Plant Ecology and Evolution 158 (1): 100–110, 2025
https://doi.org/10.5091/plecevo.144212

RESEARCH ARTICLE

Phytosociology, ecology, and distribution of *Gymnospermium odessanum* in Romania

Simona Dumitrița Chirilă[1], Mihai Doroftei[1], Marian Mierlă[1]

1 Danube Delta National Institute for Research and Development, Tulcea, Romania

Corresponding author: Mihai Doroftei (mihai.doroftei@ddni.ro)

Academic editor: François Gillet ♦ **Received** 11 December 2024 ♦ **Accepted** 14 February 2025 ♦ **Published** 25 March 2025

Abstract

Background and aims – *Gymnospermium odessanum* is a threatened plant species whose presence ranges from south to south-east in Romania. In this context, the study aims to ecological conditions and update the species distribution and identify the plant associations in which the species occurs.

Material and methods – The species' distribution was investigated for all the populations mentioned in the literature and other potential locations. Phytosociological relevés were collected in all locations in which the species is present. We applied Agglomerative Hierarchical Clustering to compare the species composition of the plant communities and to identify the main clusters, which we assigned to phytosociological associations and EUNIS habitats. We compared environmental conditions among the identified vegetation units.

Key results – The numerical analysis revealed five well-defined vegetation units, identified to five known associations. The associations in which *G. odessanum* was the most abundant were *Artemisio austriacae-Poetum bulbosae* and *Gymnospermio odessani-Celtetum glabratae*. The total number of individuals recorded in all locations is approximately 1107, with a density of 10 to 200 individuals/100 m^2. Compared to the observations made in 2007 (2135 individuals), the number of individuals has decreased. The area occupied by the population tended to decrease as well. The population's conservation status and changes in the range pattern of the habitat type are unfavourable-inadequate.

Conclusion – In the two associations in which it was the most abundant, *G. odessanum* is limited to some locations in Dobrogea, where the occupied areas have been significantly reduced due to habitat fragmentation and anthropogenic impact, including overgrazing.

Keywords

Dobrogea, ecology, rare species, slope, Berberidaceae, Romania, syntaxonomy

INTRODUCTION

Studying rare or endangered species is critically important for biodiversity conservation (Currie 2003; Agrawal and Gopal 2013; Elisafenko and Dorogina 2019). One of the rare species in the flora of Romania (Doroftei and Mierlă 2007), considered a tertiary relict (Voglmayr and Korytnianska 2015), is *Gymnospermium odessanum* (DC.) Takht. [syn. *Gymnospermium altaicum* (Pall.) Spach, *Leontice odessana* Fisch. ex Rogov, and *Leontice altaica* Pall.] from Berberidaceae Juss. It is only found in the Dobrogea (Beldie 1955; Petrescu 2001), a region in Romania with remarkable biological and ecological diversity (Bănescu et al. 2020). Human activities in this region, such as intensive agriculture, deforestation, urbanization, pollution, and poor land management practices, including overgrazing and illegal harvesting of plants, contribute to habitat loss, landscape fragmentation, and declining populations of native species. These problems are exacerbated by climate variations, which can alter the environmental conditions to which species have adapted over time.

The species has a narrow disjunctive distribution range (Scherbakova and Novosad 2018) and has been

Plant Ecology and Evolution is published by Meise Botanic Garden and the Royal Botanical Society of Belgium.

recorded in the Republic of Moldova, Ukraine, and Romania (Raab-Straube 2015). In Romania, the species is restricted to small areas, with few populations (from five to nine) in the Dobrogea region (Doroftei and Mierlă 2007; Scherbakova and Novosad 2018). In the Republic of Moldova, the species is found in seven locations in Hagimus in the Căuşeni district (Postolache 2015). In Ukraine, the species is found in 75 locations in the oblasts Mykolaiv (Kryzhevsky 1915), Kherson (Pachosky 1910), Odesa, Dnipro, and Kirovohrad (Scherbakova and Novosad 2018).

Gymnospermium odessanum is a plant species that grows in specific conditions, preferring moderate elevation (from 50 to 310 m a.s.l.) and hard substrates, such as granite, quartz, phyllite, dolerite, schists, and conglomerates (Doroftei and Mierlă 2007; Barina et al. 2017). This plant is found in grasslands, open forests, semi-arid places, under shrubs, on shaded steppe cliffs, in wet depressions of slopes, and ditches covered with grass (Doroftei and Mierlă 2007; Lytvynenko 2010; Sârbu et al. 2013). The species generally occurs on south-west hillsides. It grows on lithosols of different thicknesses, formed predominantly on rocks belonging to a Carapelit formation and on granites (Petrescu 2004). It is mentioned as a diagnostic species for the association *Gymnospermio altaicae-Celtetum glabratae* Petrescu 2001 (Doroftei and Mierlă 2007). Interestingly, the species *G. odessanum* hosts the mould *Peronospora odessana* Voglmayr & Korytn. (Voglmayr and Korytnianska 2015), which produces a pale yellow or light green colour on the plant, the infection being systemic and visible. In the Republic of Moldova, it occurs in communities with *Quercus robur* L. and *Cotinus coggygria* Scop. (Postolache 2015).

At the global, European, and European Union's levels, the conservation status of *G. odessanum* is not evaluated (EEA 2024). In Romania, the species grows only in the Dobrogea region and is considered Critically Endangered (Dihoru and Negrean 2009), Endangered (Boşcaiu et al. 1994; Dihoru and Dihoru 1994), or Vulnerable (Oltean et al. 1994; Oprea 2005).

This study aims to update the distribution and phytosociology of *G. odessanum* in Romania. The objectives of the study are (1) identifying the specific ecological conditions in which the plant grows, (2) updating species distribution in Romania, and (3) identifying the factors that limit its distribution in Romania. We hypothesize that the areas occupied by *G. odessanum* in Romania have decreased due to the intensification of grazing. In this context, research into *G. odessanum* is essential to establish effective conservation measures.

MATERIAL AND METHODS

Study species

Gymnospermium odessanum (Fig. 1) is a perennial plant (Beldie 1955), geophyte (Doroftei and Mierlă 2007) with a height of 5 to 20 cm (Sârbu et al. 2013). On the stem, there is a single leaf with a length of 5 cm. The rhizome is almost spherical, with a 1 to 2 cm diameter. The rachis splits into three long petioles. The flowers are yellow and have a diameter of 10 to 18 mm. The sepals are elliptic or ovate-oblong. The fruit is a capsule with a diameter of up to 8 mm (Beldie 1955; Sârbu et al. 2013).

This plant prefers moderate light, warm climate, and low moisture. It grows well on dry substrates and/or forest habitats. Furthermore, *G. odessanum* is identified as a diagnostic species of the phytosociological class *Quercetea pubescentis* Doing-Kraft ex Scamoni & Passarge 1959 (FloraVeg 2024).

Study area

The study was carried out in the Dobrogea region, in some locations of Tulcea County (Fig. 2), from February

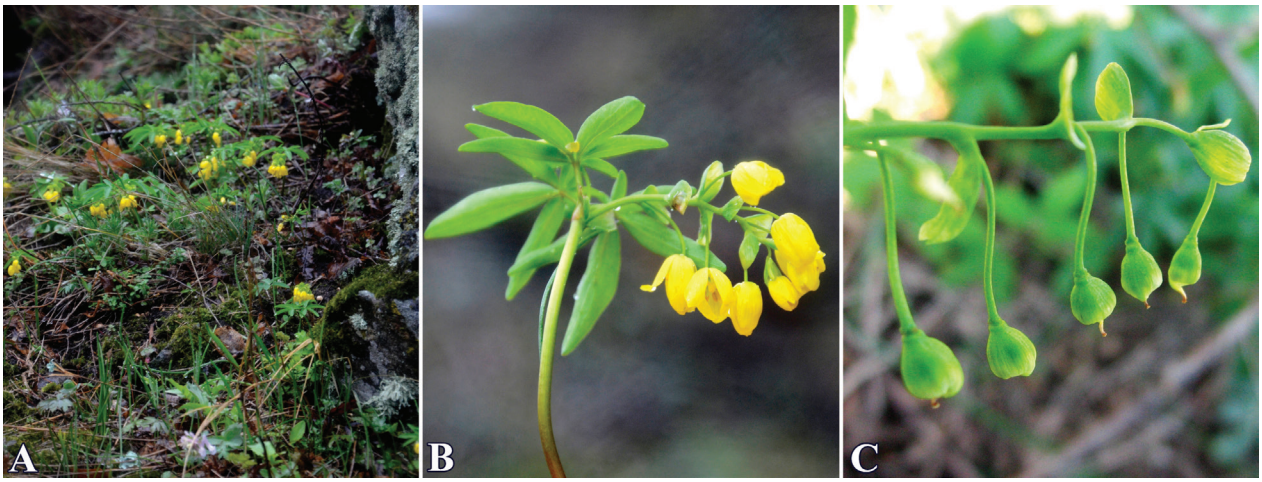

Figure 1. *Gymnospermium odessanum*. **A**. Habitat. **B**. In bloom. **C**. In the fruiting stage. Photographs A, B by Simona Dumitriţa Chirilă, and C by Mihai Doroftei.

to March 2023 and from February to March 2024. This region is bordered by the Danube River to the west, the Danube Delta to the north, and the Black Sea to the east (Bărbulescu and Postolache 2023). The area is characterized by a high aridity because Dobrogea receives small amounts of rainfall, varying from 200 to 450 mm/year, and by an annual mean temperature of 11°C (Buta and Maftei 2015). The elevation is between -27 m and 463 m a.s.l. (Bărbulescu and Postolache 2023). The dominant soil types are alisols, chernozems, leptosols, and rendzic leptosols (Soil Resources of Romania 2017; IUSS Working Group WRB 2022).

Environmental conditions

For each location where the species *G. odessanum* was identified, we presented topographical data (elevation, aspect, and slope), as well as relevant data on bioclimatic factors (annual mean temperature, annual precipitation), and soil chemistry (pH, P, and K) (Supplementary material 3). The annual mean temperature (°C) and the annual precipitation (mm) were extracted from the WorldClim database (Fick and Hijmans 2017); the elevation (m a.s.l.), aspect, and slope (°) were recorded in the field with OsmAnd v.4.7.17 (OsmAnd 2024).

The values for the soil chemical elements P, K, and soil pH (Ballabio et al. 2019) were extracted from the European Soil Database & Soil Properties (European Soil Data Centre 2019).

Population status was evaluated according to the criteria of Article 17 of the Habitats Directive (2019–2024): 1: the current trend of the area occupied by the population ("-" decreasing; "0" stable; "+" increasing); 2: the conservation status of the population ("FV" favourable; "U1" unfavourable-inadequate; "U2" unfavourable-bad); 3: the changes in the distribution pattern of habitat type surfaces ("FV" favourable; "U1" unfavourable-inadequate; "U2" unfavourable-bad).

Distribution analysis

Various sources from the literature were consulted for the species distribution: articles (Doroftei and Mierlă 2007; Barina et al. 2017; Scherbakova and Novosad 2018), floristic lists (Boşcaiu et al. 1994; Dihoru and Dihoru 1994; Oltean et al. 1994; Oprea 2005; Dihoru and Negrean 2009), identification keys (Brândză 1898; Sârbu et al. 2013). As a result, a map with the distribution of the species in Romania was created with QGIS v.3.34.3 (QGIS Development Team 2024).

Vegetation analysis

For the vegetation analysis, phytosociological relevés were made in 100 m^2 plots (Supplementary material 1). In each site (location), one to five plots were recorded. Mean percent values of the Braun-Blanquet cover-abundance scale (Cristea et al. 2004) were used: r (0.05%); + (0.5%); 1 (5%); 2 (17.5%); 3 (37.5%); 4 (62.5%); and 5 (87.5%).

The vegetation was classified using the GINGKO software of the VegAna package (Bouxin 2005). The relevés were analysed using Agglomerative Hierarchical Clustering methods (ß-flexible method, ß = -0.25, Bray-Curtis dissimilarity). The optimal number of clusters was identified based on the mean silhouette width (Rousseeuw 1987).

The synoptic table was obtained from the Juice v.7.1 software (Tichý 2002). The diagnostic species were identified using IndVal (Indicator Value; Dufrêne and Legendre 1997). A permutation test (999 iterations; de Cáceres and Legendre 2009) was used to statistically select only significantly associated species for each cluster. Diagnostic species determine the specific vegetation unit to which a group of plants belongs based on their distinct patterns of occurrence or abundance within that unit. This concept is essential to understand vegetation dynamics and ecology, as it helps classifying plant association and

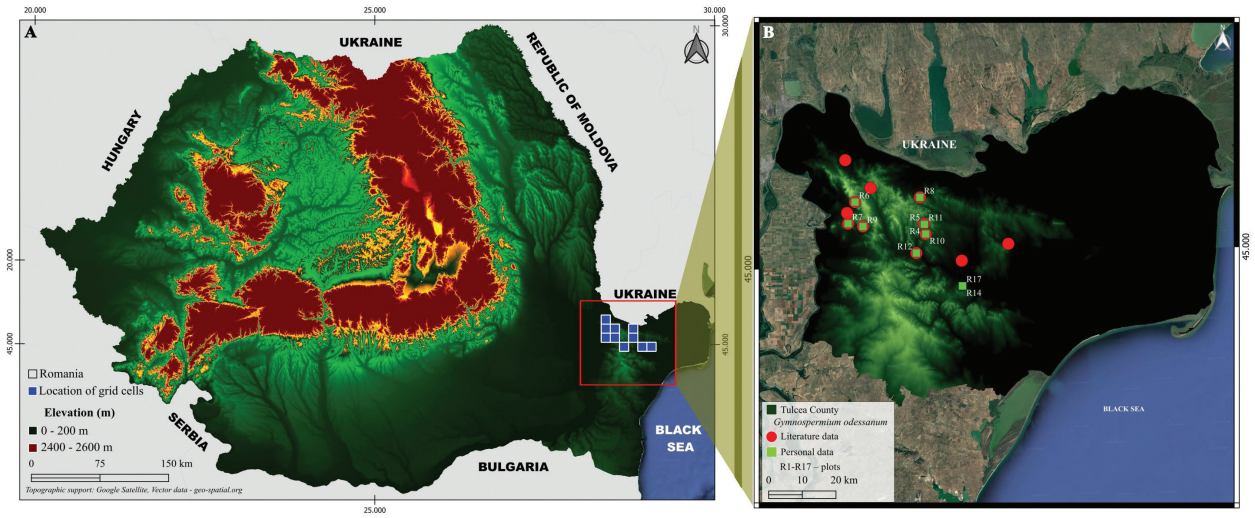

Figure 2. Map of the study area in Romania, showing the location of the grid cells (10 × 10 km) (**A**) and the distribution of the species *G. odessanum* in Romania with literature data and personal data (**B**). Map by Simona Dumitrița Chirilă.

ecological preferences and behaviours (Chytrý and Tichý 2003). The IndVal (square root) threshold was set to 0.500 (Legendre and Legendre 1998). In the synoptic table (Supplementary material 2), the species were ordered according to the diagnostic species for each cluster, and the other species were ordered according to decreasing frequency.

The classification of plant associations was based on Chifu et al. (2014) and Chifu and Irimia (2014), and plant species nomenclature followed Euro+Med (2024). The nomenclature of plant associations followed Chifu et al. (2014), and for higher-level syntaxa, Mucina et al. (2016). Habitat identification utilized the EUNIS-ESy Expert System, as detailed by Chytrý et al. (2020).

ANOVA was applied to determine whether there are significant differences between the means of the variables according to the obtained clusters. In this case, ANOVA indicated significant differences ($p < 0.05$), and the Tukey post-hoc test for multiple comparisons was applied. The stats v.4.3.2 (R Core Team 2024) and multcomp v.1.4-25 (Hothorn et al. 2008) R packages were used.

For each diagnostic species of the five clusters, two values were presented: statistical value IndVal and p value. For example, *Paeonia tenuifolia* L. had a statistical value of 1.000, suggesting a strong association with Cluster 1, and the p value for *P. tenuifolia* was 0.001.

Population changes

The number of individuals of *G. odessanum* was counted in each location. In this context, the newly collected data were compared with those collected in 2007 (Doroftei and Mierlă 2007).

RESULTS

Distribution in Romania

Currently, the species has been confirmed in the locations of Cerna (Colinele Dălchi and Chervant-Priopcea hills), Greci (Moroianu hill), Izvoarele (Consul hill), Niculițel (Sarica hill), and Trestenic (Trestenic and Teke hills) (Fig. 2). For the first time, we have identified a population of *G. odessanum* in Satu Nou (Tulcea County).

The comparative study of *G. odessanum* populations in the recorded locations shows differences in population stability and size, elevation, and the main threats to the species. The populations in Moroianu, Chervant-Priopcea, Colinele Dălchi, and Teke hills are stable, indicating relatively constant conditions for the survival and reproduction of the species. In contrast, the Sarica, Trestenic, and Consul hills populations are in decline, suggesting a significant disturbance of their habitats. Sarica hill has the largest population of *G. odessanum*, from 300 to 400 individuals. This probably reflects more favourable habitat conditions. Conversely, the Satu Nou location has the smallest population, with only 15–20 individuals, which may indicate less favourable habitat conditions. At Teke hill, the population of *G. odessanum* occurs at the highest elevation (315 m a.s.l.), and in the location of Satu Nou, the population occurs at the lowest elevation (69 m a.s.l.). All analysed populations face similar threats, such as grazing and loss of habitat characteristics. Such human activities negatively affect the stability and species distribution through habitat degradation and inter-specific competition. At all locations, the habitat distribution pattern is unfavourable-inadequate or unfavourable-bad.

Syntaxonomic overview of plant communities and related habitats

Gymnospermium odessanum populations were found to inhabit three phytosociological classes: *Festuco-Brometea*, *Crataego-Prunetea*, and *Quercetea pubescentis*. In this context, the vegetation was grouped into four orders, four alliances, and five plant associations (see also the synoptic table in Supplementary material 2).

Class: *Festuco-Brometea* Br.-Bl. & Tx. ex Soó 1947
Order: *Stipo pulcherrimae-Festucetalia pallentis* Pop 1968
All.: *Pimpinello-Thymion zygoidis* Dihoru & Doniţa 1970
Ass.: *Sedo hillebrandtii-Festucetum callieri* Sârbu et al. 1997
Ass.: *Agropyro pontici-Thymetum zygioidis* (Dihoru 1970) Dihoru & Doniță 1970

Order: *Festucetalia valesiacae* Soó 1947
All.: *Stipion lessingianae* Soó 1947
Ass.: *Artemisio austriacae-Poetum bulbosae* I. Pop 1970

Class: *Crataego-Prunetea* Tx. 1962
Order: *Paliuretalia* Trinajstić 1978
All.: *Fraxino orni-Cotinion* Soó 1960
Ass.: *Gymnospermio odessani-Celtetum glabratae* Petrescu 2004

Class: *Quercetea pubescentis* Doing-Kraft ex Scamoni & Passarge 1959
Order: *Quercetalia pubescenti-petraeae* Klika 1933
All.: *Quercion petraeae* Issler 1931
Ass.: *Fraxino orni-Quercetum dalechampii* (Roman 1974) corr. Chifu et al. 2014

The three above-mentioned phytosociological classes were assigned to major EUNIS habitat types, namely (on level 3 of the EUNIS hierarchy): R1B Continental dry grassland (true steppe), S35 Temperate and submediterranean thorn scrub, and T19 Temperate submediterranean thermophilous deciduous forest, respectively.

Cluster analysis

Results of the cluster analysis are presented as a dendrogram and a synoptic table (Supplementary material 2). The vegetation is classified into five clusters (Fig. 3) and can be assigned to different syntaxa or groups of syntaxa described in the literature.

Cluster 1: Artemisio austriacae-Poetum bulbosae

The diagnostic species are *Paeonia tenuifolia* (1.000, 0.001, ***), *Poa bulbosa* L. (0.994, 0.001, ***), *Achillea ochroleuca* Ehrh. (0.612, 0.038, *), *Jurinea mollis* (L.) Rchb. (0.612, 0.031, *), and *Salvia nemorosa* L. (0.612, 0.031, *).

It is found on Teke hill at the highest elevation (315 m a.s.l.). This cluster is characterized by a moderate diversity of species and a relatively high vegetation cover. The soil is moderately acidic and rich in potassium and phosphorus. The slopes are steep, with a southwest aspect (Table 1). The species *Achillea ochroleuca*, *Jurinea mollis*, *Paeonia tenuifolia*, and *Salvia nemorosa* are constant in this cluster, although they have a low cover. *Festuca valesiaca* Schleich. ex Gaudin has a higher cover, but the dominant species is *Poa bulbosa*. The species *G. odessanum* had a low cover of 0.5%. Of the 37 species of the relevés in this cluster, 36 are represented by the herb layer (97%), and one species by the shrub layer (3%). The soil type is leptosols.

Cluster 2: Gymnospermio odessani-Celtetum glabratae

The diagnostic species are *Celtis planchoniana* K.I.Chr. (0.991, 0.01, **), *Gymnospermium odessanum* (0.940, 0.012, **), and *Lamium purpureum* L. (0.685, 0.015, **).

It is distributed in Moroianu, Sarica, and Colinele Dălchi hills at moderate elevations (167 to 258 m a.s.l.). This cluster presents a high diversity and a high vegetation cover. The soil is moderately acidic, with a medium phosphorus concentration and a high potassium concentration, indicating a substrate supporting a rich and varied vegetation. The steep slopes, with a south aspect (Table 1), contribute to the specific microclimate and humidity conditions. The species *Asplenium trichomanes* L. and *Festuca valesiaca* had moderate average cover, but the dominant species were *Celtis planchoniana* (17.5%) and *Gymnospermium odessanum* (37.5%), with high average covers. Of the 64 plant species in this cluster, 54 are represented by the herb layer (84%). The tree layer (seven species – 11%) and the shrub layer (three species – 5%) have a lower representation. The soil types are leptosols and alisols.

Cluster 3: Fraxino orni-Quercetum dalechampii

The diagnostic species are *Polypodium vulgare* L. (1.000, 0.009, **), *Pyrus elaeagrifolia* Pall. (1.000, 0.009, **), *Quercus dalechampii* Ten. (0.993, 0.009, **), *Quercus pubescens* Willd. (0.935, 0.031, *), *Tilia tomentosa* Moench (0.926, 0.04, **), *Fraxinus ornus* L. (0.913, 0.009, **), *Thlaspi arvense* L. (0.913, 0.014, *), and *Vinca herbacea* Waldst. & Kit. (0.760, 0.024, *).

It is distributed on Consul, Trestenic, and Teke hills, with elevations from 118 to 315 m a.s.l. This cluster has a very high diversity and a high vegetation cover. The soil is moderately acidic with medium phosphorus and high potassium concentrations. The slopes are steep, with a west-northwest aspect (Table 1). The species *Potentilla taurica* Willd. ex D.F.K.Schltdl., *Crataegus monogyna*

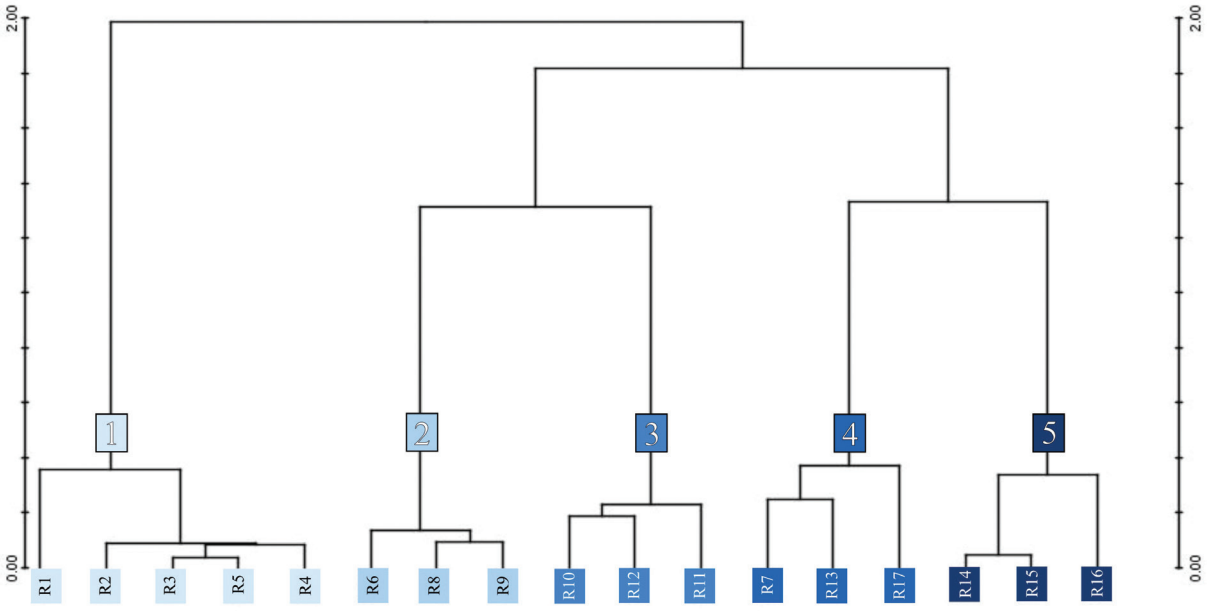

Figure 3. Dendrogram of relevés with *Gymnospermium odessanum* in Romania. Clusters: 1 – *Artemisio austriacae-Poetum bulbosae*, 2 – *Gymnospermio odessani-Celtetum glabratae*, 3 – *Fraxino orni-Quercetum dalechampii*, 4 – *Sedo hillebrandtii-Festucetum callieri*, and 5 – *Agropyro pontici-Thymetum zygioidis*.

Table 1. Values measured for the variables analysed in this study. VEGC – vegetation cover, P – phosphorus, K – potassium, BIO1 – annual mean temperature, BIO12 – annual precipitation, ELV – elevation, S – slope, Asp – aspect (SW – southwest, S – south, WNW – west-northwest). Different letters indicate significant differences (α = 0.05) according to the Tukey post-hoc test.

		Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
No. of species / 100 m^2		21 ± 3.1^a	50 ± 3.1^b	59 ± 5.1^b	30 ± 13^a	21 ± 1.5^a
Total VEGC (%)		71 ± 11.6^a	87 ± 4.1^a	97 ± 1.9^a	76 ± 21^a	75 ± 19^a
Total number of species		37	64	85	62	27
Moss layer (%)		–	–	1 (1%)	1 (2%)	–
Herb layer (%)		36 (97%)	54 (84%)	71 (84%)	54 (87%)	24 (89%)
Shrub layer (%)		1 (3%)	3 (5%)	4 (5%)	4 (6%)	3 (11)
Tree layer (%)		–	7 (11%)	9 (11%)	3 (5%)	–
Soil chemistry variables	pH	5.1 ± 0.08^a	5.9 ± 0.1^{ab}	5.6 ± 0.5^{ab}	6.4 ± 0.6^b	6.8^c
	P (mg kg^{-1})	15.6 ± 0.2^a	25.3 ± 3.7^{ab}	22.8 ± 6.4^{ab}	19.5 ± 7.8^{ab}	14.9^b
	K (mg kg^{-1})	209 ± 7.3^a	237 ± 40^a	222 ± 44^a	246 ± 25^a	261^a
Climatic variables	BIO1 (°C)	9.5^a	10.01 ± 0.2^a	10.02 ± 0.5^a	10.6 ± 0.5^b	10.9^c
	BIO12 (mm)	470^a	473 ± 8.5^a	462 ± 7.6^a	451 ± 26^{ab}	436^b
Topographic variables	ELV (m a.s.l.)	315^a	219 ± 47^{ab}	223 ± 99^{ab}	128 ± 102^b	69^c
	S (°)	21 ± 1^a	21 ± 2.5^a	20 ± 1.5^a	15.3 ± 5.7^{ab}	12.4 ± 0.1^b
	Asp	SW	S	WNW	S	S
Soil type		Leptosols	Leptosols, Alisols	Leptosols	Rendzic Leptosols	Rendzic Leptosols

Jacq., *Thymus zygioides* Griseb., *Ulmus minor* Mill., *Tilia tomentosa*, *Gymnospermium odessanum*, and *Quercus pubescens* are present, but dominant are *Fraxinus ornus* and *Quercus dalechampii*, which have key ecological roles due to their extensive cover. In this association, *G. odessanum* had a lower cover (from 0.5% to 5%) than its presence in the *Gymnospermio odessani-Celtetum glabratae* association. Of the 85 plant species, 71 species (84%) belong to the herb layer. The tree (nine species – 11%), shrub (four species – 5%), and moss (one species – 1%) layers had a low presence. The soil type is leptosols.

Cluster 4: Sedo hillebrandtii-Festucetum callieri

The diagnostic species is *Festuca callieri* (Hack. ex St.-Yves) Markgr. (0.979, 0.008, **).

It is distributed on Chervant-Priopcea hills and Satu Nou, at low elevation (69 m a.s.l.). The cluster has moderate diversity and a high vegetation cover. The soil is moderately acidic, with a medium phosphorus and high potassium concentration. The slopes are moderate, with a south aspect (Table 1). The species *Crataegus monogyna*, *Festuca valesiaca*, *Gymnospermium odessanum*, and *Ranunculus illyricus* L. are constant in this cluster, and *Polytrichum piliferum* Hedw. (moss) and *Agropyron cristatum* subsp. *brandzae* (Panţu & Solacolu) Melderis are present in a moderate proportion. *Festuca callieri* is the dominant species, with a major ecological influence due to its extensive cover. This suggests an ecosystem in which *Festuca callieri* have a central role, affecting the structure and functioning of the plant community. The species *G. odessanum* had a low cover of 0.5%. Of the 62 species, 54 belong to the herb layer (87%), four species belong to the shrub layer (6%), three species belong to the tree layer (5%), and one species belongs to the moss layer (1%). The soil type is rendzic leptosols.

Cluster 5: Agropyro pontici-Thymetum zygioidis

The diagnostic species are *Thymus zygioides* (0.945, 0.005, **) and *Agropyron cristatum* subsp. *brandzae* (0.943, 0.025, **).

This cluster is distributed in Satu Nou, at a low elevation of 69 m a.s.l. It is characterized by moderate diversity and a high vegetation cover. The soil is neutral, low in phosphorus, and rich in potassium. The slopes are moderate, with a southern aspect (Table 1). The species *Agropyron cristatum* subsp. *brandzae* and *Thymus zygioides* are present in significant proportions, and *Festuca callieri* has a low presence. The species *G. odessanum* had a low cover of 0.5%. In this cluster were included 27 species, of which 24 belong to the herb layer (89%) and three species belong to the shrub layer (11%). The soil type is rendzic leptosols.

Population changes

For most populations of *G. odessanum* analysed, a decline was recorded in 2023–2024, compared to the data from 2007 (Doroftei and Mierlă 2007). The impact of anthropogenic pressures, habitat loss, and ecological factors characteristic of each location in Dobrogea can explain the decrease in population numbers. From 2007 to 2023–2024, we recorded a significant decrease of the populations analysed in most locations, ranging from 11% on Colinele Dălchi hill to 65% on Consul hill, with the largest decrease in the number of individuals recorded on Sarica hill (620 individuals less, for a total decrease of the

Table 2. Populations characteristics of *Gymnospermium odessanum* in Romania. ATU – Administrative-Territorial Units; Climatic factors: BIO1 – Annual Mean Temperature, BIO12 – Annual Precipitation; Topographic factors: ELV – elevation, S – slope, Asp – aspect (SW – southwest, S – south, WSW – west-southwest, W – west, WNW – west-northwest, NE – northeast); Populations status: 1. The current trend of the area occupied by the population: - = decreasing, 0 = stable, + = increasing; 2. Conservation status of the population: FV = favourable, U1 = unfavourable-inadequate, U2 = unfavourable-bad; 3. Changes in the distribution pattern of habitat type surfaces: FV = favourable, U1 = unfavourable-inadequate, U2 = unfavourable-bad.

Location	ATU	Total number of individuals – 2007	Total number of individuals – 2024	Population changes	EUNIS habitat	Association	Populations status	Threats	pH	Climatic		Topographic		
										BIO1	BIO12	ELV	S	Asp
Moroianu hill / Cheile Chediului	Greci	380	170	55%	S35 Temperate and submediterranean thorn scrub	*Gymnospermio odessani-Celtetum glabratae*	1 – 0 2 – U1 3 – U1	Pasture with goats; other forms or mixed forms of interspecific competition of the flora	6	9.9	482	300	18	SW
Chervant-Priopcea hills	Cerna	70	60	14%	R16 Perennial rocky grassland of Central and South-Eastern Europe	*Sedo hillebrandtii-Festucetum callieri*	1 – 0 2 – U1 3 – U1	Moderate grazing; reduction or loss of specific habitat characteristics	5.7	10.1	481	300	22	SW
Sarica hill	Niculițel	1020	400	61%	S35 Temperate and submediterranean thorn scrub	*Gymnospermio odessani-Celtetum glabratae*	1 – - 2 – U1 3 – U2	Moderate grazing; reduction or loss of specific habitat characteristics	5.9	9.8	465	200	23	NE
Colinele Dălchi hill	Cerna	180	160	11%	S35 Temperate and submediterranean thorn scrub	*Gymnospermio odessani-Celtetum glabratae*	1 – 0 2 – U1 3 – U1	Moderate grazing; reduction or loss of specific habitat characteristics	5.8	10.3	473	200	21	WSW
Trestenic hill	Trestenic	210	100	52%	T19 Temperate and submediterranean thermophilous deciduous forest	*Fraxino orni-Quercetum dalechampii*	1 – - 2 – U1 3 – U1	Moderate grazing; reduction or loss of specific habitat characteristics	5.5	10.0	460	305	22	WNW
Teke hill	Trestenic	138	167	21%	T19 Temperate and submediterranean thermophilous deciduous forest	*Fraxino orni-Quercetum dalechampii*	1 – 0 2 – U1 3 – U1	Grazing, collection of species	5.2	9.5	470	315	19	W
Teke hill	Trestenic				R1B Continental dry grassland (true steppe)	*Artemisio austriacae-Poetum bulbosae*	1 – 0 2 – U1 3 – U1	Grazing, collection of species	5.1	9.5	470	315	22	S
Consul hill	Izvoarele	86	30	65%	T19 Temperate and submediterranean thermophilous deciduous forest	*Fraxino orni-Quercetum dalechampii*	1 – - 2 – U1 3 – U2	Pasture with goats; other forms or mixed forms of interspecific competition of the flora	6.3	10.5	455	118	20	S
Satu Nou	Mihai Bravu	51	20	38%	R1B Continental dry grassland (true steppe)	*Agropyro pontici-Thymetum zygioidis*	1 – - 2 – U1 3 – U1	Reduced population, grazing, reduction of specific habitat	6.81	10.9	436	69	12.1	S
Satu Nou	Mihai Bravu				R1B Continental dry grassland (true steppe)	*Sedo hillebrandtii-Festucetum callieri*	1 – - 2 – U1 3 – U1	High number of fallow species because of grazing, reduction of specific habitat	6.82	10.9	436	69	12.4	S

population of 61%). In contrast, an increase in individuals from 138 to 167 (21%) was observed only on Teke hill. The main factors of the species' decline were intensive grazing by goats, interspecific competition, species collection, and habitat loss (Table 2).

DISCUSSION

Distribution analysis

According to the literature *G. odessanum* was recorded only in Tulcea County (Beldie 1955), in the locations of Agighiol (Prodan 1935; Rugină and Mititiuc 2003), Deniz Tepe (Andrei 1963), Greci and Cerna (Chervant hill) (Brândză 1898; Prodan 1935; Rugină and Mititiuc 2003), Izvoarele (Consul hill) (Beldie 1955; Negrean and Anastasiu 2003; Rugină and Mititiuc 2003), Luncavița (Prodan 1935), Carasan-Teke and Sarica hill (Petrescu 2004), and Valea lui Martin (Petrescu et al. 2014). The studies regarding the distribution of the species were continued by Doroftei and Mierlă (2007), who recorded the species in five areas in the locations of Greci (Moroianu hill), Cerna (Chervant-Priopcea and Colinele Dălchi hills), Niculițel (Sarica hill), and Valea Teilor (Trestenic hill). The distribution of the species in Romania is restricted, and the populations identified in 2007 (Doroftei and Mierlă 2007) were also confirmed in our study. In addition, a new population of *G. odessanum* was discovered in Satu Nou (Tulcea County), growing in slightly different habitat conditions than the other populations (Table 2).

According to Brândză (1898), in the past *G. odessanum* was "very abundant" in northern Dobrogea. The species is now rare, raising conservation issues and requiring protective measures to prevent its disappearance. The significant change in population size is proof of the environmental and anthropogenic pressures that have exerted on it. The decrease in *G. odessanum* populations in Romania was also recorded by Sârbu et al. (2013).

In most of the areas analysed, the number of individuals is reduced compared to the observations in 2007. This can be attributed to the intense grazing and to tourists frequenting the habitats in Teke, Sarica, and Moroianu hills. The intensive use of these landscapes often leads to direct habitat destruction, changing environmental conditions and vegetation, affecting negatively the populations of *G. odessanum*. Moreover, the natural areas that can offer favourable ecological conditions to the species are limited. Even if some of these areas are included in the network of protected areas, there are no specific objectives to the safeguard of the species, which would consider elements such as the topography and the distribution algorithm (Doroftei and Mierlă 2007).

The populations developing on the rocks are subject to less anthropic pressure than those growing in the grassland. *Gymnospermium odessanum* has a reduced distribution in Romania, and human activities have a significant negative impact on the plant associations in the analysed areas. Therefore, the classification of the species *G. odessanum* as "Near Threatened" is justified.

Habitat and phytosociological preferences

Our vegetation analysis showed that *G. odessanum* thrives in a limited range of habitats. Among them are thermophilous mantle vegetation of the *Fraxino orni-Cotinion* alliance, xerophilous rocky steppic dwarf-shrub rich grasslands of the *Pimpinello-Thymion zygoidis* alliance, dry grasslands of the *Stipion lessingianae* alliance and acidophilous thermophilous oak forests of the *Quercion petraeae* alliance.

Doroftei and Mierlă (2007) reported an affinity for thermophilous mantle vegetation and acidophilus thermophilous oak forests (Petrescu et al. 2014). In 2014, Petrescu et al. (2014) reported the presence of *G. odessanum* in the association *Sedo hillebrandtii-Polytrichetum pilifieri* Horeanu & Mihai 1974. Among the plant associations in which *G. odessanum* occurs, the species develops best in the association *Artemisio austriacae-Poetum bulbosae*.

CONCLUSION

Dobrogea includes a narrow range of habitats where *G. odessanum* grows, most habitats being threatened by conservation problems and anthropogenic activities such as overgrazing combined with species harvesting. Chemistry and climatic factors differ, but common features include slightly acidic soils and moderate precipitation. Generally, the elevation of the study sites was moderate (from 69 to 315 m a.s.l.), with a steep slope and south and southwest aspect. The predominant types of soil are alisols, chernozems, leptosols, and rendzic leptosols.

The largest population of *G. odessanum* is on the Sarica hill (up to 400 individuals), but it is decreasing. The smallest population is in Satu Nou (20 individuals) where the worst conservation conditions were recorded ("U2"). The total number of individuals from all the studied places is approximately 1107, and the number of individuals/100 m^2 ranges from 10 to 200. Some habitats are threatened by overgrazing and inadequate grassland management. Therefore, more intensive conservation measures will be important for stabilizing and growing the population of *G. odessanum*.

While some populations of *G. odessanum* are stable, others have declined and continue to face this risk. Under this scenario, conservation measures must be implemented to sustain or enhance the status of each population. Optimal monitoring and management of these populations and addressing anthropogenic threats are likely essential to guaranteeing large-scale survival in this species.

Gymnospermium odessanum grows in the associations *Agropyro pontici-Thymetum zygioidis*, *Artemisio*

austriacae-Poetum bulbosae, *Fraxino orni-Quercetum dalechampii*, *Gymnospermio odessani-Celtetum glabratae*, and *Sedo hillebrandtii-Festucetum callieri*. Among these associations, *G. odessanum* occurs most frequently in the *Artemisio austriacae-Poetum bulbosae* and *Gymnospermio odessani-Celtetum glabratae* associations.

Following the observations made on the populations of *G. odessanum* in Dobrogea, the only region in Romania where the species was recorded, we consider that the areas occupied by *G. odessanum* have decreased considerably mainly due to overgrazing.

The analysis of the evolution of *G. odessanum* populations between 2007 and 2024 indicates a significant decline in individuals, due to habitat fragmentation, anthropogenic impact, and climatic variations. Thus, the most affected populations are those at Sarica hill, Consul hill, and Moroianu hill, with recorded losses ranging from 11% to 65%. Populations with a moderate decline are those at Chervant hill and Colinele Dălchi hill, indicating relative ecological stability. In this context, it is necessary to urgently implement conservation measures, such as restoring degraded habitats, monitoring the populations continuously, limiting grazing, etc. This study contributes to the knowledge of the evolution of the dynamics of the poopulations of *G. odessanum*, and can be used as an assessment tool to elaborate conservation measures.

ACKNOWLEDGEMENTS

We thank the reviewers for the valuable comments and corrections made to the manuscript.

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SUPPLEMENTARY MATERIALS

Supplementary material 1

Phytosociological relevés with *Gymnospermium odessanum* – personal data.
https://doi.org/10.5091/plecevo.144212.suppl1

Supplementary material 2

A synoptic table showing the percentage frequency of plant species in the classified plant associations. The columns 1 to 5 represent the same clusters as in the Fig. 3, namely: 1 – *Artemisio austriacae-Poetum bulbosae*, 2 – *Gymnospermio odessani-Celtetum glabratae*, 3 – *Fraxino orni-Quercetum dalechampii*, 4 – *Sedo hillebrandtii-Festucetum callieri*, and 5 – *Agropyro pontici-Thymetum zygioidis*.

https://doi.org/10.5091/plecevo.144212.suppl2

Supplementary material 3

Topographical data (elevation, aspect, and slope), bioclimatic factors (annual mean temperature, annual precipitation), and soil chemistry (pH, P, and K) for each location where *G. odessanum* was identified.

https://doi.org/10.5091/plecevo.144212.suppl3