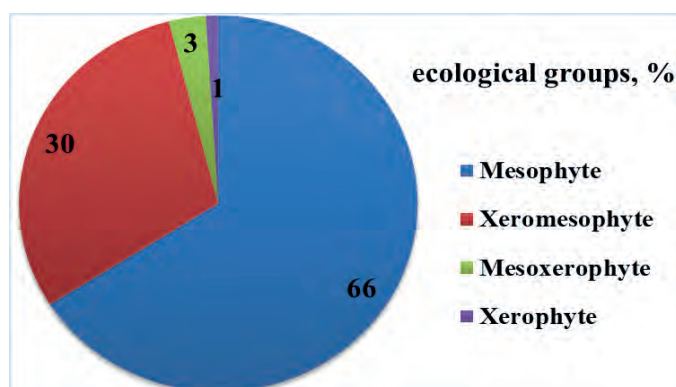


Figure 4. Spectrum of ecological groups in the flora of mud volcano Gyzmeidan in relation to hydration

Based on the method of obtaining moisture from soil horizons (Figure 5), two principal ecological groups were identified. The first group includes species with root systems confined to the 0–10 cm soil horizon, enabling them to

absorb moisture directly from precipitation. The second group comprises plants with deep root systems extending into lower soil horizons, allowing them to access moisture from groundwater reserves. The dominant group consists of

ombrophytes, predominantly therophytes (annual plants) and ephemeral-ephemerioid communities characteristic of mud volcano ecosystems. Conversely, the phreatophyte group is composed of structure-forming and dominant plants, primarily representatives of saltwort vegetation.

The distribution of species by root system types is as follows:

Ombrophytes: These plants possess shallow root systems confined to the soil's surface layer,

relying on precipitation for moisture. They account for 64 species.

Phreatophytes: This group is characterized by thick roots capable of tapping directly into groundwater, representing 10 species.

Trichohydrophytes: Species in this category have complex root systems that penetrate deeply into the soil and utilize capillary action to absorb groundwater. They are represented by 16 species (Figure. 5).

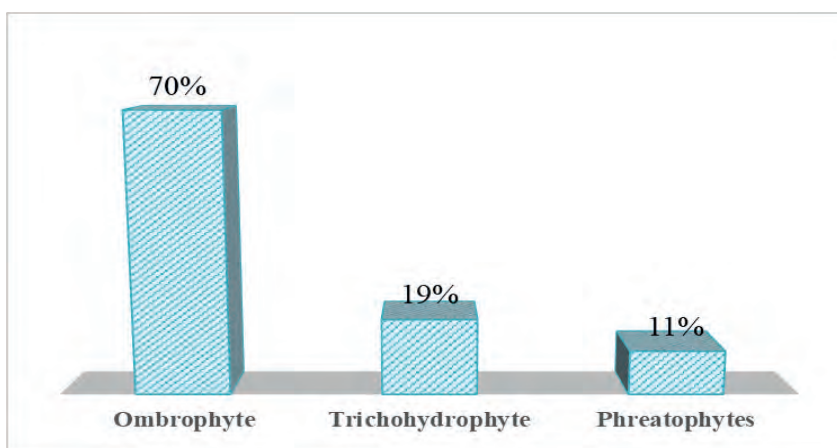


Figure 5. Spectrum of ecological groups in the flora of the mud volcano based on root system depth and moisture absorption from soil horizons.

Conclusion

For the first time, the taxonomic composition of the Gyzmeidan mud volcano in the Shamaxi-Gobustan region has been comprehensively studied, revealing a total of 90 species belonging to 81 genera and 33 families. Among these, the family *Asteraceae* (Giseke) plays a dominant role, comprising 14 species and 12 genera.

The study also found that the abundance

and diversity of vegetation increase progressively with distance from the eruptive center of the mud volcano. Life form analysis indicated that perennial herbaceous plants constitute the largest group, with 44 species, followed by annual plants with 31 species. Regarding root system types, ombrophytes were identified as predominant, accounting for 64 species.

References

- Abbasov, M., Rustamov, Kh., Rahimova, O., Rasulova, L., & Babayeva, S. (2024). Studying the gene pool of the wild ancestor of barley in Azerbaijan. *Acta Botanica Caucasica*, 3(1), 21–25.
- Abbasov, O. R., Mammadova, A. N., Akhundov, R. V., Baloglanov, E. E., Huseynov, A. R., & Yagubov, A. R. (2015). *Atlas of the World Mud Volcanoes*. Nafta-Press.
- Алиев, Ад. А., Гулиев, И. С., Дадашев, Ф. Г., & Рахманов, Р. Р. (2015). *Атлас грязевых вулканов мира*. Nafta-Press.
- Алиев, Ад. А., Гулиев, И. С., & Рахманов, Р. Р. (2019). *Каталог извержений грязевых вулканов Азербайджана (2008–2019 гг.)*.
- Бейдеман, И. Н. (1954). *Развитие растительности и почв в низменности восточного Закавказья*. АН СМССР.

- Isayeva, Sh. G., & Mehdiyeva, N. P. (2017). For the study of vegetation of mud volcanoes in Gobustan. ANAS Proceedings of the Institute of Botany, 37, 45–49.
- Gurbanov, E., & Aslanova, S. (2024). AVERAGE ANNUAL PRODUCTIVITY OF THE THYMUS-ETALUM-FESTUCOSUM FORMATION, DISTRIBUTED IN SUMMER PASTURE FIELD NO. 8 "TURKESOBABA" (AZERBAIJAN). Norwegian Journal of Development of the International Science, 126.
- Gurbanov, E., & Ibrahimov, S. (2023). Vegetation Classification Of Oil-Contaminated Soils In Azerbaijan. ACTA Botanica Caucasica, 2(1), 3-8.
- Gurbanov, E., & Rzaeva, A. A. (2017). Biomorphological Analysis and Identification of Subspecies of *Juniperus communis* in Azerbaijan. Asian Journal of Plant Science and Research, 7(3), 14-6.
- Gurbanov, E., & Rzaeva, A. (2022). Evaluation of decorative properties of some coniferous plants introduced to Absheron Peninsula. Acta Botanica Caucasica, 1(2), 3–7.
- Kurbanov, E., Aslanova, S., & Ibragimov, S. (2023). Types of Hole-Meadow and Wetlands Vegetation in Oil-contaminated Soils Siyazan District (Azerbaijan). Bulletin of Science and Practice.
- Исаева, Ш. Г. (2022). Популяция редких видов растений грязевых вулканов Гызмейдан и Торагай. Нахчыванское отделение НАНА, научные труды серия естественных и технических наук, 4, 166–173.
- Исаева, Ш. Г. (2022). Таксономия и растительный покров на территории грязевого вулкана Пирекешкюль. Научные и педагогические известия университета Одлар Юрду, 61, 80–87.
- Исаева, Ш. Г., Лянгузова, И. В., & Гасымов, Ш. Н. (2022). Содержание тяжёлых металлов в системе почва-растение на грязевом вулкане Алят (Азербайджан). Ботанический журнал, 107(10), 954–965.
- Ismayilova, L., Ahmadov, I., Gasimov, E., Rzaev, F., Sultanova, J. and Ahmadova, H. Effect of nanoparticles on the Golden Delicious apple flower fertilization process and accumulation in the fruit. Acta Botanica Caucasica, 1(2), 46–56 (2022).
- Khain, V. E., & Khalilov, E. N. (2009). Cyclicity of geodynamic processes: Its possible nature. Moscow: Scientific World.
- Korznikov, K. A. (2015). Vegetation cover at the Maguntan mud volcano (Sakhalin Island, Russia): Species composition and spatial distribution. Phytocoenologia, 45(1), 125–134. <https://doi.org/10.1007/s11268-015-9444-4>
- Mamedov, G. Sh., Khalilov, M. Y., & Mamedova, S. Z. (2010). Climate. In Ecological Atlas. Baku. Прилипко, Л. И. (1970). Растительный покров Азербайджана. Элм.
- Raunkiaer, Ch. (1937). Plant life forms. Clarendon Press.
- Шенников, А. П. (1964). Введение в геоботанику. Ленинградский ун-т.
- Ting, T. M., & Poulsen, A. D. (2009). Understory vegetation at two mud volcanoes in north-east Borneo. Journal of Tropical Forest Science, 21(3), 198–209.
- World Flora Online. (n.d.). Retrieved from <https://wfplantlist.org/>

GENETIC RESOURCES OF GRAPEVINE (*VITIS VINIFERA* L.) AND THEIR RESISTANCE TO DOWNY MILDEW

Kamila Aliyeva¹ | ORCID: 0000-0002-5344-3302

Khatira Mammadova^{1*} | ORCID: 0009-0001-6655-4327

Jabrayil Aghayev² | ORCID: 0000-0002-1984-6992

¹ Department of Biology, Baku State University, Baku, Azerbaijan

² Institute of Genetic Resources, Ministry of Science and Education of Azerbaijan, Baku, Azerbaijan

^{1*} Correspondence: xatire.esedzade@gmail.com

Article Info:

DOI: <https://doi.org/10.30546/abc.2024.3.3.514>

Pages: 36–42

Received: September 2, 2024; Revised: September 13, 2024; Accepted: October 7, 2024

Abstract. Fungal diseases have emerged as one of the most critical challenges in viticulture, significantly reducing grape yield and quality. Among these, downy mildew, caused by the fungus *Plasmopara viticola* (Berk. & Berl. & de Toni), poses a severe threat to global grapevine (*Vitis vinifera* L.) production, leading to substantial crop losses. The disease not only limits grapevine growth but also negatively affects the quality of harvested grapes, thereby impacting wine and table grape industries.

This study aimed to evaluate the resistance of grapevine genotypes to downy mildew through a natural field survey. Resistance assessments were conducted using the method developed by H.M. Shikhlinsky (2016) and a refined 5-point scale (as described by Naydenova & Nedov, 1985). To ensure result accuracy, infected leaf samples from each genotype were microscopically examined, and pathogen identification was confirmed following Benkena's methodology (1963). Data obtained from field trials were subjected to Cluster Analysis to classify the genotypes based on their resistance levels.

The analysis revealed that 3 genotypes were highly resistant, 21 were resistant, 10 were tolerant, 5 were susceptible, and 1 was highly susceptible. Notably, the genotypes Sahibi, Gulabi, and Tulkuquyrugu were categorized as highly resistant, indicating their potential as valuable candidates for breeding programs aimed at enhancing resistance to *P. viticola*. The study underscores the importance of utilizing highly resistant and resistant genotypes in grapevine breeding initiatives to mitigate the economic and agricultural impacts of downy mildew.

Keywords: *Vitis vinifera* L., downy mildew, *Plasmopara viticola*, genotype, resistance

Introduction

Azerbaijan is one of the centers of origin for grapevine (*Vitis vinifera*). As a result of many years of selection work carried out on this plant in our country, a large number of grape varieties and forms have been developed. One of the priority issues in the development of viticulture, which is one of the main sectors of the national economy, is the creation of disease-resistant and productive grape varieties and forms for more intensive development. In this regard,

evaluating the resistance of local grapevine varieties and forms to major diseases encountered in field conditions, researching resistance genes at the molecular level, and identifying new markers associated with diseases have great theoretical and practical significance.

Enriching the variety composition of vineyards, replacing low-yielding and poor-quality grape varieties with new, more productive and high-quality ones, efficiently and sustainably utilizing the genetic resources of grapevine,

and increasing the production of grapes and their processed products in the country are of great importance in terms of food security and the overall development of viticulture in the republic (Salimov et al., 2022).

In recent years, fungal diseases have become one of the most significant issues in grape fields, particularly in newly established vineyards and nurseries, where they infect the crops, reducing both yield and quality. The pathogens of fungal diseases limit grapevine growth and cause substantial yield loss. Currently, the key challenge in agriculture is the protection of crops from diseases and pests in order to increase productivity and improve quality (Shikhlinski et al., 2019). The damage and losses caused to agricultural crops by phytopathogenic organisms are excessively high (Wilcox et al., 2015).

One of the most widespread and dangerous diseases of grapevine worldwide is downy mildew, which is caused by the fungus *Plasmopara viticola* Berk. & Berl. & de Toni (Macidi et al., 2019; Feng et al., 2018). The disease is also referred to as false powdery mildew or peronosporosis. It parasitizes living plant tissues to survive. The disease develops in almost all grape-growing regions, but it is not observed in areas with dry and hot climates. It affects the green organs of the vine throughout the entire vegetation period (Shikhlinski et al., 2019; Shikhlinski et al., 2014). On the upper surface of the infected leaf, yellow, oily spots, which differ from healthy tissue, appear. These spots range in size from very small to 4–5 cm in diameter and are usually located at the tip of the leaf blade (Macidi et al., 2019; Sharifov et al., 2013).

Plant disease assessment can be based on two indicators: disease incidence and disease severity. Disease incidence is expressed as the proportion of diseased plant units in a defined population or sample. Disease severity refers to the percentage of the plant exhibiting visible disease symptoms or sporulation (Madden et al., 2017).

To conduct disease assessment, experts with appropriate knowledge and experience should be selected (Mokhtar et al., 2015). Traditional phenotyping methods primarily rely on visual evaluation of disease symptoms on grape

leaves and bunches or sporulation in artificially inoculated leaves. During visual assessment, the degree of disease symptoms or sporulation is assigned a value based on the impression perceived by the human eye.

During the evaluation process, highly resistant and responsive samples are selected from the tested specimens, after which, through intra-species and inter-species crosses, it becomes possible to obtain new, high-quality grape varieties that are resistant to diseases and pests.

Materials and Methods

The resistance of grape varieties and forms to downy mildew disease was assessed using the method developed by H.M. Shikhlinski (2016) and the 5-point scale improved by Naydenova and Nedov (1985). The phytopathological evaluation of grapevines was conducted under natural conditions.

During the phytopathological evaluation of grape clusters infected with downy mildew in natural conditions:

- **0 points:** No damage observed on the clusters.
- **1 point:** A slight bluish coating observed on individual berries.
- **2 points:** Infection of the berries in the clusters ranges from 1% to 10%.
- **3 points:** Infection of the berries in the clusters ranges from 10% to 30%.
- **4 points:** Infection of the berries in the clusters ranges from 30% to 50%, with visible damage on the berries.
- **5 points:** Infection of the berries in the clusters exceeds 50%, with cracks and visible damage on the berries.

The evaluation results of the studied samples were grouped using Cluster Analysis. This analysis allows for the visual grouping of genotypes. Cluster analysis was performed using the UPGMA method and the Euclidean distance index in the PAST statistical software package.

During the evaluation conducted under natural conditions, in addition to observing the characteristic symptoms of downy mildew disease on the grapevine clusters and leaves, samples were examined under a microscope to

confirm that the disease was indeed caused by *Plasmopara viticola* (Berk. & Berl. & de Toni). Fungal diseases in plants are numerous and diverse. Systematic microscopy, the use of a humid chamber, isolating the pathogen into a pure environment, and sometimes inoculating the host plant are generally accepted methods for making an accurate diagnosis of the disease (Agayev et al., 2017).

The advantage of studying fungi in humid chambers is that it allows observation of the fungus in its intact state, with all its characteristic features, especially the conidiophores of

hyphomycete fungi and the pattern of conidia distribution on them (whether singly, in chains, or in heads).

To ensure the accuracy of the evaluation results, a sample of infected leaves was taken from each specimen, and the pathogen was observed under a microscope. For this, the method developed by Benkena (1963) was used (Agayev et al., 2017). Experiments in humid chambers were conducted on fresh, newly collected samples because, over time, they lose their viability.

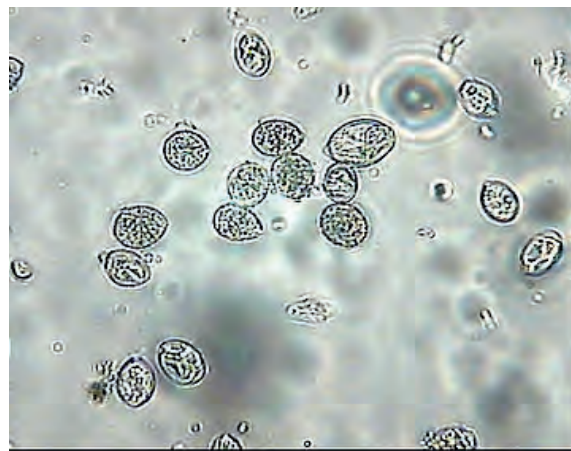


Figure 1. Microscopic structure of *Plasmopara viticola* (Berk. & Berl. & de Toni) fungal spores.

The fungal spore formation was studied by placing collected samples in a humid chamber. Small tissue fragments (3–10 pieces, depending on the specimen) were placed evenly at the bottom of Petri dishes, ensuring they did not touch each other and were positioned at least 1 cm from the chamber's side walls. For tissue samples from leaf spots, the infected fragments ranged from 2 to 5 mm in diameter.

Sterilization was essential to remove external microflora from the tissue particles. The samples were treated with 50% alcohol for 1–2 minutes and then sequentially rinsed with sterile water. To set up the humid chamber, filter paper moistened with sterile water was placed in Petri and Koch dishes. Additional sterile water was added to the bottom of the dishes, and the filter paper on the chamber lid was moistened as needed.

Observations were conducted at intervals of 24, 48, and 72 hours. After 28 hours,

characteristic spore-bearing structures and unicellular, colorless conidia heads of *Plasmopara viticola* were observed on the edges of the leaf tissue, forming a mildew-like appearance. These structures were clearly visible under the microscope (Figure 1). The presence of these features confirmed that the causative agent of the disease was *Plasmopara viticola* (Wikipedia, n.d.).

Results and Discussion

Phytopathological evaluation of the susceptibility of 40 grapevine varieties and forms to *Plasmopara viticola* (Berk. & Berl. & de Toni) was conducted under natural field conditions at the Absheron Research Base. The evaluation revealed significant differences in resistance levels among the studied grapevine varieties. The detailed resistance levels for clusters and leaves are presented in Table 1.

Table 1.

**Resistance levels of grapevine varieties to *Plasmopara viticola*
(Berk. & Berl. & de Toni)**

№	Name of the Grape Variety	Resistance in the Cluster (points)	Resistance in the Leaf (points)	№	Name of the Grape Variety	Resistance in the Cluster (points)	Resistance in the Leaf (points)
1	Shafeyi	2	2	21	Zalxa	4	4
2	Dagh uzumu	2	2	22	Danagozu	4	4
3	Sarı kishmish Naxchivan	5	5	23	Gara uzum Mahmudu	3	3
4	Hafizali	2	2	24	Gara kishmish Nakhchivan	4	4
5	Tulkuquyruglu	1	1	25	Gara kishmish	4	4
6	Qara kurdashi	2	2	26	Agh gulabi	4	4
7	Agh kalambir	2	2	27	Nabi uzum	3	3
8	Khazani	2	2	28	Gahvayi kishmish	2	2
9	Gara hənəqirna	2	2	29	Goch uzumu	2	2
10	Sahibi	1	1	30	Badamli	2	2
11	Gulabi	1	1	31	Inak amcayi	2	3
12	Asgari	2	2	32	Tabarza	2	2
13	Agh huseyni	2	2	33	Sari shafeyi	2	2
14	Tezyetishan tumsuz	2	2	34	Nargizi	3	3
15	Agh shani	3	3	35	Davachi halmasi	2	2
16	Sarigila	3	3	36	Tozlayici	2	2
17	Gara Nakhchivan khatunu	3	3	37	Gush urayi	2	2
18	Malahati	3	3	38	Shamakhi marandisi	2	2
19	Farashi	3	3	39	Aghadayi	3	3
20	Girmizi kishmish	3	3	40	Khindogni	2	2

The Absheron Scientific Research Base, situated on the Absheron Peninsula, experiences a hot and dry climate. In this region, signs of downy mildew disease (*Plasmopara viticola*) are predominantly observed during the spring and early summer when conditions are more

favorable for the pathogen's development. However, as the season progresses, increasing temperatures and low humidity create an unfavorable environment, halting the development and spread of the disease.

Table 2.

Phytopathological assessment of downy mildew resistance

Infection Rates	Resistance Score	Downy Mildew (Leaf)	Downy Mildew (Cluster)
Highly resistant	1.0–1.5	3	3
Resistant	2.0–2.5	21	21
Tolerant	3.0–3.5	10	10
Unstable	4.0–4.5	5	5
Very unstable	5.0	1	1
Total	-	40	40

As seen in the table, a phytopathological assessment of downy mildew disease (on leaves and clusters) was conducted under natural conditions. As a result of the evaluation of the grape clusters, 3 varieties were classified as highly resistant, 21 as resistant, 10 as tolerant, 5 as susceptible, and 1 as highly susceptible.

The research findings indicate that among the varieties, only one showed a highly susceptible reaction to the main fungal diseases. This can be explained by the fact that the

development and spread of the pathogen were hindered due to unfavorable conditions on the Absheron Peninsula. Specifically, there was insufficient humidity for the pathogen's development and spread. A sufficient level of relative humidity is essential for the growth and dissemination of these fungi.

Cluster analysis: The cluster analysis was performed using the PAST statistical software package, based on the UPGMA method and the Euclidean distance index (Figure 2).

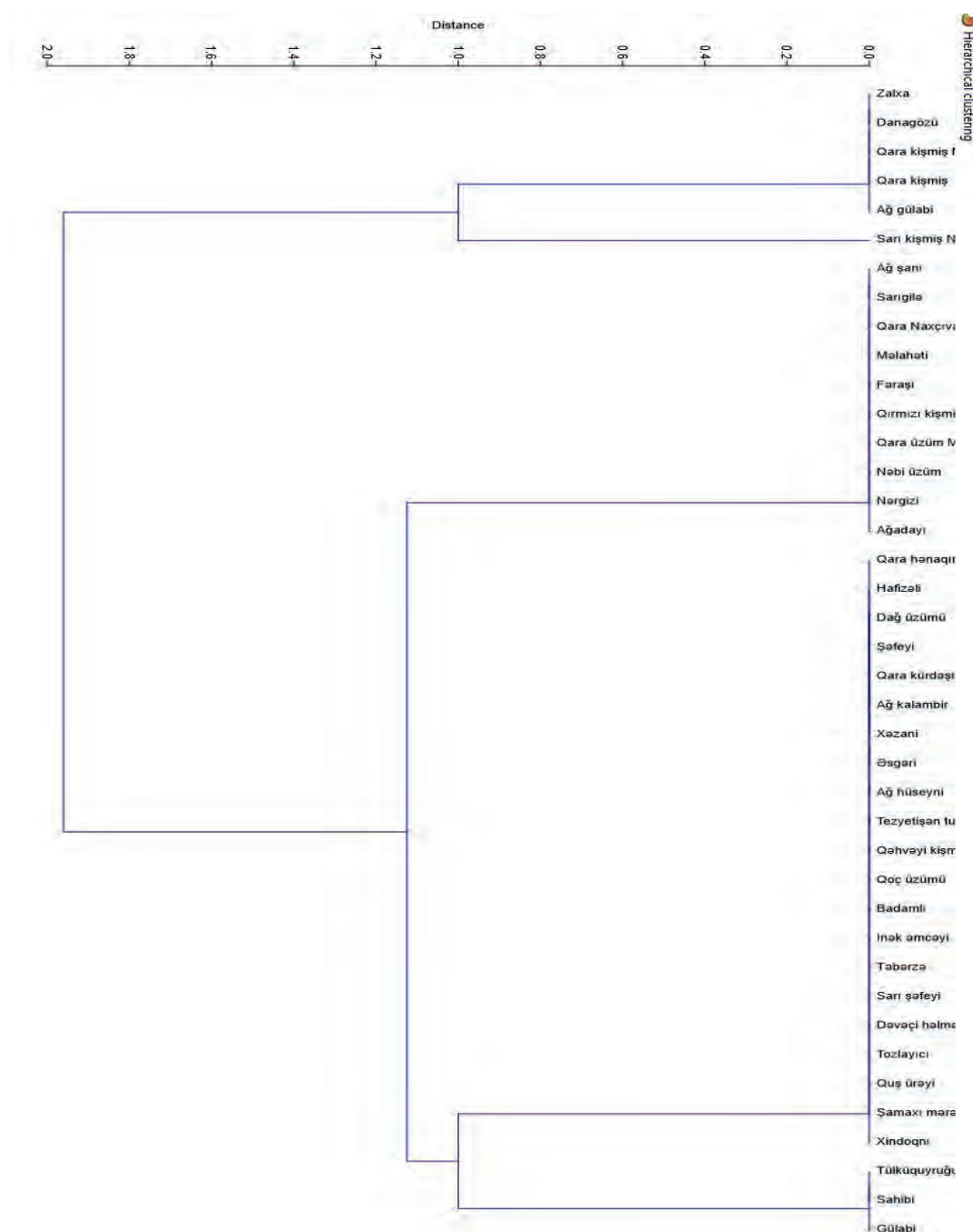


Figure 2. Dendrogram constructed based on Euclidean distance.

It is well-known that cluster analysis is an important method used to reveal the similarities

and differences between genotypes. In our study, the genotypes under investigation grouped into five main clusters based on the examined characteristics, as shown in the dendrogram. As mentioned earlier, the cluster analysis visually shows that the evaluated grape genotypes have clustered into five main groups based on their infection levels.

In the first cluster, five varieties, which were rated 4, were categorized as susceptible. The second cluster contained one variety, rated 5, classified as highly susceptible. In the third cluster, ten varieties, rated 3, were categorized as tolerant. The fourth cluster contained twenty-one varieties, rated 2, which were considered resistant. Finally, the fifth cluster included three varieties, rated 1, classified as highly resistant. Among the samples, the genotypes Sahibi, Gulabi, and Tulkuguyrugu were rated as highly resistant.

The selection of resistant grape varieties

from both highly resistant and resistant forms is recommended for use in breeding programs aimed at developing grape varieties resistant to pathogens.

Conclusion

The phytopathological evaluation of 40 grapevine varieties under natural field conditions revealed significant differences in their susceptibility to downy mildew disease (*Plasmopara viticola*). Among the tested varieties, Sahibi, Gulabi, and Tulkuguyrugu were identified as highly resistant genotypes. These findings suggest that these genotypes represent valuable resources for breeding programs aimed at developing new grapevine varieties with enhanced resistance to downy mildew. Incorporating these resistant varieties into intra- and interspecific crosses holds great potential for improving disease management and ensuring sustainable viticulture practices.

References

- Abbasov, M., Rustamov, Kh., Rahimova, O., Rasulova, L., & Babayeva, S. (2024). Studying the gene pool of the wild ancestor of barley in Azerbaijan. *Acta Botanica Caucasica*, 3(1), 21–25.
- Agayev, C. T., Cabbarov, S. F., Huseynova, A. A., & Agayeva, N. K. (2017). *Experimental methods for studying phytopathogenic fungi - Methodological guidelines*. Baku: Teacher Publishing House.
- Feng, X., Nita, M., & Anton, B. B. (2018). Evaluation of quinoxifen resistance of *Erysiphe necator* (grape powdery mildew) in a single Virginia vineyard. *Plant Disease*, 102(12), 2586–2591. <https://doi.org/10.1094/PDIS-02-18-0171-RE>
- Gurbanov, E., & Aslanova, S. (2024). AVERAGE ANNUAL PRODUCTIVITY OF THE THYMUS-ETALUM-FESTUCOSUM FORMATION, DISTRIBUTED IN SUMMER PASTURE FIELD NO. 8 "TURKESOBABA" (AZERBAIJAN). *Norwegian Journal of Development of the International Science*, 126.
- Gurbanov, E., & Ibrahimov, S. (2023). Vegetation Classification Of Oil-Contaminated Soils In Azerbaijan. *ACTA Botanica Caucasica*, 2(1), 3-8.
- Gurbanov, E., & Rzayeva, A. (2022). Evaluation of decorative properties of some coniferous plants introduced to Absheron Peninsula. *Acta Botanica Caucasica*, 1(2), 3–7.
- Hassanpanah, D., Gurbanov, E., Gadimov, A., & Shahriari, R. (2007). Reduction of nitrate accumulation in potato by use of potassium humate for human safety. *Iranian Biomedical Journal*, 11(1), 461.
- Kurbanov, E., Aslanova, S., & Ibragimov, S. (2023). Types of Hole-Meadow and Wetlands Vegetation in Oil-contaminated Soils Siyazan District (Azerbaijan). *Bulletin of Science and Practice*.
- Macidi, I. (2019). *Atlas of diseases of fruit and berry plants*. Universal Publishing and Printing House.
- Madden, L. V., Hughes, G., & van den Bosch, F. (2017). The study of plant disease epidemics. *The American Phytopathological Society*. <https://doi.org/10.1094/9780890545058>
- Mokhtar, U., El Bendary, N., Hassenian, A. E., Emary, E., Mahmoud, M. A., Hefny, H., & Tolba, M. F. (2015). SVM-based detection of tomato leaf diseases. In A. Abraham, A.-E. Hassanien, & V. Snášel (Eds.), *Intelligent Systems'2014. Advances in Intelligent Systems and Computing* (Vol. 323, pp. 641–652). Springer. https://doi.org/10.1007/978-3-319-11310-4_55
- Panahov, T. M., Salimov, V. S., & Zari, A. M. (2010). *Viticulture in Azerbaijan*. Baku: Teacher Publishing

House.

- Salimov, V., Huseynov, M., & Shukurov, A. (2022). Grape: Agro-technical aspects, agrochemical treatment, and integrated pest management. Baku: Teacher Publishing House.
- Sharifov, F. (2013). Viticulture. Baku: Teacher Publishing House.
- Shikhlinski, H. (2014). Pests, diseases, and control methods of fruit, berry, and grape plants. Baku: Teacher Publishing House.
- Shikhlinski, H., & Mammadova, N. (2019). Methods for assessing the spread of diseases and pests of agricultural crops. Baku: Teacher Publishing House.
- Wikipedia. (n.d.). Conidophores and sporangia of *Plasmopara viticola*. Retrieved from https://bg.m.wikipedia.org/wiki/%D0%A4%D0%B0%D0%B9%D0%BB:Conidophores_and_Sporangia_of_Plasmopara_viticola.jpg
- Wilcox, W. F., Gubler, W. D., & Uyemoto, J. K. (2015). Compendium of grape diseases, disorders, and pests (2nd ed.). American Phytopathological Society Press.

PHYTOSOCIOLOGICAL INVESTIGATION OF COASTAL WATER SWAMP PLANT COMMUNITIES OF AZERBAIJAN

Vagif ATAMOV^{1*} | ORCID: 0000-0002-6718-7979

Murat MUSAYEV² | ORCID: 0000-0002-4897-9241

^{1*}Recep Tayyip Erdoğan University, Faculty of Arts and Sciences, Department of Biology, 53100, Rize, Türkiye

²Ministry of Defense Industry, Aerospace Research Agency, Ecological Institute, Baku Azerbaijan

^{1*} Correspondence: Vagif.atamov@erdogan.edu.tr

Article Info:

DOI: <https://doi.org/10.30546/abc.2024.3.3.516>

Pages: 43–58

Received: August 20, 2024 | Revised: September 13, 2024 | Accepted: September 28, 2024

Abstract. This study was carried out during 2007 and 2018. The aim was to report the vegetation of swamps of Azerbaijan. A total of 95 plant associations. We recorded 33 pure aquatic associations, 13 wet grass associations, 8 aquatic forest associations and 16 hydrohalophyte associations. There are 24 plant associations in coastal water-swamp habitats. These associations are; *Phragmitetum communis*, *Typho angustifoliae-Phragmitetum communis*, *Scirpo-Phragmitetum communis*, *Typhetum angustifolia*, *Typhetum latifoliae*, *Potamogetono-Typhetum domingensis*, *Scirpetum lacustris*, *Potamogeton -Schoenoplectetum litoralis*, *Butomo- Eleocharitetum palustris*, *Cladio-Schoenetum lacustris* ass. nova, *Scirpetum marittimi*, *Triglochino-Bolboschoenetum marittimi*, *Sparganietum poluedrum* ass. nova, *Butometum umbellati*, *Caricetum dilutae* ass. nova, *Caricetum vasicariae*, *Typhetum angustifoliae* ass. nova, *Schoenoplectetum litoralis* ass. nova, *Calamagrostisatum epigejosae* ass. nova, *Hippurisetum vulgarisae* ass. nova, *Caricetum ripariae* ass. nova, *Cyperetum pseudocyperae* ass. nova, *Heleocharitetum iupalustrisi* ass. nova, *Heleocharitetum euuniglumisi* ass. nova. troops. Out of these 13 associations have already been reported, and 11 are newly described associations for the aquatic vegetation of Azerbaijan.

Keywords: Habitat, associations, vegetation. Water-Swamps, Azerbaijan.

Introduction

Much work has been done and published on the aquatic ecosystems lately (Altay et al., 2024). The classification of aquatic plant associations in the world too are attracting much attention due to their importance in the era of climate change (Yucel et al., 1995). All these studies have enlightened the fact that these habitats are rich in plant diversity (Rivaz-Martinez, S., Gonzales, et al. (2001). Dubnya (2006) and Mucina., Bültmann et al. (2016). Earlier Aliyev (1969), Babayev (1974), Efəndiyeva (1989), Musayev (2010) and others have studied the water-swamp plants of Azerbaijan. According to the habitat diversity the plant cover on the habitats around rivers, streams and water

channels shows 312 taxa which is richer than swamps with only 160 taxa. In all 127 taxa are found in the calm, slow-flowing waters and 114 taxa in saline lakes and alongside seashores (Atamov and Musayev, 2018).

Atamov (2008) has reported that Hydrohalophytes are common in the coastal areas of the Caspian Sea. In water-marsh vegetation, cryptophytes, hemicryptophytes and therophytes are dominant in number and are among the characteristic features of this vegetation. These types of plants easily adapt to the water-swamp environment and can easily reproduce on such habitats. Some of the aquatic plants with rhizomes and perennial herbaceous stems grow easily in saline lakes and swamps, others flourish in

freshwater lakes and swamps. The distinctive and dominant species of these types of plants sometimes form pure and sometimes mixed associations.

The coastal water-swamp ecosystems have been investigated at length, but the methods valid in the world have not been used in the classification of vegetation, especially based on the principle of dominance, without taking into account habitats, phytocenological structure of vegetation and ecological conditions.

The floristic and phytosociological characteristics of the communities within the borders of Azerbaijan can be outlined as; aquatic plant associations, aquatic forest associations and plant associations of halophytic aquatic areas (Grossgeym, 1948; Aliyev, 1969; Prilipko, 1970, Babayev, 1974; Efendiyeva, 1989; Şaksuvarov, 1994; Hacıyev, 1992; Hacıyev, Mailov et al. 1993; Talibov, Ibrahimov 2008; Musayev, 2010; Musayev, Atamov, 2015, 2017, 2018; Gurbanov, Huseynova, 2019).

Our aim in this study was to investigate the floristic and phytosociological characteristics of plant associations belonging to coastal water marsh habitats.

Maretials and Methods

Field studies were carried out between 2007 and 2018 in the lakes and swamps located in the plain and mountainous regions of Azerbaijan, in seaside areas, especially in Lankaran plain (Great and Small Kızılağaç Gulf), Samur Deveçi plain (Devechi Port), Candar Lake and plains and plains of Nakhchivan. The mountainous parts included: Batabat lake, Araz deryçası, Göy-göl lake in Ordubad land. The plant specimens were collected during different vegetation perio and identification was done following the 8-volumes on the «Flora of Azerbaijan» (Karyagin, 1961). These plant specimens were

deposited in the Herbarium of the Laboratory of Botany Institute of the Azerbaijan National Academy of Sciences. Life forms of plants were given according to the Raunkier (1934) system. The phytosociological characteristics of plant associations and presentation of vegetation tables was given according to the «smallest area» principle method (Braun-Blanquet 1964). The syntaxonomic naming of the associations was followed according to Weber et al., (2000).

Results and Discussion

The water-swamp vegetation of Azerbaijan was investigated for the first time according to the Braun-Blanquet (1964) method and the syntaxonomic evaluation done. We found 19 plant associations in aquatic habitats (Musayev, Atamov 2020), 8 in submerged oak associations (Atamov, Musayev, 2017), and 16 plant associations in aquatic hydrohalophyte habitats (Atamov, Musayev, 2020). The plant associations widely distributed in the coastal marsh habitats of Azerbaijan were classified for the first time according to their phytosociological characteristics following Braun-Blanquet method, and new plant associations were determined. These associations are distributed in rivers, lakes and swamps, and in places with low water depth. The lower parts of the stems of these plants, known as helophyte plants, are located in soil that is always or seasonally under water, commonly known as swamps. These plants have a developed root system and therefore grow easily on such habitats.

Various associations belonging to this class are spread over large areas in our study area (Figure 1). It was not possible to set an exact boundary between these units, because most of the taxa participating in the formation of the unit are common species, it is also possible to see that they migrate to other units.



Figure 1. Some characteristic taxa participating in the phytocenological structure of coastal water-swamp plant associations: a. *Phragmites communis*, b. *Arundo donax*, c. *Numphae alba*, d. *Lythrum salicaria*, e. *Alisma plantago-aquatica*

1. *Phragmitetum communis* (Gams 1927) Schmale 1929

This association is found in all regions of Azerbaijan. The water depth varies between 0-150 (350) cm, the cover between (10) 50-100 percent, number of taxa varies between 2-8 depending on the environmental conditions. Among the associate taxa: *Phragmites communis*, *Schoenoplectus litoralis*, *Typha domingensis*,

Bolboschoenus maritimus var. *maritimus*, *Spirodela polyrhiza*, *Lemna trisulca*, *Potamogeton perfoliatus*, *Ceratophyllum demersum*, *Typha angustifolia*, *Sparganium erectum*, *Sagittaria sagittifolia*, *Alisma lanceolatum*, *Cyperus longus*, are the taxa participating in the plant cover and phytocenological structure of this association (Table 1).

Table 1.

Phytocenological characteristics of the *Phragmitetum communis* (Gams 1927) Schmale 1929, *Thypha angustifoliae-Phragmitetum communis* R.Tx & Preis 1942, *Phragmito-Menyanthemum trifoliatum* Adigüzel et al. 2009, *Scirpo-Phragmitetum communis* W.Koch 1926, *Typhetum angustifolia* Pignatti 1953, *Typhetum latifoliae* (Soo 1927) Lang 1973 associations.

Sample area No	541	542	543	544	545	546	547	548	549	550	Life form	Occurrence class
Field width (m2)	25	25	25	25	25	16	16	16	16	16		
Altitude (m)	100	80	80	100	300	500	800	1000	150	200		
Inclination (%)	0	0	0	0	0	0	0	0	0	0		
Weed height (cm)	2,5	2,8	2,4	2,4	2,0	1,8	2,3	2,0	1,9	2,4		
Soil type	B	B	B	B	B	B	B	B	B	B		
Number of species	9	10	10	8	8	9	15	13	13	12		
Covering degree %	100	85	80	95	100	80	85	90	85	90		
Character taxa of the association												
<i>Phragmites communis</i>	44	33	33	44	44	33	33	33	33	33	Hk	V
<i>Schoenoplectus litoralis</i>	.	.	.	.	.	.	+	.	+	+	Hk	II
<i>Thypha angustata</i>	.	.	+	.	.	.	.	.	.	.	Hk	I
<i>Bolboshoenus maritimus</i>	.	+	.	.	.	.	.	.	.	+	Hk	I
<i>Arundo donax</i>	+	.	.	.	+	.	.	.	.	.	Hd	I
<i>Lemna trisulca</i>	.	.	.	+		.	.	+	.	.	Hd	I
<i>Potamegaton perfoliatus</i>	.	.	.	.	.	+	+	.	.	.	Hd	I
Sample area No	653	654	655	656	657	658	659	660	661	662		
<i>Thypha angustifolia</i>	33	33	22	11	33	33	34	33	33	33	Hk	V
<i>Vallisneria spiralis</i>	+	.	.	+	.	.	+	.	.	.	Hd	II
Sample area No	301	302	303	304	305	306	307	308	309	310		
<i>Schoenoplectus lacustris</i> ssp. <i>lagustris</i>	33	+	33	11	11	22	22	11	33	33	Hk	V
<i>Phragmites communis</i>	+1	11	+	11	11	11	.	+	.	+	Hk	IV
<i>Bolboschoenus maritimus</i> var. <i>maritimus</i>	.	+	.	+	+	+	+	+	.	.	Hk	III
Sample area No	441	442	443	444	445	446	447	448	449	450		
<i>Menyanthes trifoliata</i>	55	55	55	54	55	54	44	44	54	44	Hd	V
<i>Phragmitescommunis</i>	44	22	.	33	33	33	33	33	33	33	Hk	V

Sample area No	461	462	463	464	465	466	467	468	469	470		
<i>Typha angustifolia</i>	33	33	34	32	11	+	44	43	33	33	Hk	V
<i>Schoenoplectus lacustris</i>	+	.	.	+	11	22	.	.	+	+	Hk	III
Sample area No	451	452	453	454	455	456	457	458	459	460		
<i>Typha latifolia</i>	33	33	44	43	33	34	32	11	44	33	Hk	V
<i>Schoenoplectus lagustris</i>	+	.	.	.	+	.	+	11	.	.	Hk	II
Accompanying taxa												
<i>Ceratophyllum demersum</i>	.	+	.	.	.	.	.	.	+	.	Hd	I
<i>Thypha angustifolia</i>	.	.	11	.	.	.	+	.	.	.	Hk	I
<i>Spargonium erectum</i>	.	.	.	.	+	.	.	.	.	+	Hk	I
<i>Sagittaria sagittifolia</i>	+	.	.	.	.	.	.	+	.	.	Hk	I
<i>Alisma lanceolatum</i>	.	.	.	+	.	.	.	.	.	.	Hk	I
<i>Cyperus longus</i>	.	+	.	.	.	+	+	.	+	.	Hk	III
<i>Carex distans</i>	.	.	.	.	.	+	.	.	.	+	Hk	I
<i>Epilobium hirsutum</i>	.	.	+	.	.	.	.	.	+	.	Hk	I
<i>Lycopus europaeus</i>	.	.	.	.	.	.	.	+	.	.	Hk	I
<i>Alisma plantago-aquatica</i>	.	.	.	.	.	.	.	.	.	+	Hk	I
<i>Lemna gibba</i>	.	.	+	.	.	.	.	.	.	.	Hd	I
<i>Typha angustifolia</i>	+	.	.	+	.	.	.	.	+	+	Hk	II
<i>Agrostis stolonifera</i>	.	.	.	.	.	+	.	+	.	.	Hk	I
<i>Ranunculus ophioglossifolius</i>	.	.	.	.	.	.	+	.	+	+	Hk	II
<i>Alopecurus aequalis</i>	.	+	+	.	.	.	.	.	.	.	Hk	I
<i>Polygonum lapathifolium</i>	.	.	.	.	.	.	+	.	+	.	Hk	I

In figure 2a, the life forms of this union and the results of the evaluations are shown, these present the frequency of occurrence of the types in the sample areas. In the phytocological structure of this association, in which

hydrophytes and hemicryptophytes participate, species show very different frequency of occurrence according to the sample areas. This can be related to the chemical composition of the water.

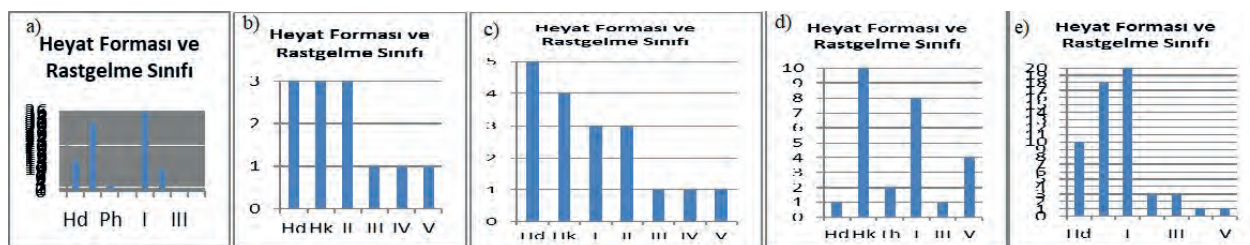


Figure 2. Evaluation of taxa participating in the phytosociological structure of some coastal swamp plant associations according to life form and occurrence class. a. *Phragmitetum communis*, b. *Thypha angustifoliae-Phragmitetum communis*, c. *Phragmito-Menyanetum trifoliatae*, d. *Scirpo-Phragmitetum communis*, e. *Typhetum angustifolia*.

2. *Typho angustifoliae* – *Phragmitetum communis* R Tx Preis. 1942.

The troops can be seen in the swampy areas of the plain in Samur-Dəvəçi, Kur-Araz and Naxçıvan. It is encountered with a phytocenological structure with water depth varying between 0-150 cm, cover degree varying between 50-100%, and cover size varying between 200-300 cm. The number of species participating in the flora and phytocenological structure of this association varies between 1 and 5. *Vallisneria spiralis*, *Potamogeton perfoliatus*, *Schoenoplectus litoralis*, *Myriophyllum spicatum* are the characteristic species of the association (Table 1).

In Fig. 2(a), the life form of this union and the results of the evaluations showing the frequency of occurrence of the types in the sample areas are given. In the phytocenological structure of this association, in which hydrophytes and hemicryptophytes participated, species with very different frequency of occurrence were encountered according to the sample areas, and it was concluded that this was related to the chemical composition of the soil and water environment in which the association spread.

3. *Phragmito-Menyanthetum trifoliatae* Adigüzel et al. 2009

This association is found around the lakes in the mountainous areas of Little Qafqaz and Naxchivan (Lake Batabat). On the edges of Lake Batabat, the species *Menyanthes trifoliata* and *Phragmites communis* settle according to the amount of sediment in the water, and it seems that there is a clear root competition between them as they choose similar places. *Phragmites communis* is more common in places close to the coast, where sandworms proliferate. As the depth increases towards the middle part of the lake, *Menyanthes trifoliata* becomes dominant. The flora composition of this association, which has a general cover level of 80-90%, is considered superior because the character types are superior. Other species other than the *Carex* species have also been encountered (Table 1).

In the Figure 2(b), the life form of this union and the results of the evaluations showing the frequency of occurrence of the types in the sample areas are given. In the phytocenological

structure of this association, in which hydrophytes and hemicryptophytes participated, species with very different frequency of occurrence were encountered according to the sample areas, and it was concluded that this was related to the chemical composition of the soil and water environment in which the association spread.

4. *Scirpo-Phragmitetum communis* W. Koch 1926.

It is a widely spread plant association and spreads along the Khazar sea coasts. It is found in areas where the lay cover is 60-100%, the medium density is 200-300 cm, and the water depth is 0-50 (300) cm. The flora of the association includes: *Schoenoplectus lagustris*, *Bolboschoenus maritimus* var. *maritimus*, in water *Nymphaea alba*, *Ceratophyllum demersum*, *Hydrocharis morsus-ranae*, *Sparganium erectum* ssp. *neglectum*, *Potamogeton pectinatus* and *Myriophyllum spicatum* (Table 1).

In the Figure 2(c), the life form of this union and the results of the evaluations showing the frequency of occurrence of the types in the sample areas are given. In the phytocenology structure of this association, in which hydrophytes, therophytes and hemicryptophytes participate, species with very different frequency of occurrence according to the sample areas were encountered, and it was concluded that this was related to the chemical composition of the soil and water environment in which the association spread.

5. *Typhetum angustifolia* Pignatti 1953.

Kur-Araz plain, Samur-Davaçi and Alazan-Eyriçay valleys and Naxçıvan are swampy and water depth is 0-100(150) cm, lay cover is between 60-100%, cover size is 200-250(300) cm, taxon number is 2 - It is encountered in the form of units ranging from 9 to 9. In the flora of the association: *Potamogeton perfoliatus*, *Schoenoplectus lacustris*, *Sch. litoralis*, *Lemna minor*, *Butomus umbellata*, *Nymphaea alba*, *Sparganium erectum* ssp. *erectum*, etc. The species participate in the phytocenological structure of the association (Table 1).

In the Figure 2(d), the life form of this union and the results of the evaluations showing the frequency of occurrence of the types in the

sample areas are given. In the phytocenological structure of this association, in which hydrophytes and hemicryptophytes participated, species with very different frequency of occurrence were encountered according to the sample areas, and it was concluded that this was related to the chemical composition of the soil and water environment in which the association spread.

6. *Typhetum latifoliae* (Soo 1927) Lang 1943.

Samur-Deveci plain, Kür-Araz plain, Bozdağ swamps and places around the canal, where the water depth is 10-50 cm, the cover level varies between 60-100%, the cover structure is 150 cm, the number of taxa is 3-8. and basically; Taxa *Potamogeton pectinatus*, *Schoenoplectus*

lagustris, *Ceratophyllum demersum*, *Hydrocharis morsus-ranae*, *Lythrum salicaria*, *Ludwigia palustris*, *Polygonum amphibium*, *Paspalum paspaloides* are encountered (Table 1).

In the Figure 2(e) the life form of this association and the frequency of occurrence of its types in the sample areas are shown. In this association hydrophytes and hemicryptophytes participate in general. In the phytocenology, species with very different frequency of occurrence according to sample areas are encountered, the reason being chemical composition of the land and water environment in which the union spreads.

has been reached.

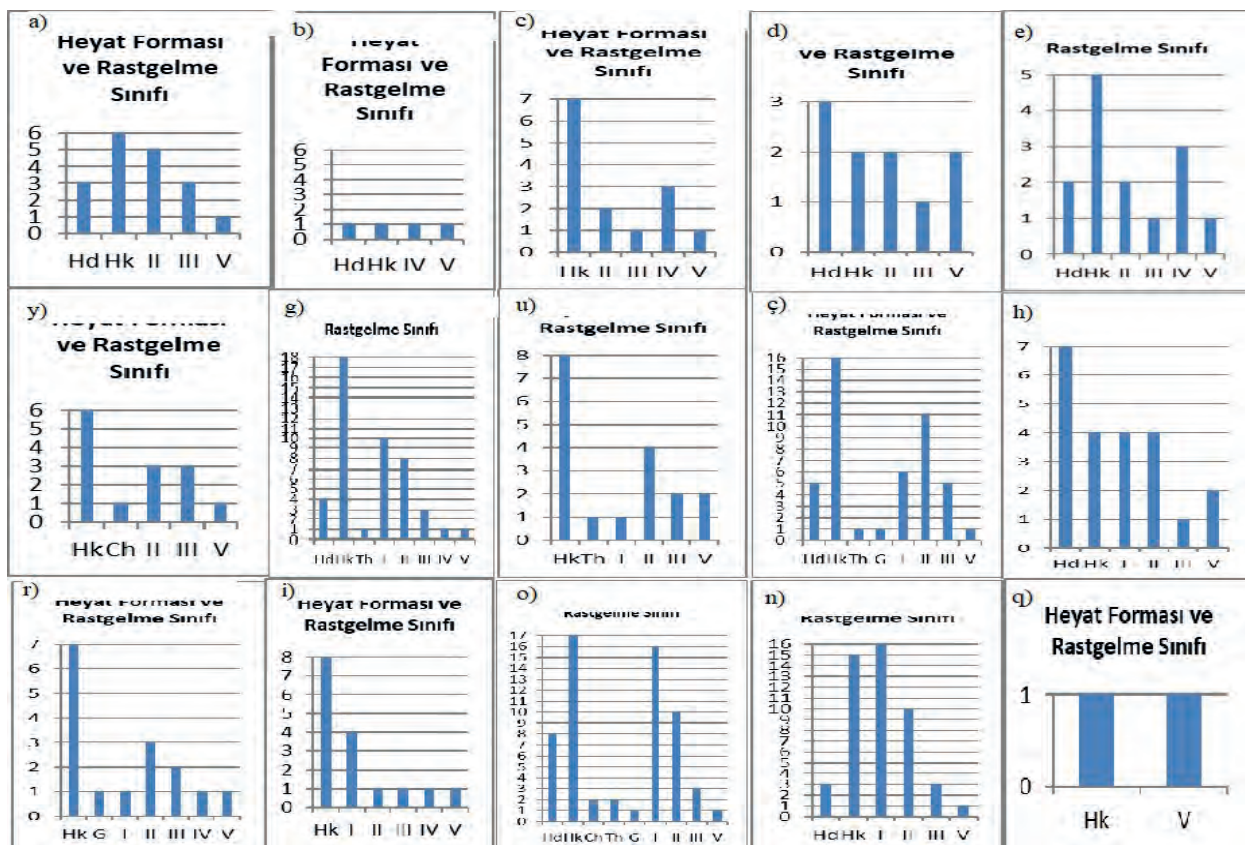


Figure 3. Evaluation of taxa participating in the phytosociological structure of some coastal swamp plant associations according to life forms and occurrence classes: a. *Typhetum latifoliae*, b. *Potamogeton-Typhetum angustifolia*, c. *Scirpetum lacustris*, d. *Potamogeton-Schoenoplectetum litoralis*, e. *Butomo-Helecharitetum vulgaris*, f. *Schoenetum lacustris*, g. *Scirpetum silvatici*, h. *Triglochino-Bolboschoenetum seagull*, i. *Sparganietum poluedrum*, j. *Caricetum dilutae*, k. *Caricetum vesicarie*, l. *Typhetum angustifoliae*, m. *Schoenoplectetum litoralis*, n. *Calamagrostisetum epigejosae*

In the Figure 3(a), the life form of this union and the results of the evaluations showing the

frequency of occurrence of the types in the sample areas are given.

In the phytocenological structure of this association, where hydrophytes and hemicryptophytes participate and which is deprived in terms of flora, species with very different frequency of occurrence according to the sample areas were encountered, and it was concluded that this is related to the chemical composition of the soil and water environment in which the association spreads. It was determined in places where the water depth is 100-25 cm. The degree of cover in the above water area is 100%, in the part submerged it is 5-30%, and the cover height is 200-400 cm. *Potamogeton pectinatus*, *Thypha domingensis*, as well as *Myriophyllum*

pectinatus and *M. spicatum* were encountered.

7. *Scirpetum lacustris* Schamale 1939.

In the mountainous parts of the Lankaran plain, Kur-Araz plain, Samur-Davachi, Qobustan, Absheron, Naxchivan, in swampy areas, in places with a water depth of 0-50 (100) cm, the degree of cover is between 40-10%, cover size 100-200 cm. It is a plant association that varies between. With the dominant species in its flora; *Vallisneria spiralis*, *Potamogeton perfoliatus*, *Myriophyllum spicatum*, *Phragmites communis*, *Paspalum paspaloides*, *Potamogeton pectinatus*, *Ceratophyllum demersum*, species are included (Table 2).

Table 2.

Phytocenological characteristics of the *Potamogetono-Typhetum angustifolia* ass. nova, *Scirpetum lacustris* Schamale 1939, *Potamogeto-Schoenoplectetum litoralis* Vural, Duman et.al.1994, *Butomo-Helecharitetum vulgaris* ass. nova, *Schoenetum lacustris* ass. nova, *Scirpetum silvatici* ass.nova, *Triglochino-Bolboschoetum maritime* Behçet 1994, *Sparganietum poluedrum* ass. nova, *Butometum umbellati* (Konczak 1968) Phillippi 1973, *Caricetum dilutae* ass. nova, *Caricetum vesicarie* Br-Bl.et Denis 1926, *Typhetum angustifoliae* Pignatti 1953, *Potamogeto-Schoenoplectetum litoralis* Vural Duman et. Al. 1994, *Calamagrostisetum epigejosae* ass.nova, *Hippurisetum vulgarisae* ass.nova associations.

Sample area No	201	202	203	204	205	206	207	208	209	210	Life form	Occurrence class
Field width (m2)	8	8	8	10	10	10	4	4	10	10		
Altitude (m)	80	90	100	100	120	200	250	250	300	300		
Inclination (%)	5	7	6	7	7	5	5	7	8	8		
Weed height (cm)	80	110	120	80	90	90	85	70	120	120		
Soil type	B	B	B	B	B	B	B	B	B	B		
Number of species	4	3	3	3	6	4	5	8	3	3		
Covering degree %	75	70	85	80	80	80	75	70	85	75		
Character taxa of the association												
<i>Potamogeton pectinatus</i>	33	33	44	33	33	11	33	33	44	33	Hd	V
<i>Thypha angustifolia</i>	22	11	.	+	11	+1	11	+	.	+	Hk	IV
Sample area No	712	713	714	715	716	717	718	719	720	721		
<i>Bolboscheanus maritimus</i>	11	33	33	32	11	33	44	44	34	33	Hk	V
<i>Triglochin maritima</i>	22	+1	+1	11	+1	+1	+	+1	11	+1	Hk	V
Sample area No	722	723	724	725	726	727	728	729	730	731		
<i>Sparganium polyedrum</i>	22	12	11	22	33	23	23	11	22	22	Hk	V

<i>Puccinellia distans</i>	+1	+1	-	-	-	+1	11	+1	-	-	Hk	III
Sample area No	732	733	734	735	736	737	738	739	740	741		
<i>Butomus umbellatus</i>	11	12	11	+1	+	11	12	11	22	+1	Hk	V
<i>Potamogeton perfoliatus</i>	22	11	22	33	33	+1	+1	22	11	12	Hd	V
Sample area No	742	743	744	745	746	747	748	749	750	751		
<i>Carex diluta</i>	33	33	22	22	12	11	33	23	23	22	Hk	V
<i>Juncus articulatus</i>	+1	-	11	+1	+	11	-	-	+1	11	Hk	IV
Sample area No	231	232	233	234	235	236	237	238	239	240		
<i>Carex vesicaria</i>	33	22	33	33	22	11	11	33	33	22	Hk	V
<i>Juncus effusus</i>	+1	+	.	.	+1	11	11	.	.	11	Hk	III
Sample area No	42	43	44	45	46	47	48	49	50	51		
<i>Thypha angustifolia</i>	33	22	32	44	32	22	33	44	34	33	Hk	V
<i>Potamogeton trichoides</i>	+	-	-	-	+	+1	+1	-	-	-	Hd	II
Sample area No	251	252	253	254	255	256	257	258	259	260		
<i>Schoenoplectus littoralis</i>	44	44	33	33	32	34	11	33	22	33	Hk	V
<i>Potamogeton pectinatus</i>	.	.	.	.	+	.	+1	+	+	.	Hk	III
Sample area No	321	322	323	324	325	326	327	328	329	330		
<i>Calamogrestis epigeos</i>	44	44	44	44	44	44	44	44	44	44	Hk	V
<i>Lythrum salicaria</i>	-	+	-	+	-	-	+	-	-	+	Hk	II
Sample area No	311	312	313	314	315	316	317	318	319	320		
<i>Hippurus vulgaris</i>	44	44	44	33	34	34	34	34	44	44	Hk	V
<i>Potamogeton luceus</i>	+	+	+	+	+	+	+	+	+	+	Hd	V
Accompanying taxa												
<i>Polygonum amphibium</i>	+	.	+	.	+	+	.	+	.	.	Hk	III
<i>Paspalum paspaloides</i>	.	.	.	+	.	.	+	.	.	+	Hk	II

In the Figure 3(b), the life form of this union and the results of the evaluations showing the frequency of occurrence of the types in the sample areas are given. In the phytocenological structure of this association in which hemicryptophytes participate, species with very different frequency of occurrence according to the sample areas were encountered, and it was concluded that this was related to the chemical composition of the edaphic-hydroecological

environment in which the association spread.

8. *Potamogeto- Schoenoplectetum littoralis* Vural, Duman et.al.1994

Water depth varies between 100-350 cm, cover for above-water plants is 70-80%, cover degree of the submerged part is 20%, cover height varies between 200-250 cm. Among the above-water plants, *Schoenoplectus littoralis*, submerged plants: *Potamogeton pectinatus* and *Myriophyllum spicatum* show their species

frequency of occurrence of the types in the sample areas are given. In the phytocenological structure of this association, in which therophytes and hemicryptophytes participated, species with very different frequency of occurrence were encountered according to the sample areas, and it was concluded that this was related to the chemical composition of the soil and water environment in which the association spread.

13. *Sparganietum poluedrum* ass. nova

This union is mainly located in the Kur-Araz plain, Kur plain, and Lankaran plain of Azerbaijan, and rarely in the swamps and lake edges up to the mountains and central mountain range, water depth: 0-100 cm, cover degree between 50-100%, cover height. It is a unit of 50-100 cm, the number of which varies between 2-8. Flora: *Puccinellia distans*, *Phragmites communis*, *Typha latifolia*, *Agrostis stolonifera*, *Schoenoplectus lacustris*, *Plantago maritima*, *Typha angustifolia*, *Hippuris vulgaris* are more common (Table 2).

In the Figure 3(p), the life form of this union and the results of the evaluations showing the frequency of occurrence of the types in the sample areas are given. In the phytocenological structure of this association, in which therophytes and hemicryptophytes participated, species with very different frequency of occurrence were encountered according to the sample areas, and it was concluded that this was related to the chemical composition of the soil and water environment in which the association spread.

14. *Butometum umbellati* (Konczak 1968) Phillippi 1973.

This union includes the Samur-Devechi and Kur-Araz plains of Azerbaijan, Kur plain, Lankaran and Naxchivan plains with water depths of 0-70(100) cm, cover degree of 50-80(100)%, cover density of (20)70-100 (20%). 150) sm, type number (1) varies between 2-6. Flora: *Potamogeton perfoliatus*, *Trapa hyrcana*, *Valisneria spiralis*, *Ceratophyllum demersum*, *Myriophyllum verticillatum*, *Ceratophyllum submersum*, *Ranunculus trychophyllus*, *Alisma plantago-aquatica*, *Polygonum amphibium*, *Bolboschoenus moritimus* etc. types are

included (Table 2).

In the Figure 3(y), the life form of this union and the results of the evaluations showing the frequency of occurrence of the types in the sample areas are given. In the phytocenological structure of this association, in which hydrophytes and hemicryptophytes participated, species with very different frequency of occurrence were encountered according to the sample areas, and it was concluded that this was related to the chemical composition of the soil and water environment in which the association spread.

15. *Caricetum dilutae* ass. nova

All over Azerbaijan, from the plain to the middle mountain range, in swamps, swampy areas, on the edges of streams, water channels and water channels, and sometimes in flattened swamps, water depth is 10-50 (60) cm, cover degree is 70-90%, cover density is 50-60 cm. The number of taxa is between 3 and 10 and it coexists with the dominant plant species: *Juncus articulatus*, *Menyanthes trifoliata*, *Orchis palustris*, *Ranunculus repens*, *Valeriana officinalis*, *Oenanthe fistulosa*, *Phragmites communis* species are included in the phytocenology structure of the association as subsidiary species (Table 2).

In the Figure 3(i), the life form of this union and the results of the evaluations showing the frequency of occurrence of the types in the sample areas are given. In the phytocenological structure of this association, in which geophytes and hemicryptophytes participated, species with very different frequency of occurrence were encountered according to the sample areas, and it was concluded that this was related to the chemical composition of the soil and water environment in which the association spread.

16. *Caricetum vesicariae* Br.-Ch. et Denis 1926

Swampy and water depth 0-20 cm, cover degree 6-100%, cover size 30-100 cm, number of taxa varying between 3-6, flora: *Juncus effusus*, *Epilobium anatolicum*, *Cirsium arvense* subsp. *arvense* is an association in which the species *Alopecurus arundinaceae*, *Menyanthes trifoliata*, *Carex pseudocyperus* and *Rumex*

hydrolophatum participate (Table 2).

In the Figure 3(j), the life form of this union and the results of the evaluations showing the frequency of occurrence of the types in the sample areas are given. In the phytocenological structure of this association, whose flora includes only hemicryptophytes, species with very different frequency of occurrence according to the sample areas were encountered, and it was concluded that this was related to the chemical composition of the soil and water environment in which the association spread.

17. *Typhetum angustifoliae* Pignatti 1953

This union can be found in the coastal areas of the Khezer coast of Azerbaijan, in the Kur-Araz plain, in the Mil, Mughan and Shirvan plains, in marshy areas in the regular parts of Bozdag, in places close to the sea coast, and around the water channels. In particular, the flora of the association varies between 0-50 cm, water depth 60-90 (100) %, cover size (80) 100-150 (200) cm, taxon number (1) 2-11: *Potamogeton trichoides*, *Ceratophyllum demersum*, *Myriophyllum spicatum*, *Urticularia australis*, *Lemna minor*, *Salvinia natans*, *Oenanthe aquatica*, *Spirodela polyrhiza* and *Polygonum persicaria* (Table 2).

In the Figure 3(k), the life form of this union and the results of the evaluations showing the frequency of occurrence of the types in the sample areas are given. In the phytocenology structure of this association, which belongs to various life forms (hydrophyte, xamophyte, therophyte, geophyte) and consists mostly of hemicryptophytes, species with very different frequency of occurrence according to the sample areas were encountered, and this is related to the chemical composition of the soil and water environment in which the association spreads. It has been concluded.

18. *Potamogeto-Schoenoplectetum litoralis* Vural Duman et. Al. 1994

It is a plant association with water depth varying between (5) 10-50 (100) cm, cover degree varying between 60-90 (100) %, cover size

varying between 60-150 (250) cm, and taxon number varying between (2)3-10. Flora: *Potamogeton peetinatus*, *Nymphaea alba*, *Trapa hyrcana*, *Myriophyllum spicatum*, *Ceratophyllum demersum*, *Mentha aquatica*, *Najas marina*, *Eleocharis microcarpa* species such as are encountered (Table 2).

In the Figure 3 (g) the life form of this union and the results of the evaluations showing the frequency of occurrence of the types in the sample areas are given. In the phytocenological structure of this association, in which hydrophytes and hemicryptophytes participated, species with very different frequency of occurrence were encountered according to the sample areas, and it was concluded that this was related to the chemical composition of the soil and water environment in which the association spread.

19. *Calamagrostisetum epigejosae* ass. nova.

This association is found in flat and plain areas of our country, and in seaside areas where grunt water is on the surface. In places where the water depth is 150-200 (250) cm, it is a monodominant unit with a cover varying between 50-100% and a cover structure varying between 120-200 cm (Table 2).

In the Figure 3(s), the life form of this union and the results of the evaluations showing the frequency of occurrence of the types in the sample areas are given. The phytocenology structure of this association, in which hemicryptophytes participate, is simple and monodominant, indicating that it is an association that does not vary according to sample areas, has a very dense population and a high frequency of occurrence, and has a simple structure where no other participating neurons are encountered due to the pressure of the dominant species.

20. *Hippurisetum vulgarisae* ass. nova.

It is an association with a water level of 30-50 cm, a cover level of 50% and a cover size of 15 cm, and the dominant species in its flora are *Potamogeton lucens* and *P. pectinatus* (Table 2).

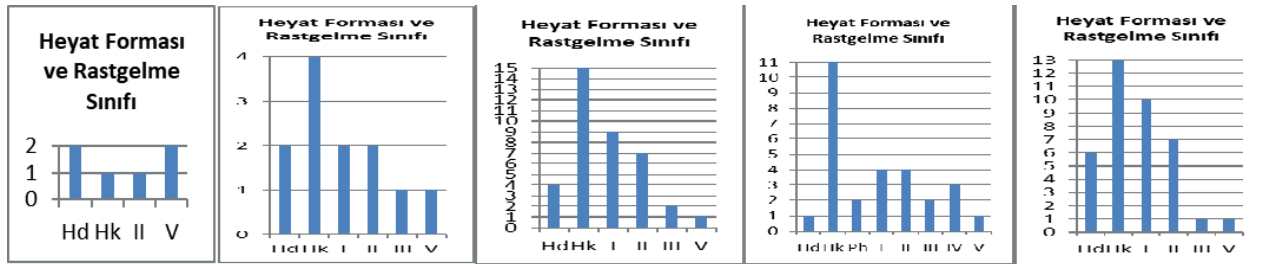


Figure 4. Evaluation of taxa participating in the phytosociological structure of some coastal water-swamp plant associations according to life forms and coincidence class: a. *Hippuris setum vulgarisae*, b. *Caricetum ripariae* c. *Cyperetum pseudocyperae*, d. *Heleocharetum iupalustrisi*, e. *Heleocharetum euuniglumisi*

Figure 4(a) shows the life form of this union and the evaluation results showing the frequency of occurrence of its types in the sample areas. In the phytocenological structure of this association, in which hydrophytes and hemicryptophytes participated, species with very different frequency of occurrence were encountered according to the sample areas, and it was concluded that this was related to the chemical

composition of the soil and water environment in which the association spread.

21. *Caricetum riparia* ass. nova.

Its flora has a water depth of 5-50 cm, a cover level of 70-100%, and a cover height of 30-120 cm. *Potamogeton lucens*, *Urticularia australis*, *Bolboschoenus maritimus*, *Polygonum amphibium*, *Calamagrostis epigejos* species are the participating association (Table 3).

Table 3.

Phytocenological characteristics of the *Caricetum ripariae* ass. nova, *Cyperetum pseudocyperae* ass.nova, *Heleocharetum iupalustrisi* ass.nova, *Heleocharetum euuniglumisi* ass.nova, associations.

Sample area No	221	222	223	224	225	226	227	228	229	230	Life form	Occurrence class
Field width (m2)	4	4	4	8	8	8	16	16	8	8		
Altitude (m)	1100	1100	1250	1270	1300	1350	1390	1450	1450	1420		
Inclination (%)	5	5	5	5	5	5	5	4	4	4		
Weed height (cm)	C*	C	CQ*	Q*	Q	CQ	CQ	ŞQ*	ŞQ	Q		
Soil type	55	70	65	65	70	50	55	60	70	65		
Number of species	ÇB	ÇB	ÇB	ÇB	BÇ	BÇ	BÇ	ÇB	ÇB	ÇB		
Covering degree %	2	3	4	2	2	2	2	3	2	4		
Sample area No	85	80	80	85	90	90	85	80	85	80		
Character taxa of the association												
<i>Carex riparia</i>	43	33	33	34	44	44	43	33	34	33	Hk	V
<i>Potamogeton lecons</i>	.	+	+	.	.	.	.	+	.	+	Hd	II
Sample area No	341	342	343	344	345	346	347	348	349	350		
<i>Cyperus pseudocyperus</i>	11	33	32	22	11	11	+	33	33	33	Hk	V
<i>Carex vesicaria</i>	+1	.	.	+1	11	+1	11	+	.	+	Hk	IV
Sample area No	341	342	343	344	345	346	347	348	349	350		
<i>Heleocharis iupalustris</i>	11	+1	11	22	33	33	32	32	23	23	Hk	V
<i>Rorippa prostrata</i>	.	11	11	+1	.	.	+1	.	.	+	Hk	III
Sample area No	341	342	343	344	345	346	347	348	349	350		

<i>Heleocharis euuniglumis</i>	33	33	32	22	23	34	33	11	32	33	Hk	V
<i>Polygonum amphibulum</i>	+	.	.	+1	+1	.	.	+1	+	.	Hk	III
Accompanying taxa												
<i>Urticularia australis</i>	.	.	+	.	+	.	.	.	.	.	Hd	I
<i>Bulboschoenus maritimus</i>	+	+	.	+	.	+	.	.	+	+	Hk	III
<i>Polygonum amphibium</i>	.	.	+	.	.	.	+	+	.	.	Hk	II
<i>Calamagrostis epigeios</i>	.	.	.	.	.	.	.	.	.	+	Hk	I
C*- swamp, Q* west, CQ* south west, SQ* north west												

In the Figure 4(b), the life form and the results of the evaluations are shown together with the frequency of occurrence in the sample area. The phytocenological structure of this association includes hydrophytes and hemicryptophytes, species with very different frequency of occurrence are encountered according to the sample areas, which is related to the chemical composition of the soil and water environment in which the association spreads.

20. *Cyperetum pseudocyperae* ass. nova

The water depth here is 0-20 cm, cover degree is 60-100 percent, cover size is 50-100 cm, number of taxa varies between 1-6. Major ones are; *Carex vesicaria*, *Rumex hydrolaphatum*, *Lythrum salicaria*, *Myriophyllum spicatum*, *Typha angustifolia*, *Schoenoplectus lacustris*, *Spartanium erectum* ssp. *erectum*, *Alisma plantago-aquatica*, *Juncus articulatus*, *Mentha aquatica*, *Paspalum paspaloides*, *Salix triandra*, *S. alb* (Table 3).

In the Figure 4(c), the life form of this union and the results of the evaluations showing the frequency of occurrence of the types in the sample areas are given. It was concluded that in the phytocenological structure of this association, in which phanerophytes, hydrophytes and hemicryptophytes participated, species with very different frequency of occurrence were encountered according to the sample areas, and that this was related to the chemical composition of the soil and water environment in which the association spread.

23. *Heleocharetum iupalustrisi* ass. nova.

Water depth varies between 0-50 cm, cover degree 60-100%, cover size 30-50(100) cm, taxon number varies between 4-7 and it is found in lake shores and swamps all over Azerbaijan. In its phytocenological structure; *Rorippa sylvestris*, *Paspalum paspaloides*, *Polygonum amphibium*, *Butomus umbellatus*, *Bolboschoenus maritimus*, *Alopecurus aequalis*, *Carex elata*, *Schoenoplectus littoralis*, *Typha angustifolia*, *Ceratophyllum demersum*, *Myriophyllum spicatum*, *Nasturtium*, *Agrostis gigantea*, *Triglochin maritima*, *Juncus gerardi*, *Alisma plantago-aquatica* some taxa participates (Table 3).

In the Figure 4(d), the life form of this union and the results of the evaluations showing the frequency of occurrence of the types in the sample areas are given. It has been concluded that in the phytocenological structure of this association, in which hydrophytes and hemicryptophytes participate, species with very different frequency of occurrence are encountered according to the sample areas, and that this is related to the chemical composition of the soil and water environment in which the association spreads.

24. *Helocaretum euuniglumisi* ass. nova.

Its flora varies between 0-50 cm, water depth 80-100%, cover size 40-50 cm; Participation of species *Polygonum amphibium*, *Rorippa amphibia*, *Potamogeton trichoides*, *Ranunculus sanicifolius*, *Elatine altinstrum*, *Alopecurus aequalis*, *Potamogeton lucens*, *P. natans*, *P. Perfoliatus*. It is found in the mountainous areas

of Deveci, Qobustan, Lenkeran, Kur-Araz plain, Naxçıvan (Table 3).

In the Figure 4(e), the life form of this union and the results of the evaluations show the frequency of occurrence of the types in the sample areas. In the phytocenological structure of this association, we come across hydrophytes and hemicryptophytes, species with very different frequency of occurrence are encountered according to the sample areas, which is due to the chemical composition of the soil and water environment in which the association spreads.

Discussion and Conclusion

The water-swamp vegetation has been and is being investigated globally. It is generally classified floristically and phytosociologically at the community level (Dubnya, 2006; Rivaz-Martinez, Gonzales, et al., 2001; Mucina L, Bültmann H, et al., 2016). In Türkiye, wetlands (Behçet, 1994a, 1994b; Behçet Altan 1994; Seçmen and Leblebici, 1996), saline wetlands (Aydoğdu et al., 2002; Hamzaoğlu and Aksoy, 2009) and flooded areas have been studied at length. Some phytosociological studies have been carried out by Kutbay et al., (1998). In the wetlands of Türkiye, a total of 23 plant associations are reported to be distributed in water, 31 in the coastal meadows, 7 in wet meadows, 1 in wetland tree communities, and 21 are saline associations (Seçmen and Leblebici, 1996).

Yucel et al., (2010) have examined the heavy metal biomonitoring features of the *Myriophyllum spicatum* plants, distributed alongside the Porsuk River in Eskişehir-Türkiye. Ocakverdi et al., (2009) have noted that water-swamp associations are common in the vegetation of Kısır Mountain, which are spreading from the inner streams to the alpine zone. Some of these associations can be found in the water marsh plant

associations of the high mountainous regions of Azerbaijan. In the research conducted by Korkmaz et al. (2012) in Golardi Wildlife Protection Area in Samsun Province; a syntaxonomic evaluation of dune, saline and forest type vegetation has been done. Following their syntaxonomic classifications, it was determined that the water-swamp vegetation of Azerbaijan consists of a total of 95 plant associations, including 12 classes, 16 orders, 26 alliances. It has also been determined that there are 24 plant associations according to the phytosociological characteristics of the vegetation diversity of coastal water-swamp habitats: *Phragmitetum communis* (Gams 1927) Schmale 1939, *Typho angustifoliae-Phragmitetum communis* R. Tx Preis. 1942, *Scirpo-Phragmitetum communis* W. Koch 1926, *Typhetum angustifolia* Pignatti 1953, *Typhetum latifoliae* (Soo 1927) Lang 1973, *Potamogeton-Typhetum domingensis* Vural Duman et al. 1994, *Scipetum lacustris* Schmale 1939, *Potamogeton-Schoenoplectetum litoralis* Vural Duman et al., 1994. *Butomo- Eleocharitetum palustris* Golub et al. 1991, *Scirpetum seagull* Beeft 1957, *Triglochino-Bolboschoenetum seagull* Behçet 1948, *Butometum umbellati* (Konczak 1968) Phillippi 1973, *Caricetum vasicariae* Br. Bl. et Denis 1926, *Caricetum dilutae* ass. Nova, *Cladio-Schoenetum lacustris* ass. Nova, *Sparganietum poluedrum* ass. Nova, *Typhetum angustifoliae* ass. nova, *Schoenoplectetum litoralis* ass. Nova, *Calamagrostisetum epigejosae* ass. Nova, *Hippurisetum vulgarisae* ass. Nova, *Caricetum ripariae* ass. Nova, *Cyperetum pseudocyperae* ass. Nova, *Heleocharitetum iupalustris* ass. Nova, *Heleocharitetum euuniglumisi* ass. nova. 13 of these plant association have already been published in the literature, and 11 of them are; They are newly defined associations for the coastal water marsh habitats of Azerbaijan.

References

- Aliyev, C. (1969). Flora i Rastitelnost vodoyomov Azerbaydjana i ich khozyaystvennaya znachenie. Avtoref. Dis dokt. Biol. Nauk., Baku, 52.
- Atamov V. (2008). Phytosociological Characteristics the Vegetation of the Caspian's Shores in Azerbaijan. International Journal of Botany, 4(1), 1-13.
- Atamov V. & Musayev M. (2017). Azərbaycan'ın Sucul Vejetasyonunun Coğrafi Özellikleri. Biyoloji Bilimleri Araştırma Dergisi, 10(1), 37-43.
- Atamov V., Musayev M. & Cabbarov M. (2017). Aquatic Forest Plant Associations of Azerbaijan.

- Journal of Anatolian Environmental and Animal Sciences, 2(2), 23-28.
- Aydoğdu M., Hamzaoglu E. & Kurt L. (2002). Nev halophytic syntaxa from Central Anatolia (Turkey). Israel Journal of Plant Science, 50, 313-323.
- Babayev F. (1974). Flora i rastitelnost gornich ozer Makogo Kavkaza-Avtoref. diss. Kand biol. Nauk., Baku, 31.
- Behçet L. (1994a). Van Gölü Makrofit Vegetasyonunun fitososyolojik Yönden Araştırılması. Turkish Journal of Botany, 18, 229-243.
- Behçet L. (1994b). Erçek, Turna ve Bostaniçi (Van) Göllerinin Vegetasyonu. Turkish Journal of Botany, 18, 305-312.
- Behçet L. & Altan Y. (1994). Van, Erçek, Turna ve Bostaniçi Göllerinin Sucul Florası. Tr. J. of Botany, 18(2), 91-98.
- Braun-Blanquet J. (1964). Pflanzensoziologie Grundzüge der Vegetationskunde. Springer Verlag, Wien and New York.
- Efendiyeva Ş. (1989). Vodno-bolotnaya flora i rastitelnost Apşeronskogo prilegayuşich poluoostrova i ostrovov-Avtoref.dis.kand biol. nauk. Baku, 22.
- Karyagin I. (1961). Flora Azerbaydjana (1950-1961) Iz vo AN Az.SSR, Baku, t. 1-8.
- Gadjiev V., Mailov A., Atamov V. & Ponomarenko L. (1991). Resursı Phragmites australis (Cav.) i Arundo donax L. Vi Azerbaydjane. Rastitelnıe resursı, 27 (3), 42-47.
- Gurbanov, E., & Aslanova, S. (2024). AVERAGE ANNUAL PRODUCTİVİTY OF THE THYMUSETA-VİCAETUM-FESTUCOSUM FORMATION, DİSTRİBUTED İN SUMMER PASTURE FIELD NO. 8" TURKESOBAN"(AZERBAİJAN). Norwegian Journal of Development of the International Science, 126.
- Gurbanov E., Huseynova H. (2019). Map of botanical - geographical zoning of the Caspian coast in the territory of the Republic of Azerbaijan (scale 1:600000), Baku.
- Gurbanov, E., Ibragimov, S., & Huseynova, K. (2022). Plant ecological research for the bioremediation from pollution by oil and oil products in Absheron Peninsula (Azerbaijan). Bulletin of Science and Practice.
- Gurbanov, E., & Ibrahimov, S. (2023). Vegetation Classification Of Oil-Contaminated Soils In Azerbaijan. ACTA Botanica Caucasica, 2(1), 3-8.
- Gurbanov, E., Huseynova, H. Z., & Ibrahimov, Sh. I. (2020). Methods for determining soil contamination by oil and petroleum products and indicator plants in the north of Caspian Sea. International Journal of Agriculture and Biological Sciences, 4, 84–89.
- Gurbanov, E., & Rzaeva, A. A. (2017). Biomorphological Analysis and Identification of Subspecies of Juniperus communis in Azerbaijan. Asian Journal of Plant Science and Research, 7(3), 14-6.
- Gurbanov, E., & Rzaeva, A. (2022). Evaluation of decorative properties of some coniferous plants introduced to Absheron Peninsula. Acta Botanica Caucasica, 1(2), 3–7.
- Dubyna D. V (2006). Higher aquatic vegetation. Kiev, 412.
- Grossgeym, A. A. (1948). Rastitelnıy pokrov Kavkaza. İzd-vo MPİP, Moskov, 51-59.
- Hassanpanah, D., Gurbanov, E., Gadimov, A., & Shahriari, R. (2007). Reduction of nitrate accumulation in potato by use of potassium humate for human safety. Iranian Biomedical Journal, 11(1), 461.
- Hacıyev V. D., Mailov A. I., Atamov V.V & Ponomarenko L. I (1991). Zapası Phragmites australis (Cav.) Trin.ek. Steud. i Arundo donak L. vi Azerbaydjane. J. Rastitelnıy resursı, 3, 42-46. 666
- Hacıyev V. C. (1992). Rastitelnıy pokrov Azerbaydjana. GK geodezii i kartografii Azerb. Respubliki, Baku, 242.
- Hamzaoglu E. & Aksoy A. (2006). Phytosociological Study on the Halophytic Communités of Sultan-sazlığı (Inner Anatolia/Turkey). Ekoloji, 16(60), 8-15.
- Hassanpanah, D., Gurbanov, E., Gadimov, A., & Shahriari, R. (2007). Reduction of nitrate accumulation in potato by use of potassium humate for human safety. Iranian Biomedical Journal, 11(1), 461.

- Hassanpanah D., Gurbanov E., Gadimov A., Shahrairi R. Effect of potassium humate on advanced potato cultivars for water deficit tolerance in Ardabil region, Iran. In: From Molecular Understanding to Innovative Applications of Humic Substances; 2008, vol. 2, pp. 647-650.
- Hirivnak R. (2002). Aquatic plant communities in the catchment area of the Ipeľ river in Slovakia and Hungary. Part II. Classes Potametea. Thaiszia Journal of Botany. Kosice. 12, 137-160.
- Huseynova, H.Z. (2021) The classification of desert and semi-desert vegetation of the Caspian coast (Azerbaijan). Bulletin of Science and Practice 7/11: 43–50. <https://doi.org/10.33619/2414-2948/72/05>
- Huseynova, H. Z. (2023). New distribution areas of some species of plants on the southern part of the Caspian coast. Biosystems Diversity, 31(1), 123–130. <https://doi.org/10.15421/012313>
- Kurbanov, E., Aslanova, S., & Ibragimov, S. (2023). Types of Hole-Meadow and Wetlands Vegetation in Oil-contaminated Soils Siyazan District (Azerbaijan). Bulletin of Science and Practice.
- Ibrahimov E. (2008). Rastitelnost Nachçivanskoy Avtonomnoy Respubliki, produktivnost i botaniko geografičeskiy rayonirovanie. Diss. Dokt. Biol. Nauk., Baku, 437.
- Ismayilova, L., Ahmadov, İ., Gasimov, E., Rzayev, F., Sultanova, J. and Ahmadova, H. Effect of nanoparticles on the Golden Delicious apple flower fertilization process and accumulation in the fruit. Acta Botanica Caucasica, 1(2), 46–56 (2022).
- Korkmaz H., Mumcu U., Alkan S. & Kutbay HG. (2012). A Syntaxonomic Research on Psammophile, Hygrophile and Forest Vegetation of Golardi (Terme/Samsun) Wildlife Reserve. Ekoloji, 21(85), 64-79.
- Musayev M. Q. (2010). Contemporary ecology of the flora and vegetation of the charming water bodies of the Kur-Araz plain, Baku, "Elm", 140.
- Musayef & Atamov, (2020) Phytosociological Features of Aquatic Plant Communities of Azerbaijan Anatolian Environment. and Animal Journal, 2020, 5, No:4, (655-667)
- Mucina L, Bültmann H, Dierßen K, Theurillat JP, Raus T, Čarni A, (2016). Vegetation of Europe: hierarchical floristic classification system of vascular plant, bryophyte, lichen, and algal communities...Applied vegetation science 19, 3-264
- Ocakverdi H., Vural M. & Adıgüzel N. (2009). Vegetation of Kısır Dağı (Kars-Ardahan/Turkey). J. Biological Diversity and Conservation, 2(2), 1 37.
- Prilipko L. I. (1970). Rastitelnyy pokrov Azerbaydjana, Baku. 169. Raunkier, C. 1934. The life forms of plants and statistical plant geography., Oxford, 48-51.
- Rivaz-Martinez S., Gonzales FF., Izco, J., Loidi J., Lousa M. & Penas, A. (2001). Syntaxonomical checklist of vascular Plant communities of Spain and Portugal to association level. Itineta Geobotanica, 14(5), 1-341.
- Seçmen Ö. & Leblebici E. (1996). Türkiye wetland plants and vegetation, Ege University Faculty of Science Publications No:158, 404.
- Şaksuvarov R. T. (1994=). Psammofitnaya rastitelnost pribrejnoy polosı Kaspiyskogo morya (Samur Divicinskaya allyuvialnomorskaya) nizmennost. Avtoref. Dissert. kand. biol. nauk. Baku.
- Talıbov T. & Ibrahimov E. (2008). Taxonomic spectrum of the flora of Nakhchivan Autonomous Republic. Nahçıvan, 350.
- Weber H. E., Moravec J. & Theurillat, J. (2000). Code of phytosociological nomenclature. Journal of Vegetation Science, 11, 739-768.
- Yüce E., Edirnelioğlu E., Soydam S., Çelik S. & Çolak G. (2010). Myriophyllum spicatum (Spiked water-milfoil) as a biomonitor of heavy metal pollution in Porsuk Stream/Turkey. J. of Biological Diversity and Conservation, 3(2), 133-144.

**A NEW NATURAL HYBRID *CAMPANULA* x *KUSADASIENSIS* (CAMPANULACEAE)
FROM WESTERN ANATOLIA, TURKIYE**

Emine Alcitepe^{1*} Orcid ID: |0000-0003-2569-3598

Fergan Karaer² Orcid ID: |0000-0003-3781-2128

¹Manisa Celal Bayar University, Akhisar Vocational School, Manisa-Türkiye.

²Ondokuz Mayıs University, Faculty of Education, Department of Mathematics & Science, Kurupelit/Samsun, Türkiye.

^{1*}Correspondence: eminealcitepe@yahoo.com

Article Info:

DOI: <https://doi.org/10.30546/abc.2024.3.3.518>

Pages: 59–73

Received: August 28, 2024 | Revised: September 3, 2024 | Accepted: September 28, 2024

Abstract. A newly discovered natural hybrid, *Campanula xkusadasiensis* (Campanulaceae: subgenus *Campanula*, sect. *Quinqueloculares*), from Kuşadası province (Aydın, Turkey) in western Anatolia, is described and illustrated. This hybrid was identified during field studies and conservation projects, distinguishing itself from its parental taxa, *C. lyrata* subsp. *lyrata* and *C. hagielia*, by morphological differences such as its softly hirsute stems, ovate-cordate basal leaves, and infundibular corolla shape. The hybrid's micromorphological characters, including seed coat ornamentation and pollen structure, were analyzed using SEM and compared to its parents. The ecological preferences of *C. xkusadasiensis* indicate a restricted distribution on calcareous rocks within maquis habitats. Its conservation status is assessed as Critically Endangered (CR) due to limited population size, restricted area of occupancy (AOO < 10 km²), and ongoing anthropogenic pressures. This study provides comprehensive data on the hybrid's taxonomy, habitat, micromorphology, and conservation needs, contributing valuable insights into hybridization within *Campanula* and supporting biodiversity preservation efforts in western Anatolia.

Key words: *Campanula*, endemic, hybridization, Anatolia, conservation.

Introduction

The highest diversity in the *Campanula* L. (1753: 163) is found in the mountain ranges of the eastern Mediterranean and the Caucasus area and including approximately 420–450 taxa across a wide range of habitats in the Northern Hemisphere. The *Campanula* taxa are usually perennial herbs to shrubby in some cases, and some of them are annual herbs growing in different habitats such as maquis, forests, woodlands, grasslands. There are many species of *Campanula* which are local or narrow endemics and specialized chasmophytes adapted to the microclimate and edaphic conditions. 160 taxa of the genus are distributed around the Mediterranean Region (Federov, 1957, Fedorov&Kovanda, 1978, Papatsou&Phitos, 1975,

Contandriopoulos, 1984, Runemark&Phitos, 1996, Park et al., 2006, Lammers, 2007a, b, Cano-Maqueda&Talavera, 2011, Khansari et al., 2012, POWO, 2019, Phitos, 2021).

The Anatolian Peninsula is an important centre of diversity of *Campanula* species in Mediterranean Region (MedR) and SW Asia. Damboldt (1978) recorded 95 taxa and 3 imperfectly known and 5 doubtfully recorded taxa and 2 ornamental species *Campanula* from the Flora Türkiye area. According to the available data, there are 139 taxa, 127 species of *Campanula* (including 75 endemics) in Türkiye classified in six subgenera: These are *Campanula* (18 section, 91 taxa, 84 species and 56 endemic), *Rapunculus* (Boiss.) Charadze (three section 21 taxa, 18 species and six endemic), *Megalocalyx*

Damboldt (one section, seven taxa and species, three endemic), *Roucelia* (Dumort.) Damboldt (one section, six taxa and species, three endemic), *Brachycodonia* (Fedorov) Damboldt (one section, two taxa and species, one endemic) and *Sicyodon* (Feer) Damboldt (one section, one taxa and species, one endemic) (Güner, 2000, Alçitepe&Yıldız, 2010, Alçitepe, 2011, İkinci, 2012, Aytaç&Duman, 2013, Yıldırım et al., 2019, Ozdol et al., 2022).

Natural hybridization between species is recognized as an important evolutionary strength and a phenomenal part of sympatric speciation. Hybridization may result in a new species only if the hybrid lineage could be established as viable progenies through vegetative (or clonal) propagation, or allopolyploids events, or other homoploid speciation mechanisms (Arnold, 2004, Celep et al., 2020). Interspecific hybridisation creates new phenotypes within several ornamental plant species including the *Campanula* due to their characteristics such as easy adaptation to the environment, showy flowers, and long flowering vegetation period. In the ornamental plants industry, hybridization between species is mostly used as a method to increase genetic diversity (Abbott et al., 2013, Röper et al., 2012, 2015, Phitos, 2016).

Although hybrid species are not common in nature in *Campanula* members, there are some exceptions. Several hybrid species have reported by Nyman (1999), mainly in the *Heterophylla* sect. (Kovanda, 1977, 1999, Roquet et al., 2008). However, no hybrids have been recorded among *Campanula* species in the sect. *Quinqueloculares* (Boiss.) Phitos in Turkey.

The *C. x kusadasiensis* Alçitepe & Karaer was discovered during field studies of “Project titled the morphological, anatomical, and palynological study of the sect. *Quinqueloculares* (*Campanula*) in Turkey (Alçitepe, 2005), and “Bell flowers (*C. tomentosa* Lam. and *C. vardariana* Bocquet) Species Conservation Action Plan (SCAP) Project”. Some of the collected specimens, which are only found in the Kuşadası and Samsun Mountain have been identified under the section *Quinqueloculares* due to differences in stem length, basal leaf lamina, pedicel, corolla shape, anthers position, and calyx appendages.

In this paper, we aim to describe and illustrate the new natural hybrid species with notes on its micromorphology and taxonomy and provide data on habitat, and conservation status.

Materials and Methods

During 2004, 2005 and 2020 many flowering and fruiting specimens of *Campanula* was collected from Aydın province in Turkey and stored in the herbarium of Alçitepe and OMUB. We reviewed and consulted the descriptions and identification keys of the Flora of Turkey (Damboldt, 1978, Güner, 2000) and the flora closely related to the Flora of Turkey (Dimopoulos et al., 2020, Aghabeigi, 2010, Ghazanfar&Edmondson, 2013, Fedorov, 1957).

The morphological characters of studied specimens were examined by a binocular stereoscopic microscope. Pollen and seed coat morphology were studied with light microscopy (LM) and scanning electron microscopy (SEM). The Wodehouse technique was applied for pollen in LM studies (Erdtman, 1966). The micrographs of SEM photos were taken with a Zeiss Gemini 500 device at the Celal Bayar University-Applied Science Research Centre, Manisa and were taken with JEOL JMS 5200 device at the Laboratory of the Faculty of Dentistry of Ege University, Izmir. In this study, for palynological studies the terminology of Punt et al. (1994) and seed surface morphology, the terminology of Stearn (1978) and Barthlott (1981) were used. Photographs of living material were taken with a Nikon D300 digital camera. After identifying the samples, it was searched in articles collected from the flora of Turkey and Western and Southern Anatolia and determined as new taxa (Damboldt, 1978, Duman, 1999, Alçitepe &Yıldız, 2010, Alçitepe, 2011, Aytaç&Duman, 2013, Yıldırım&Şenol, 2014, Yıldırım 2013, 2018).

Specimens were compared with many specimens of potentially related species in EGE, GAZI, HUB, ISTE, ISTF and UPA. Type photographs of the parental species were obtained from the B, G and LD herbaria. We used the geographical range of the new species in the form of the extent of occurrence (EOO) and area of occupancy (AOO) to categorize the threat status using

the GeoCAT tool (IUCN, 2016, Bachman et al., 2011).

Results

Taxonomic treatment

Campanula x kusadasiensis E. Alcitepe & F. Karaer nothosp. nov. (*Campanula lyrata* Lam. subsp. *lyrata* x *Campanula hagielia* Boiss.) (Figure 1-6)

Type: — TURKEY. B1 Aydın: Kuşadası, Dilek Peninsula-Büyük Menderes Delta National Park, 1. Genderma land, Dipburun area, rocky places, and in maquis, 07. 05. 2020, 30 m, E. Alçitepe 3245 (holotype OMUB! isotype Alcitepe!).

Biennial or perennials, slightly softly hirsute and pubescent. **Stems** erect or flexuous or ascending, 36-77 cm with thick scaly and much irregularly branched from base. 10-15 leafy, slightly puberulent conspicuous nerved. **Basal leaves**, ovate-cordate to cordate, crenate-serrate, 3.8-7 x 2.6-6 cm with long unequally lobulated, conspicuous reticulate-pinnate nerved, petiole 6.5-16.5 cm. Lower cauline leaves 3.5-5 x 2.5-3.5 cm (excluding petiole) sub similar to basal, often ovate-cordate to sub lyrate with long unequally lobulate petiole; upper cauline leaves, oblong lanceolate, 2.5-7.5 x 1-3 cm, irregularly dentate-serrate, smaller and narrower,

sessile. **Inflorescence** in racemes or lax panicles; bracts shorter than calyx, hispid. **Flowers** erect, pedicellate (3-15 mm). **Calyx** lobe 3.0-5.0 x 1.5-4.0 mm, pubescence, narrowly triangular-lanceolate to lanceolate, softly hirsute margin, slightly recurved, less than to more than ½ length of corolla tube, appendage, ovate, softly long hirsute, wholly concealing ovary. **Corolla** violet-blue, cylindrical to narrowly infundibular, 13-34 mm long slightly short, tube 12-30 x 6-11 mm, pubescent outside. **Stamens** (6-) 7-12 mm, filiform part of filament, base oblong-elliptic, shorter than style. Pistil 14-28 mm, stigmas 5, ovary 5-locular. **Capsule** 5-8 x 4-8 mm, hemispherical, erect. **Seeds** 0.5-0.63 x 0.26-0.35 mm, glabrous, flattened, oblong to elliptic or lanceolate, light brown, shiny.

Diagnosis: *C. x kusadasiensis* is similar to *C. lyrata* subsp. *lyrata* and *C. hagielia*. Boiss. It is distinguished from *C. lyrata* subsp. *lyrata* by its the softly hirsute plumage condition and the ovate-cordate to orbicular-cordate shape of the base leaves. It is a cylindrical to narrowly infundibular corolla shape and from both species by the narrowly triangular-lanceolate to lanceolate shape of the calyx lobe and the acuminate (Table 1).

Table 1

Comparison of diagnostic characters of *C. x kusadasicum* and related taxa

Characters	<i>C. x kusadasicum</i>	<i>C. lyrata</i> subsp. <i>lyrata</i>	<i>C. hagielia</i>
Habit	Erect, flexuous or ascending, much irregularly branched	1-many-stemmed or ascending with main robust stem, erect	1-many-stemmed erect or flexuous, irregularly branched
Stem	Softly hirsute and pubescent	Scabrid, sub hispid	Softly hirsute or pubescent
Stem length(cm)	59.8±14.02(36-77)	37.36±15.07 (15-88)	66.61±17.69 (35-70)
Basal leaves	Ovate-cordate to orbicular-cordate, with long unequally lobulated petiole, crenate, serrate margin	Lyrate, oblong-ovate long lobulate petiolate, serrate, crenate margin	Cordate-ovate, cordate, sub lyrate with long lobulate-petiolate, crenate-serrate margin
Basal leaf lamina (cm)	W:4.08±0.95 (2.6-6)	2.42±0.5 (1.3-4)	3.05±0.79 (2-5)
	L:5.12±1.07 (3.8-7)	3.13±0.72 (2-4.5)	8.69±4.07 (2.5-10)
Petiole(cm)	10.7±2.9 (6.5-16.5)	7.81±1.70 (2-12)	7.48±3.04 (3.5-14)

Lower cauline leaves	Sub similar to basal often ovate-cordate to sub lyrate	Lanceolate to linear	Similar to basal
Pedicel (mm)	6.88±3.59 (3-15)	12.07±5.43 (2.5-22)	11.03±13.39 (2-52)
Calyx lobe	Narrowly triangular-lanceolate to lanceolate, softly hirsute margined,	Narrowly triangular	Ovate-lanceolate,
Calyx lobe (mm)	W :3.94±0.74 (1.5-3)	W :3.58±1.26 (2-6)	5.21±1.76 (4-7)
	L :11.18±2.7 (8-17)	L :9.75±1.5 (3-15)	10.53±2.3 (6-16)
Calyx lobe/ Corolla tube	As long as or longer than corolla tube	to ½ or 1/3 as long as	Less than to more than ½ length of corolla tube
Calyx appendage	Ovate, densely softly hirsute	Ovate, densely and roughly hirsute or subhispid	Ovate, densely softly hirsute
Calyx appendage(mm)	W :2.65±0.7 (1.5-4)	W :2.65±0.98 (1.5-5)	W :2.06±0.32 (1.5-4)
	L : 3.94±0.74 (3-5)	L :3.89±0.84 (2.0-6.0)	L :4.63±1.02 (3-7)
Corolla	Cylindrical to narrowly infundibular	Cylindrical to narrowly infundibular	Broadly cylindrical to infundibular
Corolla (mm)	21.7±7 (13-34)	24.7±4.28 (10-36)	21.21±3.81(16-35)
	W :8±1.61 (6-11)	W :5.41±0.86 (4-12)	W :9.71±2.14 (6-14)
	L :21.5±6.8 (12-30)	L :18.9±2.33 (5-28)	L :16.12±3.16 (11-30)
Stamen (mm)	8.5±1.87 (6-12)	7.76±0.83 (5.5-11)	10.4±1.96 (7-14)
Pistil (mm)	9.15±2.47 (14-28)	20.21±2.33 (13-33)	14.52±2.67(13.5-27)
Capsule	Densely and stiffly hair	densely and stiffly hair	densely and softly hair
Capsule(mm)	5-8x4-8	5-13x4-12	6-13x5-12

Etymology: — The epithet of the new taxon refers to the type locality in the province of Aydın-Kuşadası, Turkey. The Turkish name of this species is given as “Kuşadası çanı”, according to the guidelines of Menemen et al. (2013).



Figure 1. Holotypus of *C. x kusadasiensis* Alcritepe & Karaer (Alcritepe-3245)

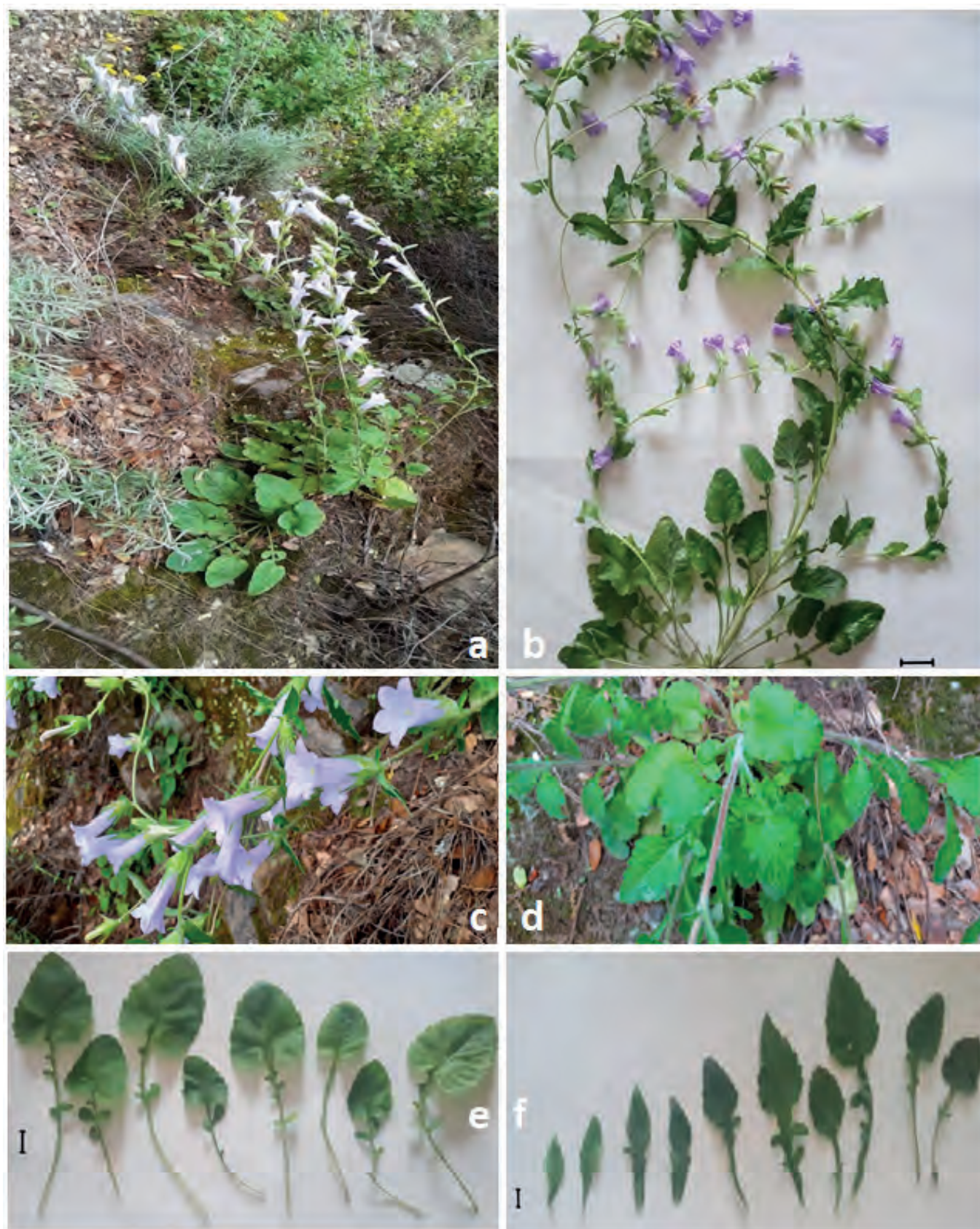


Figure 2. *C. x kusadasiensis* at the flowering stage in the type locality. (a) Natural habitat; (b) Flowering specimen (scale bar = 3 cm); (c) Flowers; (d) Basal leaves in the natural habitat; (e) Basal leaves (scale bar = 2 cm); (f) Petiolate lower cauline leaves and sessile upper leaves (scale bar = 1 cm). Photos by E. Alçitepe.

Distribution, habitat, phenology and ecology: —*C. x kusadasiensis* is known Aydın, Kuşadası and Samsun Mountain and grows in the MedR (Aegean) of Turkey, therefore it is a West Med (W. Med.) floristic region element. From the ancestral species *C. lyrata* subsp. *lyrata* wide distribution in the W. Black Sea region, Marmara, Aegean and Mediterranean regions. *C. hagielia* has local distribution only in Aegean region (Muğla, Aydın) and Eastern Aegean

islands. The life cycles for both species are more or less close to each other. Therefore, the hybrid new species may be present in other areas where the presumed parental species are sympatric in the W. Anatolia region of Turkey. The new hybrid grows on calcareous rocks in open maquis and to 20-30 m mostly with the exceptions of 600 m and obligate rupicola's plant (Figure 2,3).

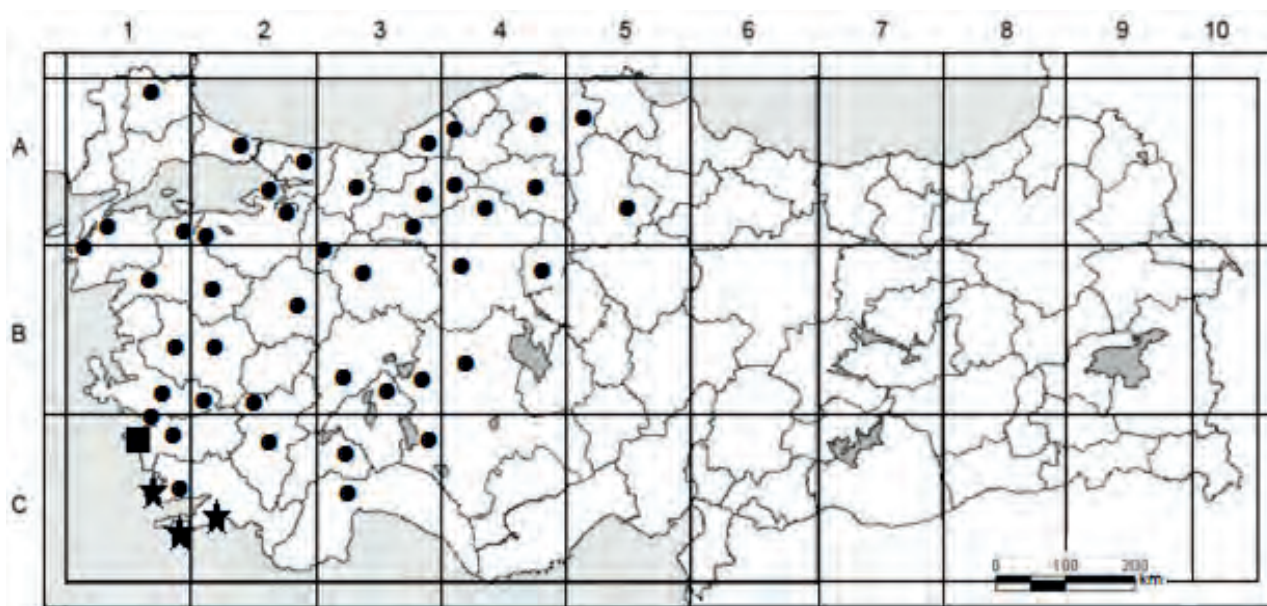


Figure 3. Distribution area of *C. lyrata* subsp. *lyrata* (●), *C. hagielia* (★), *C. x kusadasiensis* (■) (Davis' Grid System)

While flowering periods of this natural hybrid species were observed in April-May from early June, its fruiting periods have been observed from late June to early July. Associated species at the type locality include: **Alyssum hirsutum* Bieb. var. *caespitosum* Dudley (LC), *A. sibiricum* Willd., **Iberis carica* Bornm. (LC), *Fumaria petteri* Reichb. subsp. *thuretii*, (Boiss.) Pugsley, *Ranunculus muricatus* L., **Arenaria luschanii* McNeill (VU), **Dianthus lydus* Boiss. (LC), **Silene splendens* Boiss. (VU), *Velezia quadridentata* Sibth. & Sm, *Erodium malacoides* (L.) L'Her., *Hypericum perfoliatum* L., *Lathyrus aphaca* L. var. *pseudoaphaca* (Boiss.) P.H. Davis, *L. grandiflorus* Sibth. & Sm., *Bupleurium gracile* d'Urv., **Campanula lyrata* subsp. *lyrata*, **Helichrysum heywoodianum* P.H. Davis (CR), **C. tomentosa* (VU), *Nonea obtusifolia* (Willd.) DC., *Samolus valerandi* L, **Origanum sipyleum*

L. (LC), *Micromeria juliana* (L.) Benth. ex Rchb., **Cyclamen mirabile* Hildebr. (EN) and *Muscari neglectum* Guss. Ex Ten., Taxa denoted here by an asterisk are endemic to Turkey.

Conservation status: — A new taxon endemic to Turkey. It is distributed from south and southwest of Kuşadası to Mount Samsun in the southwest of Aydın. The population of *C. x kusadasiensis* was calculated as occupying an area. Its AOO is estimated to be less than 10 km², and EOO is approximately less than 1,2 km². It is known from two disjunct localities from Kuşadası and Samsun Mountain and subpopulations isolated from one another. Total number of individuals is estimated to be less than 1100 and anthropogenic or grazing effects were observed on the population. Because it is a recently discovered species, studies to explore its range were carried out. But the species was not

observed in other sites with appropriate soil and climate characteristics. Following the criteria laid out by the IUCN (2016), the new taxon is categorized as 'Critically endangered-CR' (criteria B2 ab (i, iii), on account of its restricted distribution, habitat quality, number of mature individuals.

Paratypes: — TURKEY. B1 Aydın: Kuşadası, Dilek Peninsula-Büyük Menderes Delta National Park, 1. Genderma land, Dipburun Area, rocky places, in maquis, c. 20-30 m, 03. 05. 2003, *E. Alçıtepe* 3245a! ibid, area near the national park entrance, in maquis, 20-30 m, 05.05. 2003, *E. Alçıtepe* 2151! ibid, slopes of Nero Bay, calcareous rocks, c.70-100 m, 07.05. 2003, *E. Alçıtepe* 3261! Aydın: Samsun Mountain, rocky places, 50-100 m, 03.05. 2003, *E. Alçıtepe* 2147! Samsun Mountain, Tekçam, c. 600 m, 29.05.1969, *N. Başaran*, *M. Çetindağ* 16855 EGE! Büyük Kalamaki, Uzunoluk, Sarıkaya vicinity, c. 150 m, 28.04.1974, *E. Leblebici*, *Ö. Seçmen*, *A. Yürül* 12793 EGE!

Additional specimens examined: — *C. lyrata* subsp. *lyrata*: *C. lyrata* subsp. *lyrata*: A1 Balıkesir: Balıkesir–Marmara Island, 550m, 14.05.1968, F. Öktem 1072, Çanakkale: Çanakkale–Eceabat, 350m, Sarger 63-73 EGE! Kırklareli: Demirköy Forest, 21km from Poyralı, 06.10.1966, A. Baytop 10455, ISTE! A2 Balıkesir: Balıkesir-Susurluk highway, opposite Varan facilities, maquis, 200m, 10.5.2004, *E. Alçıtepe* 2250! Bursa: Uludağ, Aras-Soğukpınar Road, 16.5.1944, Heillbornn 2887, ISTF! İstanbul: Belgrad Forests, Balls 2396; Burgaz Island, 30.04.1950, Berk 2924, ISTE! Kocaeli: Dil hills, 19.05.1959, A. Baytop 5340, ISTE! Yalova: Termal, Southern, 20.06.1971, A. Baytop 20583, ISTE! A3 Ankara: Beypazarı, Aladağ Valley, 700m, 26.5.1971, Y. Akman, 8482, ANK! Bolu: Yedigöller road 10km after Bolu, 900m, K. Alpınar 59450, ISTE! Sakarya: Geyve Boğazi Bağlarbaşı Village, 10.06.1972, A. Baytop 22363, ISTE! Zonguldak: Göbü, İstasyon district, 50m, 23.06.1984, M. Demirors 1199, ANK! A4 Ankara: Cankaya, 28.05.1935, Balls 2354; ANK! Kızılcahamam, *P. nigra* forest, 7.7.1953, Huber-Murath, Birand, & Zohary 3341, ANK!, Bolu: Gerede-Aktaş Forest, 1600m, 3.7.1975, O. Ketenoğlu 419, ANK! Çankırı: Atakaracalar, Dumanlı

Mountain, Abaza Stream location, stream side, 1350-1450m, 5.7.1991, A. Duran 1308, GAZI! Kastamonu: Ilgaz District, Ilgaz Mountains, *Q. pubescens* community, 1300m, 15.6.1982, Akman, Yurdakulol & Demirors 12085, ANK! Zonguldak: between Kozlu and Zonguldak, roadside, 80m, 5.5.1951, H. Demiriz 10968, ISTF! A5 Çorum: Kargı, Ada Mountain, around Avşar village, *P. brutia* forest, 500-600m, 30.5.1976, M. Kılınç 2713, EGE! Kastamonu: Tosya, Seki village, 1000-1200m, 18.6.1975, M. Kilinc 1052, ANK! B1 Balıkesir: Edremit, in olives, 08.05.1966, H. Peşmen 832, EGE! Kazdağı, Koşara and church area, 1100m, 17.10.1970, F. Öktem 18786, ISTE! Çanakkale: Assos, stony slopes, 50-60m, 19.5.2002, *E. Alçıtepe* 2110! Troy, open spaces, 50 m, 20.5.2002, *E. Alçıtepe* 2111! İzmir: Yamanlar Mountain, 800-900m, 15.05.2002, *E. Alçıtepe* 2109! Bergama, Kozak-Kıranlı village, roadside, 10.7.2004, *E. Alçıtepe* 2278! Tire, maquis, 50-100 m, 22.5.2002, *E. Alçıtepe* 2112! Manisa: Gediz 4.6.1955, Walter 58, B Photo! Soma Madenci Çeşmesi, roadside, 600m, 12.5.1977, Seçmen & Görk 17151, EGE! B2 Balıkesir: Mount Sındırgı, east of Kertil Park, *P. brutia*, 350m, 5.6.1972, Oflaz, Oğuz, Seçmen & Leblebici 10209, EGE! Denizli: Denizli-Buldan, Hub. -Mur. 5363; İzmir: Ödemiş-Bozdağ, around Mermeroluk, 1350 m, 16.6.1972, Leblebici 10059, EGE! Kütahya: Between Simav-Sındırgı, 47km from Simav to Sındırgı, Pinmurt locality, 400 m, 5.6.1972, Seçmen, Oğuz, Oflaz & Leblebici 16885, EGE! Manisa: Salihli-Bozdağ road, next to the Yayla restaurant, 900 m, 10.5.1975, Seçmen, Öztürk & Kesercioğlu 23941, EGE! B3 Afyon: Dazkırı, north of Sarıkavak village, steppe, 1030m, 18.6.1984, Z. Aytaç 1316, GAZI! Bilecik: Between Bozüyük and İnönü, Beet field edge, 750m, 01.06.1973, A. Baytop 25187, ISTE! Eskişehir: Sündiken Mountain, above Alpagut, 350m, 3.6.1971, T. Ekim 362, ANK! Isparta: Gelendost, 22.05.1966, Regel, Peşmen & Oğuz 185, EGE! Konya: Akşehir Sultan mountains, Çobankaya, 1000-1100 m, 26.04.1974, G. Dökmeçi 28462, ISTE! B4 Ankara: Dikmen Creek, Romieuy 5992; ad Angora Galatiae (Elmadagh), Bornmüller 1892, B. Photo! Konya: Loras Mountain, Southern, 1900 m, 12.5.1989, Tatlı, Eyce, & Serin 9038, KNYA! C1 Aydın: Kuşadası slope,

rocky ridges, 09.04.1971, F. Öktem 19134, ISTE! Didim road, 10.04.1971, F. Öktem 19211, ISTE! İzmir: Selçuk, Belevi Fire Area, 23.04.1970, Oflas 5516, EGE! Ephesus Ruins, 31.05.1972, A. Baytop 22804 ISTE! Muğla: Bodrum Mountain, Gulluk 50m, D. 40926! Bodrum, mt. E of Karatoprak, garigue, 16.4.1972, H. Runemark & P. Wendelbo 72, LD-Foto! Datça Peninsula, 7-8 km NW of the town of Datça, Limestone 20.4.1972, H. Runemark & P. Wendelbo 146, LD Foto! Milas, Beçin Castle, 275m, 15.5.2004, E. Alçitepe 2260! C2 Denizli: Honaz Mountain, Baymanlı Stream Side, 1400m, 14.06.1963, A. Baytop 25661 ISTE! Muğla: Silsiluk mach Yatağan in maquis, in vor Çine, 12.6.1955, Walter 377, B Photo! Derekoy-Marmaris, 10m, 26.3.1956, Davis et Polunin 25402, ANK! Köyceğiz, Kaunos ruins, maquis northern slope, calcareous land, 15-200 m, 8.5.2003 E. Alçitepe 2377! C3 Antalya: Elmalı, Gümüş district, C. libani forest, 1300m, 13.05.1973, R. Çetik 2211, ANK! Burdur: Burdur-Antalya Road, 33 km from Antalya before, *Arbutus-Quercus* community, 25.05.1966, A. Baytop 9557, ISTE! Isparta: Dedegöl Mountain, 1400m, Sorger 65-43-22; Konya: Beyşehir-Kurucuova, Musallaaltı locality, southeast slope, valley ridges, 1400m, 15.06.1980, M. Serin 661, KNYA! C4 Karaman: Around Kazancı District, 900-1100m, 19.6.1983, H. Sümbül 26268, HUB! Konya: Taşkent, stony slopes, 1200-1300 m, 22.6.2002, E. Alçitepe 2120!

C. hagielia — (Turkey). C1 Muğla: Reşadiye to Cumali, 300m, D. 41229! Datça Peninsula, 7-8 km NW of the town of Datça Limestone, 20.04. 1972, H. Runemark & Wendelbo 145 LD Foto! between Milas to Bafa lake, rocky places, 370 m, 04.05.2003, E. Alçitepe 2144! C2 Muğla: Bozburun, 50-100 m, Dudley (D. 35483!); Fethiye, Hisarönü, Belceğiz, 1450 m, 11.05.1967, Peşmen, Oğuz, & Leblebici 4903 EGE! Marmaris, Datça road, 23.05.1969, K. Walter 16853 EGE! Between Muğla to Çine, rocky places, 03.05.1979, Seçmen, Leblebici & Bekat 17463, EGE! Turgutbayır, on road, 120m, 19.05.1982, A. Çirpıcı 25150 ISTF! Dalyan, Kaunos kalkmauern im archaologischen ansgrabungsgelände, 20 m. NN, 06.04. 1992, TH. Raus 17793B Foto! Ibid. 90-100 m, 08.05. 2003, E. Alçitepe 2135! Kaunos road, in maquis, c. 100 m, 08 .05.2003,

E. Alçitepe 2136! Ortaca, Dalyan, Bozburun Tepesi, Kargıcak Bay, maquis, calcareous land, 0-50 m, 14.04.1992, Güner, Duman & Dönmez 26099 HUB! Between Muğla to Gökova, on road, calcareous rocks, 300m, 23.04.1978, A. Baytop, 39070 ISTE! ibid. c.350 m, 04.04.2003, E. Alçitepe 2145! ibid. 670m, 16.05.2004, E. Alçitepe 2253! Köyceğiz to Kaunos road, in maquis, cliffs, 50-100 m, 08.05.2003, E. Alçitepe 2136! Muğla to Köyceğiz road, calcareous rocks, 375m, 16.05.2004, E. Alçitepe 2252! between Muğla to Marmaris, Sakar Pass, calcareous rocks, 650 m, 16.05. 2004, E. Alçitepe 2263! – (Greece. East Aegean Islands). Khalki, Gathorne – Hardy 766! Rodos, mt. Filerimo, Bourgeau 109! ibid. 200 m, Snogerup 22120; Mt. Phleremo, A. Carlström 6219 LD Foto! in lapidubus soli Paini in va Rhodos versus, Spelunram sraionum, 06.04.1889, Richden 0126/2003-25 B Foto! de mont Santoz Elio pro Salakos frkosu Bourgeau, 30.05.1990, Feer 7574 G Foto! An Felsen nfube des monte S. Setfano bei Rhodi, 03.05.1938, V. Engelhardt 82 B Foto! Burgberg von Lindos, kalkfels blüte dunkelblau, 100 m, 09.03.1967, J. Et F. Markgraf 0126/2003-28 B Foto, ibid. 21 May 1971, K. Faber 168145 B Foto! Felsen an den Sieben Quellen, 20.05. 1971, K. Faber 158147 B Foto! In sl, Rodhos 1 km E moni kami-ri, Felswand, kalk (100 m. NN), 10.05.1995, R. Jahn 0126/2003-22 B Foto! Ad meridiem porti, 80-120 m, Ad rupes calcareous praeruptas septemtriones cpectantes, 15.04.1974, N. Greuter 11865, UPA!

Discussion

C. x kusadasiensis is included in Sect. *Quinqueloculares*, which includes 13 taxa, 12 species and 10 of which are endemic to Turkey (Damboldt, 1978, Alçitepe&Yıldız, 2010, Alçitepe, 2011, Yıldırım, 2013, 2019). This section is characterised by biennial or perennial, usually monocarpic, stems usually tall. Calyx appendages large, reflexed. Ovary 5-locular, stigmas 5. Capsule opening by 5 basal pores.

The new taxon described here resembles *C. lyrata* subsp. *lyrata* and *C. hagielia* in the same section (Table 1). *C. x kusadasiensis* mainly differs from these related taxa by the softly hirsute plumage condition and the ovate-cordate to orbicular-cordate shape of the base leaves.

The cylindrical to narrowly infundibular corolla shape and from both species by the narrowly triangular-lanceolate to lanceolate shape of the calyx lobe and the acuminate (Figure 4). Pollen properties of *C. x kusadasicum*, *C. lyrata* subsp. *lyrata* and *C. hagielia* are mostly triporate, spheroidal, isopolar and exine tectate (Figure 3). These properties are often observed in *Campanula* species (Erkara et al., 2008). Despite these common characteristics, there are a number of differences between them. *C. x kusadasicum* is smaller than the parents, with a pollen diameter of 21.0 – 23.9 μm and 22.0–30.5 μm in *C. hagielia* and 15.7–25.2 μm in *C. lyrata* subsp. *lyrata*. There are also differences in pore diameter and exine thickness. *C. x kusadasicum*, pore diameter is smaller than the parents with 3.75–5.02 μm and exine thickness is thinner than others with 0.65–0.55 μm . *C. x kusadasicum*, sculpturing pattern of exine was regulate-micro reticulate and micro echinate even it is granulate-scabrate and micro echinate in *C. lyrata* subsp. *lyrata* and *C. hagielia*. *C. x kusadasicum*, the spinules are longer than the others in length (0.25–0.55 μm). Comparing the number of spinules, the number falling to

5 μm^2 is 33–36 in *C. hagielia*; 40–45 in *C. lyrata* subsp. *lyrata*; and is the least with 10 – 21 in *C. x kusadasicum* (Table 2; Figure 5). The seeds of the two species do not differ significantly in colour and shape compared to hybrid individuals. The seeds are oblong to elliptic or lanceolate. Colour is on a scale ranging from light brown to yellowish brown. From the point of view of seed coat ornamentation, both *C. lyrata* subsp. *lyrata* and *C. hagielia* were classified as type II, subtype IIA in the previous study. It is defined as: Type II is characterised by areoles laterally compressed to such a degree that the lumen is essentially linear, giving the seedcoat a faintly striate appearance. The striations are regular and prominent radial walls. *C. lyrata* subsp. *lyrata*'s inner structure of the lumen is striate and *C. hagielia*'s is scabrate. Hybrid individuals also fall into this class (type II) with the seed coat surface, which has a striped appearance with side-printed walls. In fact, *C. x kusadasiensis*, which is closer to *C. hagielia* in terms of the width of the areoles, appears to be striate like *C. lyrata* subsp. *lyrata*, compared to the inner structure of the lumen. (Table 2; Figure 6).

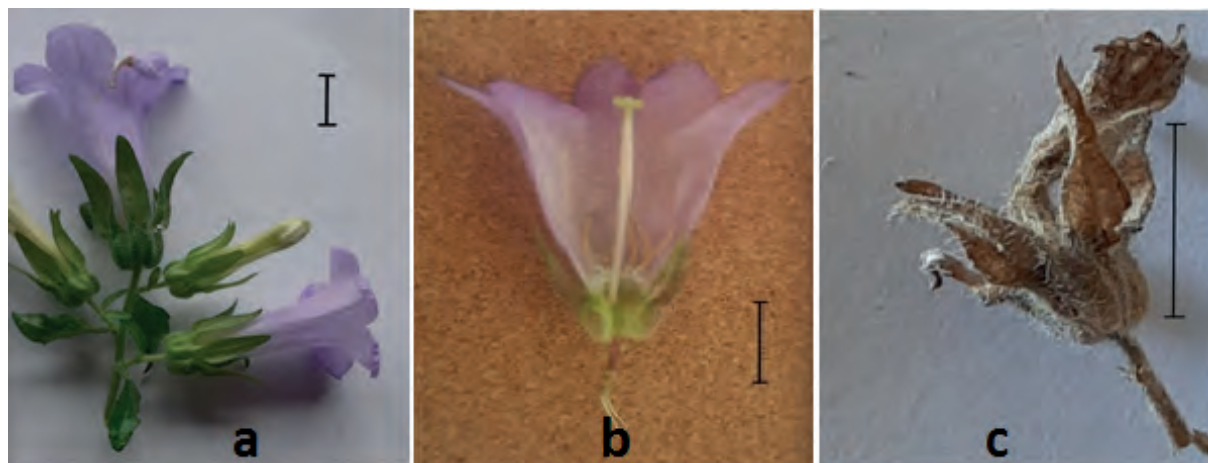


Figure 4. Stereoscopic microscope images of *C. x kusadasiensis* a: Calyx, b: Stylus and stamen, c: capsule (bar 1cm)

Table 2.

Seed and palynological characters *C. lyrata* subsp. *lyrata*, *C. hagielia* and *C. x kusadasiensis*

Characters		<i>C. x kusadasiensis</i>	<i>C. lyrata</i> subsp. <i>lyrata</i> M± S (V)	<i>C. hagielia</i> M± S (V)
Seed (µm)	3 1 8 ± 2 7 . 4 (266-350)	350±50 (300-400)	350±50 (300-400)	360±40 (300-400)
	5 6 8 . 8 3 ± 4 6 (500-633)	620±70 (500-700)	620±70 (500-700)	550±40 (500-600)
	Type-IIa	Type-IIa	Type-IIa	Type-IIa
	Medium	Broad	Broad	Broad
	Striate	Striate	Striate	Scabrate
Pollen (µm)	2 1 . 6 0 ± 1 . 6 3 (15.7-25.2)	22.5±0.92(21.0-23.9)	22.5±0.92(21.0-23.9)	26.26±1.85(22.0-30.5)
Ground sculpture	4.41±0.69(3.1-5.7)	4.33±0.43(3.75-5.02)	4.33±0.43(3.75-5.02)	4.25±0.77(3.1-6.3)
	1.02±0.18(0.7-1.5)	1.00±1.08(0.65-1.1)	1.00±1.08(0.65-1.1)	1.04±0.10(0.7-1.2)
	0.25-0.50	0.25-0.55	0.25-0.55	0.25-0.50
	40-45	10-21	10-21	33-36
	Granulate-scabrate with micro echinate	Regulate with micro echinate	Regulate with micro echinate	Granulate-scabrate with micro echinate

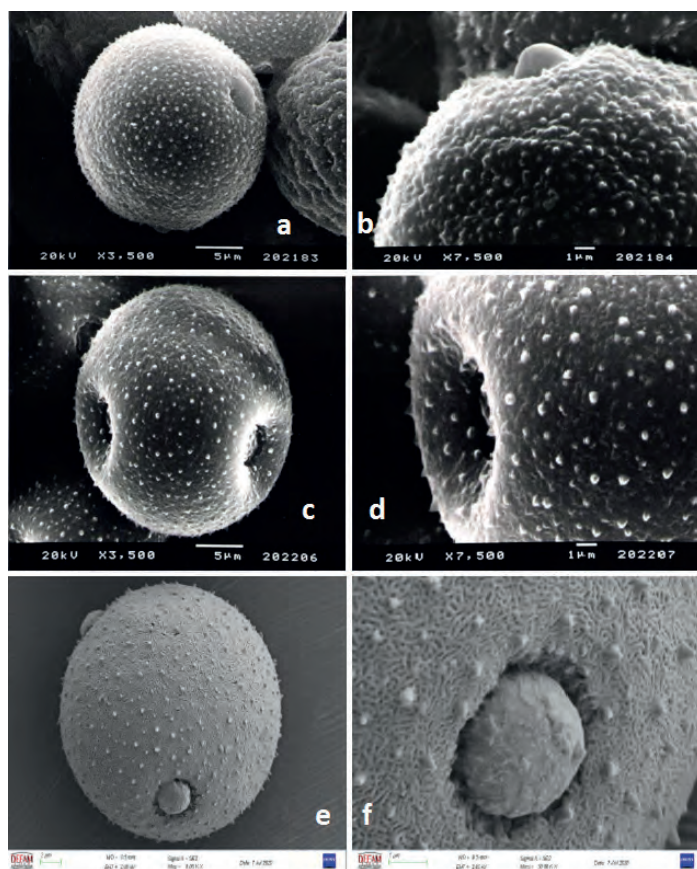


Figure 5. SEM photographs of the pollen structure of a, b: *C. lyrata* subsp. *lyrata* c, d: *C. hagielia* (Alçitepe 2012); e, f: *C. x kusadasiensis*

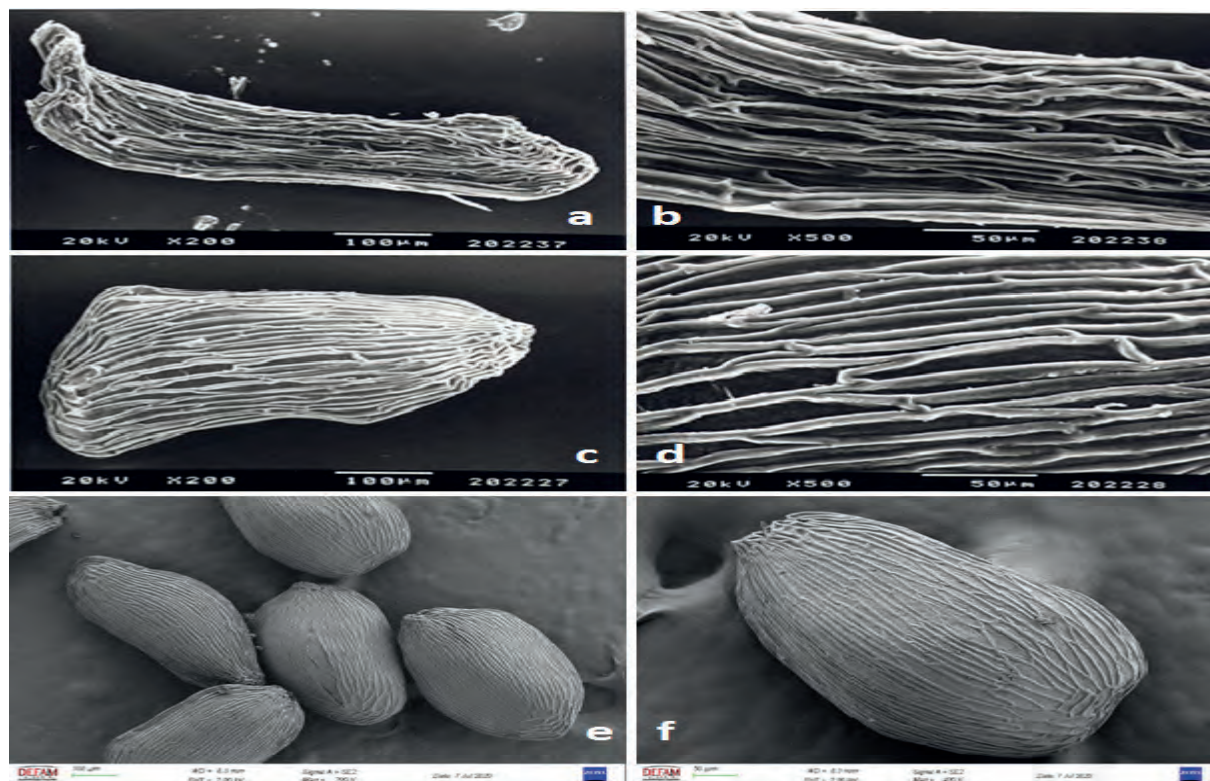


Figure 6. SEM photographs of the seed-coat surface of a, b: *C. lyrata* subsp. *lyrata*; c, d: *C. hagielia* (Alçitepe 2010) and e, f: *C. x kusadasiensis*

Conclusion

In this study, we described and characterized *Campanula x kusadasiensis*, a newly discovered natural hybrid from Kuşadası province in western Anatolia, Türkiye. Morphological, micromorphological, and ecological comparisons revealed its intermediate characteristics between its parental species, *C. lyrata* subsp. *lyrata* and *C. hagielia*. Key diagnostic features include unique calyx morphology, leaf structure, and pollen sculpturing, which distinguish the hybrid from both parental taxa.

The conservation status of *C. x kusadasiensis* has been assessed as critically endangered (CR) based on its limited distribution, restricted habitat, and small population size. Its presence in only two disjunct localities underscores the urgent need for targeted conservation efforts to preserve its habitat and prevent further population decline due to anthropogenic activities.

This discovery highlights the significance of hybridization as an evolutionary process in the genus *Campanula*. Furthermore, the findings contribute to the broader understanding

of biodiversity and endemism in the Mediterranean region, particularly in Türkiye, which serves as a hotspot for *Campanula* diversity. Future studies focusing on genetic analyses and ecological interactions will be critical in understanding the evolutionary dynamics and ensuring the preservation of this unique hybrid species.

Acknowledgements

We are grateful to the “Species Conservation Action Plan Project” that was supported by IV Regional Directorate of the Ministry of Forestry and Water Affairs of the Republic of Türkiye, to Celal Bayar University scientific research Unit which has supported our research (Project Number: 2002/91). Special thanks go to M. İbrahim Çolak (Republic of Türkiye Ministry of Agriculture and Forestry, Regional Manager) and Sıla Gizem Bihter Alçitepe for support in excursion and article reviews. The authors thank the curators of B, EGE, G, GAZI, HUB, ISTE, ISTF, LD and UPA herbaria.

References

- Abbott, R. J., Albach, D., Ansell, S., Arntzen, J. W., Baird, S. J. E., Bierne, N., & Boughman, J. (2013). Hybridization and speciation. *Journal of Evolutionary Biology*, 26(2), 229–246. <https://doi.org/10.1111/jeb.12001>
- Aghabeigi, F. (2010). *Campanula* L. In Assadi, M. et al. (Eds.), *Flora of Iran* (Vol. 66, pp. 5–75). Research Institute of Forests and Rangelands.
- Alçitepe, E. (2005). Türkiye’de yayılış gösteren *Campanula* L. cinsine ait *Quinqueloculares* (Boiss.) Phitos (*Campanulaceae*) seksiyonu türleri üzerinde morfolojik, anatomik ve palinolojik bir çalışma. (Doctoral dissertation). Celal Bayar University, Manisa.
- Alçitepe, E. (2010). Studies on seed morphology of *Campanula* L. Section *Quinqueloculares* (Boiss.) Phitos (*Campanulaceae*) in Turkey. *Pakistan Journal of Botany*, 42(2), 1075–1082.
- Alçitepe, E., & Yıldız, K. (2010). Taxonomy of *Campanula tomentosa* Lam. and *C. vardariana* Bocquet from Turkey. *Turkish Journal of Botany*, 34, 191–200. <https://doi.org/10.3906/bot-0904-64>
- Alçitepe, E. (2011). New combinations in *Campanula* L. Sect. *Quinqueloculares* from Turkey. *Pakistan Journal of Botany*, 43(5), 2243–2254.
- Alçitepe, E. (2012). Comparative pollen morphology of Sect. *Quinqueloculares* (*Campanulaceae*) in Turkey. *Biologia*, 67(5), 875–882. <https://doi.org/10.2478/s11756-012-0087-8>
- Arnold, M. L. (2004). *Natural hybridization and evolution*. Oxford University Press. <https://doi.org/10.1093/oso/9780198503045.001.0001>
- Aytaç, Z., & Duman, H. (2013). A new species and two new records from Turkey. *Turkish Journal of Botany*, 37, 1055–1060. <https://doi.org/10.3906/bot-1211-31>
- Bachman, S., Moat, J., Hill, A. W., de la Torre, J., & Scott, B. (2011). Supporting Red List threat assessment with GeoCAT: Geospatial conservation assessment tool. *ZooKeys*, 150, 117–126. <https://doi.org/10.3897/zookeys.150.2109>
- Barthlott, W. (1981). Epidermal and seed surface characters of plants: Systematic applicability and some evolutionary aspects. *Nordic Journal of Botany*, 1, 345–355. <https://doi.org/10.1111/j.1756-1051.1981.tb00952.x>
- Cano-Maqueda, J., & Talavera, S. (2011). A taxonomic revision of the *Campanula lusitanica* complex (*Campanulaceae*) in the Western Mediterranean region. *Annales Botanici Fennici*, 68, 15–47. <https://doi.org/10.5735/085.048.0204>
- Celep, F., Raders, E., & Drew, B. T. (2020). Two new hybrid species of *Salvia* (*S.* × *karamanensis* and *S.* × *doganii*) from Turkey: Evidence from molecular and morphological studies. *Turkish Journal of Botany*, 44, 647–660. <https://doi.org/10.3906/bot-2003-30>
- Contandriopoulos, J. (1984). Differentiation and evolution of the genus *Campanula* in the Mediterranean region. In Grant, W. F. (Ed.), *Plant biosystematics* (pp. 140–175). Academic Press.
- Damboldt, J. (1978). *Campanula* L. In Davis, P. H. (Ed.), *Flora of Turkey and the East Aegean Islands* (Vol. 6, pp. 2–64). Edinburgh University Press.
- Dimopoulos, P., Raus, T., & Strid, A. (Eds.). (2020). *Flora of Greece web: Vascular plants of Greece. An annotated checklist. Version III*. Retrieved December 20, 2022, from <http://portal.cybertaxonomy.org/flora-greece/>
- Duman, H. (1999). Two new species of *Campanula* L. (*Campanulaceae*) from SW Turkey. *Edinburgh Journal of Botany*, 56(3), 355–360. <https://doi.org/10.1017/S0960428600002068>
- Erdtman, G. (1966). *Pollen morphology and plant taxonomy: Angiosperms*. Hafner Publishing Company.
- Erkara, I. P., Ocak, A., & Pehlivan, S. (2008). Pollen morphology of some Turkish *Campanula* spp. and their taxonomic value. *Bangladesh Journal of Botany*, 37(1), 33–42.
- Fedorov, A. (1957). *Campanula* L. In Komarov, V. L. (Ed.), *Flora of the USSR* (Vol. 24, pp. 126–501). Moscow & Leningrad: Academy of Sciences of the USSR.
- Fedorov, A. A., & Kovanda, M. (1978). *Campanula* L. In Tutin, T. G., Heywood, V. H., Burges, N. A., &

- Valentine, D. H. (Eds.), *Flora Europaea* (Vol. 4, pp. 74–93). Cambridge University Press.
- Ghazanfar, S., & Edmondson, J. (2013). *Flora of Iraq*. Royal Botanic Gardens, Kew.
- Güner, A. (2000). *Campanula* L. In Güner, A., Özhatay, N., Ekim, T., & Başer, K. H. C. (Eds.), *Flora of Turkey and the East Aegean Islands* (Suppl. 2, Vol. 11, pp. 171–175). Edinburgh University Press.
- Gurbanov, E., Ibragimov, S., & Huseynova, K. (2022). Plant ecological research for the bioremediation from pollution by oil and oil products in Absheron Peninsula (Azerbaijan). *Bulletin of Science and Practice*.
- Gurbanov, E., Huseynova, H. Z., & Ibrahimov, Sh. I. (2020). Methods for determining soil contamination by oil and petroleum products and indicator plants in the north of Caspian Sea. *International Journal of Agriculture and Biological Sciences*, 4, 84–89.
- Hassanpanah, D., Gurbanov, E., Gadimov, A., & Shahriari, R. (2007). Reduction of nitrate accumulation in potato by use of potassium humate for human safety. *Iranian Biomedical Journal*, 11(1), 461.
- Kurbanov, E., Aslanova, S., & Ibragimov, S. (2023). Types of Hole-Meadow and Wetlands Vegetation in Oil-contaminated Soils Siyazan District (Azerbaijan). *Bulletin of Science and Practice*.
- İkinci, N. (2012). *Campanula* L. In Güner, A., Aslan, S., Ekim, T., Vural, M., & Babaç, M. T. (Eds.), *Türkiye Bitkileri Listesi (Damarlı Bitkiler)* (pp. 303–311). Istanbul: Nezahat Gökyiğit Botanik Bahçesi ve Flora Araştırmaları Derneği Yayını.
- IUCN. (2016). The IUCN Red List of Threatened Species. Version 2016.1. Retrieved from <http://www.iucnredlist.org>
- Khansari, E., Zarre, S., Alizadeh, K., Attar, F., & Aghabeigi, F. (2012). Pollen morphology of *Campanula* (Campanulaceae) and allied genera in Iran with special focus on its systematic implication. *Flora*, 207(3), 203–211. <https://doi.org/10.1016/j.flora.2012.01.002>
- Kovanda, M. (1977). Polyploidy and variation in the *Campanula rotundifolia* complex. *Folia Geobotanica et Phytotaxonomica*, 12, 23–89.
- Kovanda, M. (1999). *Campanula* x *iserana* (*C. rhomboidalis* x *C. rotundifolia*), a new hybrid in *Campanula*. *Thaiszia. Journal of Botany*, 9, 15–18.
- Lammers, T. G. (2007a). Campanulaceae Jussieu. In Kadereit, J. W., & Jeffrey, C. (Eds.), *The Families and Genera of Vascular Plants* (Vol. 8, pp. 26–57). Springer.
- Lammers, T. G. (2007b). World checklist and bibliography of Campanulaceae. The Royal Botanic Gardens, Kew.
- Menemen, Y., Aytaç, Z., & Kandemir, A. (2013). Türkçe bilimsel bitki adları yönergesi. *Bağbahçe Dergisi*, 47, 28–31. (In Turkish).
- Nyman, Y. (1999). *Campanula occidentalis* (Campanulaceae), a new species from the Canary Islands. *Willdenowia*, 1(2), 113–116. <https://doi.org/10.3372/wi.29.29113>
- Ozdol, T., Altınoğlu, Y., Deniz, I. G., & Yıldırım, H. (2022). A new variety of *Campanula myrtifolia* (Campanulaceae) from South Anatolia, Türkiye. *Herbarium Turcicum*, 1, 37–43.
- Papatsou, S., & Phitos, D. (1975). Two new taxa from eastern Aegean. *Notes from the Royal Botanic Garden Edinburgh*, 34(2), 203–204.
- Park, J., Kovacic, S., Liber, Z., Eddie, W. M. M., & Schneeweiss, G. M. (2006). Phylogeny and biogeography of isophyllous species of *Campanula* (Campanulaceae) in the Mediterranean Area. *Systematic Botany*, 31(4), 862–880. <https://doi.org/10.1600/036364406779695879>
- Phitos, D. (2016). The section *Quinqueloculares* of the genus *Campanula* (Campanulaceae) and its polymorphism. *Taxonomic review of the last decades. Botanika Chronika*, 21, 91–102.
- Phitos, D. (2021). Reinstating *Campanula nisyria* as a distinct species of Sect. *Quinqueloculares* (Campanulaceae). *Flora Mediterranea*, 31, 101–107. <https://doi.org/10.7320/FIMedit31.101>
- POWO. (2019). Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. Retrieved from <http://www.plantsoftheworldonline.org>

- Punt, W., Blackmore, S., Nilsson, S., & Thomas, A. L. (1994). Glossary of pollen and spore terminology. Utrecht: LPP Foundation, Laboratory of Palaeobotany and Palynology, University of Utrecht.
- Röper, A. C., Lütken, H., Hegelund, J. N., Petersen, K. K., Christensen, B., & Müller, R. (2012). Effect of different ovule isolation times on the embryo development of *Campanula* hybrids. *Acta Horticulturae*, 953, 161–166. <https://doi.org/10.17660/ActaHortic.2012.953.18>
- Röper, A. C., Orabi, J., Lütken, H., Christensen, B., Thonning Skou, A. M., & Müller, R. (2015). Phenotypic and genotypic analysis of newly obtained interspecific hybrids in the *Campanula* genus. *PLoS ONE*, 10(9), e0138524. <https://doi.org/10.1371/journal.pone.0138524>
- Roquet, C., Sáez, L., Aldasoro, J., Susanna, A., Alarcón, M. L., & Garcia-Jacas, N. (2008). Natural delimitation, molecular phylogeny, and floral evolution in *Campanula*. *Systematic Botany*, 33(2), 203–217. <https://doi.org/10.1600/036364408784571535>
- Runemark, H., & Phitos, D. (1996). A contribution to the distribution of the genus *Campanula* section *Quinqueloculares* in Greece. *Botanika Chronika*, 12, 5–8.
- Stearn, W. T. (1978). *Botanical Latin* (2nd ed.). David & Charles.
- Yıldırım, H., & Şenol, S. G. (2014). *Campanula alisan-kilincii* (Campanulaceae), a new species from eastern Anatolia, Turkey. *Turkish Journal of Botany*, 38(1), 22–30. <https://doi.org/10.3906/bot-1304-48>
- Yıldırım, H. (2013). *Campanula mugeana* sp. nov. (Campanulaceae) from western Anatolia, Turkey. *Nordic Journal of Botany*, 31(4), 419–425. <https://doi.org/10.1111/j.1756-1051.2012.00002.x>
- Yıldırım, H. (2018). *Campanula leblebicii* (Campanulaceae), a new chasmophyte species from western Turkey. *Phytotaxa*, 376(2), 114–122. <https://doi.org/10.11646/phytotaxa.376.2.2>

PRODUCTION OF DRUG NANOPARTICLES FROM MEDICINAL PLANT EXTRACTS

Ismat Ahmadov^{1*} | ORCID: 0000-0002-3029-3102Kamala Gahramanova² | ORCID: 0009-0007-4047-8729Ziyaddin Mammadov¹ | ORCID: 0000-0001-8009-194X¹Baku State University, Department of Chemical Physics of Nanomaterials, Baku, Azerbaijan²Baku State University, Department of Molecular Biology and Biotechnology, Baku, Azerbaijan^{1*}Correspondence: ismetahmadov@mail.ru

Article Info:

DOI: <https://doi.org/10.30546/abc.2024.3.3.520>

Pages: 74–83

Received: August 20, 2024 | Revised: September 13, 2024 | Accepted: September 28, 2024

Abstract. *Important areas of nanotechnology such as nanodiagnostics, nanopharmacology, nanotransplantation, nanotherapeutics, and nanotherapy are emerging as the most promising medical technologies. Among these, nanopharmacology stands out as the most crucial. Thorough research and regulation of the physicochemical properties of nanoparticles enable their utilization in key medical areas such as therapy, diagnostics, transplantation and tissue culture acquisition, as well as in pharmacology. This will significantly greatly contribute to the advancement of nanomedicine. Therefore, it is essential to further enhance the methods used in preparing nanomedicines, including nanoencapsulation, surface functionalization of nanoparticles, and the production of medicinal nanoparticles through the synthesis of extracts from medicinal plants. While each of these methods offers its own benefits, the primary concern lies in ensuring the effective absorption and biocompatibility of resulting nanoparticles, which are critical properties for medical applications. Nanomedicines obtained through nanoencapsulation, nanoparticle surface functionalization, and drug nanoparticle synthesis will play a pivotal role in addressing significant challenges posed by traditional drugs, optimizing for therapeutic delivery, and navigating the diverse biological barriers present in various patient populations and diseases.*

Key words: *nanotechnology, nano pharmacology, medicinal plants, nano drug, nanoencapsulation, nanoparticle functionalization, green synthesis, drug nanoparticles.*

Introduction

The flora of Azerbaijan is rich in medicinal plants. According to data provided by the Institute of Botany, 1547 species (37%) out of 4500 species of these plants are recognized as medicinal plants. Currently, 1161 types of them are used in folk medicine. 525 species have been tested and proposed as drugs in pharmacology (Miranda, 2021). Among the medicinal plants of our flora, more than 25 species of wild rose and alder have been considered official medicinal plants. Although plants have been used in folk medicine since ancient times, the term medicinal plants was first used in 1967 in the

context of hallucinogenic plant research (Handa et al., 2008). A medicinal plant is a plant whose organs (flowers, leaves, roots, stems, fruits, and seeds) are directly used in the treatment of any disease. Due to the healing properties of medicinal plants, their biodiversity has been preserved by people for centuries until the present day (Kim et al., 2009).

The use of medicinal plants is due to the presence of biologically active molecules with pharmacological properties. These biologically active molecules, called secondary metabolites, alkaloids, glucosides, saponins, vaccines, essential oils, bitter substances, mucus, vitamins,

resins, and phytoncides are present in different amounts depending on the type of plants and the organ from which they are collected (Offord et al., 2002).

Another method of obtaining nanomedicines is the functionalization of synthesized nanoparticles with drugs. Nanoparticles obtained by this method act as drug carriers. Currently, the key to the effectiveness of medicinal preparations is their timely delivery to the target, in a short period and the required dose (Jain, 2008). In traditional treatment methods, the introduction of medicinal substances into the body is mainly done through injection, oral (digestive route), and ointment. Each of these methods faces certain limitations. To overcome these limitations, it is necessary to protect the active substances contained in the drugs, work well with the kinetics of releasing the drug at the right time and place, control it precisely, set the target with high sensitivity and deliver the right dose (Farjadian et al., 2019).

The technology of creating nanomedicines is the most promising technology to overcome these limitations. Nanodrug technology is favorable for the development of drug delivery systems, as it allows precise control over the size, shape, number, volume, direct openings, and surface properties of the drug delivery system

(Rea et al., 2014). Some pre-obtained extracts are used as medicinal substances in the form of tinctures and liquid extracts, but some require further processing. One of these processing procedures is the encapsulation of extracts. In encapsulation, inert biopolymers, including gelatin, are used. The advantage of using gelatin is that the size and molecular structure of the particles obtained during encapsulation significantly increase the effectiveness of the extract (Goldenstedt et al., 2008).

Min Chul Kwona and coworkers (2012) encapsulated the aqueous extract of *Centella asiatica* L. using gelatin. The sizes of the extract capsules they received were even in the nano range. From the results of the experiments, it was clear that the encapsulation efficiency of *Centella asiatica* L. extracts is 70% (Kwon et al., 2012) and also the effectiveness is 50% higher than that obtained by using other encapsulation methods, for example, cellulose double liposomes (Jin et al., 2009). The encapsulation and nanoparticle formation of extracts can primarily reduce the application dose of extracts, prevent cytotoxicity, protect the body from side effects, and ultimately lead to the conservation of plant resources (Jeong et al., 2009).

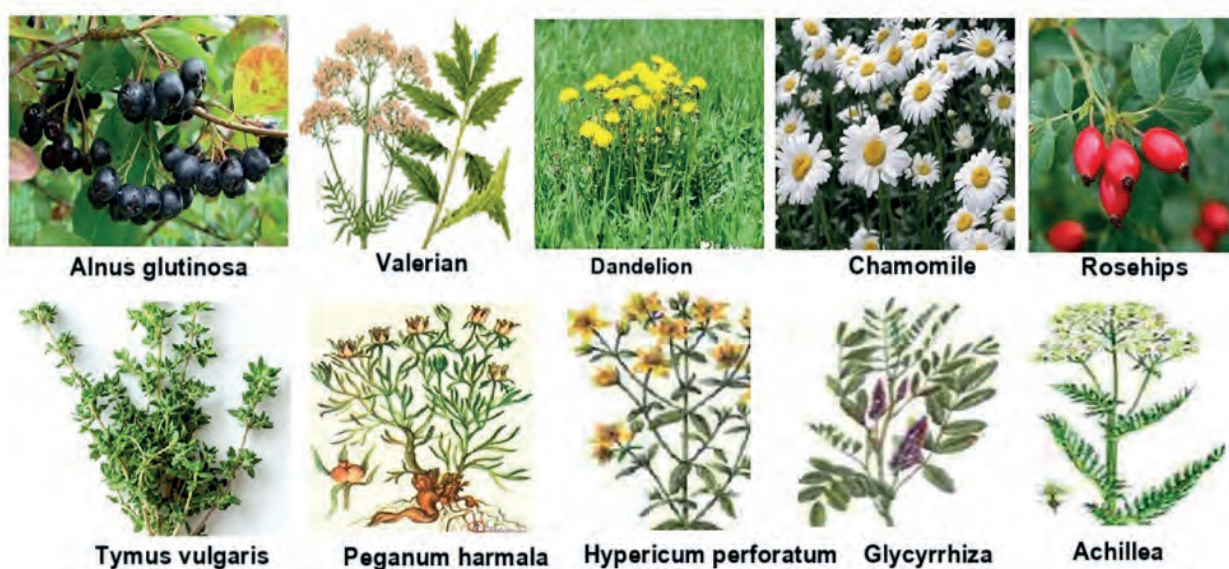


Figure 1. Some medicinal plants from the flora of Azerbaijan

Some of the pre-obtained extracts are used as medicinal substances in the form of tinctures and liquid extracts, while others require further

processing. One of these processing procedures is the encapsulation of extracts. In encapsulation, inert biopolymers, including gelatin, are

used. The advantage of using gelatin is that the size and molecular structure of the particles obtained during encapsulation significantly increase the effectiveness of the extract (Goldenstedt et al., 2008). Min Chul Kwon and coworkers (2012) encapsulated the aqueous extract of *Centella asiatica* L. using gelatin. The sizes of the extract capsules they obtained were even in the nano range. From the results of the experiments, it was clear that the encapsulation efficiency of *Centella asiatica* L. extracts was 70% (Kwon et al., 2012), and the effectiveness was 50% higher than that obtained by using other encapsulation methods, such as cellulose double liposomes (Jin et al., 2009). The encapsulation and nanoparticle formation of extracts can primarily reduce the application dose of extracts, prevent cytotoxicity, protect the body from side effects, and ultimately lead to the conservation of plant resources (Jeong et al., 2009).

Experiments show that nanoscale encapsulation of medicinal plant extracts significantly increases their application effects. For example, the biological activity of nano-sized particles obtained from the extract of *Centella asiatica* L. plant is significantly increased. They penetrate skin cells relatively quickly (2 times faster), and it was observed that 80% of nanoparticles remain in the epidermis for a long time

(Tao & Desai, 2003). Thus, nano-encapsulation of extracts of medicinal plants will facilitate the purification of the main effective active compound contained in it and increase its economic efficiency.

A second method of obtaining nanomedicines is the functionalization of synthesized nanoparticles with drugs. Nanoparticles obtained by this method act as drug carriers. Currently, the effective delivery of medicinal preparations relies on their timely delivery to the target, in a short period and the required dose. Traditional treatment methods involve the introduction of medicinal devices into the body mainly through injection, oral ingestion, and ointments. Each of these methods has its limitations. To overcome these limitations, it is necessary to protect the active substances contained in the drugs, work well with the kinetics of releasing the drug at the right time and place, control it precisely, target with high sensitivity, and deliver the right dose. The technology of creating nanomedicines is the most promising technology to overcome these limitations. Nanodrug technology is favorable for the development of drug delivery systems, as it allows for precise control over the size, shape, number, volume, direct openings, and surface properties of the drug delivery system (Park et al., 2006).

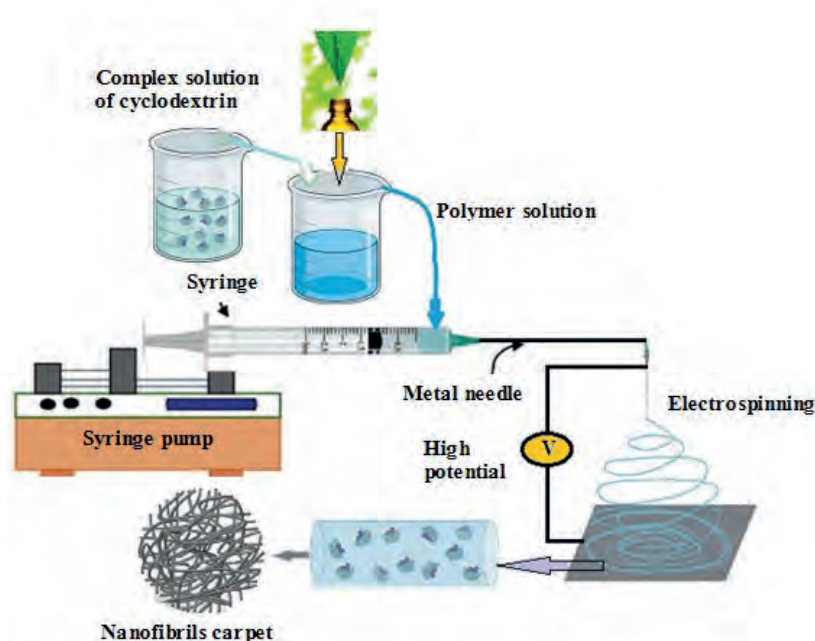


Figure 2. Encapsulation of extracts in polymer by electrospinning method

Lipid systems such as liposomes and micelles are part of the first generation of nanomedicines in nanoparticle-based therapy. These liposomes and micelles are primarily made from gold and magnetic nanoparticles (Rea et al., 2014). These nanoparticles serve multiple purposes, including drug delivery, imaging, and treatment. Medicinal nanoparticles help protect the gastrointestinal tract, enable the delivery of poorly water-soluble drugs to their intended site, and facilitate the absorption of medicinal substances through endocytosis.

The process of nanoparticle surface functionalization is intricate and involves several stages. A key challenge in this process is selecting the appropriate interaction forces between the biologically active molecule and the nanoparticle surface. The initial step in nanoparticle surface modification involves

adding an organic functional group (such as R-NH_2 , R-COOH , etc.) necessary for binding biological molecules. It is advisable to use homo- or hetero bifunctional cross-linkers for this purpose. Amino silanes with an amino group are commonly used binders for silica nanoparticles, while SH or -NH_2 groups are effective cross-linkers for gold nanoparticles due to their ability to form covalent bonds with the nanoparticle surface (Banihashem et al., 2020). Difunctional linkers of thio-carboxylic acids have functional groups at one end that can be utilized to bind ligands (Chen et al., 2016).

In the case of carbon-based nanoparticles, the presence of sp^2 hybridized carbon atoms is crucial for forming functional groups on the nanoparticle surface. By oxidizing the nanoparticles, it is possible to create -COOH , -OH , and -C=O bonds on the surface (Yue et al., 2019).

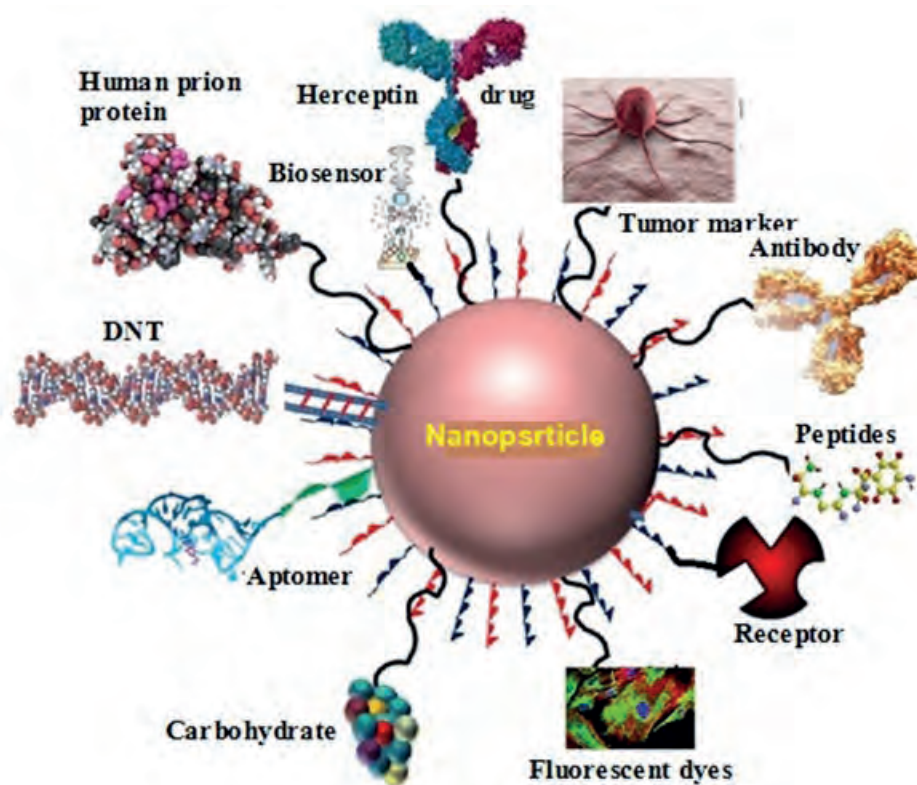


Figure 3. Functionalized nanoparticle

For surface functionalization of nanoparticles, it is convenient to use two different conjugations: non-covalent and covalent conjugations. In non-covalent bonds, a large number of weak interactions (electrostatic, ionic, van der Waals, hydrophobic interactions, and

hydrogen bonds) play a key role (Nobs et al., 2004). Non-covalent bonds do not affect the structure of the molecules used and their interaction with biological targets can be easily influenced by various variables such as pH and ionic strength (Luo et al., 2016).

The functionalization of the surface of various types of nanoparticles through covalent bonds allows for several levels of modification and many can be used to achieve structures with different functions (Chen et al., 2017). The covalent binding of ligands to the surface of nanoparticles can be achieved by using different binding molecules. Due to the polymer nature, high molecular weight molecules can be attached to the surface of nanoparticles, and bio-conjugation of bound ligands can be used to reduce steric hindrance (Deirram et al., 2019).

An example is PEG, which can be synthesized with specific functional groups at the ends and used as homo bifunctional or hetero bifunctional linkers to perform a wide range of functionalization processes. Pagels et al. (2020) showed that the production of specific hetero bifunctional PEG molecules is still an active area of research and how this molecule can be very useful for designing effective nanoplatforms for medical applications. Generally, covalent bonds are used to attach ligands that are useful for achieving targeting and/or reducing nanoparticle toxicity.

Recently, the use of pH- and temperature-sensitive bonds for drug release from drug-carrying nanoplatforms has been extensively studied (Edwards et al., 1998). The tumor microenvironment is very acidic compared to the normal microenvironment. Therefore, pH-sensitive nanoplatforms are particularly suitable for drug release controlled by the acidity of the tumor environment. In a weakly acidic environment, such as the tumor environment, the nanoparticles release dopamine as a result of the hydrolysis of the boron-ester bond between the two molecules. This smart release results in inhibition of vascular endothelial cell migration and tubule formation.

A third method of obtaining nanomedicines is the direct synthesis of nanoparticles in extracts of medicinal plants. When nanoparticles are synthesized in the extract of medicinal plants, there is a high probability that biologically active molecules (of medicinal nature) contained in the extract will bind to their surface. The combination of specific medicinal molecules on the surface of nanoparticles creates

the possibility of using them as nanomedicine. In the process of synthesizing nanoparticles in plant extracts (Green synthesis), the biologically active molecules contained in it act as both reducing agents and stabilizers. It is also possible to attach other molecules to the surface of the formed nanoparticles.

Researchers use FTIR, TEM, XRD, and Raman spectroscopy analyses to determine the stabilizer, which groups of surface-attached molecules are attached to the surface of the nanoparticle, and the crystal structure, size, and shape of the synthesized nanoparticles. During the synthesis of nanoparticles in plant extracts, it is possible to determine which groups of biological molecules interact with the nanoparticle surface by recording FTIR spectra. To do this, FTIR spectra of the extract are initially taken. Then, the FTIR spectra of the nanoparticle synthesized in this extract are recorded.

For example, a comparative analysis of the FTIR spectra of silver (Ag) nanoparticles synthesized in the gum tree (*Anogeissus latifolia*) extract with the spectra of that extract can be conducted. In the FTIR spectra of the extract, peaks of the main absorption bands at 3425, 2928, 2368, 2341, 2122, 1635, 1406, 1311, 1234, 1068, and 1028 cm^{-1} are observed (Kora et al., 2012).

The broadband peak at 3425 cm^{-1} is caused by valence oscillations of OH groups. Peaks corresponding to wave numbers 2928, 1406, and 1234 cm^{-1} are caused by stretching, bending, twisting, and rocking vibrations of methylene groups. The broad 2122 cm^{-1} band observed only in this extract belongs to molecules with carbonyl-type groups. The 1635 cm^{-1} peak with a deeper band belongs to asymmetric carboxyl groups. The band peak at 1311 cm^{-1} is the peak of the symmetrically stretched carboxylate group. The peaks at 1068 and 1028 cm^{-1} are the peaks of stretching vibrations of C–O ether and alcohol groups, respectively.

In the extract containing Ag nanoparticles, peaks of 3431, 2964, 2345, 2304, 1728, 1632, 1385, 1260, and 1024 cm^{-1} were recorded. From the comparison of the peaks, it is evident that the peak at 3425 shifted to 3431 cm^{-1} , the peak at 1635 shifted to 1632 cm^{-1} , and the peak

at 1311 shifted to 1385 cm^{-1} . This indicates that Ag nanoparticles interacted with hydroxyl and carboxylate groups. A new 1728 cm^{-1} band peak was observed in the extract-synthesized Ag nanoparticles, corresponding to carbonyl valence vibrations in aldehydes, ketones, and carboxylic acids (Mukherjee et al., 2008).

The appearance of the band peak at 1728 cm^{-1} and the disappearance of the peak at 2122 cm^{-1} indicate that the synthesis of Ag nanoparticles occurs with the presence of hydroxyl and carbonyl groups. Identification of biologically active molecules involved in their stabilization during the synthesis of nanoparticles in the extracts is also possible by the Raman spectroscopy method. In the spectra recorded by the Raman spectroscopy method, strong and sharp spectrum bands of biologically active molecules bound to the nanoparticle are observed. For example, the peak of the spectrum band at 240 cm^{-1} for Ag nanoparticles synthesized in the extract of *Anogeissus latifolia* gum

tree belongs to the valence vibrations of Ag-N (Biswas et al., 2007) and Ag-O bonds (Chowdhury & Ghosh, 2004). The peaks of the 1351 and 1523 cm^{-1} band belong to the valence symmetric and asymmetric vibrations of the C=O group (Chowdhury & Ghosh, 2004).

The strengthening of the valence bonds of CO₂ indicates that the COO group is directly attached to the surface of the nanoparticle. Wide 1040 cm^{-1} , sharp 1123 cm^{-1} . Peaks at 827 cm^{-1} are caused by in-plane and out-of-plane bending of C-H bonds in sugars (Vigneshwaran et al., 2007). It is also known that proteins bind to nanoparticles through electrostatic interaction of free amino groups or negatively charged carboxyl groups (Farjadian et al., 2019). Therefore, during the synthesis of nanoparticles in the extracts containing proteins, there is a great possibility that protein molecules will bind to the surface of the nanoparticles or form a coating.

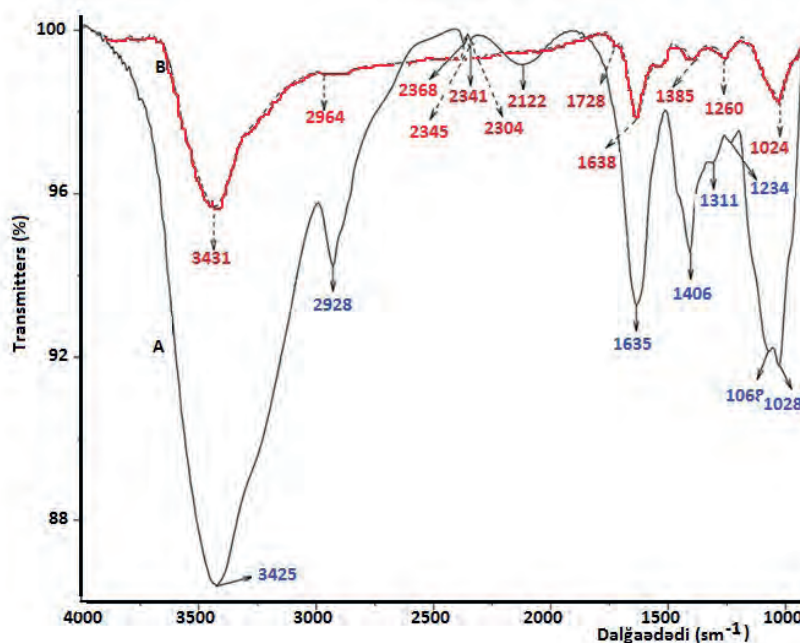


Figure 4. FTIR spectra of *Anogeissus latifolia* gum tree extract (A) and Ag nanoparticle synthesized to this extract (B) (Mukherjee et al., 2008).

The absorption spectrum peak at a wavelength of 280 nm noted in Figure 5A belongs to the electronic excitation of tryptophan and tyrosine residues. The protein molecular covering of the Ag nanoparticle synthesized in the extract is also clearly visible in TEM images

(Figure 5B). Therefore, the results obtained by Raman spectroscopy confirm that proteins together with carbohydrate molecules cover and stabilize nanoparticles during synthesis in extract. This suggests that biologically active molecules of protein and carbohydrate nature can

participate in the formation of nanoparticles, combining with their surface in various ways to create drug-carrying systems (Biswas et al., 2007; Vigneshwaran et al., 2007).

The shape, crystal structure, and size of nanoparticles synthesized in medicinal plant extracts play a crucial role in their absorption into cells, migration in organs, accumulation, and elimination. The X-ray diffraction (XRD) method allows accurate structural analysis of synthesized nanoparticles. For example, characteristic diffraction peaks of 38.3° , 44.6° , 64.8° , 77.6° , and 81.9° are observed in the XRD spectra of

unsynthesized Ag nanoparticles in the extract of *Anogeissus latifolia* gum tree (Figure 6). These diffraction peaks correspond to the (111), (200), (220), (311), and (222) planar peaks of the metallic silver crystal structure at the indicated degrees. The interplanar distances in the crystal were 2.348 Å, 2.030 Å, 1.437 Å, 1.229, and 1.175 Å, respectively, consistent with standard silver values. Thus, the XRD spectra confirm that the Ag nanoparticle synthesized in the extract has a highly crystalline structure (Mukherjee et al., 2008; Kora et al., 2012).

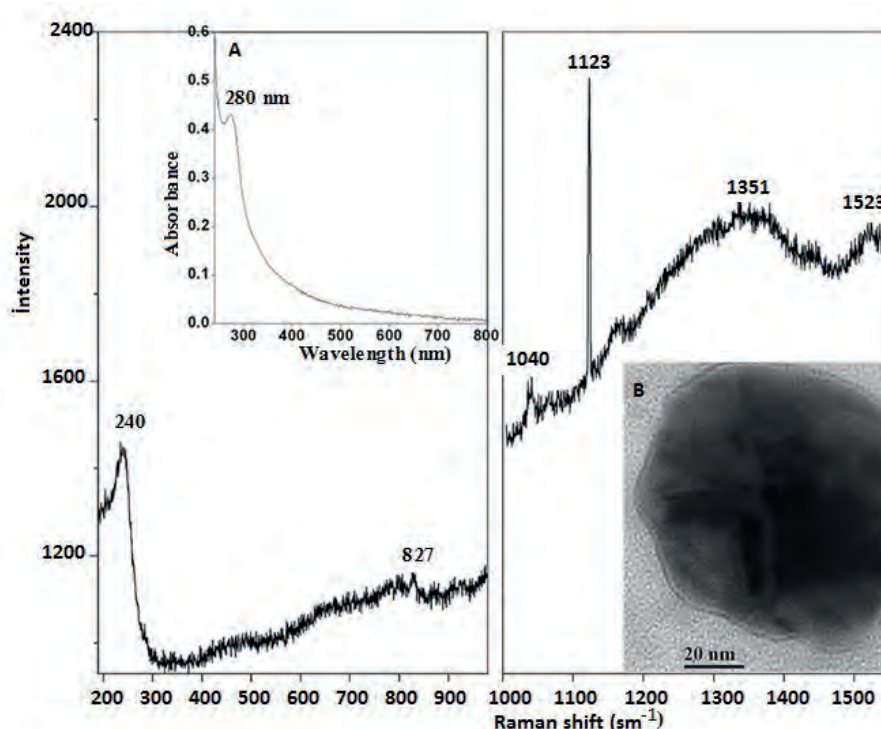


Figure 5. UV-vis spectrum of *Anogeissus latifolia* gum tree extract (A) and TEM image of Ag nanoparticles synthesized in this extract (B) (Mukherjee et al., 2008).

Discussion

The application of nanotechnology in medical practice has already begun to achieve significant advancements in addressing fundamental issues in this field. Key areas of nanotechnology, such as nanodiagnostics, nanopharmacology, nanotransplantation, nanotherapeutics, and nanotherapy, are emerging as the most promising medical technologies. Undoubtedly, nanopharmacology stands out as the most crucial of these technologies. By utilizing this technology to address challenges in drug use and

application in medical practice, a revolution in safeguarding human health is possible.

Most modern drugs are synthetic, and their production is intricate and costly. Many specific drugs are not accessible to all individuals, and complications and side effects pose additional challenges. Issues such as the failure to deliver drugs to the target site at the required time and in the necessary amount significantly impact their effectiveness. Traditional drug delivery systems often necessitate high doses for drug delivery, leading to increased frequency

of administration (Farjadian et al., 2019). Additionally, poor solubility in conventional drug delivery systems can greatly diminish the efficacy of drugs (Jain, 2008).

Utilizing nanoparticles as drug carriers, encapsulating drugs in nanoparticle forms, and administering drugs in nanoparticle forms offer numerous advantages over traditional drug delivery systems. These advantages include more precise delivery of therapeutic biomolecules to the target tissue or cell, reduced total dosage and potential mitigation of toxic side effects, increased stability of active pharmaceutical ingredients post-administration, enhanced safety and effectiveness, consistent release of drugs into diseased cells at the appropriate time, passive absorption and accumulation of drugs in areas of pathology such as tumor cells, and the potential for cost-effective production and availability of nanodrugs (Farjadian et al., 2019).

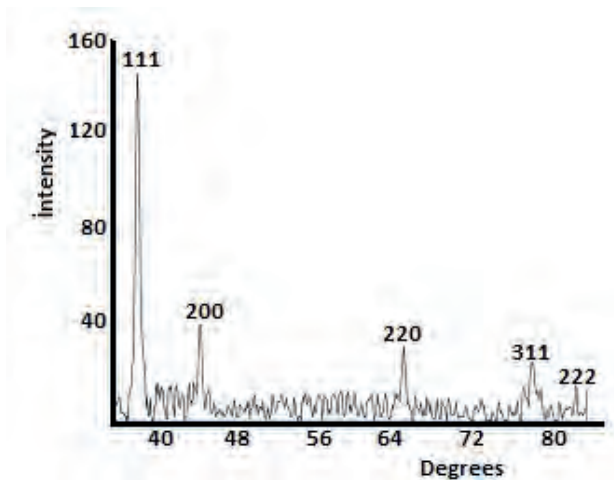


Figure 6. XRD spectrum of Ag nanoparticles synthesized in the extract of *Anogeissus latifolia* gum tree (Mukherjee et al., 2008).

Conclusion

In recent years, the development of nano drug delivery strategies has significantly increased the potential applications of nanoparticles in medicine. In-depth research and regulation of the physicochemical properties of nanoparticles allow their use in important areas of medicine such as therapy, diagnostics, transplantation and obtaining tissue cultures. This also extends to pharmacology, and greatly contributes to the development of nanomedicine. Therefore, the methods used in the preparation of nanomedicines, nanoencapsulation, surface functionalization of nanoparticles, and the production of medicinal nanoparticles through the synthesis of extracts of medicinal plants require further improvement. Although each of these methods has its advantages, the main issue is the effective absorption and biocompatibility of the obtained nanoparticles, which are the most important properties for medical applications. The technology of nanomedicine production will allow to open new ways to solve another drug problem - the strategy of «personalized medicine». This review article discusses three important technologies for obtaining nanomedicines, nanoencapsulation, nanoparticle surface functionalization, and drug nanoparticle synthesis. These nanomedicines will play a crucial role in overcoming important problems of conventional drugs, optimizing therapeutic delivery, and addressing heterogeneous biological barriers found in different patient populations and diseases.

References

- Banihashem, S., Nezhati, M. N., & Panahia, H. A. (2020). Synthesis of chitosan-grafted-poly(N-vinyl-caprolactam) coated on the thiolated gold nanoparticles surface for controlled release of cis-platin. *Carbohydrate Polymers*, 227, 115333. <https://doi.org/10.1016/j.carbpol.2019.115333>
- Biswas, N., Kapoor, S., Mahal, H. S., & Mukherjee, T. (2007). Adsorption of CGA on colloidal silver particles: DFT and SERS study. *Chemical Physics Letters*, 444, 338–345.
- Chen, J., Zhang, Y., Zhang, M., Yao, B., Li, Y., & Huang, L. (2016). Water-enhanced oxidation of graphite to graphene oxide with controlled species of oxygenated groups. *Chemical Science*, 7, 1874–1881. <https://doi.org/10.1039/c5sc03828f>
- Chen, S., Florinas, S., Teitgen, A., Xu, Z. Q., Gao, C., Wu, H., et al. (2017). Controlled Fab installation onto polymeric micelle nanoparticles for tuned bioactivity. *Science and Technology of*

- Advanced Materials, 18, 666–680. <https://doi.org/10.1080/14686996.2017.1370361>
- Chowdhury, J., & Ghosh, M. (2004). Concentration-dependent surface-enhanced Raman scattering of 2-benzoylpyridine adsorbed on colloidal silver particles. *Journal of Colloid and Interface Science*, 277, 121–127.
- Edwards, H. G. M., Falk, M. J., Sibley, M. G., Alvarez-Benedi, J., & Rull, F. (1998). FT-Raman spectroscopy of gums of technological significance. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, 54, 903–920.
- Farjadian, F., Ghasemi, A., Gohari, O., Roohtan, A., Karimi, M., & Hamblin, M. R. (2019). Nanopharmaceuticals and nanomedicines currently on the market: Challenges and opportunities. *Nanomedicine*, 14, 93–126.
- Gurbanov, E., & Aslanova, S. (2024). AVERAGE ANNUAL PRODUCTIVITY OF THE THYMUS-ET-CAECUM-FESTUCOSUM FORMATION, DISTRIBUTED IN SUMMER PASTURE FIELD NO. 8" TURKESO-BA"(AZERBAIJAN). *Norwegian Journal of Development of the International Science*, 126.
- Gurbanov, E., & Ibrahimov, S. (2023). Vegetation Classification Of Oil-Contaminated Soils In Azerbaijan. *ACTA Botanica Caucasica*, 2(1), 3-8.
- Goldenstedt, C., Birer, A., Cathignol, D., Chesnais, S., El Bahri, Z., Massard, C., et al. (2008). Delivery by shock waves of active principle embedded in gelatin-based capsules. *Ultrasonics Sonochemistry*, 15, 808–814.
- Hajiyeva, S., Babayeva, S., Mustafayeva, Z., Izzatullayeva, V., Guvendiyev, V., & Hajiyev, E. (2024). ASSESSMENT OF GENETIC DIVERSITY AMONG WILD POMEGRANATE (PUNICA GRANATUM L.) GENOTYPES OF AZERBAIJAN USING ISSR MARKERS. *Acta Botanica Caucasica Volume*, 3(2), 14-20.
- Hassanpanah D., Gurbanov E., Gadimov A., Shahrairi R. Effect of potassium humate on advanced potato cultivars for water deficit tolerance in Ardabil region, Iran. In: *From Molecular Understanding to Innovative Applications of Humic Substances*; 2008, vol. 2, pp. 647-650.
- Handa, S. S., Khanuja, S. P. S., Longo, G., & Rakesh, D. D. (2008). Extraction technologies for medicinal and aromatic plants (1st ed., No. 66). United Nations Industrial Development Organization and the International Centre for Science and High Technology.
- Hassanpanah, D., Gurbanov, E., Gadimov, A., & Shahriari, R. (2007). Reduction of nitrate accumulation in potato by use of potassium humate for human safety. *Iranian Biomedical Journal*, 11(1), 461.
- Kurbanov, E., Aslanova, S., & Ibragimov, S. (2023). Types of Hole-Meadow and Wetlands Vegetation in Oil-contaminated Soils Siyazan District (Azerbaijan). *Bulletin of Science and Practice*.
- Ismayilova, L., Ahmadov, İ., Gasimov, E., Rzayev, F., Sultanova, J. and Ahmadova, H. Effect of nanoparticles on the Golden Delicious apple flower fertilization process and accumulation in the fruit. *Acta Botanica Caucasica*, 1(2), 46–56 (2022).
- Jain, K. K. (2008). Nanomedicine: Application of nanobiotechnology in medical practice. *Medical Principles and Practice*, 17, 89–101.
- Jeong, H. S., Han, J. G., Ha, J. H., Kim, Y., Oh, S. H., Kim, S. S., et al. (2009). Antioxidant activities and skin-whitening effects of nanoencapsulated water extract from *Rubus coreanus* Miquel. *Korean Journal of Medicinal Crop Science*, 17, 83–89.
- Jin, H., Xia, F., Jiang, C., Zhao, Y., & He, L. (2009). Nanoencapsulation of lutein with hydroxypropylmethyl cellulose phthalate by supercritical antisolvent. *Chinese Journal of Chemical Engineering*, 17, 672–677.
- Juan José Maldonado Miranda. (2021). Medicinal plants and their traditional uses in different locations. *Phytomedicine*, Chapter 7, 207–223.
- Kim, W. J., Kim, J. H., Veriansyah, B., Kim, J. D., Lee, Y. W., Oh, S. G., et al. (2009). Extraction of bioactive components from *Centella asiatica* using subcritical water. *Journal of Supercritical Fluids*, 48, 211–216.

- Kew, K. M., Quinn, M., Quon, B. S., & Ducharme, F. M. (2016). Increased versus stable doses of inhaled corticosteroids for exacerbations of chronic asthma in adults and children. *Cochrane Database of Systematic Reviews*, Issue 6. <https://doi.org/10.1002/14651858.CD007524.pub4>
- Kora, A. J., Beedu, S. R., & Jayaraman, A. (2012). Size-controlled green synthesis of silver nanoparticles mediated by gum ghatti (*Anogeissus latifolia*) and its biological activity. *Organic and Medicinal Chemistry Letters*, 2(17).
- Luo, Y., Cai, X., Li, H., Lin, Y., & Du, D. (2016). Hyaluronic acid-modified multifunctional Q-graphene for targeted killing of drug-resistant lung cancer cells. *ACS Applied Materials & Interfaces*, 8, 4048–4055. <https://doi.org/10.1021/acsami.5b11471>
- Min Chul Kwon, W. Y. C., J. S. K., C. S. Y., H. W. L., H. S. K., et al. (2012). Enhancement of the skin-protective activities of *Centella asiatica* L. urban by a nano-encapsulation process. *Journal of Biotechnology*, 157, 100–106.
- Mukherjee, P., Roy, M., Mandal, B. P., Dey, G. K., Mukherjee, P. K., Ghatak, J., et al. (2008). Green synthesis of highly stabilized nanocrystalline silver particles by a non-pathogenic and agriculturally important fungus *T. asperellum*. *Nanotechnology*, 19, 075103–075109.
- Nobs, L., Buchegger, F., Gurny, R., & Allémann, E. (2004). Current methods for attaching targeting ligands to liposomes and nanoparticles. *Journal of Pharmaceutical Sciences*, 93, 1980–1992. <https://doi.org/10.1002/jps.20098>
- Offord, E. A., Gautier, J. C., Avanti, O., Scaletta, C., Runge, F., Krämer, K., et al. (2002). Photoprotective potential of lycopene, β -carotene, vitamin E, vitamin C, and carnosic acid in UVA-irradiated human skin fibroblasts. *Free Radical Biology and Medicine*, 32, 1293–1303.
- Park, S. H., Oh, S. G., Mun, J. Y., & Han, S. S. (2006). Loading of gold nanoparticles inside the DPPC bilayers of liposome and their effects on membrane fluidities. *Colloids and Surfaces B: Biointerfaces*, 48, 112–118.
- Rea, I., Martucci, N. M., De Stefano, L., Ruggiero, I., Terracciano, M., Dardano, P., et al. (2014). Diatomite biosilica nanocarriers for siRNA transport inside cancer cells. *Biochimica et Biophysica Acta (BBA) - General Subjects*, 1840, 3393–3403. <https://doi.org/10.1016/j.bbagen.2014.09.009>
- S. L. Tao & T. A. Desai. (2003). Microfabricated drug delivery systems: from particles to pores. *Advanced Drug Delivery Reviews*, 55, 315–328.
- Vigneshwaran, N., Ashtaputre, N. M., Varadarajan, P. V., Nachane, R. P., Paralikar, K. M., & Balasubramanya, R. H. (2007). Biological synthesis of silver nanoparticles using the fungus *Aspergillus flavus*. *Materials Letters*, 61, 1413–1418.
- Wei, D., & Qian, W. (2008). Facile synthesis of Ag and Au nanoparticles utilizing chitosan as a mediator agent. *Colloids and Surfaces B: Biointerfaces*, 62, 136–142.
- Yue, L., Sun, C., Cheng, Q., Ding, Y., Wei, J., & Wang, R. (2019). Gold nanorods with a noncovalently tailorable surface for multi-modality image-guided chemo-photothermal cancer therapy. *Chemical Communications*, 55, 13506–13509. <https://doi.org/10.1039/c9cc07131h>
- Zhang, Z., Xu, J., Chen, W., & Chen, T. (2018). Functionalized nanoparticles in targeting tumor-associated macrophages. *Nanomedicine: Nanotechnology, Biology, and Medicine*, 14, 1–16. <https://doi.org/10.1016/j.nano.2017.10.002>

THE ALGAE OF THE SOUTHERN COASTS OF THE CASPIAN SEA (LANKARAN DISTRICT)

Aytaj Muradova¹ | ORCID: 0009-0003-3528-9043Shakhar Mukhtarova¹ | ORCID: 0000-0002-7627-1443Yashar Feyziyev² | ORCID: 0000-0002-7011-6354¹ Institute of Botany, Ministry of Science and Education, 40 Badamdar Ave., Baku, AZ1004, Azerbaijan² Institute of Molecular Biology and Biotechnologies, Ministry of Science and Education, 11 Izzat Nabiyev, Baku, AZ1073, Azerbaijan²Correspondence: y.feyziyev@imbb.science.az**Article Info:**DOI: <https://doi.org/10.30546/abc.2024.3.3.525>

Pages: 84–95

Received: August 25, 2024 | Revised: September 18, 2024 | Accepted: September 8, 2024

Abstract. *Macrophyte algae and microalgae of the southern shores of the Caspian Sea (Republic of Azerbaijan, Lankaran district, and Gizilaghaj National Park) were studied from March to December 2022. A total of 29 algae species were identified, 11 of which were located in Gizilaghaj National Park. These species belong to Chlorophyta (9), Bacillariophyta (7), Cyanobacteria (6), Charophyta (4), and Rhodophyta (3). Oscillatoriaceae, Spirogyraceae, Cladophoraceae, and Naviculaceae were the leading families. Lyngbya and Spirogyra dominated the upper littoral zone, while Cladophora dominated the sublittoral zone. Twenty-seven species were recorded as new to this region, with Cladophora albida, C. ruchingeri, Ulva torta, Colaconema elegans, Corallina officinalis, and Jania virgata being recognized as both new and rare species. Seasonal biodiversity peaked in July. Ecological analysis highlighted pollution tolerance levels based on the Saprobic system. These findings emphasize the ecological importance of the region and the need for further studies to conserve its biodiversity.*

Keywords: *ecology group, macrophyte, new species, rare species, taxonomic analysis*

Introduction

The most common macroalgae are representatives from the divisions Chlorophyta (green), Rhodophyta (red), Phaeophyceae (brown), Xanthophyta (yellow-green), Chrysophyta (gold) and microalgae from the division Bacillariophyta (diatoms). Some divisions of algae are minor components of the benthos algoflora of reservoirs. The flora of well-studied regions is dominated by green algae (35-37% of species), blue-green algae (24-35% of the flora), red algae (14-20% diatoms), and each of the yellow-green algae accounts for 14-21% (Sheath and Cole 1992; Necchi et al., 2000).

The Caspian Sea contains approximately 45% of the worldwide lake's water. Unlike the

seas associated with the ocean and other water basins, it has its own meteorological and biological regime. Its flora and fauna have a unique richness. The phytoplankton of the Caspian Sea is a habitat for both freshwater algae and algae inhabiting brackish waters. This is due to the low salinity of the Caspian Sea, which is 12.7-12.8 ‰ at present (Kosarev and Yablonskaya, 1994).

The South Caspian Sea area, to which the Republic of Azerbaijan belongs, is very deep (ocean depth exceeds 1000 m) and accounts for 66.0% of the total water volume of the sea (volume: 45,800 km³; area: 168,000 km²; average depth: 325 m; maximum depth: 1025 m) (Kosarev and Yablonskaya, 1994; Aladin and

Plotnikov, 2004). The Caspian Sea has been significantly altered by technogenic activities, primarily as a result of changes in water flow and the destruction of water bodies in the system (Dumont, 1995; Kideys et al., 2008; Bagheri et al., 2013). Currently, many problems pose an ecological threat to the sensitive ecosystem of the Caspian Sea. The increase in population in the coastal areas of the Caspian Sea, the increase in the volume of various types of wastewater entering the sea (industrial, agricultural), the expansion of oil production, and the connection of the Caspian Sea with other open water bodies through the Volga Canal create many problems (Shams and Asharzadeh, 2008). Among them, the increase in water temperature, eutrophication, and the excessive input of nutrients into the Caspian Sea in the late 20th century can be noted (WHO, 1999).

Currently, the ecological situation in the Caspian Sea is very tense. As a result of various and increasing anthropogenic impacts on algae, the ranges of some algae species are shrinking, some species are disappearing, and the morphology and reproduction of other species are changing. The problem is more acute in the shelf zone of the sea: dead zones have already appeared in these areas (Karaeva, 2002).

Although algae in the Azerbaijani sector of the Caspian Sea have been studied since the 60s of the 20th century, there is not enough information about their biodiversity and habitats. For example, early studies of diatoms of the Caspian Sea were carried out only in the form of monitoring, and 309 species and intraspecific taxa belonging to two classes, three orders, three semiorders, and eight families were registered (Karaeva, 1960; 1972). As a result of studies carried out in 1961-1963, 76 species belonging to 4 divisions, 6 classes, 15 orders, 21 families, 42 genera were identified, of which 38 species and 1 subspecies were found in the Baku bay, 12 species (8 green, 3 red and 1 chara) belong to the southern shores of the Caspian Sea (Zaberkhinskaya, 1968). Summarizing the literature data related to the blue-green algae of the phytoplankton of the Caspian Sea, and the data obtained in the course of many years of original research, 85 species and intraspecific taxa have

been identified, of which only 18 taxa are inherent for the Azerbaijan sector of the Caspian Sea (Nuriyeva, 2020).

There is little information on the quantitative distribution and floristic composition of phytoplankton in the Caspian Sea. Furthermore, since there is no data characterizing the entire marine area for a given period, both year and season, it is difficult to imagine its depth- and area-dependent changes associated with biotic and abiotic factors, especially during precipitation, and annual and interannual changes in water level. It should be emphasized that the species composition of phytoplankton in the Caspian Sea is much poorer than in the Black and Azov Seas. Thus, 343 species were recorded in the Caspian Sea (Babayev, 1968; Proshkina-Lavrenko, 1965), 750 in the Black Sea, and 417 in the Azov Sea (Ivanov, 1965). The first place in the phytoplankton of the Caspian Sea is occupied by green algae with 127 taxa, diatoms have 111, and blue-green 74 taxa.

The dominant phytoplankton species in the Middle and South Caspian include *Skeletonema costatum* (Greville) Cleve, *Thalassionema nitzschioides* (Grunow) Mereschkowsky. The second main division, which dominates in terms of the number of species, is the blue-green algae division. Particularly widespread species are *Anabaena bergii* f. *minor* (Kisselev) Elenkin, *Anabaenopsis tanganyikae* (G.S.West) V.V. Miller and *Aphanizomenon flos-aquae* Ralfs ex Bornet & Flahault (Babayev, 1968).

In this paper, the results of the study of algae biodiversity on the southern shores of the Caspian Sea (Lankaran district and Gizilaghaj National Park) are presented. The taxonomic structure of algae collected from the coastal areas was analyzed, and rare and new species of research area were identified. An analysis of the bioecological properties of algae was carried out.

Materials And Methods

Algae were collected in March - December on the coast of the Lankaran district (including the Gizilaghaj National Park). Lankaran is located between the western coast of the Caspian Sea and the foothills of the Talysh mountains

and stretches for 100 km from the river Bolharu in the north to the river Astarachay in the south. Several small rivers also flow into the sea in this area. The humid subtropical climate, mild winters, dry and hot summer days, rainy autumn and spring determine the rich flora and fauna of this region.

Algae samples taken at a distance of 50-100 m, from the upper, supra-, sublittoral and coastal parts of the sea were used for the study. The destination points where the algae were collected are demonstrated in the map shown in Figure 1. The water column, seabed, solid substrate (hydraulic devices, etc.), and macrophyte algae were studied as living substrates. A plankton cup was used for sampling, and phytoplankton was collected by passing water through a filter of gas material No. 25 and No.77 (21). To collect benthos species, a bathymeter and a three-liter flask were used. For a further and detailed study of the materials, 4% formalin was added to the algae suspension. To study epilithic diatoms, samples of bottom sediments were taken using a glass tube 8 mm in diameter and 1 m long at a distance of 2-3 m from the shore and transferred to plastic containers, and 10% formaldehyde was added. After settling the sludge samples, the water was drained off and the sludge was transferred to Petri dishes (Van

Der Werff, 1999). Samples containing diatoms were centrifuged and boiled after the addition of H_2O_2 . Then, diatoms were purified from acid and organic matter. The purified material was used to prepare permanent samples for the identification of diatoms (Hasle, Fryxell, 1970).

A scanning electron microscope (JSM-35, Japan) was used to identify diatoms, and an optical microscope (Nikon E100) was used to identify algae of other divisions. Traditional methods were used for morphological characterization and identification of algae (Zinova, 1967; Zaberzhinskaya, 1968; David, 1986; Schmid, 1994; Fourtanier and Kociolek, 2011; Seckbach and Kociolek, 2011; Kulikovskiy and Kuznetsova, 2014; Afanasiev et al., 2016; Afanasiev et al., 2020; Nuriyeva and Vinogradova 2020).

The most recent databases (AlgaeBase (Guiry, Guiry, 2022), California Academy, Alga Terra) were used to indicate the names of the designated algae species. The algae distribution map was prepared in ArcGIS 10.7 (Figure 1, 2). The temperature of the aquatic environment was measured with a laboratory thermometer, and the pH was measured using a portable pH meter WTW-3110 (Germany). The coordinates of the sampling points, where the algae were gathered are marked.

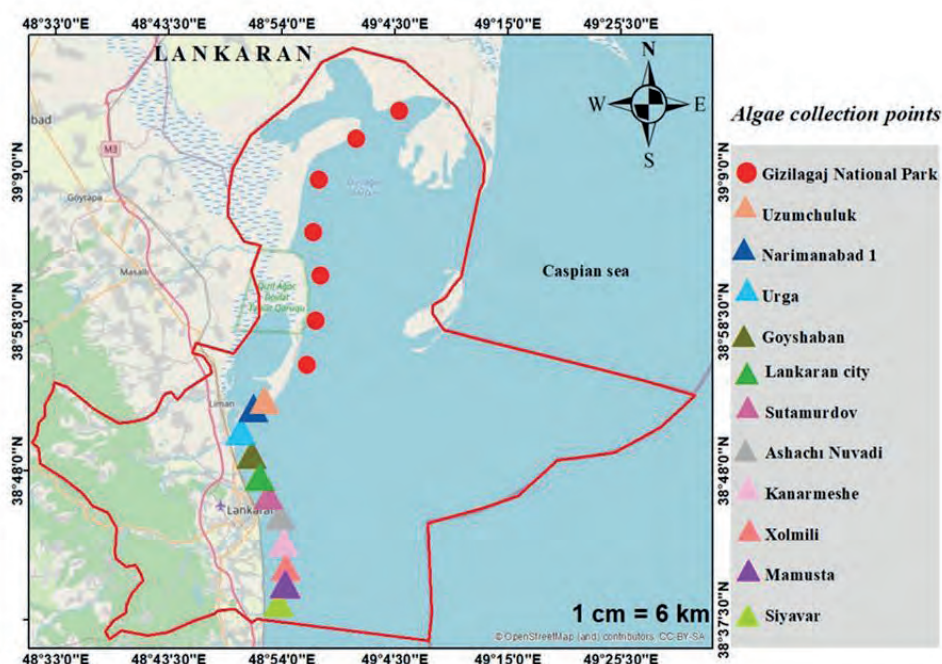


Figure 1. Algae sampling points in the coastal areas of the Lankaran district.

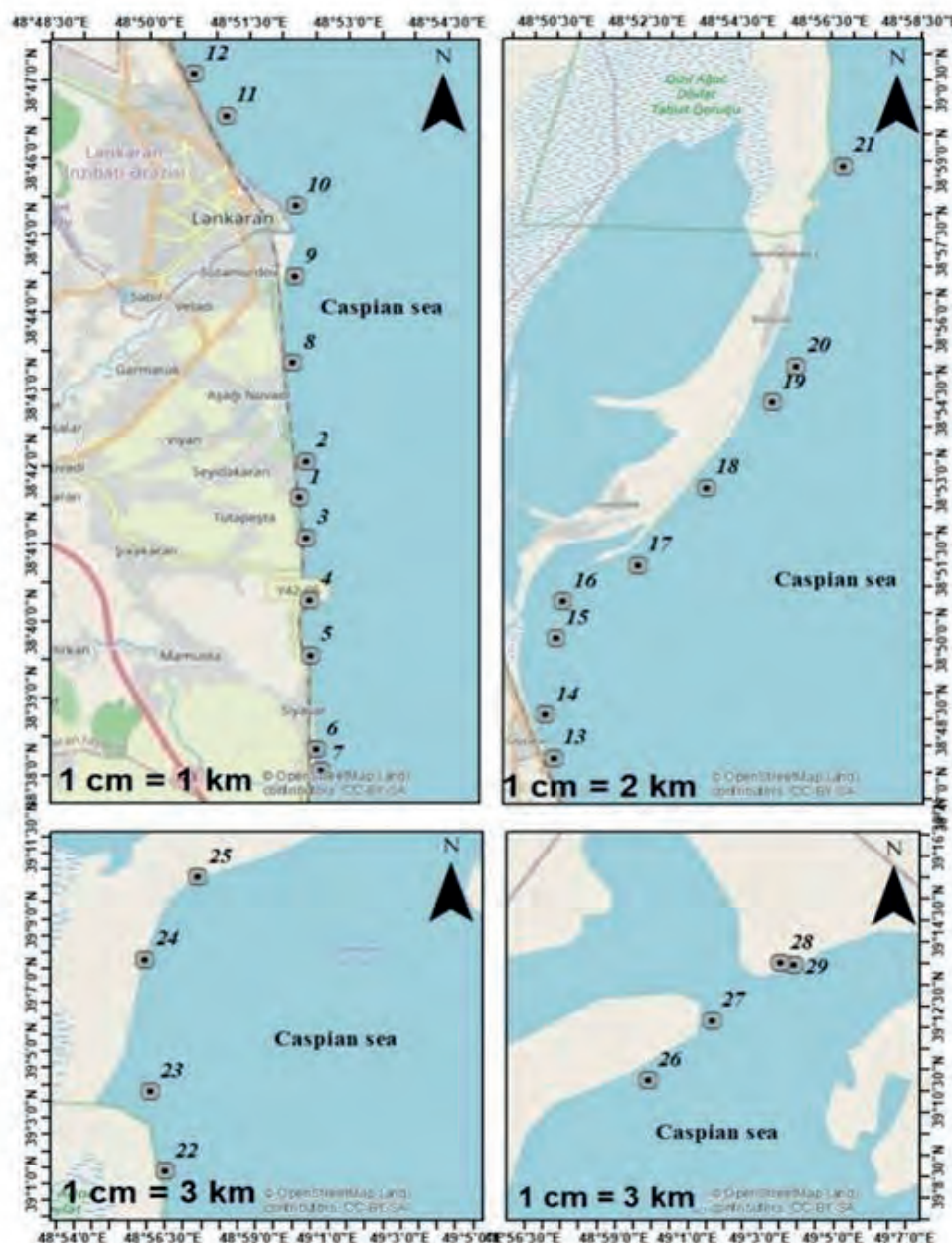


Figure 2. Map of algae distribution on southwestern shores of the Caspian Sea

1. *Lyngbya aestuarii*, 2. *Lyngbya majuscula*, 3. *Oscillatoria sancta*, 4. *Neidium productum*, 5. *Nodularia spumigena*, 6. *Cladophora sericea*, 7. *Cladophora albida*, 8. *Rhizoclonium riparium*, 9. *Spirogyra majuscula*, 10. *Colaenema elegans*, 11. *Ulva tepida*, 12. *Spirogyra porticalis*, 13. *Spirulina subsalsa*, 14. *Ulnaria ulna*, 15. *Jania virgata*, 16. *Oscillatoria limosa*, 17. *Cladophora glomerata*, 18. *Corallina officinalis*, 19. *Iconella capronii*, 20. *Craticula halophila*, 21. *Cladophora fracta*, 22. *Spirogyra circumlineata*, 23. *Cladophora ruchingeri*, 24. *Nitzschia denticula*, 25. *Ulva torta*, 26. *Cladophora vagabunda*, 27. *Navicula trivialis*, 28. *Cymbella cistula*, 29. *Spirogyra crassa*.

Results And Discussion

1. *Taxonomic analysis.* 29 species belonging to 5 divisions, 14 orders, 16 families, 18 genera were identified in the studied area – The southwestern shores of the Caspian Sea (Figure 3, Tables 1, 2). Among them, 3 species

belong to red (Rhodophyta), 4 species – charo (Charophyta), 6 species – blue-green (Cyanobacteria), 7 species – diatoms (Bacillariophyta), and 9 species to green (Chlorophyta) algae.

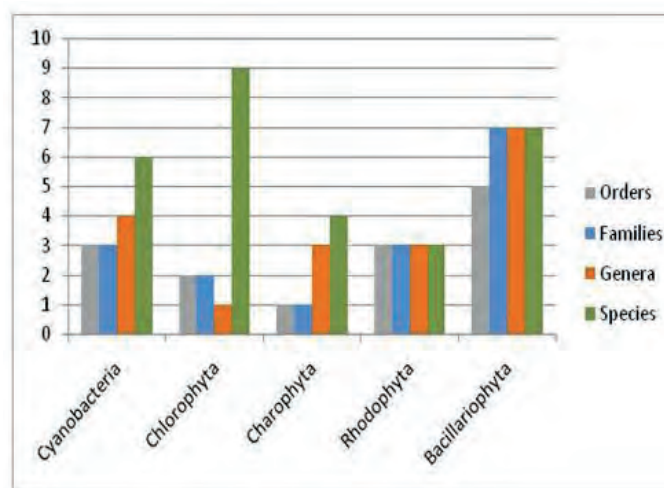


Figure 3. Total taxa number of orders, families, genera, species

Table 1.

Algae of the southern shores of Caspian Sea (Lankaran district) and their collection points

Species	Destination point	Bioecological features
<i>Lyngbya aestuarii</i>	38°41.606'N 48°52.246'E (Kholmili vill.)	Widespread plankton-benthos species. Occurs in salt and brackish waters, seas, and fresh waters. Related to the cosmopolitan species (Figure 2. 1; Figure 5. A)
<i>Lyngbya majuscula</i>	38°41.830'N 48°52.265'E (Kanaramesha vill.)	Typical marine species. Found also in some fresh waters. (Figure 2. 2; Figure 5. B)
<i>Oscillatoria sancta</i>	38°41.080'N 48°52.359'E (Kholmili vill.)	Inhabits in fresh and brackish water. Belongs to the plankton and benthos ecology group. Is a widespread species. (Figure 2. 3; Figure 5. C)
<i>Oscillatoria limosa</i>	38°50.256'N 48°50.380'E (Urge vill.)	Found in shallow and slow-flowing, often dirty and brackish waters. Related to the cosmopolitan species. (Figure 2. 16; Figure 5. D)
<i>Nodularia spumigena</i>	38°39.556'N 48°52.420'E (Mamusta vill.)	Widespread in fresh, brackish, and salt waters. (Figure 2. 5; Figure 5. E)
<i>Spirulina subsalsa</i>	38°47.777'N 48°50.419'E (Goyshaban vill.)	Occurs in seas, brackish, coastal, inland waters, benthos, and plankton, as well as in hot springs. (Figure 2. 13; Figure 5. F)
<i>Cladophora albida</i>	38°38.057'N 48°52.569'E (Siyavar vill.)	Widespread. Can be found along the sea coast, in the supralittoral, sublittoral zone, in shady places, on rocks, and with brown algae. (Figure 2. 7; Figure 5. G)
<i>Cladophora fracta</i>	38°58.900'N 48°56.778'E (Gizilaghaj Bay)	Fresh and saltwater species. Also occurs in waters with low salinity. Common in eutrophic habitats. Most common in spring. (Figure 2. 21; Figure 5. H)
<i>Cladophora glomerata</i>	38°51.410'N 48°52.270'E (Narimanabad vill.)	A freshwater and brackish water species, widely distributed in the temperate zone. Mostly found in seawaters with a salinity of up to 17%. (Figure 2. 17; Figure 5. I)
<i>Cladophora sericea</i>	38°38.332'N 48°52.499'E (Siyavar vill.)	Is encountered in nearshore, littoral, and sublittoral zones. Develops on stones and rocks, and also is found in association with macrophytic algae. Belongs to marine species. (Figure 2. 6; Figure 5. J)

<i>Cladophora ruchingeri</i>	39°3.780'N 48°56.120'E (Gizilaghaj Bay)	Found on rocks and stones, in the upper part of the sublittoral zone. (Figure 2. 23; Figure 5. L)
<i>Cladophora vagabunda</i>	39°10.766'N 48°59.931'E (Gizilaghaj Bay)	A marine species, found on rocks, stones, in the upper part of the sublittoral, supralittoral zones, and on the coast, on sufficiently protected coasts. Thallus sometimes even cling to pebbles, bark, or grow as an epiphyte. Forms floating masses on the surface of shallow estuaries and lagoons; may lie in dirty cushions on the surface of salty shallow waters. Can penetrate from seawater to salt water, usually up to 15% salinity. (Figure 2. 26; Figure 5. K)
<i>Rhizoclonium riparium</i>	38°43.352'N 48°52.158'E (Ashagi Nuvadi vill.)	Have vegetation in fresh, brackish, and sea waters. Plants are found throughout the year, most often in spring, summer, and autumn, less often in winter. (Figure 2. 8; Figure 5. M)
<i>Ulva tepida</i>	38°45.595'N 48°51.749'E (Lankaran city beach)	Found in bays and estuaries. (Figure 2. 11; Figure 5. N)
<i>Ulva torta</i>	39°10.268'N 48°57.428'E (Gizilaghaj Bay)	Occurs in bays and estuaries in a mix with other filamentous green algae. (Figure 2. 25; Figure 5. O)
<i>Spirogyra crassa</i>	39°13.480'N 49°3.955'E (Gizilaghaj Bay)	A freshwater species, found in the estuaries. (Figure 2. 29; Figure 5. P)
<i>Spirogyra majuscula</i>	38°44.463'N 48°52.182'E (Sutamurdov vill.)	A freshwater species, found in the estuaries. (Figure 2. 9; Figure 5. Q)
<i>Spirogyra circumlineata</i>	39°1.382'N 48°56.522'E (Gizilaghaj Bay)	A freshwater species, found in the estuaries, and also in the bays. (Figure 2. 22; Figure 5. R)
<i>Spirogyra porticalis</i>	38°47.097'N 48°50.659'E (Goyshaban vill.)	It is a freshwater species found in the estuaries (Figure 2. 12; Figure 5. S)
<i>Colaconema elegans</i>	38°45.388'N 48°52.208'E (Lankaran city beach)	Found on the coasts on stones, shells, and the surface of other algae. (Figure 2. 10; Figure 5. T)
<i>Corallina officinalis</i>	38°52.862'N 48°53.762'E (Uzumchuluk vill.)	The species is found along the sea coast, in the sublittoral zone, on stones and rocks. (Figure 2. 18; Figure 5. U)
<i>Jania virgata</i>	38°50.037'N 48°50.466'E (Urge vill.)	Found on stones, in the part of the shell, at a depth of 0.5-2 m. (Figure 2. 15; Figure 5. V)
<i>Cymbella cistula</i>	39°13.515'N 49°3.565'E (Gizilaghaj Bay)	Found in peat (moss) floors, lakes, rivers, ponds, reservoirs, swamps, estuaries, and seas. (Figure 2. 28; Figure 5. W)
<i>Iconella capronii</i>	38°54.465'N 48°55.223'E (Gizilaghaj Bay)	It occurs in different types of water bodies. (Figure 2. 9; Figure 5. X)

<i>Craticula halophila</i>	38°55.144'N 48°55.753'E (Gizilaghaj Bay)	Found in swamps, estuaries, and seas. (Figure 2. 20; Figure 5. Y)
<i>Navicula trivialis</i>	39°12.165'N 49°1.684'E (Gizilaghaj Bay)	Found in rivers, ponds and reservoirs, bays. (Figure 2. 27; Figure 5. Z)
<i>Nitzschia denticula</i>	39°7.780'N 48°55.976'E (Gizilaghaj Bay)	Found in rivers, springs and reservoirs, bays (Figure 2. 24; Figure 5. A ₁)
<i>Neidium productum</i>	38°40.277'N 48°52.413'E (Mamusta vill.)	Found in rivers, springs and reservoirs, bays, estuaries. (Figure 2. 4; Figure 5. B ₁)
<i>Ulnaria ulna</i>	38°48.593'N 48°50.230'E (Goyshaban vill.)	Found in different types of water basins. (Figure 2. 14; Figure 5. C ₁)

Table 2.

**Ecological indicators of algae species found on southern shores (Lankaran dst.)
of the Caspian Sea**

Division	Species	Saprob	Ecological grup	Temp., °	pH	Ecological zone Littoral zone (intertidal)		
						Upper littoral	Supra littoral	Sub littoral
Cyanophyta	<i>Lyngbya aestuarii</i>	o	pl., ben.	19	7.5	+		
	<i>L. majuscula</i>	–	pl.	12	8	+		
	<i>Oscillatoria sancta</i>	β-α	pl., ben.	26	7.5		+	
	<i>O. limoza</i>	β	pl., ben.	17	7.5	+		
	<i>Nodularia spumigena</i>	o-α	ben.	26	7.5	+		
	<i>Spirulina subsalsa</i>	o-β	pl., ben.	25	7.5	+		
Chlorophyta	<i>Cladophora albida</i>	–	pl., ben.	24			+	+
	<i>C. fracta</i>	o-α	pl., ben.	17	7.5			+
	<i>C. glomerata</i>	β-o	pl., ben.	17	7.5			+
	<i>C. sericea</i>	–	pl.,ben.,eph.	11	7.5			+
	<i>C. ruchingeri</i>	–	pl.,ben.,eph.	25	7.6			+
	<i>C. vagabunda</i>	–	pl.,ben.,eph.	27	7.5		+	+
	<i>Rhuzoclonium riparium</i>	–	pl.	11	7.5			+
	<i>Ulva tepida</i>	–	ben.	23	7.5		+	
	<i>U. Torta</i>		ben.	18	7.5		+	
Charophyta	<i>Spirogyra crassa</i>	β	ben.	11	7.5		+	
	<i>S. majuscula</i>	o-α	pl.	23	7.5	+		
	<i>S. circumlineata</i>	α-β	ben.	15	7.5	+		
	<i>S. particalis</i>	α-β	ben.	23	8	+		
Rhodophyta	<i>Colaconema elegans</i>	–	pl.,ben.,eph.	17	7.4			+
	<i>Corallina officinalis</i>	–	pl.,ben.,eph.	22	7.3			+
	<i>Jania virgata</i>	–	pl., ben.	22	7.6		+	

Bacillariophyta	<i>Cymbella cistula</i>	o-β	ben.	11	8.0	+		
	<i>Iconella capronii</i>	β	ben.	13	8.0	+		
	<i>Navicula halophila</i>	β	eph.	22	7.8	+		
	<i>Craticula halophila</i>	α	eph.	18	7.8		+	
	<i>Nitzschia denticula</i>	x-β	pl., ben.	27	7.6	+		
	<i>Neydium productum</i>	Oligohalob-indifferent	eph.	10	7.6	+		
	<i>Umaria ulna</i>	β	eph.	18	7.5	+		

Note: pl.- plankton, ben.- benthos, eph.- epilit, α - alfasaprob, β - betasaprob, x-β - xeno-betasaprob, o - oligosaprob, α-β - alfabetamezosaprob, o-α - oliquo-alfamesosaprob, o-β - oligobetanesosaprob, β-α - beta-alfamesosaprob, β-o - oligo-betamesosaprob

According to the botanical-geographical regionalization of Azerbaijan, 23 species are new for this region distribution area (*Lyngbya aestuarii*, *L. majuscula*, *Oscillatoria sancta*, *O. limosa*, *Nodularia spumigena*, *Spirulina subsalsa*, *Cladophora fracta*, *C. glomerata*, *C. sericea*, *C. vagabunda*, *Rhizoclonium riparium*, *Ulva tepida*, *Spirogyra crassa*, *S. majuscula*, *S. circumlineata*, *S. porticalis*, *Cymbella cistula*, *Iconella capronii*, *Craticula halophila*, *Navicula trivialis*, *Nitzschia denticula*, *Neidium productum*, *Ulnaria ulna*) and 6 species are rare (*Cladophora albida*, *C. ruchingeri*, *Ulva torta*, *Colaconema elegans*, *Corallina officinalis*, *Jania virgata*). Three of the rare species belong to the Chlorophyta division (*Cladophora albida*, *C. ruchingeri*, *Ulva torta*), and three other species belong to the Rhodophyta family (*Colaconema elegans*, *Corallina*

officinalis, *Jania virgata*). Nine new for this distribution area (*Cladophora fracta*, *C. vagabunda*, *Spirogyra circumlineata*, *S. crassa*, *Craticula halophila*, *Navicula trivialis*, *Cymbella cistula*, *Iconella capronii*, *Nitzschia denticula*) and two rare species (*Cladophora ruchingeri*, *Ulva torta*) of algae were identified on the coasts belonging to Gizilaghaj National Park.

As seen in Figure 4, the algae biodiversity was highest in July. Three species were identified in December, six species in May, seven species in September, and 13 species in July, while species belonging to Rhodophyta and Charophyta divisions were not found in December. Microphotographs of algae samples from the southern shores of the Caspian Sea, obtained using optical and electron microscopes, are shown in Figure 5.

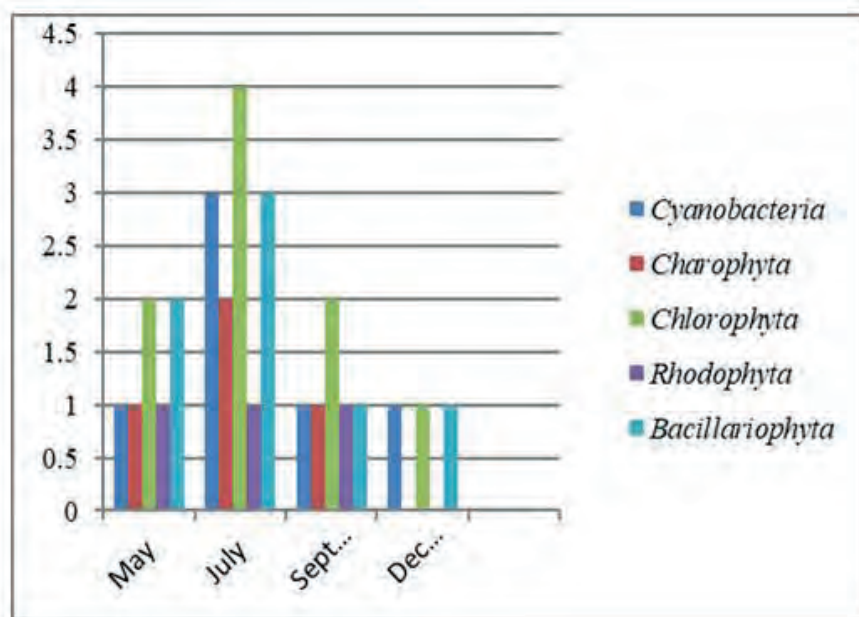


Figure 4. Annual species collection chart: 2022 families, genera, species. (May, July, September, December).



Figure 5. View of species under the scan electron microscope (SEM) and light microscope: A. *Lyngbya aestuarii*, B. *Lyngbya majuscula*, C. *Oscillatoria sancta*, D. *Oscillatoria limosa*, E. *Nodularia spumigena*, F. *Spirulina subsalsa*, G. *Cladophora albida*, H. *Cladophora fracta*, I. *Cladophora glomerata*, J. *Cladophora sericea*, K. *Cladophora vagabunda*, L. *Cladophora ruchingeri*, M. *Rhizoclonium riparium*, N. *Ulva tepida*, O. *Ulva torta*, P. *Spirogyra crassa*, Q. *Spirogyra majuscula*, R. *Spirogyra circumlineata*, S. *Spirogyra porticalis*, T. *Colaenema elegans*, U. *Corallina officinalis*, V. *Jania virgata*, W. *Cymbella cistula*, X. *Iconella capronii*, Y. *Craticula halophila*, Z. *Navicula trivialis*, A1. *Nitzschia denticula*, B1. *Neidium productum*, C1. *Ulnaria ulna*.

2. *Ecological analysis.* The results of our study showed that the algal flora of the southwestern shores of the Caspian Sea in the Lankaran district consists of eight species belonging to planktonic and benthic types, eight species of benthic, six species belonging to planktonic, benthic and epilithic types, four species of epilithic types, and three species of planktonic type. The results of the ecological analysis are shown in Table 2. The species were observed

in the temperature range of 11-27°C and pH range of 7.5-8.0.

According to the degree of water pollution in the Saprobic system (Barinova et al., 2006), five species belong to β -mesosaprobic type, three species are oligo- α -mesosaprobic type, two species are oligo- β -mesosaprobic type, two species are oligo- α -mesosaprobic, one belongs to oligosaprobic type, one belongs to α -mesosaprobic and xeno- β -mesosaprobic types,

and one species is oligohalobic-indifferent type. 15 of the studied species were collected from upper-, seven species from sup-, five species from supra- and two species from both supra- and sublittoral zones (Table 2).

In the Caspian Sea, the *Cyanobacteria* division is a widespread group of living organisms and an integral part of the aquatic ecosystem. This is the leading branch in terms of algae diversity, but it occupies the second place in the Caspian Sea after diatoms. Information about blue-green algae is contained in the studies of Kireeva, Shchapova (1957), where 33 species of blue-green algae were found in the benthos of the Caspian Sea. Among these species, *Lyngbya aestuarii*, *L. majuscula*, *Oscillatoria nigra* are noted in the Azerbaijan part of the Caspian Sea. According to our research, the species *L. aestuarii*, *L. majuscula* were identified. In the course of our present studies, 6 species were found from 92 species mentioned in previous studies (Nuriyeva, Vinogradova, 2020). Among 309 species and intraspecies taxa of diatoms found earlier in the Caspian Sea (Karaeva, 1972), we found only one species, named after the new nomenclature *Iconella capronii* (previous name: *Surirella capronii*). In other studies (Zabberzhinskaya, 1968)), 13 species are mentioned in the Azerbaijan part of the southern coast of the Caspian Sea, however, in our studies, we found only two of them.

Conclusion

As a result of the studies carried out on the southwestern coast of the Caspian Sea (coasts covering the territory of the Lankaran district of the Republic of Azerbaijan, including the Gizilaghaj National Park), new and rare species of algae were discovered, and their taxonomic structure and ecological characteristics were studied. Of the 29 species, 27 are new to the research area. Representatives of 5 divisions of algae were found in the study area, of which

the representatives of Chlorophyta (31%), Bacillariophyta (24.2%), and Cyanobacteria (20.7%) divisions are dominant. Other discovered species – representatives of the Charophyta and Rhodophyta divisions occur less frequently. The lack of comprehensive (and new) data on the algal flora of other coastal areas makes it difficult to make an in-depth comparison of algal species found in the southern coastal areas with other regions of the Caspian Sea. On the other hand, due to the low density of industrial enterprises and the low intensity of sea transport, the study area and close territories cover the shores of the Caspian Sea, which are relatively less polluted by industrial waste. Undoubtedly, the difference in the ecological situation in this part of the sea gives reason to assume that, perhaps, the algae that inhabited the southwestern coastal regions of the Caspian Sea have a different composition of species compared to other parts of the sea. However, the discovered algae, together with algae from other parts of the sea, make up the general algal spectrum of the Caspian Sea. This, in turn, requires a detailed and comprehensive study of the ecological situation of other coastal areas of the Caspian Sea and the algae species settled there in order to complete a study of the algae spectrum in the coastal areas of the Caspian Sea, to determine the relationships between the species that make up it, and to clarify the role of ecological factors in the distribution of species.

Acknowledgment

This work was supported by the Presidium of Azerbaijan National Academy of Sciences (Grant dated 18.01.2022) and the Ministry of Science and Education of the Azerbaijan Republic.

The Authors are grateful to S.T.Kalantarov for his technical assistance.

References

- Afanasyev, D.F., Kamnev, A.N., Sushkova, E.G., & Steinhagen, S. (2016). The field guide to *Ulva* species found in the Black, Azov, Caspian Seas and eastern Baltic. Moscow. Publ. house «Перо», 50 p. (Афанасьев, Д.Ф., Камнев, А.Н., Сушкова, Е.Г., Штайнхаген, С. (2016). Полевой определитель водорослей рода *Ulva* Черного, Азовского, Каспийского морей и

Восточной Балтики. М.: Издательство «Перо», 50 с.).

- Afanas'yev, D.F., Sushkova, E.G., & Kamnev, A.N. (2020). Marine and brackish species of Cladophoraceae and Aegagropila, found in the Ponto-Caspian basin. The field guide. Moscow Publ. house «Pero», 76 p. (Афанасьев, Д.Ф., Сушкова, Е.Г., Камнев, А.Н. (2020). Морские и солоноватоводные виды водорослей семейства Cladophoraceae и рода Aegagropila Понто-Каспийского бассейна: полевой определитель. М.: Издательство «Перо», 2020, 76 с.).
- Aladin, N.V. & Plotnikov, I.S. (2004). Hydrobiology of the Caspian Sea. In: J.C.J. Nihoul, P.O. Zavialov, P.P. Micklin (Eds), Dying and Dead Seas, NATO ARW/ASI Series, Kluwer Academic Publisher, Dordrecht: 185-226.
- Babaev, G.V. (1968). Composition and distribution of phytoplankton in the Middle and Southern Caspian. In: Biology of the Middle and Southern Caspian. Nauka, Moscow, p. 50-63. (Бабаев Г.В. (1968). Состав и распределение фитопланктона в Среднем и Южном Каспии. В кн.: Биология Среднего и Южного Каспия. М.: Наука, с. 50-63.)
- Bagheri, S., Sabkara, J., Mirzajani, A.R., Khodaparast, S.H., Yosefzad, E., & Foong, S.Y. (2013). List of zooplankton taxa in the Caspian Sea waters of Iran. J. Mar. Biol., 1-7. doi: 10.1155/2013/134263
- Barinova, S.S., Medvedeva, L.A., & Anisimova, O.V. (2006). Biodiversity of environmental indicator algae. Pilies Studio, Tel Aviv. 498 p. (Баринаова С.С., Медведева Л.А., Анисимова О.В. (2006). Биоразнообразие водорослей-индикаторов окружающей среды. Пилес Студия, Тель-Авив., 498 с.).
- California Academy: www.calacademy.org
- David, G.M. (1986). Morphology, taxonomy and inter-relationships of the ribbed araphid diatoms from the genera Diatoma and Meridion (Diatomaceae: Bacillariophyta). Phycologia. 25(2): 269-270. <https://doi.org/10.2216/i0031-8884-25-2-269.1>
- Dumont, H.J. (1998). The Caspian Lake: History, biota, structure, and function. Limnol. Oceanogr., 43: 44-52. doi: 10.4319/lo.1998.43.1.0044
- Fourtanier, E., Kociolek, J.P. (2011). Catalogue of Diatom Names. California Academy of Sciences. <http://researcharchive.calacademy.org/research/diatoms/names/index.asp>.
- Guiry, M.D. & Guiry, G.M. (2023). AlgaeBase. World-wide electronic publication, National University of Ireland, Galway. <https://www.algaebase.org>. (Accessed March 2023).
- Hasle, G.R. & Fryxell, G.A. (1970). Diatoms: cleaning and mounting for light and electron microscopy. Transactions of the American Microscopical Society, 89(4): 469-474. <https://doi.org/10.2307/3224555>
- Hassanpanah, D., Gurbanov, E., Gadimov, A., & Shahriari, R. (2007). Reduction of nitrate accumulation in potato by use of potassium humate for human safety. Iranian Biomedical Journal, 11(1), 461.
- Hassanpanah D., Gurbanov E., Gadimov A., Shahraiiri R. Effect of potassium humate on advanced potato cultivars for water deficit tolerance in Ardabil region, Iran. In: From Molecular Understanding to Innovative Applications of Humic Substances; 2008, vol. 2, pp. 647-650.
- Ivanov, A.I. (1965). Characteristics of the qualitati vecomposition of the Black Sea phytoplankton. Issledovania planktona Chernogo i Azovskogo morei. Nauk. Dumka, Kiev, 17-35. (in Russian)
- Iskender, E., Jafarzadeh, S., & Muradova, B. (2024). MORPHOLOGY DESCRIPTION AND TAXONOMY OF PYRUS L. SPECIES OF NORTH-EASTERN PART OF THE GREAT CAUCASUS. Acta Botanica Caucasica Volume, 3(2), 30-39.
- Ismayilova, L., Ahmadov, İ., Gasimov, E., Rzayev, F., Sultanova, J. and Ahmadova, H. Effect of nanoparticles on the Golden Delicious apple flower fertilization process and accumulation in the fruit. Acta Botanica Caucasica, 1(2), 46–56 (2022).
- Karaeva, N.I. (1960). On the biology of benthic diatoms of the Caspian Sea coast. Bot. Jour., 45(5): 767-770. (Караева, Н.И. (1960). К биологии бентических диатомовых водорослей

- побережья Каспийского моря. Бот. журн., 45(5): 767-770).
- Karaeva, N.I. (1972). Benthic diatom algae of the Caspian Sea. Elm, Baku. 258 p. (Караева Н.И. (1972). Диатомовые водоросли бентоса Каспийского моря. Баку, «Элм», 258 с.).
- Karaeva, N.I. (2002) Methodology of botanical monitoring of the Caspian Sea. Baku, Adiloglu, 20 p.
- Kurbanov, E., Aslanova, S., & Ibragimov, S. (2023). Types of Hole-Meadow and Wetlands Vegetation in Oil-contaminated Soils Siyazan District (Azerbaijan). Bulletin of Science and Practice.
- Kideys, A.E., Roohi, A., Eker, E., Melin, F. & Beare, D. (2008). Increased chlorophyll a levels in the southern Caspian Sea, following an invasion of jellyfish. Research Letters in Ecology, 1-4. <https://doi.org/10.1155/2008/185642>
- Kireeva, M.S. & Shchapova, T.F. (1957). Materials on the systematic composition and biomass of algae and higher aquatic vegetation of the Caspian Sea. Proceedings of the Institute of Oceanology of the USSR Academy of Sciences. Biological studies of the seas, 23: 125-137. (Киреева, М.С., Щапова, Т.Ф. (1957). Материалы по систематическому составу и биомассе водорослей и высшей водной растительности Каспийского моря. Труды Института океанологии АН СССР. Биологические исследования морей, 23: 125-137).
- Kosarev, A.N. & Yablonskaya, E.A. (1994). The Caspian Sea. SPB Academic Publication, Moscow, 259 p.
- Kulikovskiy, M.S. & Kuznetsova, I.V. (2014) Biogeography of freshwater Bacillariophyta L. Basic concepts and approaches. Algology, 2: 125-146. <https://doi.org/10.1615/InterJAlgae.v16.i3.10> (Куликовский, М.С., Кузнецова, И.В. (2014) Биogeография пресноводных Bacillariophyta L. Основные концепции и подходы. Альгология, 2: 125-146).
- Necchi, O.J.R & Branco, C.C.Z., Branco L.H.Z. (2000). Distribution of stream macroalgae in São Paulo State, southeastern Brazil. Algological Studies, 97: 43-57.
- Nuriyeva, M.A. & Vinogradova, O.M. (2020). Caspian cyanobacteria of Azerbaijan: a complete checklist with ecological and geographical characteristics. Algologia, 30(4): 325-340. <https://doi.org/10.15407/alg30.04.325>
- Proshkina-Lavrenko, A.I. & Makarova, I.V. (1968) Algae of the Caspian Sea plankton. Nauka, Leningrad, 291 p. (Прошкина-Лавренко А.И., Макарова И.В. (1968) Водоросли планктона Каспийского моря. Л.: Наука: 291 с.)
- Schmid, A.M.M. (1994). Aspects of morphogenesis and function of diatom cell walls with implications for taxonomy. Protoplasma. 181: 43-60. <https://doi.org/10.1007/BF01666388>
- Schwoerbel, J. (2013). Methods of Hydrobiology. New York. 200 p.
- Seckbach, J. & Kociolek, P. (2011). The diatom world. New York. 533 p.
- Shams, M. V. & Afsharzadeh, S. (2008). Study of phytoplankton changes in Zayandehroodlake. Iranian Journal of Biology, 25(2): 316-328.
- Sheath, R. G., & Cole, K. M. (1992). Biogeography of stream macroalgae in North America. Journal of Phycology, 28(4), 448-460.
- Van Der Werff, A. (1999). A new method of concentrating and cleaning diatoms and other organisms. Verhandlungen des Internationalen Verein Limnologie, 12: 276-277.
- WHO (1999). Toxic Cyanobacteria in Water: A Guide to their Public Health Consequences, Monitoring and Management. Geneva: World Health Organization.
- Zaberzhinskaya, E.B. (1968). Algae flora of macrophytes of the Caspian Sea. PhD thesis, Baku, 234 p. (Забержинская, Э.Б. (1968) Флора водорослей макрофитов Каспийского моря. Автореф. дисс. на соиск. уч. ст. к. б. н., Баку, 234 с.).
- Zinova, A.D. (1967). Identifier of green, brown and red algae of the southern seas of the USSR. Nauka Moscow, Leningrad. 396 p. (Зинова А. Д. (1967). Определитель зеленых, бурых и красных водорослей южных морей СССР. М., Л.; Наука, 396 с.).

INVESTIGATION OF SECONDARY SUCCESSION IN THE FOREST FIRE AREA IN KAZMA VINEYARDS (KAHRAMANMARASH/TURKIYE) REGION

Cihangir Uygun^{1*} | ORCID:0000-0001-7980-7752

Erol Yorulmaz¹ | ORCID: 0009-0009-4257-4639

Fatih Taş¹ | ORCID: 0000-0002-3747-8476

¹Akedaş Primary School, Yamaçtepe Mah. 93054 Sok. No:6/A, Onikişubat, Kahramanmaraş, Türkiye

^{1*}Correspondence: uygunch@gmail.com

Article Info:

DOI: <https://doi.org/10.30546/abc.2024.3.3.530>

Pages: 99–109

Received: August 20, 2024 | Revised: September 13, 2024 | Accepted: September 28, 2024

Abstract. In this study, the renewal of vegetation in the 12 years after the fire in the 32-hectare red pine forest destroyed by the forest fire that started on 17/06/2012 and was completely extinguished on 23/06/2012 in the region called Kazma Bağları, located 10 km from Kahramanmaraş city centre, was examined. The study used observational data obtained from field trips carried out regularly since the year after the fire. According to the study results, the first plant samples in the fire area appeared a year later. The first examples generally belong to annual or biennial herbaceous plants whose seeds can be carried by birds or the wind. Permanent vegetation on the land began to take shape in the third year following the fire. Some species such as *Helleborus vesicarius* Aucher, and *Tragopogon porrifolius* subsp. *longirostris* (Sch.Bip.) Greuter, *Helichrysum plicatum* (D.C.) subsp. *plicatum*, *Astragalus macrocephalus* Willd. subsp. *finitimus* (Bunge) Chamberlain were commonly seen in the area before the fire have not yet been seen twelve years after the fire. The results of the study are important in terms of showing the damage caused by forest fires to the vegetation and the process it takes for the area to regain cover.

Keywords: Ahır Mountain, forest fire, secondary succession, Kahramanmarash, areas

Introduction

Today, forest areas cover 29.53% of the world's area and spread over 44 billion km². The concept of forest in general; is An ecosystem, a life, formed by trees, shrubs, shrubs and all kinds of herbaceous plants of a certain size, structure and density spread in an area, mosses, lichens, ferns and fungi, and various micro and macro-organisms living underground and above ground, together with the natural environment in which they live. It can be defined as biocoenosis (Baysal, 2008).

Our world today is generally divided into various realms: Holarctic, Mediterranean, African, Indian, Islands and Pacific, Palaeotropical, Neo-intertropical, Southern Africa, Antarctica,

Andean and Australia. Turkey is located within the borders of the first two of these regions, that is the Holarctic and Mediterranean realms, and includes three major phytogeographical region elements: Euro-Siberian, Irano-Turanian and Mediterranean (Anşın, 1999).

Our country has a very special and rich position in terms of biodiversity, considering its geography. Located at the intersection of three phytogeographic regions and hosting different climate types, the natural assets of our country are almost as rich as a continent (Gökyiğit, 2013). Our country's biological diversity is increasing day by day with discoveries. The richness of natural diversity also requires the protection of this richness. Our country is also very

rich in terms of plant diversity. Almost one-third of the plants distributed in our country, which hosts around 12000 plant species, are endemic to our country (Özhatay et al., 2009). There are many different types of forests in our country, which are rich in terms of forest assets as well as plant diversity (OGM, 2020). Different types of forest vegetation can be seen regionally depending on climate, soil structure and altitude (Kılınç & Kutbay, 2007). Especially the so-called “Anatolian diagonal”; High endemism is observed in the area starting from the Amanos Mountains to the Eastern Black Sea Region, and different forest types can be found in this region due to the influence of landforms, elevation and climate (Kılınç & Kutbay, 2007).

The richness of biological diversity and forest existence brings with it some risks. The biggest of these risks is forest fires. Regardless of the reason why forest fires occur, they can cause major changes in the biodiversity of the region where they occur. Fire risk increases especially in areas with a Mediterranean climate with dry summer periods (Pausas & Vallejo, 1999). Especially in regions where coniferous trees and maquis are dense, human-caused fires are predominantly seen. These fires can cause great damage depending on the characteristics of the area where they occur. With climate change, meteorological and climatic conditions such as a rise in temperature, an increase in drought, and continuous heat waves increase the number of forest fires and regions exposed to fires (Calda et al., 2020). In the Mediterranean Basin, forest fires occur frequently, especially in summer and dry autumn and spring periods. This situation is an ecological problem whose importance is increasing day by day (Tatlı & Türkeş, 2014).

Mountain ecosystems are complex systems affected by changing environmental factors; Topographic conditions, especially elevation, directional extensions of mountains, ruggedness, slope, temperatures, precipitation, plant distribution and soil conditions, play an important role in these systems and cause the formation of different ecological habitats (Atalay, 2008). Mountainous areas are isolated environments that lead to changes in plant diversity as well as

an increase in the number of locally distributed plant taxa (Duran, 2013).

Succession is the situation in which one plant community is replaced by another in natural ecosystems (Gökkuş & Koç, 2001). Progressive succession refers to the complexity of the cover and a forward change in the vegetation due to the increase in species diversity in the vegetation seen in an area, and regressive or retrogressive succession refers to the change seen in the decrease in the density and species diversity of the vegetation due to any factor (fire, natural disasters, overgrazing, etc.). It is called (Akman & Ketenoğlu, 1987). Changes occurring in vegetation can be examined in three different ways: Phenomenological changes, primary succession and secondary succession (Akman & Ketenoğlu, 1987). Phenological changes may be seasonal or periodic changes occurring in an area, or they may occur as the emergence and disappearance of geophytes in an ecosystem with woody species. Primary succession is the formation of cover in an area where there was no previous vegetation. Secondary succession is the development of a new cover as a result of the destruction or change of the cover in an area for any reason (Akman & Ketenoğlu, 1987).

Kahramanmaraş province, which is the subject of our study, is almost a miniature of our country. Geographically, our province is located at the intersection of the Mediterranean, Southeastern Anatolia, Central Anatolia and Eastern Anatolia regions, and is also phytogeographically located at the intersection of the Mediterranean and Iran-Turan regions. Due to these features, it is very rich in terms of biodiversity and endemism (Özhatay et al., 2009). Kahramanmaraş city centre is located on the foothills of Ahır Mountain, an important plant area (IPA) (Özhatay et al., 2008). For this reason, the higher parts of the mountain are generally used as plateaus. The area located on the western slopes of Ahır Mountain and surrounded by vineyard houses is locally called “Kazma Vineyards” (Fi.

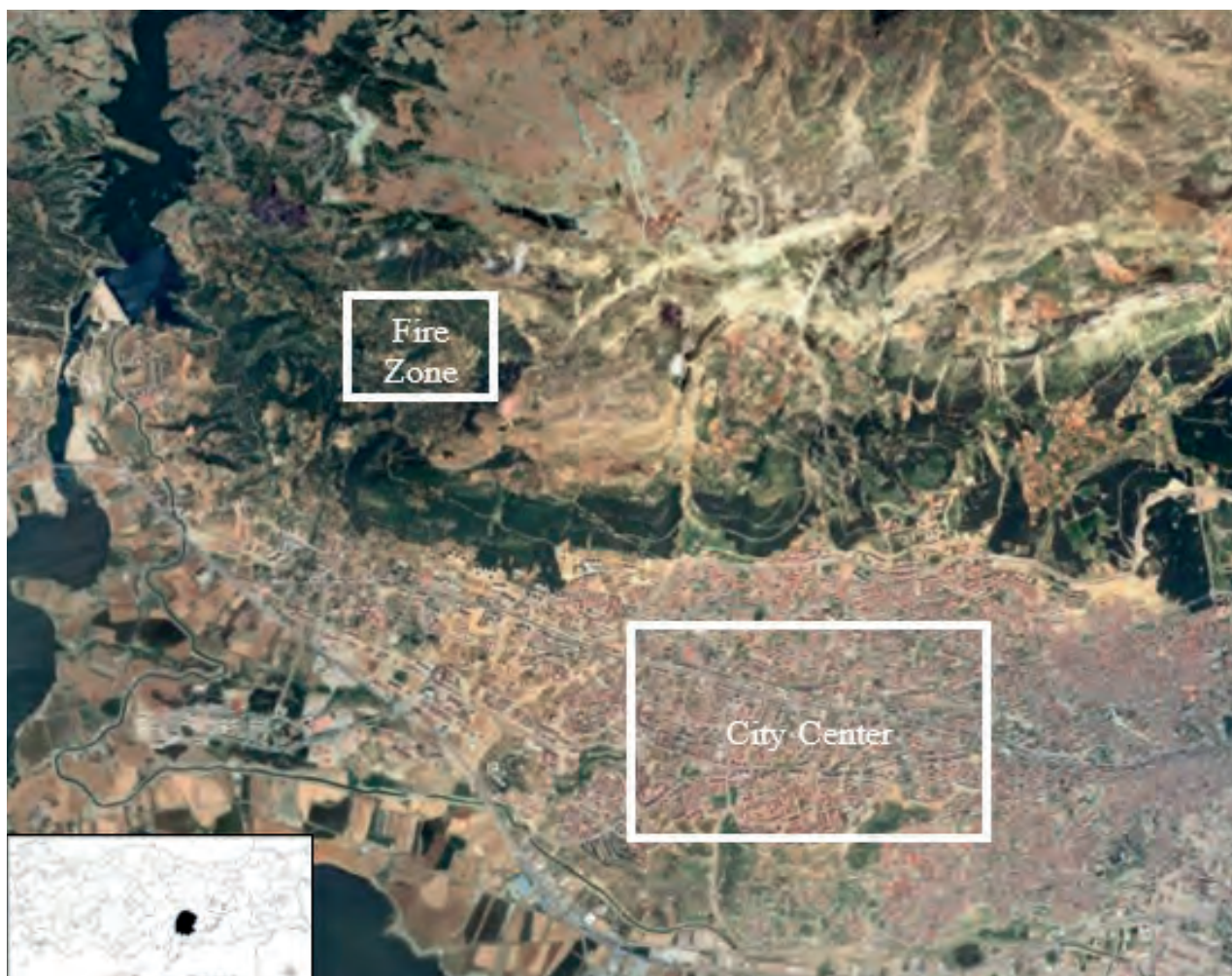


Figure 1. Location of the fire zone

This region starts from an altitude of approximately 800 m and rises to 1150 m and is entirely composed of *Pinus brutia* Ten. It is covered with forest. *Quercus cerris* is occasionally found in areas adjacent to the forest in the region. *Q. libani* Olivier, *Q. coccifera* L. and *Q. infectoria* subsp. There are also maquis formed by *boissieri* (Reuter) O. Schwarz species. As you go to the northwestern parts of the area, *Styrax officinalis* L., *Ostrya carpinifolia* Scop. Their communities are concentrated in forest clearings and form a maquis formation. Especially along the western foothills, where settlements are dense, the forest has been degraded and fruit trees and viticulture have become widespread. If the area is 1450 m and above, a sub-alpine vegetation begins.

An area of 32 hectares was damaged in the forest fire that started on June 17, 2012, in the mentioned region and was completely extinguished on June 23, 2012. 30 hectares of the

damaged area is productive forest area, and 2 hectares is degraded forest area. In our study, studies and field observations carried out in the fire area or nearby areas were used.

Materials and Methods

The research was carried out based on field studies conducted between 2012 and 2023. In addition, records of field studies conducted by the authors and previous studies in nearby areas conducted before 2012 were also used for comparison. In determining the vegetation before the fire, studies were carried out in the field and photographs and notes from our field trips were used. Post-fire data is based on data obtained from regular field trips every year. Plant samples are stored in the KSUH (Kahramanmaraş Sütçü İmam University Herbarium). In the post-fire period, the area was visited regularly and the formation of the vegetation was photographed and field records were kept. P.H.

DAVIS's work "Flora of Turkey and The East Aegean Island" was taken as the main source in the description of the samples.

Results and Discussion

The most comprehensive study carried out in the field before the fire was the study titled "Upper Ceyhan Valley Flora" (Tatlı et al., 2002). In this study, 412 plant species were identified from the area including the fire zone. Pre-fire observations made in the field also coincide with this study. Additionally, in the study titled "Flora of the High Mountain Steppes of Ahır, Binboğa and Öksüz Mountains" conducted by Aytaç and Duman (2005), the flora of the high steppes of the regions close to the fire area was studied. Doygun et al. (2014) observed the changes in the vegetation cover of Ahır Mountain observationally with their study "Investigation of Kahramanmaraş - Ahır Mountain Vegetation Change with Remote Sensing Method". Kısakürek et al. (2014) in their study titled "Investigation of Kahramanmaraş - Ahır Mountain Vegetation in Line with Bioclimatic Levels", determined the bioclimatic layers for Ahır Mountain by using Kahramanmaraş meteorology station data and examined the relationships between bioclimatic layers and vegetation distribution. Özhatay et al. According to (2005),

Ahır Mountain, where the study area is located, is also an important plant area (IPA). A direct study on secondary succession has not been conducted in the field before.

Pre-Fire Period Vegetation

There are no direct records from the pre-fire period in the literature studies. Considering the studies and observations made in the surrounding area, *Pinus brutia* Ten forest is densely present in the area and different types of maquis are the dominant vegetation in the forest clearings (Figure 2). As you move to the west of the area, forest cover decreases and maquis cover increases (Figure 3). This has resulted in a decrease in the canopy area and an increase in both species diversity and density of herbaceous species. *Ostrya carpinifolia* Scop., which is not seen elsewhere in the area and *Paliurus spina-christi* Mill. species are seen in the western regions. Again, in this region, *Astragalus* species densely serve as cover. In areas close to the upper border of the fire area, *Acantholimon acerosum* subsp. *brachystachyum* (Boiss.) Doğan&Akaydın, *Acantholimon libanoticum* Boiss. and *Acantholimon kotschyi* (Jaub. &Spach) Boiss. types are seen.



Figure 2. Some species seen intensively in the pre-fire period (1. *Helychrisum* sp., 2. *Iris persica*, 3. *Astragalus* sp.)



Figure 3. General view of the area before the fire (2011) (Image Source: Google Earth Pro software).

Snow cover can be seen in the area until the beginning of February. For this reason, vegetation generally does not appear on the land until the beginning of March. From the beginning of March, geophytes begin to show themselves. *Crocus chrysanthus* (Herb.) Herb is abundant in forest clearings. This type is widely seen. In addition, *Iris persica* L. is one of the first species to emerge, especially on the stabilized road at the lower border of the fire area and in the sloping area between the road and the forest area. As we move westward, members of the *Helleborus vesicarius* Aucher and *Helychrisum* genera begin to emerge. In April and May, as the snow cover disappears, underground waters rise and temperatures increase, a rapid herbaceous vegetation begins to emerge in the area. During this period, *Salvia multicaulis* Vahl., *Salvia absconditiflora* Greuter & Burdet, *Scutellaria orientalis* subspecies, *Scutellaria salviifolia* Benth., *Muscari neglectum* Guss., *Crupina crupinastrum* (Moris) Vis. species are seen frequently. Starting from the end of May, spiny and hard-bodied

Asteraceae members, *Astragalus* and *Hedysarum* species and *Epipactis helleborine* (L.) Crantz. species are becoming dominant in the area. Starting from mid-May, Poaceae members also show themselves in the field. Starting from June, especially when the temperatures exceed 30 °C, the herbaceous species in the area are rapidly replaced by hard-bodied herbs and shrubby species. In July and August, spiny Asteraceae species, *Delphinium peregrinum* L., *Dianthus* species and *Xeranthemum annuum* L. specimens are frequently seen in the area. After August, the number of flowering plants in the area decreases rapidly. During this period, *Plumbago europaea* L. species, *Echinops* species, *Cirsium* species and some heat-resistant Asteraceae species can be seen in some parts of the area. In the autumn period, although rare, autumn geophytes are encountered. Since there is frequent snow cover in the area during the winter, the flora generally consists of woody species and maquis species.

Post-Fire Period

First 3 years after fire (between July 2012 and November 2015)

During this period, the destruction of the fire on the land can be seen (Figures 4, 6 & 7). Many plant species cannot be seen, especially in April-May-June, when the flora is rich before the fire. Hard-bodied herbs and geophytes can mostly spread in the area (Figure 5), while

annual herbaceous species are concentrated starting from the lowest border of the fire zone. In addition, in the first year following the fire, geophytes dominated the area, especially *Crocus graveolens* Boiss et. Reuter and *Iris persica* L. species spread in the openings in the burned areas.



Figure 4. View from the area after the fire is extinguished

The vegetation remained very weak due to human impacts such as intense reclamation work in the area in 2013 and 2014 and the opening of access roads to access the logs in the forest. The most obvious change in the area during this period is the descent into the forest of some species that were previously seen above the upper limit of the area. *Securigera grandiflora* Boiss, *S. varia* (L.) Lassen sub-species, *Butiminaria butiminosa* (L.) C.H.Stirt, species are examples of these plants. Additionally, Apiaceae members, which are rarely seen

in the area, were seen in greater numbers in the post-fire period (Figure 8). 2015 is the year when the vegetation is more clearly shaped. During this period, the remnants of the fire and its impact on the soil significantly decreased, and herbaceous species found more spreading areas thanks to the cleaning of the soil surface through rainfall and floods. In the parts of the area that were not destroyed, vegetation similar to that before the fire continues to exist.

Since May 2015, some species such as *Salvia verbenaca* L. and *Teucrium polium* L., which

have not been seen before in the area, have started to spread, although not very densely. Especially the edges of the stabilized road close to the forest, which separates the forest area and the vineyard houses, have created a very dense and rich cover with the seeds brought by the rain. During this period, maquis density in the fire area also increased. Especially *Juniperus oxycedrus* L., *Quercus coccifera* L. and *Quercus cerris* L. var. *cerris* species have expanded their

distribution areas considerably. In addition, members of the *Styrax officinalis* L. species began to be seen more in areas closer to the road, on the western border of the area and in the lower part of the road that was not affected by the fire. Despite all this, the diversity of the area and the density of vegetation are much weaker than before the fire.



Figure 5. Some species observed in the three years after the fire (1. *Linaria kurdica*, 2. *Turgenia latifolia*, 3. *Centaurea virgata*)

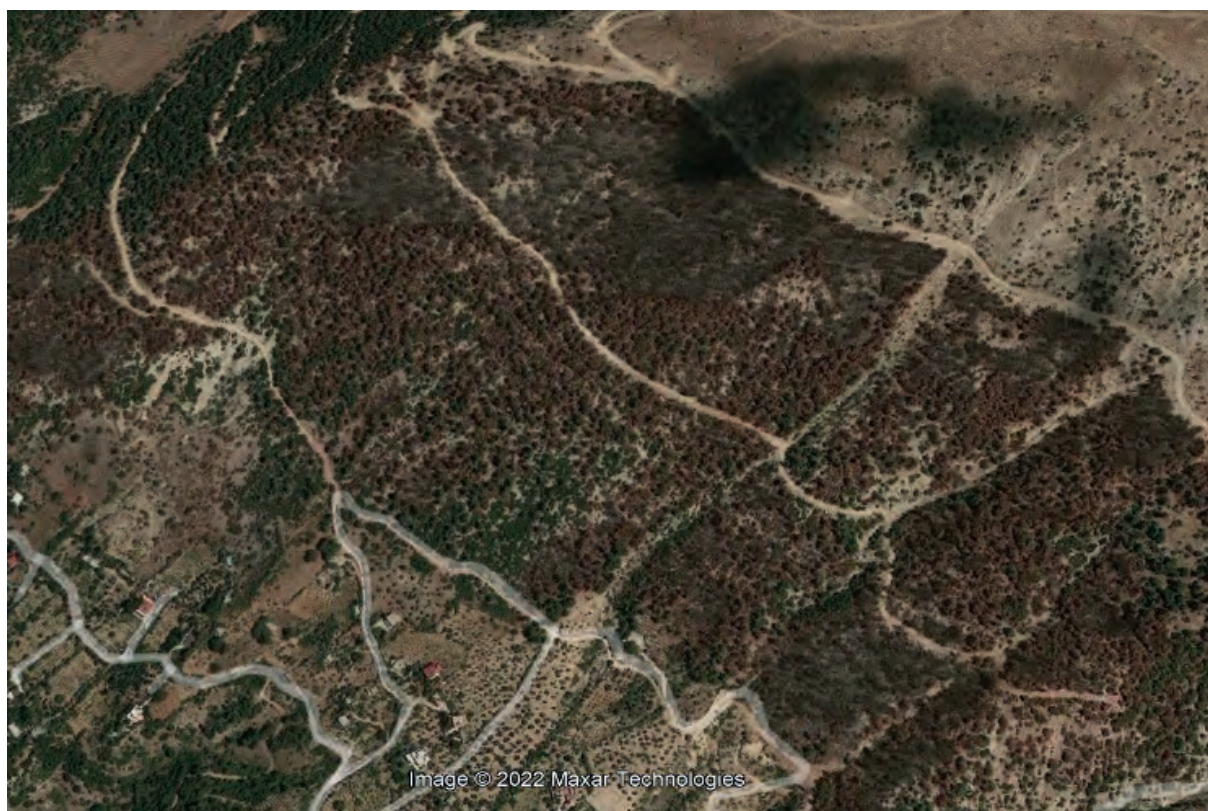


Figure 6. General view of the area soon after the fire (Image Source: Google Earth Pro software)



Figure 7. General view of the area in 2014 (Image Source: Google Earth Pro software)

4th – 7th years after the fire (between January 2016 and November 2019)

Vegetation began to take shape clearly in the area in the fourth year following the fire (Figure 9). In parallel with the maquis formation in the fire area, herbaceous species decreased in density and were replaced by hard-bodied perennials. However, diversity continued to increase at the borders of the fire area. During this period, species that were seen in the area before the fire but were not seen in the first three years began to appear. In addition, *Allium ampeloprasum* L. and *Centaurea tomentella* Hand.-Mazz species have started to show themselves, especially in areas close to the road. The most important issue here is that the

species that were densely distributed in higher regions before the fire expanded their distribution areas after the fire. The main reason for this may be that the destroyed forest area previously served as a barrier for these species. *Lactuca* sp., which was previously encountered from ~1300 m altitude, which is the upper limit of the forest. and *Linaria* sp. species have also begun to be seen at lower elevations. In the openings formed, *Hypericum* sp., *Scrophularia* sp., *Scabiosa* sp., *Convolvulus* sp., *Serratula cerinthifolia* (Sm.) Boiss., *Alcea apterocarpa* (Fenzl.) Boiss., *Michauxia campanuloides* L'Herit ex Aiton, *Dianthus anatolicus* Boiss., *Papaver dubium* L. species have begun to spread.



Figure 8. Some species seen between the 4th and 7th years after the fire (1. *Cichorium inthybus*, 2. *Klasea cerinthifolia*, 3. *Onosma* sp.)

The area began to take on an appearance close to the pre-fire period from the middle of this period, that is, from the fifth year. However, the same level has not been reached in terms of vegetation density and periodic species richness.

8th - 10th years after the fire (January 2020 - July 2022)

Towards the end of the 8th year following the fire, the forest area began to reshape

(Figure 10 & 11). Although no planting was done in the area, *Pinus brutia* Ten. seedlings emerging through seeding are noteworthy. In addition, widespread maquis formation is also seen. In the 9th and 10th years, the vegetation has gained its characteristics. Especially from the end of April, herbaceous plants began to appear densely in the area, and *Sideritis*, *Stachys* and *Salvia* species were found in groups.



Figure 9. General view of the area in 2017 (Image Source: Google Earth Pro software)



Figure 10. A view of the fire area in 2020

Especially in the clearings within the forest and on the sides of the roads, Lamiaceae and Asteraceae members are densely visible. In addition, Fabaceae members also show themselves from the end of May. Another striking situation during these periods is the local deterioration observed due to the increase in the number of wild boar (*Sus scrofa*) in the area. After the fire, the wild boar population in the area increased rapidly and herd populations began to be seen

all over the fire area. The damage caused by the herds on both the soil and the vegetation reaches serious dimensions in some places. In addition to this, human-induced damage is also observed around the vineyard houses in the area. In contrast, the vegetation of the area has reached an appearance very close to the pre-fire period.



Figure 11. General view of the area in 2020 (Image Source: Google Earth Pro software)

The study results showed that when the long-term effects of forest fires are combined with human-induced problems, it takes approximately 8 years for the vegetation to recover. At the end of this period, the cover is reshaped, and some species seen in the pre-fire period cannot be observed again after the fire; on the other hand, some species that were not in the area before the fire or were in neighbouring

areas were moved to the fire area (Table 1 and Table 2). In addition, it was observed that fire-related damage was seen in the fire area in the first 5 years, the forest area rapidly became maquis, the number of hard-stemmed species increased, and both the number and density of herbaceous plant species decreased compared to before the fire.

Table 1.

Species seen before the fire but not seen again after the fire

Name of Taxa	Date of observation before the fire	Habit/location
<i>Euphorbia anacampseros</i> Boiss.	30.04.2008	Water gully surroundings within forest areas
<i>Astragalus macrocephalus</i> Willd. subsp. <i>finitimus</i> (Bunge) Chamberlain	12.07.2009	In the open area between the forest and the road, on a shady slope facing north.
<i>Tragopogon porrifolius</i> subsp. <i>longirostris</i> (Sch.Bip.) Greuter	18.04.2009	Road sides
<i>Helichrysum plicatum</i> (D.C.) subsp. <i>plicatum</i>	26.06.2010	Border of vineyard houses and forest area, open steppe area.
<i>Veronica thymoides</i> subsp. <i>pseudocinerea</i> M.A.Fish.	19.05.2011	Stony slopes
<i>Hesperis bicuspidata</i> (Willd.) Poir.	19.05.2011	Steppe near forest opening
<i>Campanula stricta</i> var. <i>stricta</i> L.	09.07.2011	Between the Road side and the stony slopes
<i>Nigella stellaris</i> Boiss.		Road sides
<i>Scutellaria brevibracteata</i> subsp. <i>brevibracteata</i>	10.06.2012	Road side

Table 2.

Taxa seen after the fire that were not seen before the fire

Taxa	Date of observation after the fire	Habit/location
<i>Salvia verbenaca</i> L.	01.05.2014	Forest sides
<i>Teucrium polium</i> L.	14.06.2014	Water gully, stony places
<i>Allium ampeloprasum</i> L.	14.06.2014	Road sides
<i>Linaria kurdica</i> subsp. <i>pycnophylla</i> (Boiss. & Balansa) P.H.Davis	25.06.2016	All over the fire area
<i>Linum pubescens</i> Banks&Sol	19.05.2016	All over the fire area
<i>Centaurea tomentella</i> Hand.-Mazz	15.07.2019	The fire area is surrounded by roadsides and forest clearings.

Another result of the study is that coniferous trees that are eliminated in fire areas are generally replaced by maquis, and it takes eight to ten

years for forest cover to emerge in areas where no reclamation or planting is done. Especially since fire damage to the soil affects the subsoil

temperature, humidity and above-ground fauna, it is observed that the germination and spreading characteristics of plants also change. Increasing average temperatures cause changes in the flowering periods of plants. This leads to periodic changes in the cover in the area. For example, *Crocus* sp. members that started to be observed in April in the pre-fire period can be observed from the end of March after the fire. The decrease in the forest cover in the area and its complete disappearance in a certain region also affected the climate character of the area. As a result of this, differences are also seen in the vegetation. In the area where shade plants were seen in the pre-fire period when the forest cover was lush, shade plants decreased in number and diversity after the fire. In particular, the disappearance of the needle leaves covering the soil surface has also created an opportunity for spreading plants. *Convolvulus* species can find wide distribution areas in the steppes formed in the forest. The removal of needle leaves on the soil also provided the opportunity for the spread of hard-stemmed and durable steppe plants. In these areas, relatively widespread and durable species such as *Butiminaria butiminosa* (L.) C.H.Stirt, *Onobrychis galegifolia* Boiss. escaped downstream from the fire area and spread along the road bordering the area.

Our observations and field studies have shown that forest fires cause irreparable damage to the areas where they occur and that this period is even longer in areas where rehabilitation is not carried out. Especially when areas with narrowly distributed endemic plants are destroyed, this can cause the extinction of these species. As fire areas expand, the damage increases. The proximity of fire areas to settlements also directly affects succession. Succession in areas close to settlements takes longer. Factors such as grazing, construction, road construction, and opening of mining areas in the area also have negative effects on succession.

Since our study in the study area is based on observation, it may not provide detailed

information about the area's flora. If comparative and detailed floristic studies are conducted in the fire areas and these studies are supported, clearer results will certainly be obtained. In addition, field observations have shown that coniferous forests have lower fire resistance. Because broad-leaved trees and maquis located in the fire area were less affected by the fire.

Conclusion

This study highlights the significant ecological impacts of the forest fire that occurred in the Kazma Bağları region of Kahramanmaraş in 2012. Observations over a 12-year period have demonstrated that forest fires not only cause immediate destruction of vegetation but also lead to long-term ecological changes. The initial recovery, characterized by annual and biennial herbaceous plants, began within a year after the fire, while permanent vegetation started forming in the third year. However, some key species that were present before the fire, such as *Helleborus vesicarius*, *Astragalus macrocephalus*, and *Helichrysum plicatum*, have not reappeared, indicating potential local extinctions.

The study revealed that the affected forest area has largely transitioned into a maquis-dominated ecosystem, with coniferous regeneration occurring only sporadically. This transformation is likely influenced by post-fire soil changes, microclimatic shifts, and human activities such as grazing and land use near the affected area. Additionally, the prolonged recovery period and the absence of pre-fire species underscore the importance of active ecological restoration efforts, especially in areas rich in endemic and narrowly distributed species.

In conclusion, the findings emphasize the critical need for sustainable forest management practices, long-term ecological monitoring, and conservation strategies to mitigate the long-lasting effects of forest fires and support biodiversity recovery in fire-affected ecosystems.

References

- Akman, Y., & Ketenoğlu, O. (1987). *Vejetasyon ekolojisi*. Ankara Üniversitesi, Ankara-Türkiye.
- Anşin, R. (1999). 21.Mart Dünya Ormancılık Günü Nedeniyle Ülkemiz Orman ve Florası Üzerine Genel Bir Bakış ve Bazı Öneriler. *Orman Mühendisliği Dergisi*, (6).
- Atalay, İ. (2008). *Ekosistem ekolojisi ve coğrafyası*. Çevre ve Orman Bakanlığı Yayınları, 628 pp.
- Aytaç, Z., & Duman, H. (2005). The Steppic flora of high mounts Ahir, Oksus and Binboga (Kahramanmaraş, Kayseri, Turkey). *Flora Mediterr*, 15, 121-78.
- Baysal, M. (2008). *Çangal Ormanı (Sinop-Ayancık) vasküler bitkiler florası* (PhD Thesis). Ankara Üniversitesi Fen Bilimleri Enstitüsü, Ankara.
- Calda, B., Nazan, A. N., Turp, M. T., & Kurnaz, L. (2020). İklim Değişikliğinin Akdeniz Havzasındaki Orman Yangınlarına Etkisi. *International Journal of Advances in Engineering and Pure Sciences*, 32(1), 15-32.
- Commission. (2020). *Türkiye Orman Varlığı 2020*. Ankara: Orman Genel Müdürlüğü Yayınları, 58 pp.
- Davis, P. H. (1965-1988). *Flora of Turkey and The East Aegean Islands* (Vols. 1-11). Edinburgh University Press, Edinburgh, UK.
- Doygun, H., Kısakürek, S., Erdoğan, N., & Hatipoğlu, I. H. (2014). Kahramanmaraş-Ahir Dağı Bitki Örtüsü Değişiminin Uzaktan Algılama Yöntemi ile İncelenmesi. II. Ulusal Akdeniz Orman ve Çevre Sempozyumu, Isparta, Türkiye, 22-24.
- Duran, C. (2013). Türkiye'nin bitki çeşitliliğinde dağlık alanların rolü. *Biyoloji Bilimleri Araştırma Dergisi*, 6(1), 72-77.
- Gökyiğit, A. N. (2013). *Türkiye'nin Biyolojik Zenginliği ve Korunması*. İstanbul: ANG Vakfı Yayınları, 111 pp.
- Gökkuş, A., & Koç, A. (2001). Mera ve çayır yönetimi. Atatürk Üniversitesi Ziraat Fakültesi Ders Yayınları, 228.
- Gurbanov, E., & Aslanova, S. (2024). AVERAGE ANNUAL PRODUCTIVITY OF THE THYMUS-ETALUM-FESTUCOSUM FORMATION, DISTRIBUTED IN SUMMER PASTURE FIELD NO. 8" TURKESOBABA"(AZERBAIJAN). *Norwegian Journal of Development of the International Science*, 126.
- Gurbanov, E., Ibragimov, S., & Huseynova, K. (2022). Plant ecological research for the bioremediation from pollution by oil and oil products in Absheron Peninsula (Azerbaijan). *Bulletin of Science and Practice*.
- Gurbanov, E., Huseynova, H. Z., & Ibrahimov, Sh. I. (2020). Methods for determining soil contamination by oil and petroleum products and indicator plants in the north of Caspian Sea. *International Journal of Agriculture and Biological Sciences*, 4, 84-89.
- Hassanpanah, D., Gurbanov, E., Gadimov, A., & Shahriari, R. (2007). Reduction of nitrate accumulation in potato by use of potassium humate for human safety. *Iranian Biomedical Journal*, 11(1), 461.
- Hassanpanah D., Gurbanov E., Gadimov A., Shahriari R. Effect of potassium humate on advanced potato cultivars for water deficit tolerance in Ardabil region, Iran. In: *From Molecular Understanding to Innovative Applications of Humic Substances*; 2008, vol. 2, pp. 647-650.
20. Huseynova, H. Z. (2023). New distribution areas of some species of plants on the southern part of the Caspian coast. *Biosystems Diversity*, 31(1), 123-130. <https://doi.org/10.15421/012313>
- Kılınç, M., & Kutbay, H. G. (2007). *Bitki coğrafyası*. Ankara: Palme Yayınları, 303 pp.
- Kısakürek, Ş., Doygun, H., & Gözcü, M. (2014). Kahramanmaraş-Ahir Dağı Bitki Örtüsünün Biyoiklim Katları Doğrultusunda İncelenmesi. II. Ulusal Akdeniz Orman ve Çevre Sempozyumu, 22-24.
- Kurbanov, E., Aslanova, S., & Ibragimov, S. (2023). Types of Hole-Meadow and Wetlands Vegetation in Oil-contaminated Soils Siyazan District (Azerbaijan). *Bulletin of Science and Practice*.
- Özhatay, N., Byfield, A., & Atay, S. (2008). Türkiye'nin 122 önemli bitki alanı. WWF Türkiye (Doğal

- Hayatı Koruma Vakfı), 478 pp.
- Özhatay, N., İlçim, A., & Ok, T. (2009). Ahır Dağı'nın Sessiz Güzelleri: 200 Yabani Çiçek. İstanbul: Kahramanmaraş İl Çevre ve Orman Müdürlüğü Yayınları, 96 pp.
- Pausas, J. G., & Vallejo, V. R. (1999). The role of fire in European Mediterranean ecosystems. In Remote sensing of large wildfires (pp. 3-16). Springer, Berlin, Heidelberg.
- Tatlı, A., Akan, H., Tel, A. Z., & Kara, C. (2002). The flora of upper Ceyhan valley (Kahramanmaraş/Turkey). Turkish Journal of Botany, 26, 259-275.
- Tatlı, H., & Türkeş, M. (2014). Climatological evaluation of Haines forest fire weather index over the Mediterranean Basin. Meteorological Applications, 21(3), 545-552.
- Uygun, C., İlçim, A., Karaman, S., Kazanchi, I., & Bağcı, S. (2024). FLORA OF SARIMSAK MOUNTAIN (ANDIRIN/KAHRAMANMARASH/TURKIYE). Acta Botanica Caucasica Volume, 3(2), 46-63.
- Uygun, C., Kazancı, I., & Bağcı, S. (2024). FLORA OF THE TIRIL MOUNTAIN (ANDIRIN/KAHRAMANMARASH/TURKIYE). Acta Botanica Caucasica, 3(1), 15-20.

CONTENTS

Elshad Gurbanov, Afaq Rzayeva THE CURRENT STATE OF JUNIPERUS FOETIDISSIMA WILLD. CENOPOPULATIONS IN AZERBAIJAN	4
Vagif Novruzov, Aynur Bayramova, Elanura Cavadova ECO-FLUORESCENT CHARACTERISTICS OF THE FLORA OF THE GANGA RIVER BASIN	10
Ilham Garagurbanlı, Aytaj Asgarova, Sevda Babayeva, Elnara Ahmadova, Nargiz Abdullayeva, Vusala Izzatullayeva, Zamina Sarhadova, Sevil Suleymanova, Mehraj Abbasov ASSESSMENT OF GENETIC VARIATION IN AZERBAIJANI HAZELNUT (CORYLUS AVELLANA L.) GENOTYPES THROUGH ISSR MARKERS	17
Shabnam Isayeva, Shakir Gasimov FLORA OF MUD VOLCANO IN THE EASTERN PART OF THE GREATER CAUCASUS (AZERBAIJAN)	27
Kamila Aliyeva, Khatira Mammadova, Jabrayil Aghayev GENETIC RESOURCES OF GRAPEVINE (VITIS VINIFERA L.) AND THEIR RESISTANCE TO DOWNY MILDEW	36
Vagif ATAMOV, Murat MUSAYEV PHYTOSOCIOLOGICAL INVESTIGATION OF COASTAL WATER SWAMP PLANT COMMUNITIES OF AZERBAIJAN	43
Emine Alcitepe, Fergan Karaer A NEW NATURAL HYBRID CAMPANULA x KUSADASIENSIS (CAMPANULACEAE) FROM WESTERN ANATOLIA, TURKIYE	59
Ismat Ahmadov, Kamala Gahramanova, Ziyaddin Mammadov PRODUCTION OF DRUG NANOPARTICLES FROM MEDICINAL PLANT EXTRACTS	74
Aytaj Muradova, Shakhar Mukhtarova, Yashar Feyziyev THE ALGAE OF THE SOUTHERN COASTS OF THE CASPIAN SEA (LANKARAN DISTRICT)	84
Cihangir Uygun, Erol Yorulmaz, Fatih Taş INVESTIGATION OF SECONDARY SUCCESSION IN THE FOREST FIRE AREA IN KAZMA VINEYARDS (KAHRAMANMARASH/TURKIYE) REGION	96



ISSN 2958-0536



www.botanic.az