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ИЗДАНИЕ НА ПРИРОДОНАУЧНИОТ МУЗЕЈ НА РЕПУБЛИКА СЕВЕРНА МАКЕДОНИЈА

BOTIM I MUZEUT TË SHKENCAVE DE NATYRËS E REPUBLIKËS SE MAQEDONISE SË VERIUT

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Photo on the cover page: *Sedum erythraeum* Griseb. (Photo: Z. Nikolov).



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# *Sedum erythraeum* Griseb. (Crassulaceae) in the flora of the Republic of North Macedonia

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**Abstract**

*Sedum erythraeum* is an endemic species, distributed in North Macedonia and Greece. There are also data for the presence of this species in Serbia. Described as a species by Grisebach (Pelister Mt, south-western part of North Macedonia), its status varied, from species rank to subspecies of *Sedum alpestre* or, in some cases, even as synonymic of *Sedum alpestre*. In this study, we keep the species status of *S. erythraeum*. Apart from the Pelister Mt, *S. erythraeum* is found on Šar Planina Mt and Osogovo Mt. The finding on the Jablanica Mt is new record for this rare species, on the territory of North Macedonia. The data of Jurišić, for the Monastery "Treskavec" (Prilep) is evidently overlook because of the low altitude.

**Key words**: *Sedum erythraeum*, endemic, taxonomic rank, protandrous, North Macedonia

## Introduction

*Sedum erythraeum* (Crassulaceae) is a tufted perennial that inhabits dump, rocky places and screes. It belongs to the subsgenus *Sedum,* Serias Alpestria ('t Hurt, 2002, sub nom. *S. alpestre* subsp. *erythraeum).* Its taxonomic rank varies, from species (Grisebach, 1843; Hayek, 1924; Micevski, 1998; Šušlevska, Arsovska, Rusevska & Melovski, 2002), to subspecies of *S. alpestrae* ('t Hart †, 2002) or synonym of *S. alpestre* (Euro+Med PlantBase). The distribution area of *S. eryhtraeum* includes North Macedonia, Greece and Serbia. There are few localities, on the territory of our country, where the presence of this species was confirmed: Pelister Mt (Locus classicus, Grisebach, 1843), Šar Planina Mt (Degen, 1902; Šušlevska, Arsovska, Rusevska & Melovski, 2002) and Osogovo Mt (Micevski, 1998). The data of Jurišić (1923) for the Treskavec Monastery (Prilep) are probably unreliable due to the more inadequate habitats for this species at low altitudes.

## Material and methods

Herbarium material of *Sedum erythraeum*, from the Jablanica Mt, was collected on two occasions: first, in 2021, during the Project "Working together for Conservation of National Endemic Plants in Macedonia" (funded by the Critical Ecosystem Partnership Fund - CEPF), and second, the material for this study, which was collected in 2025. Prepared and labelled plant material, according to commonly accepted botanical procedures, is stored in the herbarium collection of the Natural History Museum of the Republic of North Macedonia. Relevant literature sources used for material identification are as follows: Grisebach (1843), Hayek (1924), Webb, Akeroyd & 't Hart (1968), Hagemann & 't Hart (1986), Micevski (1998), 't Hart † (2002). The nomenclature followed Grisebach (1843). Photos of the habitat, habitus, different parts of the living plant, as well as of the herbarium specimen, were taken using camera. The contemporary distribution map of *S. erythraeum* in North Macedonia is also presented in the article. Some of the terms, in the part of "Description of the collected plants", were used from the 't Hart' description (2002).

## Results and discussion

*Sedum erythraeum* Griseb., Spic. Fl. Rumel. 1: 326 (1843).

### *General distribution:*

*Sedum erythreum* is distributed in North Macedonia and Greece (POWO, 2025; 't Hart, 2002, sub nom. *S. alpestre* subsp. *erythraeum*). This species is also registered in Serbia (Amidžić & Panjković,2003; Gajić, M., 1972; Janković, M., 1978-1980, 1982; Nikolić et al., 1986).

***Distribution in North Macedonia:***

Literature data: Pelister (Grisebach, 1843); Šar Planina Mt (Degen, 1902); Prilep, Mon astery "Treskavec" (Jurišić, 1923); Šar plani na Mt, Čaušica; Ceripašina (Šušlevska, Arsovska, Rusevska & Melovski, 2002).

New data: Jablanica (vill. Gorna Belica): Krstec, 1845 m a.s.l., 01.08.2021, N: 41º13.909', E: 020º31.614'; Krstec, 1840 m a.s.l., 25.06.2025, 17.07.2025, N: 41º13.901', E: 020º31.621' (Leg./Det.: Z. Nikolov).

*S. eryrhraeum* (Fig. 1) is a Balkan endemic species described by Grisebach (1843) from the Pelister Mt (Bitola). Degen (1902) and Micevski (1998) recorded this species for Šar Planina Mt and Osogovo Mt, respectively. The data of Degen (1902), for Šar Planina Mt, was later confirmed by Šušlevska, Arsovska, Rusevska & Melovski (2002). The report of Jurišić (1923), for the Monastery "Treskavec" (Prilep), is highly doubtful because it is located in a low altitude zone (Micevski, 1998). The Jablanica Mt is a new spot on the distribution map of *S. erythraeum*, in the territory of North Macedonia (Fig 5).

***Description of the collected plants**:*

Tufted perennial with numerous short, non-flowering shoots, covered with numerous, green leaves. Flowering shoots also numerous, 3.5-6 cm long, usually simple; leaves succulent, partially overlapping, imbricate, obtuse, reddish; inflorescence consist of 1-2(3) branches, every with 1-3 flowers; flowers pentamerous, sepals c. 3 mm, oblong-obtuse, reddish; petals 3.5-4 mm, reddish, subacute, with ± short, pointed tip; stamens 10, anthers pale-yellowish, filaments purplish; style slender, up to 0.5 mm, slightly curved.

The plants, collected from the locality "Krstec", on the Jablanica Mt, match the original description by Grisebach (1843), also the descriptions by Hayek (1924, sub nom. *S. erythraeum*), Micevski (1998, sub nom. *S. erythraeum*) and 't Hart (2002, sub nom. *S. alpestre* subsp. *erythraeum*). The initial specimen, gathered and photographed on 01.08.2021 (Fig. 4), was in the fruiting, while the one from 25.06.2025 - in full, flowering stage. *Sedum erythraeum* is a tufted, reddish perennial, with numerous non-flowering and flowering shoots, with dense, green leaves (Fig. 1). Beside the dominate

**Fig. 1**. *Sedum erythraeum* Griseb.- plant appearance, Krstec locality (Photo: Z. Nikolov, 25.06.2025)

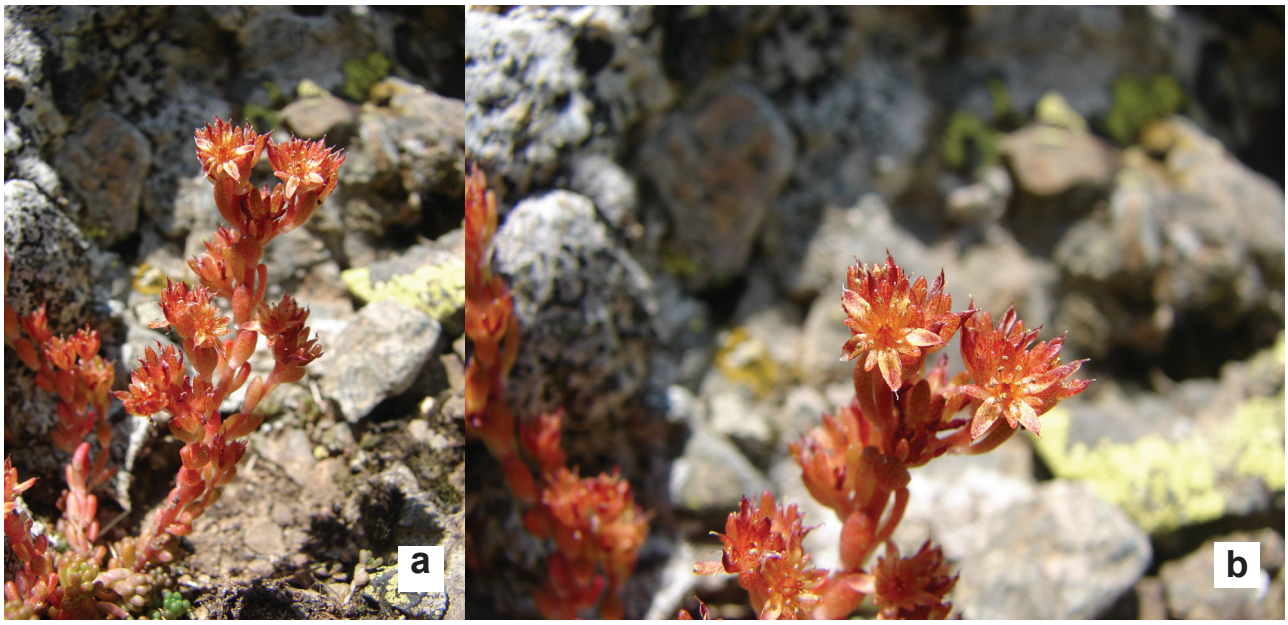


**Fig. 2.** *Sedum erythraeum* Griseb.a) branched stem b) upper part of the inflorescence (Photo: Z. Nikolov, 25.06.2025)

simple, there are also branched, flowering shoots (Fig. 2, a). The reddish petals are a little bit longer of the sepals, with ± short, pointed tip (Fig. 2, b). The inflorescence is with 1-2(3) branches, with 1-3 flowers (Fig. 2, a, b). The style up to 0.5 mm.

***Taxonomic rank***

*Sedum erythraeum* was originally described by Grisebach (1843) as a distinct species, a treatment subsequently followed by Hayek (1924), Micevski (1998), and Šušlevska, Arsovska, Rusevska &

**Fig. 3.** *Sedum erythraeum* Griseb.

Melovski (2002). Webb, Akeroyd & 't Hart (1968) referred to *S. erythraeum* as a species described from western Macedonia, but did not assign it an ordinal number in their list of recognized taxa. Later, 't Hart (2002) reduced its rank to the subspecific level, treating it as *Sedum alpestre* subsp. *erythraeum*. In current major sources, the taxonomic status of *Sedum erythraeum* remains inconsistent: in Euro+Med PlantBase it is listed as a synonym of *S. alpestre* whereas in POWO (2025) it is recognized at subspecies rank as *Sedum alpestre* subsp. *erythraeum*. Compared to *S. alpestre*, *S. erythraeum* is characterized by its distinctly reddish appearance, particularly in fruiting stage (Fig. 4, photo), smaller leaves, and a style length of 0.5-1 mm. Moreover, *S. erythraeum* is strictly allogamous, while *S. alpestre* is predominantly autogamous ('t Hart, 2002). Webb, Akeroyd & 't Hart (1968) emphasized the following diagnostics traits of *S. erythraeum*: "the dwarf habit (c. 2 cm), small leaves (c. 2.5 mm), mucronate, reddish-purple petals, and erecto-patent follicles with a longer style". Hagemman & 't Hart (1986) additionally highlighted the morphology of the squamae and the strict protandry as further differentiating characters, while noting that the taxonomic status of the species remained uncertain.

We argue that the combination of the aforementioned morphological and reproductive characteristics provides sufficient evidence for *S. erythraeum* to be retained at the species rank, as originally proposed by Grisebach (1843)

.

***Habitat***

*Sedum erythraeum* populates damp, rocky places, but also damp, grassy places, strict to water. The plants on the Jablanica Mt (locality "Krstec", 2021, 2025) grow on big rocks (Fig. 3, 4), nearby the small river, but also, a small population was found on a damp, grassy place, strict to the water, across the big rock (25.06.2025).

**Conclusion**

- On the base of the differential taxonomical characteristics, we keep the species status of *Sedum erythraeum*, following Grisebach (1843) and,

- The discovery of *Sedum erythreaum* on the Jablanica Mt is new data about the distribution of this species in the territory of North Macedonia.

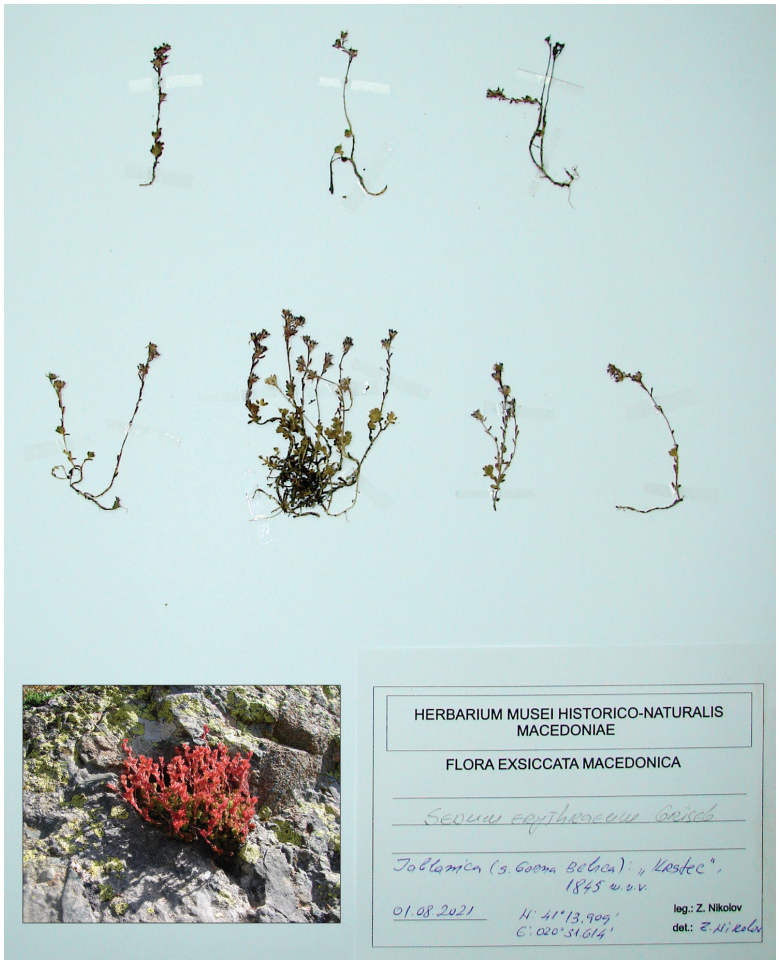


**Fig. 4.** *Sedum erythraeum* Griseb - Herbarium specimen, with photo of the living plant (01.08.2021)

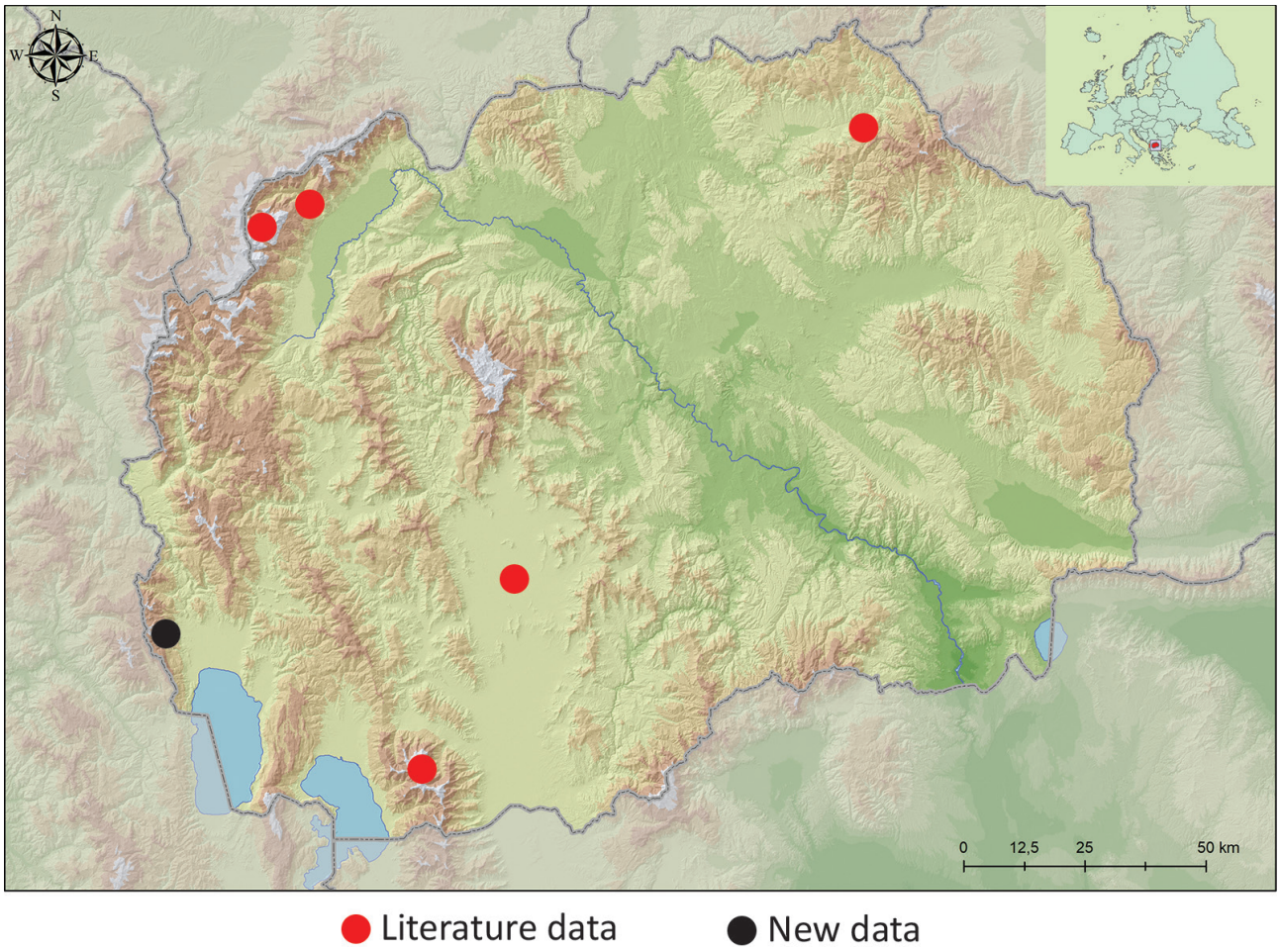


**Fig. 5.** Distribution of *Sedum erythraeum* in North Macedonia.

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# *Hieracium babae,* a new species of *Hieracium* s. str. (Asteraceae) from Baba Mt., North Macedonia

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**Abstract**

A new species, *Hieracium babae* (Asteraceae), is described from Baba Mt. in southwestern North Macedonia. It is found at eight locations, from the montane to the lower alpine zone of the mountain.The general habit and indumentum of the leaves resemble *H. velenovskyi*, an endemic species from Bulgaria and Serbia, but differs in having broader cauline leaves, acute to subacuminate middle cauline leaves, more abundant, longer and dark only at the base simple hairs within the synflorescence, ± paler, shorter and slender glandular hairs, and paler achenes. The possible hybrid origin of the new species is briefly discussed. Photographs of the holotype, living material of the new species, and a comparative herbarium specimen from the type collection of *H. velenovskyi* are presented.

**Key words:** *H. djimilense* aggregate; holotype; morphology; siliceous substrate; taxonomy.

## INTRODUCTION

Baba Mountain (also known as Pelister Mt.) is situated in the southwestern part of North Macedonia and the northwestern part of Greece. Most of its area (over 400 km²), including its highest peak, Pelister (2,601 m), lies within North Macedonia. Despite the relatively uniform siliceous geological composition and consequent limited habitat diversity, the *Hieracium* L. flora in the Macedonian part of this mountain is relatively rich. Although *Hieracium* is poorly studied here, several taxa have already been described from the mountain including *H. macedonicum* Boiss. & Orph. (Boissier 1875), *H. sparsum* subsp. *peristeriense* O. Behr, E. Behr et Zahn (Behr et al. 1937) and *H. pseuderiopus* subsp. *caparinum* Zahn (Zahn 1921–1923).

During field studies of *Hieracium* s. str. on Baba Mt. in 2022, in the valley of the Sapundžica River, I collected a few specimens of a fairly hairy representative of *H*. sect. *Prenanthoidea*, whose identification proved problematic, as it differed markedly from all other known species in the region. After an unsuccessful field search in 2023, I collected numerous specimens from seven additional localities on this mountain in 2024 and 2025, enabling a more precise and reliable identification. Detailed comparative morphological analysis revealed that the material belonged to a hitherto undescribed species. The next step was to provide a morphological description, suggest its putative origin, and establish its relationship with closely related taxa, as presented in this article.

## MATERIAL AND METHODS

Field studies were carried out on Baba Mt., North Macedonia, between 2022 and 2025. Representative plants were prepared as herbarium specimens. The holotype is deposited in the Herbarium of the Institute of Biology, Faculty of Natural Sciences and Mathematics in Skopje (MKNH), while other specimens are preserved in the author's private herbarium and the Herbarium of the Natural History Museum of the Republic of North Macedonia (HMMNH). Photographs of living plants, along with data on the habitats and populations, were recorded in the field. The collected material was used for a comparative morphological study. Numerous scans of type specimens and other herbarium collections of relevant taxa stored in European herbaria were used for comparison, including high-quality scans of three herbarium sheets from the type collection of *H.velenovskyi* Freyn (leg. J. Velenovský), comprising one specimen from Vitoša Mt. (Bulgaria) (BRNM 08603/36) and six from Stara Planina Mt. (Bulgaria) (BRNM 08605/35, 08606/35). Also examined were scans of specimens of the same species collected on Vitoša Mt. (Bulgaria) by C. Keck & Th. Pichler (W 5471, 5470, 7720), I. Urumov (SOM 89675, 89676), T. Georgiev (SOM 131010) and by M. Niketić (BEO).

## RESULTS AND DISCUSSION

***Hieracium babae* Teof., sp. nov**. (Figs. 1-7)

**Description:** *Stems* solitary or few, 40–90 cm high, up to 4 mm in diameter at base, erect, sometimes slightly flexuous, finely striate, olivaceous-green, tinged with purplish at base or rarely ± throughout, covered with numerous to dense, 1.5–3.0 mm long, whitish simple hairs, ± curved and deeply dentate to subplumose in lower part, less deeply dentate, dark based, somewhat stiff, and usually ± horizontally patent in middle and upper part; upper third also with scattered stellate hairs, accompanied apically by sparse ± pale, 0.2–0.4 mm long glandular hairs; scattered or solitary microglands often occur throughout. *Basal leaves* (2)3–4, withered at anthesis, oblanceolate to narrowly obovate, 6–12×1.8–3.0 cm, gradually or abruptly narrowed into winged petiole, obtuse, usually mucronate, denticulate; both surfaces covered with ± moderately dense deeply dentate to subplumose, 1–2 mm long simple hairs, dense on midrib and petiole beneath; margins densely ciliate; scattered or solitary microglands usually present on margins, and on midrib and along margins beneath; stellate hairs absent in all leaves. *Cauline leaves* (6–)8–11(–12), lowermost 1–2 sometimes withered at anthesis, ± soft except for the upper ones or in sunny places all ± coriaceous, usually ± undulate, green or olivaceous-green above, paler and sometimes slightly reticulately veined beneath; remotely and acutely denticulate to dentate, sometimes irregularly, with 1–3 coarser teeth on each side; ± evenly distributed, lower most leaf usually located near the base; lower and middle leaves gradually decreasing in size or lowermost smaller than proximal; upper leaves much smaller than middle, ± abruptly decreasing in size and transitioning into bracts. *Lower cauline leaves* oblanceolate to broadly oblanceolate or narrowly oblong-elliptic, gradually narrowed into a broadly winged petiole or shortly narrowed at often subpanduriform and amplexicaul base, acute to subobtuse, mucronate, including petiole or narrowed part 12–25 cm x 2.0–3.0 (in shady habitats up to 4.0) cm; both surfaces covered with numerous to moderately dense, deeply dentate to subplumose, 1-2 mm long simple hairs, dense on midrib and petiole beneath, margins densely ciliate; microglands as in basal leaves. *Middle cauline leaves*, oblanceolate, broadly oblanceolate, narrowly obovate, to narrowly (oblong) elliptic, acute, sometimes subacuminate, ± shortly narrowed (often subpanduriformly) to ± clasping amplexicaul base, indumentum as in lower leaves but with reduced dentation of simple hairs, and upper or both surfaces often glabrescent in narrow or broad area along midrib. *Upper cauline leaves* lanceolate, truncate or somewhat attenuate at base, or more frequently with cordate, semiamplexicaul base, acuminate, acute; indumentum as in middle cauline leaves but often more glabrescent. *Synflorescence* panicle, with 4–20 developed erect or rarely slightly inclined capitula and few to several aborted. *Branches* (2–)4–6(–7), arranged in upper ½–1/7 of stem, with 1–7 developed capitula, longest one 5–17 cm long; with numerous to dense or occasionally sparse on some branches, 1.5–3.5 mm long, usually ± stiff and horizontally patent, whitish, dark-based simple hairs, numerous to sparse, often becoming solitary downwards, entirely pale or ± darkish in lower half, slender, 0.2–0.4 mm long glandular hairs with yellowish glands, and scattered stellate hairs; acladium 8–20(–30) mm. *Peduncles* up to 30(–35) mm long, green or olivaceous-green; simple hairs as in branches; glandular hairs as in branches but ± dense; stellate hairs numerous to sparse; bracteoles 2–4, with dense simple and glandular hairs. *Capitula* 20–25 mm in diameter. *Involucres* 9–11 mm long, ovate at base; with numerous to subdense, whitish, dark-based, 1.5–3.5 mm long simple hairs, glandular hairs as in peduncles, and few to sparse stellate hairs at base; bracts lanceolate, up to 1.5 mm wide at base, obtuse to subacute, dark green, inners with broad pale margins. *Ligules* short, yellow, at expanded stage with glabrous or slightly ciliate apex. *Styles* greenish-brown. *Achenes* straw-colored, ca. 4 mm long. *Pappus* pale grayish. *Flowering time:* July.

**Holotype:** North Macedonia, Baba Mt., near road to mountain hut Široka, shrubby place near *Pinus peuce* forest, silicate, 1622 m, 41.026154°N, 21.181082°E, 10.7.2024, leg. & det. A. Teofilovski (MKNH, 071919).

**Isotypes:** HMMNH; herb. A. Teofilovski.

**Other collections examined (paratypes):** Baba Mt., above Sapundžica River, shrubby place, silicate, 1550 m, 40.964256°N, 21.242011°E, 23.7.2022, leg. & det. A. Teofilovski (herb. A. Teofilovski); Baba Mt., above Sapundžica River, sparse forest, silicate, 1421 m, 40.971753°N, 21.250276°E, 16.7.2024, leg. & det. A. Teofilovski (herb. A. Teofilovski); Baba Mt., above Sapundžica River, acidophilic heath, silicate, 1879 m, 40.956328°N, 21.215730°E, 16.7.2024, leg. & det. A. Teofilovski (herb. A. Teofilovski);Baba Mt., above Sapundžica River, acidophilic heath, silicate, 1858 m, 40.956050°N, 21.218102°E, 16.7.2024, leg. & det. A. Teofilovski (herb. A. Teofilovski); Baba Mt., near path between Magareška River and Jorgov Kamen, *Pinus peuce* forest, 1725–1735, 41.022948°N, 21.218655°E, 28.7.2024, leg. A. Teofilovski & Z. Nikolov, det. A. Teofilovski (herb. A. Teofilovski); Baba Mt., near road to mountain hut Široka, margin of *Pinus peuce* forest, silicate, 1658 m, 41.023637°N, 21.175536°E, 23.7.2025, leg. & det. A. Teofilovski (herb. A. Teofilovski); Baba Mt., above Malo Ezero, acidophilic heath and stony places, silicate, 2263m, 40.976586°N, 21.184633°E, 23.7.2025, leg. & det. A. Teofilovski (herb. A. Teofilovski).

**Distribution and ecological preferences:**

*H. babae* is endemic to Baba Mt. in the southwestern part of North Macedonia. It is a rare species, currently known from eight populations, each consisting of about 5 to 50 individuals. These localities form a polygonal area of 27 km², mostly consisting of suitable habitats for the species, so additional populations are likely to be found within the area. The typical habitats of this species include acidophilic heaths with *Vaccinium myrtillus* and *Juniperus sibirica, Pinus peuce* forests, and forest margins, all occurring on siliceous substrates. The altitudinal range where it has been observed so far extends from 1421 to 2263 meters a.s.l.

Additional field studies on Baba Mt. are needed to determine the full distribution range and population size of the species and to assess its conservation status.

**Taxonomic discussion:**

Based on its general habit and leaf indumentum, *H. babae* most closely resembles *H. velenovskyi* Freyn (= *H. vitošense* Zahn) (Fig. 7), originally described from the Vitoša, Stara Planina, and Rila mountains in Bulgaria (Freyn 1891), and also occurring in Serbia (Vlasina Mt.) (Zahn 1936–1938). *H. velenovskyi* is considered a member of the *H. djimilense* aggregate, whose putative hybrid origin was interpreted by Zahn (1921–1923, 1936–1938, as *H. djimilense* Boiss.) as *H. sparsum* ≤ *H. prenanthoides*. The main differences between *H. babae* and *H. velenovskyi* are presented in Table 1.

*H. babae* may also be of hybrid origin, similar to that suggested for the *H. djimilense* aggregate. The influence of *H. prenanthoides* s.l. is evident in the following morphological features: clasping, amplexicaul middle cauline leaves, often with a subpanduriformly narrowed base; occasional ± reticulate venation on the cauline leaves; and frequent occurrence of cilia at the apex of the expanded ligules. Although neither *H. prenanthoides* s.l. nor its known putative hybrid derivatives have been recorded on Baba Mt. so far, *H. prenanthoides* subsp. *bupleurifolium* (Tausch) Zahn has been found in the Macedonian part of the nearby Galičica Mt. (Zahn 1936–1938), and *H. prenanthoides s.*l. on Bistra Mt. (Teofilovski 2023).

The influence of *H. sparsum* s.l. (*H. sect. Cernua*) in the putative hybrid origin of *H. babae* is less evident, but it might be reflected in the occasional occurrence of slightly inclined capitula, the morphology of the simple and glandular hairs within the synflorescence, and in the elongated shape of the leaves. Several representatives of *H. sparsum* s.l. are known to occur on Baba Mt. (unpublished data). However, the deeply branched simple hairs in the lower plant parts of *H. babae* [1.5–2.5(–3.5) times the diameter of the hairs] might indicate influence also from a representative of H. sect. *Pannosa* or its hybridogenous derivatives, both of which occur on Baba Mt. (unpublished data). Therefore, the placement of *H. babae* within the *H. djimilense* aggregate is provisional.

**Etymology:** The name of the new species refers to Baba Mountain (southwestern North Macedonia), where it occurs as a local endemic.

**ACKNOWLEDGMENTS**

I am grateful to Dr. Marjan Niketić (Natural History Museum, Belgrade) for providing high-quality scans of numerous herbarium specimens of *Hieracium velenovskyi* from Herbarium BEO and Herbarium SOM, and to Dr. Vojtěch Taraška (Moravské zemské muzeum, Brno) for providing high-quality scans of three specimens from the original collection of *H. velenovskyi* deposited in Herbarium BRNM. I also thank Herbarium BRNM for kindly permitting the use of the scan of herbarium sheet BRNM 08603/36 in Fig. 7. I am grateful to two anonymous reviewers for reviewing the manuscript and for their valuable suggestions for improving it.

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**Table 1.** Morphological and distributional differences between *Hieracium babae* and *H. velenovskyi*.

| | ***Hieracium babae*** (Figs. 1-7) | ***H. velenovskyi*** (Fig. 8) |
|---|---|---|
| lower and middle cauline leaves | acute or middle subacuminate | acuminate, acute |
| width of widest cauline leaf | 2.0–4.0 cm | up to 2.0(3.0) cm |
| morphology of simple hairs on peduncles and involucres | whitish with dark base, 1.5–3.5 mm long | blackish, up to 1.5 mm long |
| density of simple hairs on peduncles | sparse to dense | solitary to few |
| density of simple hairs on involucres | numerous to subdense | few to sparse |
| morphology of glandular hairs on peduncles and involucres | entirely pale or darkish in lower half, with yellowish glands, slender, up to 0.4 mm long | blackish, ± robust, up to 0.7 mm long |
| apex of expanded ligules | glabrous or slightly ciliate | ± ciliate |
| color of achenes | straw-colored | pale or chestnut brown |
| distribution | endemic to Baba Mt. in SW North Macedonia | Bulgaria (Vitoša, Stara Planina, and Rila mountains) and Serbia (Vlasina Mt.) |

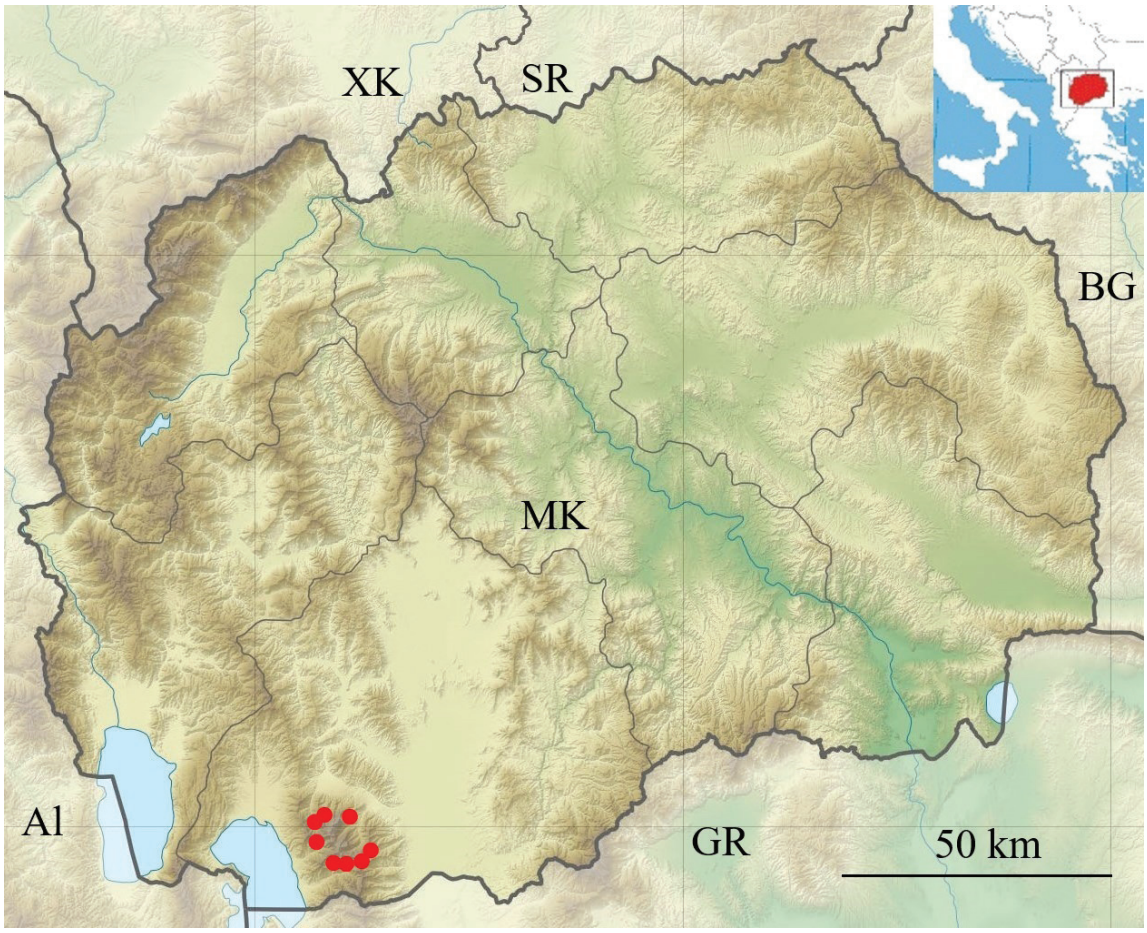


**Fig. 1**. General distribution of *Hieracium babae*.


**Fig. 2.** Holotype of *Hieracium babae* (MKNH, 071919).

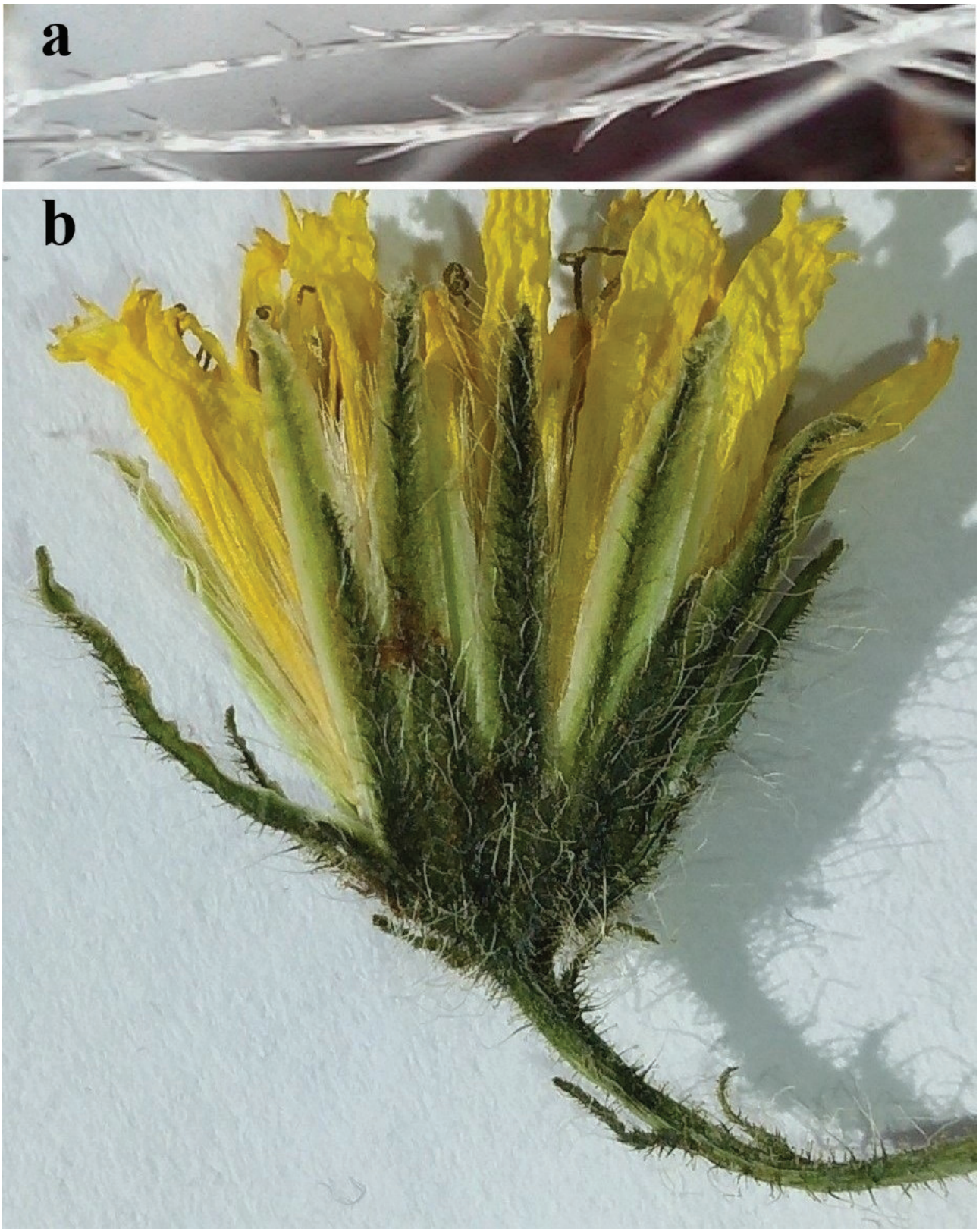


**Fig. 3.** Details from the holotype of *Hieracium babae*:
**a**. simple hairs from the lowermostcauline leaf;
**b**. capitulum. (Photo A. Teofilovski)

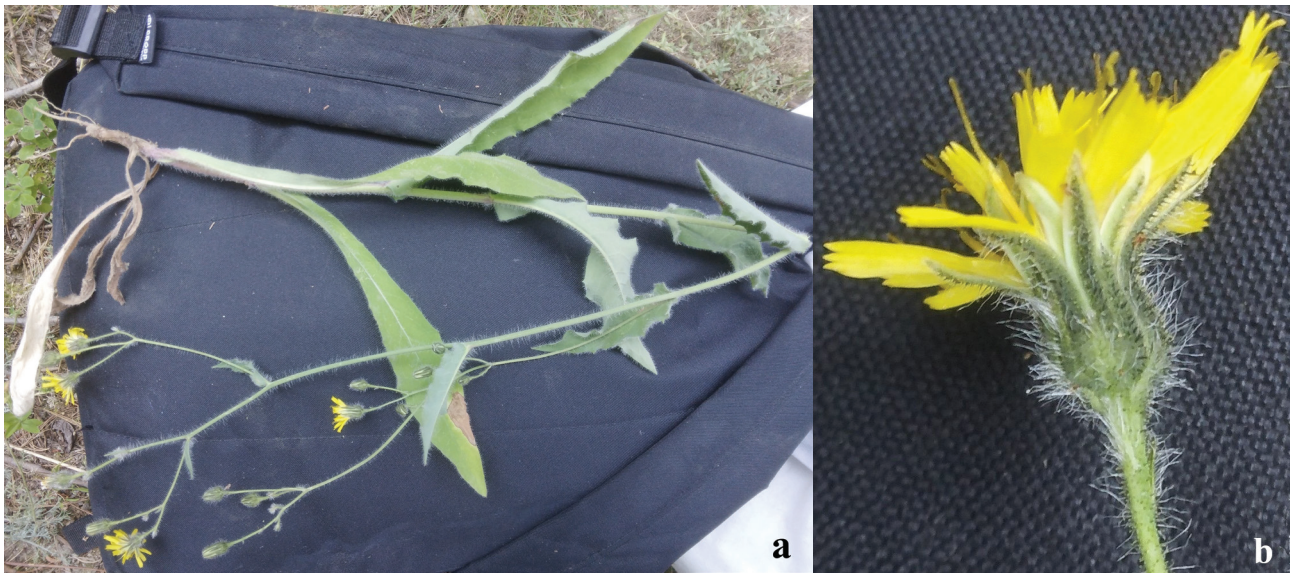


**Fig. 4.** *Hieracium babae:*
**a.** specimen from the type locality;
**b.** detail – flowering capitulum.
(10.7.2024, photo A. Teofilovski)

**Fig. 5**.*Hieracium babae*,
specimen on the type locality.
(10.7.2024, photo A. Teofilovski)


**Fig. 6**. *Hieracium babae:* a. plants in natural habitat; b. detail – basal part of a middle cauline leaf; c. detail – achenes. (Baba Mt., above Sapundžica River, 1858 m,16.7.2024, photo A. Teofilovski)


**Fig. 7** *Hieracium babae*: **a.** plants in natural habitat; **b**.detail – part of synflorescence. (Baba Mt., above Sapundžica River, 1550 m, 23.7.2022, photo A. Teofilovski)


**Fig. 8**. *Hieracium velenovskyi,*
**a.** specimen from the type collection (lectotype) collected by J. Velenovský on Vitoša Mt. in Bulgaria (BRNM 08603/36); **b.**detail - fruiting capitula, scale bar 5 mm.

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# *Stachys babunensis* Micevski (Lamiaceae), rare endemic in the flora of the Republic of North Macedonia

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**Abstract**

The aim of this study is to provide further insight into the distribution and ecology of *Stachys babunensis* in the flora of North Macedonia. It is a Macedonian endemic species, described by Micevski, in 1992, in the Babuna River Gorge (Pešti locality), near the city of Veles. In addition to this gorge, *S. babunensis* has also been found in another one – the Raec River Gorge (near Kavadarci). A review of the findings (based on the available herbarium specimens), since Micevski's discovery indicates that *S. babunensis* is indeed a rare species in the flora of North Macedonia. This conclusion is supported by the results of several visits to the Babuna River Gorge this year (2025), during which only two specimens were found. A list of characteristic species associated with *S. babunensis* in the Babuna River Gorge is presented.

**Keywords:** *Stachys babunensis,* endemic, rare, gorge, North Macedonia.

## Introduction

*Stachys babunensis* is a Macedonian endemic species, described by Micevski (1992) based on a single specimen. This material, a very hairy *Stachys* taxon ("einen grossen Polster einer stark behaarten *Stachys*-Sippe"), was found on the left side of the gorge entrance and did not match any previously known species of the genus. Matevski (2021) included this species in *Stachys* gr. *recta,* together with *S. recta* (subsp. *recta* and subsp. *rhodopaea*), *S. atherocalyx, S. beckeana,* and *S. angustifolia. S. babunensis* occurs alongside limestone cliffs (Micevski, 1992; Matevski, 2021).

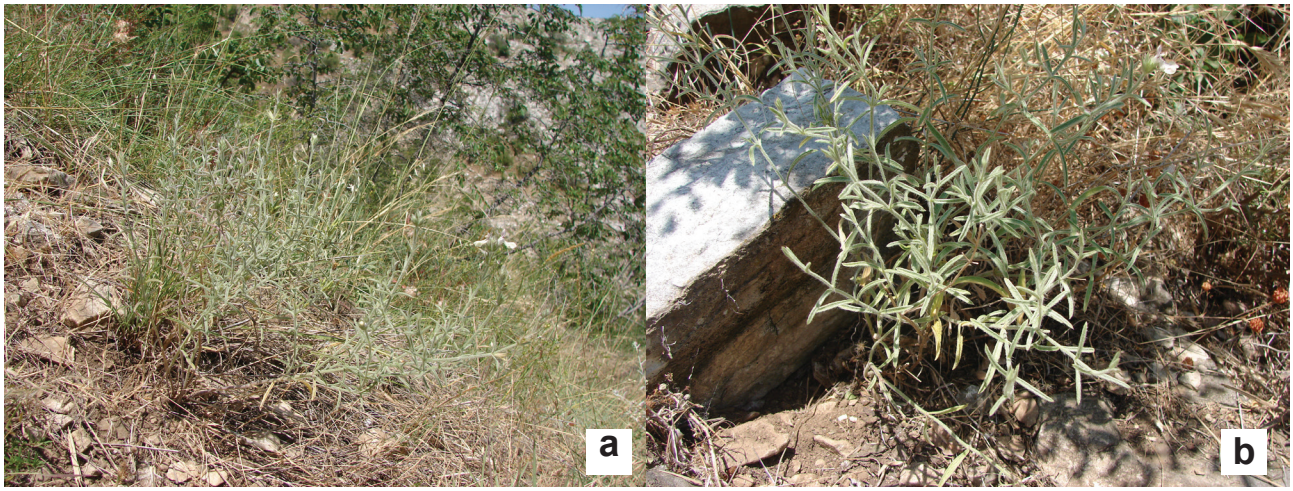


**Fig. 1**. *Stachys babunensis* Micevski (Babuna River Gorge) - a, b) habitus (Photo: Z. Nikolov).

## Materials and methods

The Babuna River Gorge (Pešti locality) was visited repeatedly in 2025. The initiative came from Milana Ranimirović, a PhD candidate from Belgrade working on *Stachys* gr. *recta,* to which *S. babunensis* also belongs. The primary purpose of the visit was to collect material in silica gel for subsequent laboratory analysis. The initial joint visit, conducted on 27 May 2025, yielded negative results. During subsequent individual visits (on 8, 13, 18, and 28 June 2025), I found only two specimens of *S. babunensis* (Fig. 1a–b). Herbarium specimens collected during these visits were deposited in the collection of the Natural History Museum in Skopje (HMMNH).

## Nomenclature and sources

The valid name of the studied species is *Stachys babunensis* Micevski. Contributions, Sec. Biol. Med. Sci., MASA, Skopje 13, 1/2:29-32 (1992). Data concerning *S. babunensis* were sourced from the literature published by Micevski (1992) and Matevski (2021). The nomenclature follows the two most current and relevant sources: Euro+Med PlantBase and POWO (2025). Photographs of living plants in their natural habitats are provided.

## Results and discussion

### *Distribution*

The Macedonian endemic species *Stachys babunensis* was originally described by Micevski (1992) based on material collected exclusively from the Babuna River Gorge. The species was subsequently recorded from a second locality, the Raec River Gorge, near Drenovo (Kavadarci), based on a specimen collected by Matevski in 2002. In the comprehensive edition *Flora of the RN Macedonia,* Matevski (2021) reaffirmed the species' distribution, providing a detailed description and confirming both the original Babuna locality (where he and Nikolov had recorded it) and the Raec locality (noting its presence in degraded *Paliurus spina-christi* stands). Nevertheless, recent field investigations aimed at verifying the occurrence in the Raec River Gorge were unsuccessful. Consequently, the original record by Matevski, dated 11 June 2002 (voucher specimen is deposited in Macedonian National Herbarium, Faculty of Natural Sciences and mathematics, Skopje – MKNH) currently represents the sole evidence of the presence of *S. babunensis* in this gorge.

*Chronology of findings at the locus classicus (Babuna River Gorge, "Pešti" locality)*

The chronology of the findings is based on herbarium specimens made available during the processing of the genus *Stachys*, for the '*Flora of the RN Macedonia*', and thereafter. The list of currently known records of *S. babunensis* from the Babuna River Gorge and Raec River Gorge is presented in chronological order:

- Micevski, K. (23.06.1991) – Babuna, six specimens (MKNH)
- Matevski, V. (3.06.2000) - Babuna, two specimens (MKNH),
- Matevski, V. (11.06.2002) – Raec, one specimen (MKNH),
- Nikolov, Z. (27.05.2012) – Babuna, one specimen (HMMNH: Nr. 10577-10578),
- Matevski, V. (28.06.2024) – Babuna, one specimen (HMMNH),
- Nikolov, Z. (08.06.2025) – Babuna, one specimen (HMMNH ), and
- Nikolov, Z. (13.06.2025) – Babuna, one specimen (HMMNH).

From this chronological overview, it can be concluded that *S. babunensis* occurs sporadically, primarily as individual specimens.

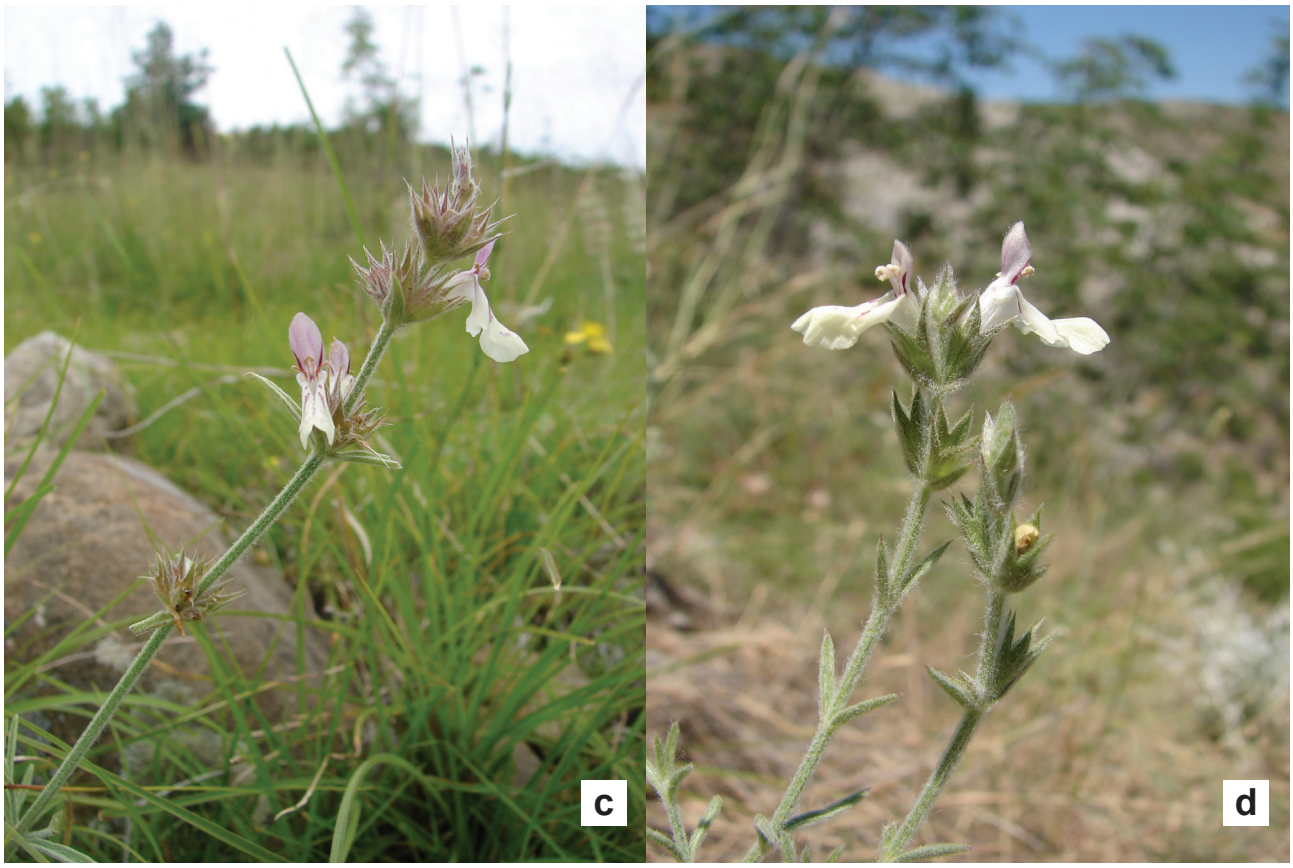


**Fig. 2**. *Stachys babunensis* Micevski / a, b) stem with branches and leaves / c, d) inflorescence (Photo: Z. Nikolov)

**Fig. 3**. *Stachys babunensis* Micevski - flowers (Photo: Z. Nikolov)

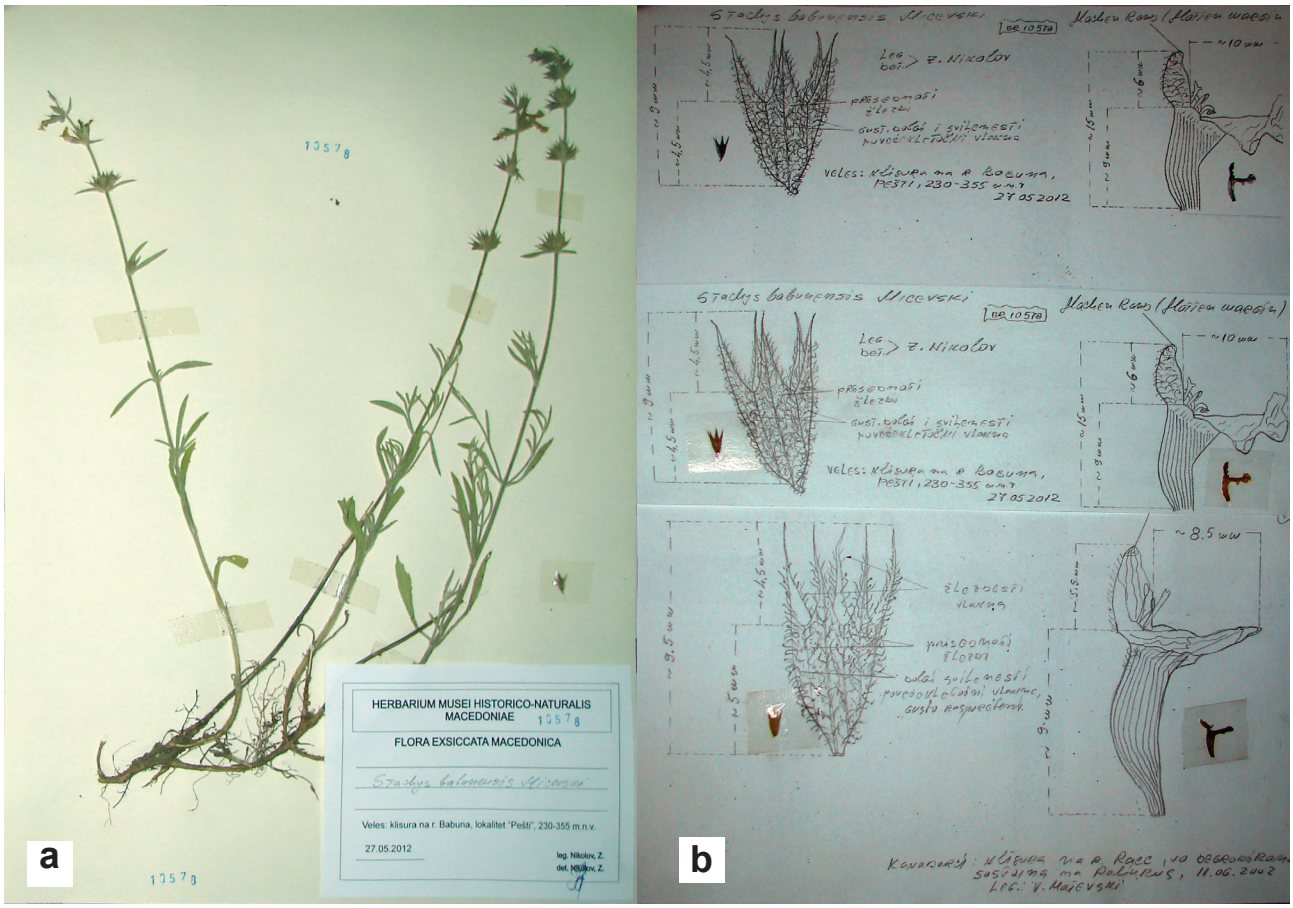


**Fig. 4**. *Stachys babunensis* Micevski
a) herbarium specimen b) drawings of calyx and corolla (Z. Nikolov)

***Habitat and Associated Flora***

*Stachys babunensis* occurs in dry, rocky, limestone habitats, specifically within the degraded *Paliurus spina-christi* community (Fig. 5). The grayish appearance of the plants allows them to blend into the environment, making them difficult to notice (Figs 1a–b, 2a–d, 3, 4a, 5). Characteristic associated species recorded during the visit on 28 June 2025 include: *Paliurus spina-christi, Asparagus acutifolius, Astragalus parnassi, Morina persica, Stachys horvaticii, Stachys recta* subsp. *rhodopaea, Teucrium capitatum, Crataegus monogyna, Prunus spinosa, Petrorhagia saxifraga, Micromeria juliana, Inula verbascifolia* subsp. *aschersoniana, Chondrilla juncea, Astragalus gladiatus, Astragalus vesicarius, Astragalus spruneri, Euphorbia myrsinites, Orobanche amethystea, Orobanche* gr. *minor (*hosts: *Inula verbascifolia* subsp. *aschersoniana, Haplophyllum albanicum), Eryngium campestre, Scabiosa rotata, Scabiosa micrantha, Scabiosa divaricata, Scabiosa argentea, Scabiosa triniifolia, Allium flavum* subsp. *flavum, Allium flavum* subsp. *tauricum, Allium guttatum* subsp. *sardoum, Allium sphaerocephalon, Campanula scutellata, Campanula lingulata, Ononis reclinata, Achillea ageratifolia, Centaurea graeca, Centaurea tymphaea, Carduus nutans, Echinops albidus, Carthamus dentatus, Carthamus lanatus, Himantoglossum hircinum, Pistacia terebinthus*. Notably, along with both specimens of *S. babunensis* recorded in the Babuna River Gorge in 2025, specimens of endemic *S. horvaticii* Micevski (from *Stachys* gr. *iva*) were also found (Fig. 5).

**Fig. 5.** *Stachys babunensis* Micevski – habitat


**Fig. 6**. Distribution of *Stachys babunensis* Micevski in North Macedonia

### *Hypothesized Taxonomic Affinities*

Morphologically, *Stachys babunensis* appears intermediate between *S. horvaticii* and *S. recta* subsp. *rhodopaea* (Velen.) Chrtek f. This suggests a potential hybrid origin, as both putative parental species are present at its locus classicus – the Babuna River Gorge (Pešti locality) (Fig. 7).


**Fig. 7**. *Stachys horvaticii* Micevski (a) and *S. recta* subsp. *rhodopaea* (Velen.) Chrtek f. (b), photographed at the locus classicus of *S. babunensis* Micevski (Babuna River Gorge).

### Conclusion

Based on the chronological data and recent field investigations, we conclude that the Macedonian endemic *Stachys babunensis* is an extremely rare and sporadically occurring species in the flora of North Macedonia. Consequently, due to the exceptionally small number of individuals, the species should be categorized as Critically Endangered (CR) according to IUCN criteria and requires urgent conservation measures.

### Acknowledgement

I am grateful to the reviewers for their constructive comments and invaluable suggestions which significantly improved the manuscript. Also, deep gratitude is extended to Aco Teofilovski for his help in determining the associated species.

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# *Orobanche artemisiae-campestris* (Orobanchaceae), a rare species in the flora of the Republic of North Macedonia

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**Abstract**

This work confirms the presence of *Orobanche artemisiae-campestris*, in the flora of North Macedonia. This rare species is, so far, known from a single, relatively unknown locality - "Lundzi", from the surrounding of the city Gevgelija, in the southern part of the country. The new find is on the Ograždеn Mt, in the eastern part of the country. *O. artemisiae-campestris* parasitizes exclusively on *Artemisia campestris.* The range extends from west to east Europe and, perhaps, also to Caucasus. Taxonomically, *O. artemisiae-campestris* is very close to *O. picridis-hieracioides (= O. picridis).*

**Key words:** *Artemisia campestris, parasitic,* North Macedonia

## Introduction

*Orobanche artemisiae-campestris* (Fig. 1.) is an obligate, root parasitic species of the family Orobanchaceae. It belongs to *Orobanche* subsect. *Minores* Teryokhin in Opred. Zarazikhovykh Fl. SSSR (ed. L.Yu. Budantsev): 39 (1993), which comprises "similar, small flowered plants, corolla typically < 20 mm" (Thorogood & Rumsey, 2020). Species of this subsection, so far registered in the flora of North Macedonia, are the following: *O. hederae* Duby, *O. amethystea* Thuill., *O. picridis-hieracioides* Vaucher ex Holandre, *O. pubescens* d'Urv., *O. serbica* Beck & Petrović, *O. minor* Sm., and *O. esulae* Pančić (Nikolov, 2024). *O. artemisiae-campestris* is strictly parasitic on *Artemisia campestris*. It prefers dry and semi-dry grasslands, sunny, warm rocky slopes, open thickets (Kreutz, 1995, Pusch, 2009).

The native range of *O. artemisiae-campetris* is from west to east Europe and, perhaps, also to Caucasus (POWO, 2025).

## Materials and methods

Plants of *O. artemisiae-campestris* have been collected during the fieldwork on the Ograždеn Mt., in eastern part of the country. Voucher specimens are deposited in the herbarium collection of Natural History Museum of North Macedonia (HMMNH). The nomenclature followed Gaudin (1829), Kreutz (1995), Pusch (2009), POWO (2025). The name *Orobanche artemisiae-campestris* Gaudin (1829) – first coined by Vaucher (1827) as "Orobanche de l'Artemise des champs" – just had priority over *O. loricata*" (Rumsey & Thorogood, 2023). The following, reliable and relevant sources have been used for determination and additional data: Gaudin (1829), Beck (1890, 1930), Chater & Webb (1972), Parabućski (1974), Delipavlov (1995), Kreutz (1995), Uhlich, Pusch & Barthel (1995), Pusch (2009), Piwowarczyk (2012), Stojanov (2020), Thorogood & Rumsey (2020), Rumsey & Thorogood (2023). Photos of alive plants as well as of the voucher specimen are also provided. In addition, the connection between the parasitic – *Orobanche artemisiea-campestris* and the host plant - *Artemisia campestris*, is preserved. Distribution of *O. artemisiae-campestris* in North Macedonia is also presented.

## Results and discusion

*Orobanche artemisiae-campestris* Gaudin, Fl. Helv. 4: 179. [Jan-Jul 1829].

Syn.: *O. loricata* H.G.L. Reichenbach, Iconogr. Bot. Pl. Crit. 7: 41, t. 682 f. 917, 1829 (1831?).

### Literature data

Beck (1930:199, sub *O. loricata*); Uhlich, Pusch & Barthel (1995, sub *O. loricata*).

Makedonien: Lundzi bei Gevgelija (Dimonie).

### New data

Ograždеn Mt. (Strumica), 774 m a.s.l., 03.06.2012; (leg./det. Z. Nikolov).

**Fig. 1.** *Orobanche artemisiae-campestris* Gaudin
(Photo: Z. Nikolov)

**Description of the species (based on the collected plants)**

Stem 27-32 cm, ± purplish, with dense, glandular hairs, giving the plants ± woolly appearance, with usually numerous scales in the lower, and few, in the upper part; the scales up to 21 mm long, 2-3 mm bright, the lowest glabrous, the upper, densely pubescent. Inflorescence (3)7-12 cm, covered with dense, glandular hairs, many flowered, compact in the beginning, later, dense in the upper, and lax, in the lower part, changing the ratio-length stem-inflorescence, from clearly shorter to almost equal. The bracts almost reaching the corolla-tip, dark-brownish, densely glandular pubescent. Calyx somewhat shorter of the corolla, the segments, lower of the middle or even near to the base, unequally bidentate, with filiform tips, densely pubescent. Corolla 18-20 mm, whitish to yellowish, to the tip of the upper lip with violet nuance and dark, violet nerves, covered from outside with light, glandular hairs; the dorsal line, after the even curved base, is somewhat straight (flat) in middle, then clearly bent to the almost entire or clearly divided into two lobes (with recurved tips) upper lip; the lower lip consists of 3, almost equal, crenate lobes. The stamens inserted at 3 mm from the corolla base, the filaments pubescent in the lower, broaden part, to the anthers - almost glabrous; the anthers are dark-brownish, glabrous. The ovarium (including style) c. 15 mm, glabrous, the light-purplish style with rare, glandular hairs. The two-lobed stigma purple or whitish, tinged with light, violet nuance.


**Fig. 2**. *Orobanche artemisiae-campestris* Gaudin **a)** flower **b)** flower with whitish stigma **c)** flower with purple stigma **d)** parasitic plant with the host *Artemisia campestris* (Ogražden Mt., 03.06.2012; Photo: Z. Nikolov)

Plants from Ogražden Mt. match the description by Gaudin (1829), Beck (1890, 1930, sub *O. loricata)*, Hayek (1929, sub O. loricata), Kreutz (1975, sub *O. artemisiae-campestris*), Uhlich, Pusch & Barthel (1995, sub *O. loricata*), Pusch (2009, sub *O. artemisiae-campestris*). The stem is ± purplish, with dense, glanduler hairs. The corolla is 18-20 mm long, whitish to yellowish, the dorsal line of the flower is somewhat even (flat) in the middle (Fig. 2, a). Then, the calyx segments are lower of the middle or almost to the base, unequally bidentate (Fig. 2, a). The filaments are pubescent at the broaden base, but to the anthers, they are almost glabrous. And, the stigma is dominanthly purplish (Fig. 2, c), rarely whitish (Fig. 2, b).

Taxonomically, *O. artemisiae-campestris* stands close to *O. picridis-hieracioides (= O. picridis)*. In addition to the different host, in comparison with *O. picridis-hieracioides (= O. picridis), O. artemisiae-campestris* "has rather robust spikes with fewer, larger flowers, rather yellowish in colour, with reddish markings" (Rumsey & Thorogood, 2023).

Pywowarczyk (2012), in her work, emphasizes the morphological similarity of *O. picridis-hieracioides (= O. picridis)* with *O. minor* and *O. artemisiae-campestris*. She noted that "the calyx segments of *O. picridis-hieracioides (= O. picridis)* are usually divided up to ½ into two similarly sized parts, while in O. artemisiae-campestris, they are divided up to the base" .

The host of *O. artemisiae-campestris* is *Artemisia campestris* (Asteraceae) (Fig. 1, 2, d, 4). During the excavation, we managed to preserve the connection between the host and the parasite (Fig. 2, d; 4). On the Ogražden Mt., *O. artemisiae-campestris* grows in sunny, rocky slopes, along the road, that leads from the town Strumica to the town Berovo (Fig. 3).

The only data, for *O. artemisiae-campestris*, on the territory of North Macedonia, we find in the work of Beck (1930), for the relatively unknown locality 'Lundzi", in the vicinity of the city Gevgelija. This data of Beck (1930) was taken over in the work of Uhlich, Pusch & Barthel (1995). The locality on Ograzden Mt. is the second one in North Macedonia where the presence of this species has been confirmed.

**Fig. 3**. *Orobanche artemisiae-campestris* Gaudin - habitat (Ogražden Mt., 03.06.2012; Photo: Z. Nikolov)

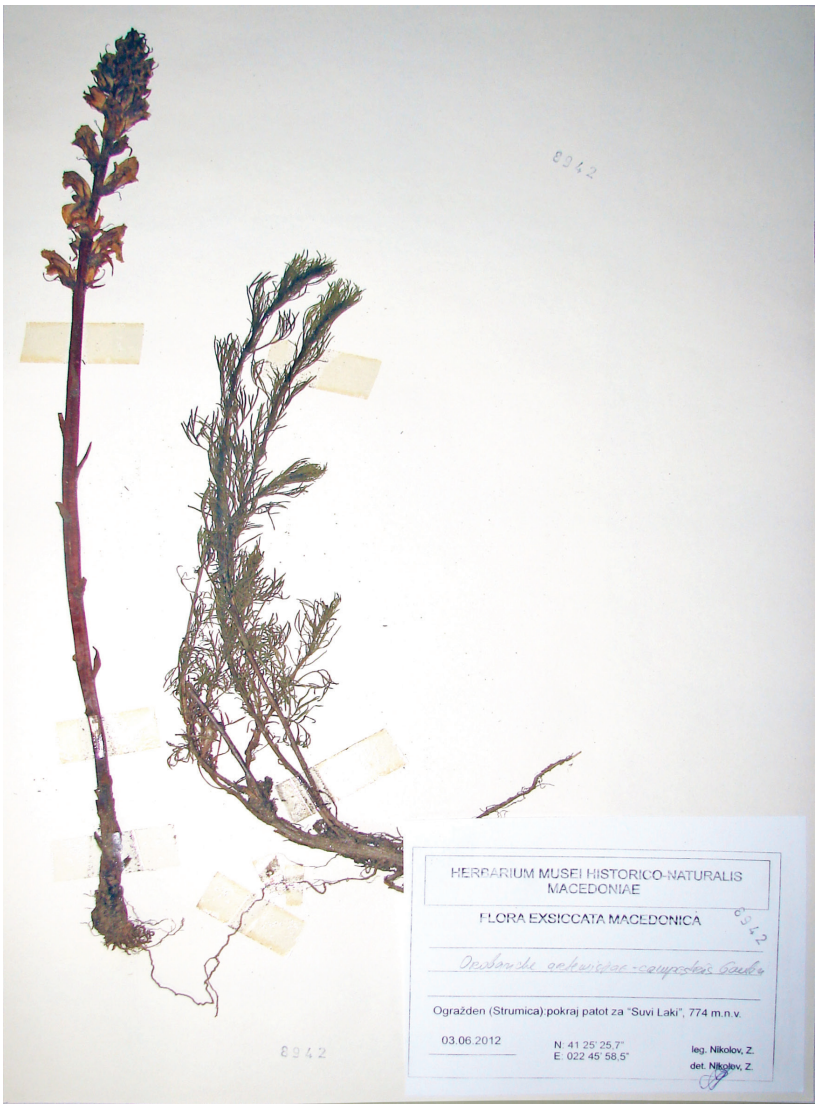


**Fig. 4.** *Orobanche artemisiae-campestris* Gaudin - voucher specimen

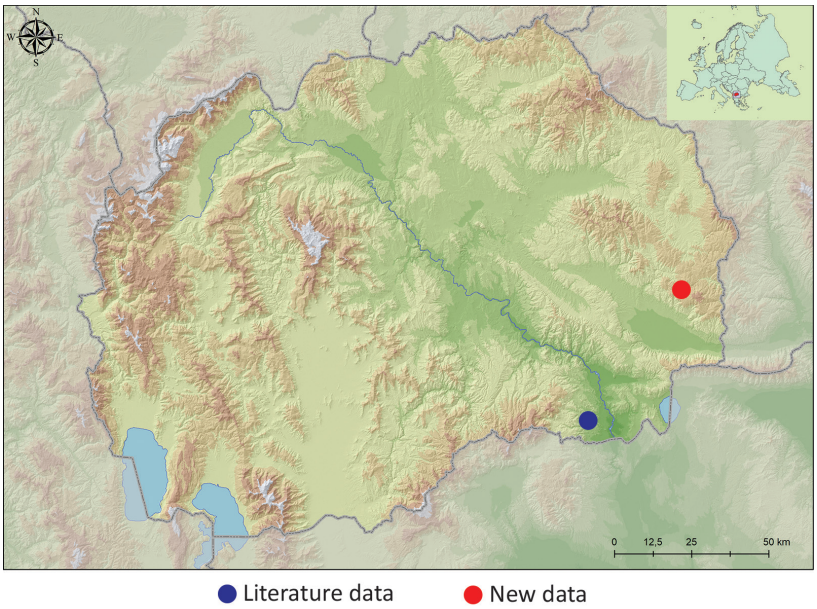


**Fig. 5.** Distribution of *O. artemisiae-campestris* Gaudin in N. Macedonia

**Conclusion**

- *Orobanche artemisiae-campestris* is a very rare species in the Macedonian flora,

- The find on the Ogražden Mt. is new, for this species, on the territory of North Macedonia.

**Acknowledgement**

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# First record of *Sisymbrium strictissimum* L. (Brassicaceae) in the Macedonian flora

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**Abstract**

*Sisymbrium strictissimum* is reported for the first time in the Macedonian flora. Two subpopulations, comprising approximately 70 individuals in total, were documented in the vicinity of the town of Debar, growing in waste places along the road between Boškov Most and the village of Gari. Photographs of living specimens and their habitat, as well as a distribution map, are provided.

**Key words:** Balkan Peninsula; North Macedonia; native distribution; subpopulations.

## Intoduction

The genus *Sisymbrium* L. (Brassicaceae) comprises 48 annual to perennial species, with a native distribution across Eurasia, most of Africa, and parts of North and South America (POWO 2025). Many of its representatives have been introduced beyond their natural ranges, which are often uncertain (Ball 1993; POWO 2025). In the flora of North Macedonia, six *Sisymbrium* species were known to occur, all of them primarily inhabiting ruderal habitats: *Sisymbrium altissimum* L., *S. irio* L., *S. loeselii* L., *S. officinale* (L.) Scop., *S. orientale* L., and *S. polyceratium* L. (Micevski & Matevski, 1995). According to Marhold (2011+), these species are native to the Balkan countries in which they occur, including North Macedonia.

In June 2025, while driving along the road between Boškov Most and the village of Gari (Debar district), I noticed a population of a *Sisymbrium* species, which was documented and identified as *S. strictissimum* L. This species has not been previously recorded from North Macedonia and it is reported here as new to its flora.

## Material and Methods

Fieldwork was conducted on 13 June 2025. Plant material was collected and prepared as herbarium specimens deposited in the private herbarium of the author. Data on population size and habitat characteristics were recorded in the field, including photographs of living plants and their habitats. Identification of the collected specimens was performed following Ball (1993).

## Results and Discussion

*Sisymbrium strictissimum* L., Sp. Pl.: 660. 1753 (Figs. 1 – 3)

**Records:** Debar district, near the road between Boškov Most and the village of Gari, 686 m, 41.541059°N, 20.631119°E, 13.6.2025, leg. & det. A. Teofilovski (herb. A. Teofilovski); Debar district, near the road between Boškov Most and the village of Gari, 630 m, 41.547175°N, 20.619672°E, 13.6.2025, leg. & det. A. Teofilovski (herb. A. Teofilovski).

These are the first records of this species in North Macedonia. It is the only perennial representative of the genus in the country, as well as the only one with undivided leaves.

The native distribution range of *Sisymbrium strictissimum* includes Europe and Central Asia (Kazakhstan) (POWO, 2025). In Europe, it is native to Albania, Austria, Bosnia and Herzegovina, Bulgaria, Croatia, the Czech Republic, France, Germany, Hungary, Italy, Kosovo, Moldova, Montenegro, Poland, Romania, Russia, Serbia, Slovakia, Slovenia, and Ukraine (Nikolić, 1972; Marhold, 2011+). As an introduced plant, it occurs in Sweden, Norway, and Finland, while in Switzerland, it is considered naturalized (Marhold, 2011+). Based on the presented data indicating the species' native occurrence in the Balkan Peninsula, its presence in North Macedonia is likewise considered native. In the Balkan Peninsula, it has so far been recorded from all countries except Greece and the European part of Turkey.

The two subpopulations of *Sisymbrium strictissimum*, recorded near the town of Debar, are approximately 1 km apart and grow in waste places along the local road to the village of Gari. The sites

are densely overgrown with *Rubus* sp. and *Clematis vitalba*. About 70 individuals were recorded at the two sites. In Albania, Kosovo, Serbia, and Bulgaria, neighboring countries of North Macedonia, this species has a fairly restricted distribution, inhabiting various natural habitats such as stony slopes, grasslands, forests, shrublands, and riverbanks (Assenov, 1970; Nikolić, 1972; Barina et al., 2017). In Bulgaria, in addition to natural habitats, it also occurs in ruderal sites such as waste places and vineyards (Assenov, 1970).

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**Fig. 1.** *Sisymbrium strictissimum*, plants in natural habitat. (Debar district, near the road between Boškov Most and the village of Gari, 686 m a.s.l., 13.6.2025, photo. A. Teofilovski)

**Fig. 2.** *Sisymbrium strictissimum*, habitat. (Debar district, near the road between Boškov Most and the village of Gari, 686 m a.s.l., 13.6.2025, photo. A. Teofilovski)

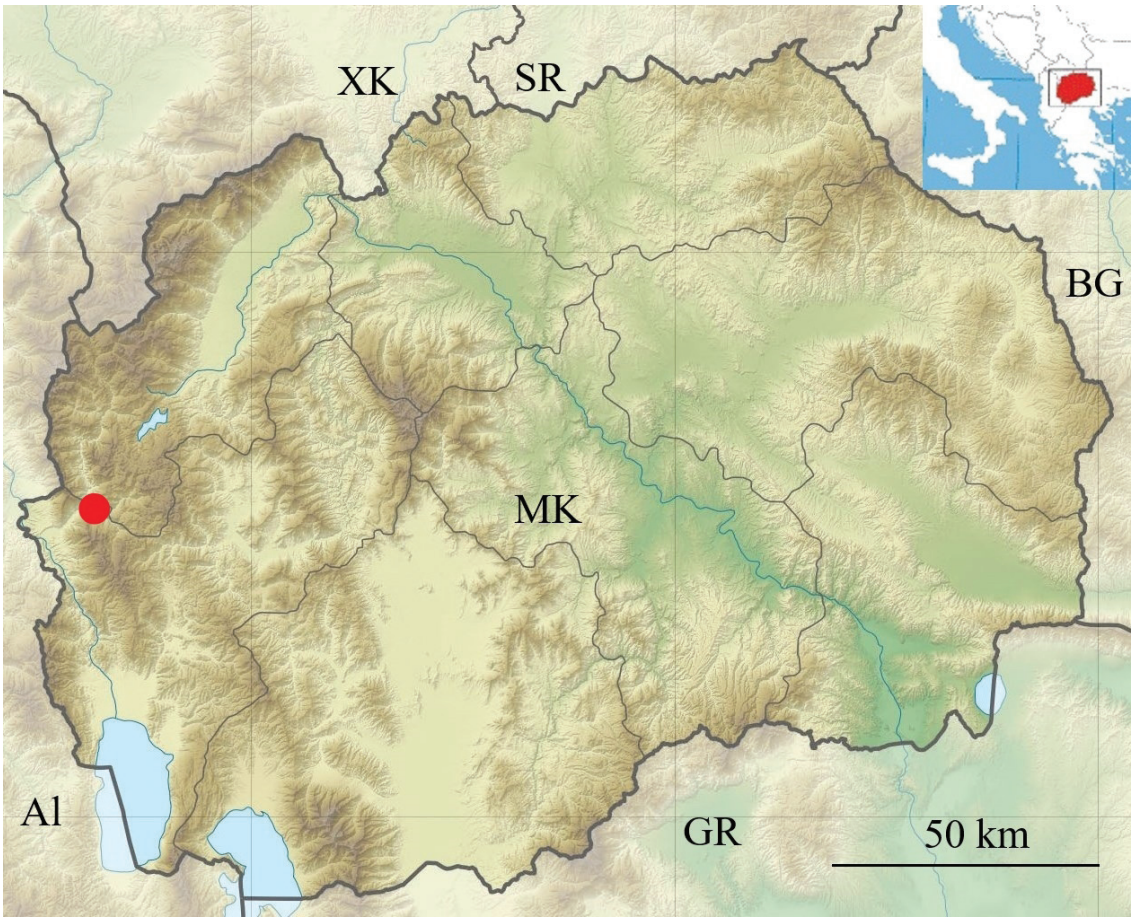


**Fig. 3**. Map of the distribution of *Sisymbrium strictissimum* in North Macedonia

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# Inferences on the paleodiet of *Dihoplus pikermiensis* (Perissodactyla, Rhinocerotidae) from the Late Miocene of North Macedonia through the application of dental mesowear analysis

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**Abstract**

Three fossil rhinocerotids have been reported from the Late Miocene of North Macedonia: *Dihoplus pikermiensis,* Miodiceros neumayri and Chilotherium sp.. The material, which was collected by Professor Risto Garevski, comes from the North Macedonian sites of Kiro Kuchuk, Prsten and Umin Dol and belongs to the paleontology collection of the National Institution Natural History Museum of North Macedonia in Skopje. The present work marks the first report on the paleodiet of fossil rhinos from North Macedonia. We worked on the *D. pikermiensis* material from Kiro Kuchuk and Prsten using the mesowear ruler method. Our results indicate browsing habits for the species at both sites, in accordance with the literature.

**Key words:** dental mesowear, rhinoceros, paleodiet, feeding

## Introduction

A notable number of fossiliferous localities have been reported from the Late Miocene of the Republic of North Macedonia. The first mention of fossils in the country comes from the Late Miocene of the Veles area, formerly known as Titov Veles (Schlosser 1921, Laskarev 1921). The most important fossiliferous localities of North Macedonia are Nerezi, Delchevo, Veles, Negotino, Kavadartsi, Valandovo and Dolni Disan, and the described faunas include mostly typical middle Turolian elements of the Pikermian biome, such as hipparionine horses, hyaenas, the primate *Mesopithecus pentelicus*, the tandem-horned rhinocerotids *Dihoplus pikermiensis* and *Miodiceros neumayri* and one species of the hornless rhinocerotid genus *Chilotherium* (Spassov et al. 2018). However, it is notable that the two tandem-horned rhinocerotids are not sympatric in Northern Macedonia, contrary to their very common and well-documented association in the Balkano-Iranian Zoogeographic Province (Giaourtsakis et al. 2006). Indeed, in North Macedonia, *M. neumayri* has only been reported from the site of Umin Dol, whereas the site of Marievo marks the westernmost limit of the genus *Chilotherium* in Europe (Geraads and Spassov 2009). The richest fossiliferous site of the country is Karaslari, featuring 22 mammal species of early Middle Turolian age (Spassov et al 2018).

In this work, we studied the dental mesowear of *Dihopolus pikermiensis* from North Macedonia, providing paleoecological data about the region for the first time. We proposed dietary inferences for this species at two localities, Kiro Kuchuk and Prsten, and discussed the implications at a regional scale. We also compared with other rhinocerotid specimens from various localities of the Balkans and the Eastern Mediterranean.


**Fig. 1:** Map of the fossiliferous sites of North Macedonia, with Kiro Kuchuk and Prsten in red font.

**Abbreviations:**

MMNH: Macedonian Museum of Natural History, Skopje; M: upper molar; P: upper premolar; d: dexter; s: sinister.

**Material and Methods**

In the present report, we examined the paleodiet of the rhinocerotid D*ihoplus pikermiensis* from the sites Kiro Kuchuk and Prsten. The material, which belongs to the Paleontology collection of the Natural History Museum of North Macedonia in Skopje, is relatively well preserved. The fossils were collected by professor Risto Garevski in the 1970s and consist of six skulls and one mandible, all attributed to *Dihoplus pikermiensis*.

With more than 15 mammal species reported, Kiro Kuchuk is the second richest fossiliferous site of North Macedonia, following Karaslari. The age of the site has been biostratigraphically determined to be early Middle Turolian. On the other hand, the site of Prsten is somewhat older; it has yielded a scarce number of fossil mammals, with its age determined as early Turolian (Spassov et al. 2018).

The material from Kiro Kuchuk and Prsten is generally in good preservation, with most cranial and mandibular features of the species easily noticeable. However, the dental mesowear analysis we opted to apply under the scope of this paper poses the restriction of utilizing only upper adult dentitions. For this reason, we did not include the numerous lower teeth available in the collection in the study, since they could not be used for mesowear analysis. Furthermore, we opted to focus this work exclusively on *D. pikermiensis*, as the only available *M. neumayri* skull, from the locality of Umin Dol, is too old and inadequately preserved in terms of dentition to allow for a mesowear study.

The material from the Macedonian Museum of Natural History has been thoroughly examined and extensively described by Spassov et al. 2018. The main cranial characteristics that allowed for the attribution of the studied material to *D. pikermiensis* were the following: the elongated nasals, the deep nasal notch, the horizontal ventral orbital surface, the position of the orbita above the anterior half of M2, the placement of the infra-orbital foramen above the posterior half of P3, the short cranial basis, the post-tympanic process overlapping the postglenoid process, infra-orbital foramen situated anteriorly (above the posterior root of P3); as far as the upper dentition is concerned, the main diagnostic characteristics of the species are the presence of a marked paracone fold, a slight constriction of both the pro-

tocone and the hypocone, a weak metacone fold on the P4, and the absence of a cingulum (Geraads 1988, Giaourtsakis et al. 2006, Geraads and Spassov 2009, Spassov et al. 2018).

We opted to study the paleodiet of *D. pikermiensis* through a dental mesowear analysis. Dental mesowear analysis is based on the classification of the tooth cusps into shape and relief categories, visible with the naked eye or with a hand lens. Dental wear is treated as two variables: occlusal relief and cusp shape. The upper teeth of browsing herbivores are characterized by high occlusal relief and sharp cusps, which is interpreted as attrition-dominated wear, whereas the dentitions of grazing herbivores tend to have low occlusal relief and blunt cusps, indicating an abrasion-dominated wear (Fortelius & Solounias 2000). This method can differentiate between grazing, mixed-feeding and browsing mammals, while also providing information about the dietary habits of the animal's last months, or even years (Ackermanns et al. 2020).

Under the scope of the present work, we opted for the application of the standardized method coined by Mihlbachler et al. (2011), known as mesowear 'ruler'. The cusp shape and occlusal relief are treated as a single parameter (cusp) and separated to seven categories, ranging from 0 (sharp cusp shape, high occlusal relief) to 6 (totally blunt cusp shape, absence of occlusal relief).

We opted for the mesowear ruler because, as a method originally crafted for the dentitions of another perissodactyl family (equids), it is better suited for rhinocerotids compared to methods originally designed based on artiodactyl ruminants (Hullot et al. 2021). Following the guidelines by Mihlbachler et al. 2018 and Hullot et al. 2021, we opted for the sampling of the second upper molar, right or left. Additionally, we followed Hullot et al. 2021, and only scored the paracone instead of choosing between the sharpest cusp (paracone or metacone) of the upper molar, as these two cusps may vary greatly in rhinos (Taylor et al. 2013). Finally, in order to reduce inter-observer error, the dental mesowear analysis was conducted by a single researcher (GS).

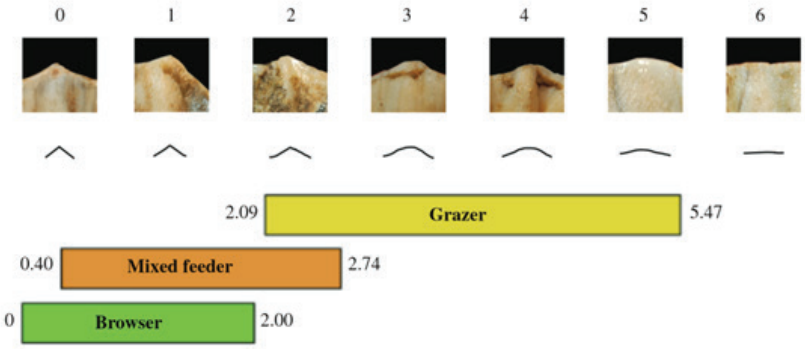


**Fig. 2:** Mesowear score using the mesowear ruler method by Jimenez-Manchon et al. 2022, illustrated with rhinoceros' (*Coelodonta antiquitatis*) dental cusps and interpretative drawings. By Hullot et al. 2024.

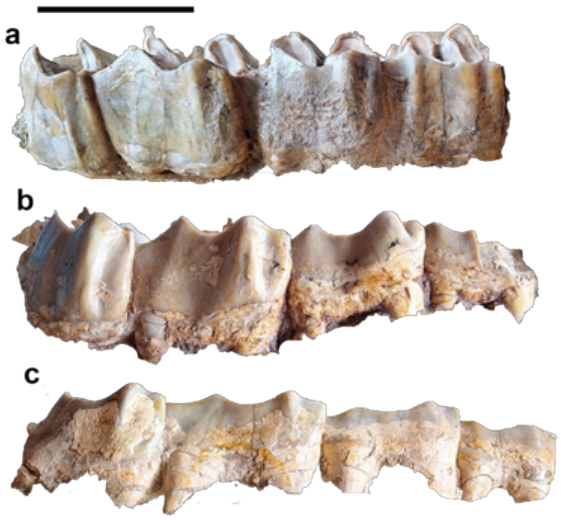


**Fig. 3:** Dentitions of *D. pikermiensis* from North Macedonia. a: MMNH-28439,upper left dentition (M3-P4) of D. pikermiensis from Kiro Kuchuk; b: MMNH-28444, upper left dentition (M3-P4) of D. pikermiensis from Prsten. c: MMNH-28442, upper right dentition (M3-P4) of D. pikermiensis from Kiro Kuchuk. Scale 10 cm.

## Results

The second molars of the examined *D. pikermiensis* skulls are characterized by high occlusal relief and a relatively sharp cusp shape. The mesowear scores were compared to the mesowear score categories provided by Jimenez-Manchon et al. 2022, reporting low scores browsers for browsers (0-2), high scores for grazers (2.09–5.47) and intermediate ones for mixed-feeders (0.4-2.74). The median of the specimens in both localities is 2 (Table 1), indicating browsing or mixed feeding habits. The very small number of specimens (n<5) does not allow for statistical comparisons.

| Specimen | Species | Site | M2s Score | M2d Score | Median |
|---|---|---|---|---|---|
| MMNH-28439 | *Dihoplus pikermiensis* | Kiro Kuchuk | 3 | 2 | 2 |
| MMNH-28441 | *Dihoplus pikermiensis* | Kiro Kuchuk | 2 | 2 | |
| MMNH-28442 | *Dihoplus pikermiensis* | Kiro Kuchuk | 2 | - | |
| MMNH-28444 | *Dihoplus pikermiensis* | Prsten | 2 | 2 | 2 |

**Table 1**: the mesowear data extracted on the left (M2s) and right (M2d) second molars of the MMNH collection.

## Discussion

It is interesting that, compared to the well-documented sympatry of at least two rhinos in the Balkan-Iranian Province (Giaourtsakis et al. 2006 and references therein), no sympatry of rhinocerotid species has been recorded in the Late Miocene of North Macedonia. The rhinos, actually, are relatively rare in the faunas of the country, with *D. pikermiensis* being the definite dominant rhinocerotid of the country.

*Dihoplus pikermiensis* is the dominant rhinocerotid of the Turolian faunal assemblages of North Macedonia. The species has been reported from many localities: it is the only rhino found in early Middle Turolian sites Kiro Kuchuk and Karaslari, as well as in the Middle Turolian site Belushka, early Vallesian site Prsten and, finally, Bashibos, the oldest site of the country, of Vallesian-lowermost Turolian age (Spassov et al. 2018). *Miodiceros neumayri* is the other tandem-horned rhino present in Northern Macedonia, reported only from the middle Turolian site of Umin Dol (Spassov et al. 2018). This species is a common perissodactyl in the Late Miocene of the Eastern Mediterranean, found in various sites of Greece, Turkey and Iran, with the site of Strumyani in Bulgaria marking its northernmost report (Giaourtsakis et al. 2006, Geraads and Spassov 2009, Spassov et al. 2019). The genus *Chilotherium* was also an important element of the Balkan-Iranian Province during the Turolian, with numerous species reported from Greece to China (Kampouridis et al. 2023 and references therein). In North Macedonia, the Late Miocene site of Marievo marks the westernmost report of the genus (Geraads and Spassov 2009, Spassov et al. 2018).

As far other localities of the Balkans are concerned, rhinocerotids have been reported in notable numbers from Bulgaria: *D. pikermiensis* is the only rhinocerotid from the early Turolian site Hadjidimovo; in the early-middle Turolian site Kalimantsi the species is sympatric with *Brachypotherium* sp., *Acerorhinus* sp. and *M. neumayri*; finally, at the early Turolian site Strumyani, *D. pikermiensis* is sympatric with *M. neumayri* (Geraads and Spassov 2009). As far as hornless genera are concerned, primitive chilothere *Eochilotherium samium* is reported from the early Turolian site Kromidovo; *Chilotherium* sp. and *Brachypotherium* sp. have been described from the middle Turolian site Ahmatovo; Turolian locality Gorna Sushitsa has yielded both *Acerorhinus* sp. and *Chilotherium* sp. along with *M. neumayri; Chilotherium* cf. *sarmaticum* has been reported from the early Upper Miocene of Oranovo; *Chilotherium* cf. *kowalevskii* is the sole rhinocerotid at the middle Turolian site Yambol; finally from the early Upper Miocene site Slatino, *Acerorhinus* sp and *D. pikermiensis* have been reported from the early upper Miocene site Slatino (Geraads and Spassov 2009, Hullot et al. 2022).

Greece has also yielded a notable number of fossil rhinoecrotids in the late Miocene

In the classical Turolian locality of Pikermi, *D. pikermiensis* is the main rhinocerotid of the fauna, along with M. neumayri and A. neleus (Giaourtsakis 2003, 2022, Athanassiou et al. 2014).

In Evia island, *D. pikermiensis* and *M. neumayri* coexist in the Turolian site of Kerassia with hornless *Acerorhinus neleus*, with *M. neumayri* being the main rhinocerotid (Giaourtsakis et al. 2006, Athanassiou et al. 2014), whereas in the synchronous locality of Halmyropotamos the only rhinocerotid present is *D. pikermiensis* (Giaourtsakis 2003, 2022 and references therein).

Rhinocerotids have also been reported from various localities of Axios valley, with a strong presence of *M. neumayri*, which has been described in the Turolian sites Dytiko, Ravin des Zouaves and Vathylakkos (Koufos 2006, Giaourtsakis 2022). The Vallesian sites Nikiti and Pentalophos also bear rhi-

nocerotids, with *M. neumayri* and *E. samium* reported from Pentalophos (Geraads and Koufos 1990, Geraads and Spassov 2009, Giaourtsakis 2022), whereas *D. pikermiensis* and *M. neumayri* coexisted in Nikiti-1 (Koufos 2006, Koufos et al. 2016, Giaourtsakis 2022).

The rich Turolian fauna of Mytilinii in Samos Island, Greece, has also yielded a number of rhinocerotid specimens, the majority of which belongs to *M. neumayri*, along with *D. pikermiensis* (Giaourtsakis et al. 2009), whereas the chilothere genera present on the island include both primitive *E. samium* and more derived *C. schlosseri* (Kampouridis et al. 2023).

The homogeneity of the Pikermian Biome as a savanna-like mammal community (Solounias et al. 1999) has been recently debated (Hullot et al. 2022 and references therein). In biogeographic terms, the Turolian faunas of North Macedonia should be clustered with the Western Local Faunal Assemblages (LFAs), including the Balkans and Northern Greece, which can be separated from the Eastern LFAs (Samos, Anatolia) from the during the Pikermian Large Mammal Event (sensu Kostopoulos 2009).

Despite the marked dietary variation they present, data on the paleoecology of rhinocerotids were relatively scarce compared to other herbivores (Hullot et al. 2022). In terms of paleodiet, *Dihoplus pikermiensis* has been described as a not highly specialized herbivore, a selective browser with low cheek teeth, favoring closed habitats characterized by dense vegetation (Giaourtsakis et al. 2006, Geraads and Spassov 2009, Hullot et al. 2022). In comparison, *M. neumayri* has been associated with occupying more arid and open landscapes and developing adaptations to feeding on increasingly lower and more hard bushy vegetation, such as the lack of incisors, the lengthening of the skull, the relatively convex mandible, the weakened protocone and strong mesostyle (Heissig 1999, Giaourtsakis et al. 2006, Geraads and Spassov 2009). Most recently, its dental signature was described as mixed feeding, including soft vegetation on the diet (Hullot et al. 2022). *Chilotherium* has been interpreted as a marsh or swamp dweller, with its short metapodials suggesting semi-aquatic habits (Beliaeva 1954), but this view has not had further support (Geraads and Spassov 2009). Based on data from the Balkan-Iranian Province, this genus has been interpreted as a mixed feeder, and a potential dietary competition or niche partitioning in cases of sympatry with *M. neumayri* (including the proximal to Kiro Kuchuk Bulgarian site of Gorna Shushitsa) has lead to the inclusion of harder browse items in the diet of the genus (Hullot et al. 2022). Moreover, the shape of the tusk can be interpreted as an adaptation to cutting this hard vegetation (Geraads and Spassov 2009). Finally, in the many cases of sympatry in the Balkan-Iranian Province, the two tandem horned species were probably not competing for the same ecological niches (Spassov et al. 2006, Geraads and Spassov 2009, Giaourtsakis 2022, Hullot et al. 2022).

With more than 15 fossil mammal species of Middle Turolian age, the fauna of Kiro Kuchuk is the second richest of North Macedonia, following only Karaslari, which has yielded 22 species. On the other hand, the material from Prsten is scarce, with an age determined to Early Turolian (Spassov et al. 2018).

Apart from *D. pikermiensis*, the other megaherbivores of Kiro Kuchuk are the large giraffine *Bohlinia attica* and the chalicothere *Ancylotherium pentelicum*. Both these animals have been decribed as browsers (Saraç et al 2002, Merceron et al. 2018). The presence of the primate *Mesopithecus pentelicus* would also indicate a forested environment. In conclusion, some degree of potential dietary competition may be expected between the megaherbivores, yet not enough data is available to support the hypothesis.

As far as Prsten is concerned, *D. pikermiensis* and the proboscidean *Choerolophodon* sp. (only one juvenile specimen) reported as the only megaherbivores of the site. *Choerolophodon* has been reported as a grazer feeding mostly on graminoids available on open habitats (Konidaris et al. 2016), therefore the two megaherbivores of the fauna would probably not be in dietary competition, as they would occupy different niches. This is a common trend in the Balkan-Iranian Province, where the co-existence of *Choerolophodon* and browsing/mixed feeding rhinocerotids is relatively common (Hullot et al. 2022).

The paleoecological reconstruction of North Macedonia during the Middle Turolian has been based on the faunal composition of the sites Karaslari and Kiro Kuchuk, and the paleoenvironment is described as dominated by open woodlands and bushlands (Spassov et al. 2018). This does not disagree with the result of our work on *D. pikermiensis* from Kiro Kuchuk, which we interpreted as a browser, coexisting either with other browsing megaherbivores (*B. attica, A. pentelicum*) or with grazing ones (*Choerolophodon* sp) in a variable environment.

## Conclusion

The paleodietary data we collected from the upper dentitions of the *D. pikermiensis* fossils from North Macedonia support a browsing or mixed-feeding diet, which is supported by previous research. This rhinocerotid coexisted with other megaherbivores in Kiro Kuchuk and Prsten, yet a dietary competition is improbable. The late Miocene faunas of North Macedonia are similar to other synchronous Southern Balkans and continental Greece faunas. We support the need of a more synthetic study of the paleodiet of the various herbivores from North Macedonia in the future, using a combination of paleo-

ecological proxies such as microwear analysis and isotopic composition; we argue that a multi-proxy paleoecological study would help better reconstruct the paleonvironmental conditions of the area and, consequently, further understand an important part of the Balkan-Iranian Province during the Miocene.

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