



First records of *Calamagrostis purpurea* (Poaceae) in the Carpathians, a relict species new to the flora of Slovakia, Ukraine, and Romania

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Received: 30 November 2021 / Accepted: 24 March 2022 / Published online: 12 April 2022
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Abstract

The first records of *Calamagrostis purpurea*, an apomictic wetland grass species with a Euro-Siberian, predominantly boreal distribution, are reported for the Carpathians. This significantly expands the species' range in Central Europe eastwards from the known localities in Austria and Czechia. Due to *in situ* finds and revision of the herbarium vouchers, *C. purpurea* was discovered in the Western Carpathians in Slovakia (the Nízke Tatry Mts) as well as in the Eastern Carpathians in Ukraine (the Chornohora Mts) and Romania (Dorna Depression, the Harghita, Bodoc Mts, Intorsura Buzaului Depression) at 6 sites in total. All these newly found localities are situated within 870–1570 m a.s.l. The locality in the Nízke Tatry Mts is at the highest elevation, while those in the Romanian Carpathians are the southeasternmost in Central Europe. In the Carpathians, *C. purpurea* is confined to undisturbed wetland habitats, which implies its relict origin in the region. A distribution map, habitat characteristics, morphological description, and images of the plants from the Carpathians are provided. Carpathian populations tested with flow cytometry are DNA-octoploid (the predominant ploidy level of the species in Europe). Because of the species' rarity and vulnerability, it is suggested to include *C. purpurea* in the next editions of the Red Data Books and/or Red Lists of the corresponding countries.

Keywords Carpathians · Distribution · New records · Rare species · Relict · Wetlands

Introduction

Calamagrostis purpurea (Trin.) Trin. belongs to the *Calamagrostis purpurea-langsdorffii-canadensis* complex (Tateoka 1974) that includes a group of closely related apomictic as well as sexual taxa with a vast range, most abundant in the north of Eurasia and North America including Greenland (Tzvelev 1974; Hultén and Fries 1986). The *C. purpurea-langsdorffii-canadensis* complex is very polymorphic (Nygren 1946, 1951; Sell and Murrel 1996), and its taxonomic treatment (which taxa are accepted and at what rank) differs considerably among authors. In Europe,

that complex is represented by three subspecies of *C. purpurea*: subsp. *purpurea*, subsp. *phragmitoides* (Hartm.) Tzvelev and subsp. *langsdorffii* (Link) Tzvelev (Euro + Med 2006–2021). The latter taxon is restricted to the north and north-east of the European part of Russia (Tzvelev 1976; Clarke 1980). Because of rather ambiguous diagnostic traits and their significant variability and unknown evolutionary history, the C, W and N European *C. purpurea* subsp. *phragmitoides* (Tzvelev 1976; Clarke 1980) or *C. phragmitoides* Hartm. (Scholz 1971; Conert 1998) is not well distinguishable (Cope and Gray 2009) from the mostly Siberian *C. purpurea* *sensu stricto*. Therefore, we use a wider circumscription that includes *C. phragmitoides* in *C. purpurea* (Nygren 1946; Mossberg and Stenberg 2018; Štech 2019; Štech et al. unpubl.). *Calamagrostis purpurea* is a Euro-Siberian species whose more or less continuous distribution range covers Fennoscandia, the Baltic states (Lithuania, Latvia, Estonia), northern Belarus, north-eastern European Russia, the Central and Southern Urals, northern Kazakhstan, Mongolia, and Siberia (mostly its boreal zone) up to the Far East (Tzvelev 1965, 1976; Tretyakov 2013; Urgamal et al. 2014; Tzvelev and Probatova 2019; Kotuchov et al.

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2019). Furthermore, it also occurs on the northern slopes of the Greater Caucasus (Tzvelev 1974; Fig. 1).

In Europe, *C. purpurea* is sporadically scattered south and west of the continuous distribution area (Fig. 1). In Central Europe, it was first discovered in the late 19th century by Hackel (1883) from Hesse in Germany. Later, after the 1960s, this species' occurrence has been recognized in Belgium, France, Switzerland, Austria, other regions of Germany, and the Czech Republic (Scholz 1971; Smejkal 1976; Conert 1998; Růžička 2005; Ondráček 2011; Štech 2013; Kaplan et al. 2020; Štech et al. 2020). It is considered a glacial relict in these countries (Scholz 1971; Dersch and Mast 2000). In addition, *C. purpurea* was first recognized in Great Britain in the 1980s and later in Ireland (Sell and Murrel 1996; Stace 2019).

The fact that the species has been long overlooked in a number of Western- and Central-European countries can be explained by its resemblance to other *Calamagrostis* species, especially *C. canescens* (Weber) Roth and *C. villosa* (Chaix) J. F. Gmel. That indicates that the distribution of *C. purpurea* is still insufficiently known and discoveries of new localities, particularly in the regions beyond its continuous distribution may be expected. Quite surprisingly, the occurrence of *C. purpurea* has not been known in the Carpathians, a European mountain system that harbours other boreal species with similar habitat needs (Soó 1939; Meusel et al. 1965–1992; Dítě et al. 2018), except for a single report from the Börzsöny Mts, Hungary (Tatár 1995) that proved to be erroneous (Štech et al. 2020; confusion with *C. villosa*). Revision of herbarium vouchers of *Calamagrostis* spp. and surveys in the suitable habitats proved that *C. purpurea* is



Fig. 1 Distribution of *Calamagrostis purpurea* in Europe and **b** in the Carpathians. 1–6: discovered localities. Map background and unit boundaries prepared by P. Turis (used with his permission)

present and native in different parts of the Carpathians in Slovakia, Ukraine, and Romania, and this occurrence is for the first time described in this paper.

Materials and methods

Study species and region

Calamagrostis purpurea belongs to section *Calamagrostis* which includes 6 other species that occur in Europe: *C. canescens*, *C. epigejos* (L.) Roth, *C. langsдорffii*, *C. pseudophragmites* (Haller f.) Koeler, *C. rivalis* H. Scholz, and *C. villosa* (Tzvelev 1974; Clarke 1980).

The main diagnostic traits in which *C. purpurea* differs from the two most similar species of the genus occurring in the Carpathians (*C. canescens* and *C. villosa*, both able to produce branched stems, similarly as *C. purpurea*) are longer leaf ligules covered with dense patent hairs (Fig. 2; in the other two species the hairs are shorter and erecto-patent, appressed or absent), characteristic structure of a floret (Fig. 3), and notably indehiscent pollen-free anthers. The identification key to distinguish *C. purpurea* from the other species of the genus *Calamagrostis* is provided e.g. by Štech (2019) and Štech et al. (2020).

Morphological description of *C. purpurea* based on the plants from the Carpathians is as follows:

Laxly caespitose, rhizomatous perennial grass. Culms 80–130 cm, rather stout, with 5–6 nodes. Leaves 4–10 mm wide, flat, slightly glaucous, adaxially with scabrid hairs mostly along the prominent veins. Upper ligule 6–15 mm, lacerate, with dense, over 50 μm , \pm patent hairs (Fig. 2).

Panicle 10–20 cm long, 2.5–4 cm wide, oblong-ovate or lanceolate in outline, nodding at maturity. Rhachis, branchlets, and pedicels scabrid with prickly hairs. Glumes subequal, 4.2–5.5 mm long, lanceolate, dark dirty-violet to greenish, with patent hairs, setaceous along keel. Callus-hairs longer than lemma. Lemma 3.0–3.2 mm, membranous, 5-nerved, notched at the apex, light-brown. Awn 1.2–1.5 mm, arising from upper 1/2–1/3 of lemma, straight and \pm parallel to the floret axis or gently curved, slightly exceeding or almost equalling lemma (Fig. 3). Anthers yellow, without viable pollen, not separating at maturity.

Calamagrostis purpurea is an apomictic species. The formation of viable pollen is very rare and is regarded as an exception (Nygren 1946; Dersch and Mast 2000). The chromosome number is reported as variable. The base chromosome number is $x=7$ and the somatic chromosome count ranges in Europe from $2n=56$ to $2n=91$, but is mostly $2n=8x=56$ (Nygren 1946; Tateoka 1974).

Calamagrostis purpurea is confined to wetlands, e.g. wet meadows, damp woodlands, mire margins, lakeshores,



Fig. 2 Upper leaf ligule in *Calamagrostis purpurea* from the Chornohora Mts, Ukraine

and river banks (Tzvelev 1976; Conert 1998; Kotuchov et al. 2019) and occurs in hygrophilous to subhygrophilous communities belonging to the classes *Alnetea glutinosae*, *Betulo-Adenostyletea*, *Molinio-Arrhenatheretea*, *Salicetea purpureae* (Dersch and Mast 2000; Jäger 2017) and *Scheuchzerio-Caricetea nigrae* (Smejkal 1976). It often forms monodominant stands (Dersch and Mast 2000; Cope and Gray 2009).

In Central Europe, *C. purpurea* prefers mid-altitude areas in the mountains within 500–1000 m a.s.l. with most of its localities situated in low mountain massifs, like those called Mittelgebirge in Germany (Scholz 1971; Štech et al. 2020). Diverse habitat conditions in higher mountain systems, notably in the Alps, do not seem beneficial for this species and it is much rarer there not only at higher altitudes close to the timberline but also within its usual altitudinal range (Štech et al. 2020).

The study region, i.e. the Carpathians is a remarkable hotspot of plant diversity at the pan-European scale (Mráz and Ronikier 2016; Breman et al. 2020). Extending through Austria, Czechia, Slovakia, Poland, Ukraine, Hungary, Romania, and Serbia that mountain system is usually divided into the Western, Eastern, Southern Carpathians,



Fig. 3 Floret of *Calamagrostis purpurea* from the Chornohora Mts, Ukraine

and the Apuseni Mts (Fig. 1). The Carpathian flora is composed of ca. 4,000 taxa that makes about 30% of the whole flora of Europe (Tasenkevich 2003). The Carpathians are an important element of the European Alpine System (Ozenda

1985), a discontinuous orographic chain that spans the continent and provides a migration route for the mountain plant species (Mráz and Ronikier 2016). The Carpathians, *inter alia*, harbour many arctic-alpine and boreal-montane species with a disjunct distribution, which were probably more abundant in the past colder epochs when climatic conditions were more favourable for them and are, therefore, generally considered glacial relicts (arctic-alpine species) or Early Holocene relicts [boreal(-montane) species, particularly those restricted to the wetlands] in this region (Dítě et al. 2018). In the Carpathians, some of these species occur at the edge of their distribution (Meusel et al. 1965–1992; Kobiv 2018).

Data collection

After a find of *C. purpurea* in Slovakia in 2015 and the discovery of populations in the Austrian Alps (see Štech et al. 2020 for details), herbaria rich in Carpathian collections (BP, BRNM, CB, CHER, CL, KRAM, LW, LWS, PR, PRC, W, WU; abbreviations after Thiers 2021) have been



Fig. 4 Locality of *Calamagrostis purpurea* in the Nízke Tatry Mts, Slovakia. The species grows there at the bottom of a glacial cirque on a flat waterlogged site in the carr of *Salix helvetica* (the greyish shrubs in the foreground)

searched by C. Pachschwöll and M. Štech for misidentified or overlooked specimens of *C. purpurea*.

In July 2020 Y. Kobiv discovered this species in the Ukrainian part of the Carpathians. Because that locality is situated near the Pozhzyzhevska Biological Station, it was possible to examine that population in more detail including habitat characteristics and morphological characters of plants. Phytosociological relevés using Braun-Blanquet's scale were taken on two 2 × 2 m plots. The content of calcium in soil was assessed by complexometric titration with the aid of metallochromic indicators, and pH(H₂O) by potentiometric measurement using a standard hydrogen electrode (Mineev 2001). Microphotographs were obtained with a Zeiss Stemi 2000-C stereo microscope equipped with a Nikon Coolpix 4500 camera.

Taxonomy and nomenclature follow Euro+Med Plant-Base (2006–2021) for vascular plants and Hodgetts et al. (2020) for bryophytes. Delimitation and names of the Carpathian orographic units follow Breman et al. (2020).

Flow cytometry

DNA-ploidy level of *C. purpurea* from the sites in Slovakia and Ukraine was analyzed using the standard methodology with Otto's buffers (i.e. the protocol 1C in Doležel et al. 2007). About 0.5 cm² of *Calamagrostis* fresh leaf was co-chopped with an equal amount of the internal standard (*Bellis perennis* L.) in 400 ml of ice-cold Otto I buffer. After ca. 10 min of incubation, 800 ml of the Otto II buffer supplemented with 2-mercaptoethanol (2 µl / ml) and DAPI (4 µg / ml) was added. The samples were run on the Sysmex CyFlow Space flow cytometer equipped with 365 nm UV-LED as a light source and fluorescence of 3000–5000 particles was recorded. The fluorescence histograms were evaluated using FlowJo 10 (TreeStar Inc.).

For comparison, 6 specimens of *C. canescens* ($2n = 4x = 28$; Krahulcová 2003) and 6 of *C. villosa* ($2n = 10x = 70$; Krahulcová 2003) from different part of Central Europe were studied; see Table S1 for locality details.



Fig. 5 Population of *Calamagrostis purpurea* in the Chornohora Mts, Ukraine

Results

Record of *Calamagrostis purpurea* from Slovakia

In the Carpathians, *C. purpurea* was first discovered by P. Koutecký in 2015 in the Nízke Tatry Mts, Western Carpathians, Slovakia (Fig. 1, locality 1). The locality is situated in the subalpine zone in a *Salix helvetica* carr (Fig. 4) at the headwaters of the Ludárov potok Stream in the glacial cirque below the summit of Mt. Ďumbier at the altitude of 1570 m a.s.l., which is the highest elevation recorded for *C. purpurea* in the Carpathians. The site lies within the Nízke Tatry National Park.

Herbarium vouchers

Slovakia, Nízke Tatry Mts, Liptovský Mikuláš district; Mt. Ďumbier: glacial cirque ca. 0.86 km NE of the summit, in a *Salix helvetica* carr at the headwaters of Ludárov potok Stream, 1570 m a.s.l., 48°56′31.9″N, 19°38′53.3″E, leg. et det. P. Koutecký, 14 July 2015 (CBFS 7258); same locality, leg. P. Turis, 6 August 2015 (P. Turis' herbarium).

Record of *Calamagrostis purpurea* from Ukraine

The species was found in the Chornohora Mts, the highest mountain range of the Ukrainian Carpathians (Fig. 1, locality 2). The locality is situated at the headwaters of the Prut River in the lower glacial cirque between Mt. Breskul and Mt. Pozhyshevskya on a large, ca. 5 ha peat bog called Tsybul'nyk. The peat bog lies on a flat area at the bottom of the cirque at the altitude of 1375–1390 m a.s.l. It is moderately drained due to the ditch that was dug over a hundred years ago to make the area more suitable for grazing. The impact of grazing on vegetation was very significant in the region until the 1970s when the nature protection regime was established in that part of the Chornohora Mts and grazing was ceased. The site belongs to the strictly protected zone of the Carpathian National Nature Park now and no human activities have been carried out there for over 40 years.

Herbarium vouchers

Ukraine, Chornohora Mts, Ivano-Frankivsk Region: peat bog Tsybul'nyk between Mt. Breskul and Mt. Pozhyshevskya, 1375 m a.s.l., 48°09′15.4″N, 24°31′48.1″E, leg. et det. Y. Kobiv, 28 July 2020 (LW 215,297, WU 0120504 [<https://wu.jacq.org/WU0120504>]).

Habitat characteristics

Calamagrostis purpurea is confined to the margins of the peat bog where it distinctly dominates in 5–6 patches of 5–100 m² each (Fig. 5). In these patches, the number of flowering stems reaches up to 50 per m². The species occurs within a 300 m wide area.

The species prefers damp conditions where the groundwater table does not reach its rhizomes and the upper root system. Therefore, *C. purpurea* occurs at the edge of the peat bog and avoids its wetter central part. The species' microhabitats are well-insolated and it does not occur even in the semi-shaded carrs. The soil is peat-rich, subacidic, with pH(H₂O) value of 5.60–5.85 and content of calcium 16.8–22.2 mg equivalents per 100 g of soil.

The locality is situated slightly below the climatic timberline, which stretches at ca. 1500–1550 m a.s.l. on the adjacent slopes but fragments of *Pinus mugo* and *Alnus viridis* krummholz are scattered within and around the site because of sufficient insolation at that treeless peat bog.

Phytosociological relevés were recorded in two patches of *C. purpurea*.

Relevé 1: 48°09′15.4″N, 24°31′48.1″E, 1375 m a.s.l., slope: 0°, area 4 m², E₀ 30%, E₁ 75%, stand height 55–70 cm, 28 July 2020; – E₀: *Sphagnum teres* 3, *Straminergon stramineum* 1; – E₁: *Calamagrostis purpurea* 4, *Filipendula ulmaria* 2, *Allium schoenoprasum* 1, *Caltha palustris* 1, *Crepis paludosa* 1, *Equisetum palustre* 1, *Valeriana dioica* subsp. *simplicifolia* 1, *Dactylorhiza cordigera* +, *Eriophorum angustifolium* +, *Homogyne alpina* +, *Pilosella aurantiaca* +, *Potentilla erecta* +, *Myosotis sylvatica* r, *Ranunculus acris* r, *Tozzia alpina* subsp. *carpatica* r.

Relevé 2: 48°09′14.5″N, 24°31′38.0″E, 1389 m a.s.l., slope: 0°, area 4 m², E₀ 35%, E₁ 70%, stand height 55–70 cm, 28 July 2020; – E₀: *Sphagnum teres* 3; – E₁: *Calamagrostis purpurea* 4, *Caltha palustris* 1, *Deschampsia cespitosa* 1, *Equisetum palustre* 1, *Jacobaea subalpina* 1, *Chaerophyllum hirsutum* +, *Picea abies* +.

Records of *Calamagrostis purpurea* from Romania

All records of *Calamagrostis purpurea* from the Eastern Carpathians, Romania, are based on the revision of previously misidentified herbarium specimens. Unfortunately, we did not have an opportunity to visit the sites during the last two years since the discovery of the specimens. Seven specimens from 4 localities were revealed. The original localization printed on the labels is presented with added notes (e.g. the current geographic names) in square brackets:

Locality 3 in Fig. 1, [Dorna Depression, Suceava county]: in dumeto palud. ad “36 sz. őrház” ad rivum Tesna [Teşna] prope pag. Kosna [Coşna], cca. 870 m.s.m., leg. Á. Boros,

30. Jul. 1942 (BP 505,891 [HNHM-TRA 00033849], W 1958–0023627). Both vouchers were originally determined as *C. canescens*. The site is situated near or within the Natura 2000 wetland area “Tinovul de la Românești” (Pop 1960; Mihalca 2012). Its approximate geographic coordinates are 47°22'3"N, 25°10'0"E.

Locality 4 in Fig. 1, [Harghita Mts, Harghita county]: in torfosis [recte: turfosis] Lucsmelléke [Luci] supra opp. Csík-szereda [Miercurea Ciuc], alt. ca. 1075 msm, leg. T. Pócs, 14. Aug. 1955 (BP 203,662 [HNHM-TRA 00034775]). This voucher was originally identified as *C. villosa* and collected in a site later declared the Natura 2000 area and IUCN Category IV nature reserve, the remarkable “Tinovul Luci” peat bog (Pop 1960; Samu and Urák 2014; Taňžau et al. 2014) with the approximate coordinates 46°18'0"N, 25°43'1"E.

Locality 5 in Fig. 1, [Bodoc Mts, Harghita county]: lacus “Sf. Ana” non procul ab oppido “Băile Tușnad”, cca. 950–1000 msm, leg. Karel Sutorý, 1986-07-01 (BRNM 379,370). This voucher was originally identified as *Calamagrostis* sp. It was collected at the shores of the volcanic Lake Sfânta Ana belonging to the “Tinovul Mohoș – Lacul Sf. Ana” Natura 2000 site at present (Pop 1960; Magyari et al. 2014b; Samu and Urák 2014). The approximate coordinates are 46°7'43"N, 25°53'21"E.

Locality 6 in Fig. 1, [Intorsura Buzaului, Covasna county]: (1) in nemorosis ad rivum Rozsdás-patak [Pîriul Ruginosu], pr. pagum Komandó [Comandău], leg. Dr. [Z.] Hargitai, 12. VII. 1941 (CL 200,162). This voucher was originally determined as *C. canescens*. – (2) in dumetosis [recte: dumetis] paludosis ad rivum Rozsdás-patak [Pîriul Ruginosu] pr. pag. Kommandó [Comandău], cca. 1000 m.s.m., leg. A. Boros, 10. Aug. 1942 (BP 405,803 [HNHM-TRA 00034400], W 1958–0023626 [http://www.jacq.org/detail.php?ID=1539194]). These two vouchers were originally determined as *C. pseudophragmites*. Locality 6 refers to the Natura 2000 site “Turbăria Ruginosu” with approximate coordinates 45°45'60"N, 26°14'48"E.

DNA-ploidy levels

The relative genome size (i.e. the ratio of *Calamagrostis* / *Bellis* mean fluorescence) is the same for both studied Carpathian populations of *C. purpurea* and significantly differs

from that of *C. canescens* and *C. villosa* (Table 1). As the ratio of the relative genome sizes between ploidy-uniform decaploid *C. villosa* and tetraploid *C. canescens* (2.15) is lower than the expected value (2.5), genome downsizing towards higher ploidy levels, as it is usual in polyploid plants (Leitch and Bennett 2004), seems to be present in the genus *Calamagrostis*. With respect to this, we infer that the ratio of *C. purpurea* / *C. canescens* (1.84) corresponds to DNA-octoploids. This is the most frequently reported ploidy level for *C. purpurea* in Europe (Štech et al. 2020).

Discussion

Phytogeography

The above results show that *Calamagrostis purpurea* occurs not only in different countries of the Carpathians – Slovakia, Ukraine, and Romania but also in the two main parts of the mountain system – the Western (one site) and Eastern Carpathians (5 sites). Its localities are scattered along most of the Carpathian arch. The two sites (in Slovakia and Ukraine) are situated in north-facing glacial cirques at a rather high elevation similar to some sites in the Alps (e.g. Lac de Champex, Valais Alps, Switzerland; Desfayes 2008), the site in Slovakia at 1570 m a.s.l. being the highest recorded in Central Europe and the only in the subalpine zone. In contrast, localities in Romania are situated at elevations around 900–1100 m a.s.l., comparable to sites in lower Central European mountain ranges in Czechia or Germany. The Carpathian records significantly expand the south-eastern limit of this species' range in Central Europe (Fig. 1) from its already known localities in Czechia and Austria (Štech et al. 2020).

The Carpathian localities of *C. purpurea* are separated by a 750–800 km disjunction from the closest occurrences (Fig. 1), which represent its main range in the north of Europe (i.e. in Lithuania, Belarus, and European Russia). Though the species is generally classified as boreal (Štech et al. 2020), in Europe it can be also referred to as boreal-montane (Preston and Hill 1997) taking into account the Central-European mountainous part of its range. A similar distribution pattern (latitudinal disjunction and absence in

Table 1 Relative genome size (RGS) of the Carpathian populations of *Calamagrostis purpurea* and comparison with similar species. *Bellis perennis* was used as the internal standard and DAPI as the stain. Localities of analyzed plants of *C. canescens* and *C. villosa* are listed in Appendix 1.

Species/Population	Number of analyzed plants	RGS (mean ± SD)
<i>Calamagrostis purpurea</i>		
Locality 1 (Nízke Tatry Mts)	3	2.63 ± 0.02
Locality 2 (Chornohora Mts)	3	2.60 ± 0.03
<i>Calamagrostis canescens</i>	6	1.42 ± 0.03
<i>Calamagrostis villosa</i>	6	3.06 ± 0.05

the South-European mountains) is exhibited by some other Euro-Siberian wetland species, e.g. *Betula humilis*, *B. nana*, *Cirsium heterophyllum*, *Ligularia sibirica*, *Pedicularis sceptrum-carolinum* or *Vaccinium microcarpum* (Soó 1939; Meusel et al. 1965–1992) though some of them prefer more acidic soil than *C. purpurea*. For instance, Tinovul Luci (locality 4), the largest peat bog of Transylvania, is famous for glacial relicts like *Betula nana* and *Ligularia sibirica* (Pop 1960; Samu and Urák 2014).

It is noteworthy that all the Carpathian populations of *C. purpurea* are confined to primary undisturbed sites (mostly mires). That significantly differs from the species' performance in the northern part of its range where it is rather common and readily colonizes vacant sites in the course of anthropogenic (Salonen and Setälä 1992) or primary successions (Doležal et al. 2008). The occurrence of *C. purpurea* in the Carpathians in undisturbed wetland habitats that have persisted for long periods of time (e.g. lakeshores, mires) implies its relict survival since colder epochs (Late Pleistocene–Early Holocene) when the climatic conditions resembled those in today's portion of its continuous range in the north of Europe (Dítě et al. 2018). This is especially likely for well-studied mires like Tinovul Luci (locality 4), as its pleniglacial vegetation resembled modern vegetation analogues in Siberia (Magyari et al. 2014a), the main distribution area of *C. purpurea* (Tzvelev 1965, 1976). The model of vegetation types in Europe at the Last Glacial Maximum by Janská et al. (2017) supports wide distribution of peatland forests and to a lesser extent minerotrophic fens potentially suitable for *C. purpurea* in the area adjacent to the Western and Eastern Carpathians and within the mountains themselves. The species prefers the edges of minerotrophic peatlands with meso- to eutrophic conditions (Euroala and Huttunen 2006) and avoids highly acidic bogs.

Interestingly enough, there is only one species' record (in Ukraine, locality 2) so far from the so-called Outer Carpathians, which stretch along the north-eastern side of the Carpathian arch and are built mostly of acidic flysch bedrock (Rudneva 1960; Kondracki 1989). The rest of the discovered localities belong to the Inner Carpathians where the bedrock is much more diverse.

Conservation

During the last decades, Carpathian plant communities have been undergoing significant successional changes triggered by massive abandonment of grazing and haymaking due to low profitability of mountain sheep and cattle farming or to the establishment of nature reserves in the region (Kuemerle et al. 2008; Kolecka et al. 2017; Kobiv and Kobiv 2020). Such restoration succession enhances the spread of tall-herb and tall-grass communities (Czortek 2018; Kobiv

2018) that could be beneficial for *C. purpurea* as their component. Notably, all the species' finds in the Carpathians come from protected areas.

As *C. purpurea* is rare in all the three countries of the Carpathian region where it was discovered, namely in Slovakia, Ukraine, and Romania, and considering that it is relict and confined mostly to large undisturbed wetland habitats that are uncommon for the mountainous landscape and are often vulnerable to anthropogenic impact and climate change (Winter 2000), it would be reasonable to include the species in the next editions of the Red Data Books and/or Red Lists of the corresponding countries or local administrative units in the Carpathian region. In all three above-mentioned countries *C. purpurea* can be categorized as Vulnerable (VU) according to the IUCN Red List categories and criteria (IUCN 2012) due to the low number of its localities, restricted area of occupancy, and small size of most populations without their evident recent decline (criteria VU D1 + D2). The conservation status of *C. purpurea* in these countries seems reasonable because it is also included in the British Red Data Book (Stewart and Wiggington 1998) and the Red Lists of Great Britain (Cheffings and Farrell 2005), Germany (Metzing et al. 2018), Czech Republic (Grulich 2012), as well as in the local Red Data Book of South Bohemia (Štech 2013) and local Red Lists of Bavaria (Scheuerer and Ahlmer 2003) and England (Stroh et al. 2014).

Conclusion and outlook

We are aware that the above results may not exhaustively reflect the distribution of *C. purpurea* in the Carpathian Mountains and the species could have more locations in the region. One of the goals of this paper is to draw attention to that overlooked species and inspire the *ad hoc* search in the most suitable wetland habitats, such as lakeshores, peat bogs, fens, stream sources in the montane forest zone and at the timberline.

Supplementary information The online version contains supplementary material available at <https://doi.org/10.1007/s11756-022-01083-x>.

Acknowledgements We thank Peter Turis (Nízke Tatry National Park Administration, Banská Bystrica) and the curators from the above-mentioned herbaria.

Funding Open access funding provided by University of Vienna.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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