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Cyperus esculentus, a little-known alien species in the flora of Bulgaria

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Abstract

Cyperus esculentus was erroneously reported for the Bulgarian flora about a century ago. In 2012, it was recorded as a new non-native species for Bulgaria. Based on revised herbarium material and field observations, this study confirms its presence in the country since 2000 and clarifies its delimitation from the taxa involved in earlier misidentifications. The paper presents data on the diagnostic characters, habitat preferences, current distribution, genome size (1C = 0.26 pg), and alien status of *C. esculentus* in Bulgaria.

Key words

adventive species, Bulgarian flora, chorology, *Cyperaceae*, genome size, nuclear DNA content, phytosociology

Citation

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Introduction

The earliest data on the presence of *Cyperus esculentus* L. in Bulgaria were from the southwesternmost part of the country – in the areas of Petrovo village (Stojanow 1921), Petrich town (Jordanoff 1931) and Marino Pole village (Stojanoff 1932). Based on these reports, it was included in the earlier editions of the *Flora of Bulgaria* (Stojanov & Stefanov 1924, 1933, 1948). Subsequently, Markova (1964) had revised those records and concluded that all specimens from the southern parts of the Struma Valley actually belonged to *C. rotundus* L. Much later, Tsoneva & al. (2012) reported *C. esculentus* as a new alien species for the Bulgarian flora. It turned out to be the first reliable report supported by photographic material, but the authors have only mentioned that it occurs on some Danube islands. The species distribution has been considered questionable for the country in the latest botanical source for the entire Bulgarian flora (Stoyanov & al. 2021).

Cyperus strigosus L. is the first alien *Cyperus* species reported for the Bulgarian flora (Tzonev & al. 2003). However, Verloove (2014) has revised these data and concluded that all Bulgarian specimens actually belong to *C. odoratus* L. Adding to the confusion, during the same period, some specimens of *C. esculentus* have been also misidentified as *C. strigosus*.

This article is aimed at clarifying the diagnostic characters of *C. esculentus*, specifying its current distribution in Bulgaria and providing some data on its phytocoenoses and habitats.

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Material and methods

The study is based on the authors' field observations and analysis of relevant literature. Personal field data include distribution records of *C. esculentus* collected between 2012 and 2025. Data on the morphology of *C. esculentus* and related taxa have been obtained from the examined personal collections and selected specimens in the SO and SOM herbaria (acronyms according to Thiers 2025+). The herbarium specimens are deposited in SOM.

During 2021-2024, 21 vegetation plots (relevés) have been sampled, presenting phytocoenoses of *C. esculentus* from the territory of Bulgaria according to the Braun-Blanquet approach (Westhoff & van der Maarel 1973), and contributing to the Balkan Vegetation Database (Vassilev & al. 2020). The sample plots were square-shaped, within the range of 16 m^2, as recommended for anthropogenic vegetation (Chytrý & Otýpková 2003).

Determination of habitats is according to the Directive 92/43/EEC (Kavrakova & al. 2009, European Commission 2013) and EUNIS habitat classification (Chytrý & al. 2020).

Genome size was estimated by a flow cytometer CyFlow SL Green (PARTEC, Germany) equipped with a green (532 nm) solid-state laser. Plant material was treated by CyStain PI Absolute P extraction and staining kit (SYSMEX) following the steps prescribed by the manufacturer. *Solanum pseudocapsicum* (2C = 2.59 pg, Temsch & al. 2022) was used as an internal standard. The samples were then measured at a rate of 10–20 nuclei per second, with 5000 nuclei for each measurement; four replicates were done, all with CV below 5%.

Results and discussion

Cyperus esculentus L., Sp. Pl.: 45 (1753) (Fig. 1).

Perennial, with numerous slender stolons ending in small elongate to globose tubers, 3-10 mm in diameter. Stems erect, 30-80 cm, triquetrous, glabrous. Leaves 20-40(-60) cm × 3-7 mm, shorter than stem, yellow-green, keeled, margin slightly revolute, smooth or scabrous towards apex. Inflorescences umbel-like, simple or rarely compound, 5-10-rayed, rays 2-8(-12) cm, bracts 4-7, ascending, lowest leaf-like, up to 30 cm long, 5 mm wide, longer than rays, spikes ± loosely oblong-ovoid, with 10-40 spikelets clustered in the upper half of the rays, rachis compressed, sparsely strigose. Spikelets divaricate or ascending, 8-15(-20) × 1.5-2.5 mm, oblong, subcompressed, imbricate, with 10-20(-25) flowers, glumes 2 mm, cymbiform, laterally golden brown to ferrugineous, with 2-3 conspicuous veins per side, after anthesis straw yellowish

Fig. 1. *Cyperus esculentus* – upper part of the stem with inflorescence (photo: S. Stoyanov).

to light brown, keel ± sharp, light green, apex acute, margins scarious. Nutlets up to 1.5 mm, obovoid, obtusely trigonous, dark brown, with reticulate-papillose surface.

In Bulgaria, in the first half of the 20th century, all collected specimens and reports of *C. esculentus* turned out to be *C. rotundus*. The species are quite similar in their spikelet shape and could be confused with each other, especially after anthesis, as in both the color of glumes fades to straw yellowish. During flowering, they are easily distinguishable. The spikes of *C. esculentus* have 10-40 spikelets, 8-15 mm long, divaricately arranged, and the glumes are golden-brown to ferrugineous tinged laterally (versus spikelets up to 10, usually more than 20 mm long, erecto-patent, glumes dark reddish tinged laterally in *C. rotundus*).

At the beginning of the 21st century, the invasion of *C. esculentus* in Bulgaria coincided with the appearance of another non-native species, *C. odoratus* (initially erroneously reported as *C. strigosus*). That has led to further confusion and misidentifications. *Cyperus esculentus* and *C. odoratus* have ± similar inflorescences – terminal, simple to compound, 5-10-rayed umbels, with ± loosely oblong-ovoid to cylindrical spikes, and spikelets 10-40(-60), divaricate to ascending. *Cyperus esculentus* is well-distinguished by its spikelet characteristics: spikelets oblong, 8-15(-20) × 1.5-2.5 mm, 10-20(-25)-flowered, glumes imbricate, laterally golden-brown to ferrugineous, with sharp light green keel (versus spikelets narrowly linear, ± zigzag in their length, 5-15 × 0.7-1.0 mm, 3-6(-10)-flowered, glumes not overlapping, laterally pale brown to reddish brown, keel ± obtuse, with a broad green strip in *C. odoratus*).

The three taxa under consideration can be distinguished mainly by the characters of their spikes and spikelets (Figs 2–4). When inflorescences are absent or damaged, underground organs provide a reliable diagnostic character. *Cyperus esculentus* forms solitary, terminal, well distinct tubers (Fig. 5), whereas *C. rotundus* produces tubers arranged in chains along the rhizomes (Wills 1987), and *C. odoratus* develops short rhizomes with fibrous roots (Wu & al. 2010). The presence of terminal tubers greatly facilitates field identification and allows a clear distinction of *C. esculentus* from the remaining species.

Distribution in Bulgaria. So far, *C. esculentus* has been reliably recorded in the following floristic regions: Northeast Bulgaria, Danubian Plain, Forebalkan (*Eastern*), and Rhodopi Mts (*Eastern*).

The species is found mainly in North Bulgaria, along the banks of Danube River, lower reaches of river Iskar, and a few other localities along river Osam. A single locality with two records has been found in South Bulgaria, in wet habitats on the banks of the Studen Kladenets Reservoir, Kardzhali District (Fig. 6). Most records are associated with the Danube and Iskar rivers. However, the isolated occurrences along river Osam and the locality near Studen Kladenets Reservoir suggest independent establishment of new populations. This spatial pattern indicates that dispersal in Bulgaria is likely driven both by downstream transport along the river corridors and by occasional anthropogenic introductions.

The review of *Cyperus* specimens in SO and SOM herbaria has revealed that the earliest records of *C. esculentus* in Bulgaria date back to 2000. All previous collectors have confused it with *C. strigosus* (see *Revised specimens*). Considering that all collections of the species are after 2000, as well as the fact that its distribution is associated with the riparian communities on the Danube, Iskar and Osam rivers (the most vulnerable habitat to contamination by invasive species), it could be inferred that the species has an adventive origin in the Bulgarian flora.

General distribution. The native distribution range of the species comprises North America, South America, Africa, South Europe, West and South Asia. The alien range of the species includes West and Central Europe, East Asia, Australia and Oceania (POWO 2025). In the Balkans, outside Bulgaria, the species has been reported from Albania, Croatia and Greece as a native species (Jiménez-Mejías & Luceño 2011+), and from Slovenia as an alien species (Jiménez-Mejías & Luceño 2011+; Vreš & Šilc 2021).

Habitats and phytocoenoses. *Cyperus esculentus* grows in muddy, sandy, gravelly, and at least temporarily wet habitats, mostly on exposed riverbanks. Based on the collected data, it is found in phytocoenoses of the classes *Bidentetea* Tx. et al. ex von Rochow 1951, *Phragmito-Magnocaricetea* Klika in Klika et Novák 1941, *Isoëto-Nanojuncetea* Br.-Bl. et Tx. in Br.-Bl. et al. 1952, and *Digitario sanguinalis-Eragrostietea minoris* Mucina, Lososova et Šilc in Mucina et al. 2016. The cover/abundance of *C. esculentus* varies between 15%-65% in most communities of the class *Bidentetea*, whereas it is a companion species in the other classes. The other widespread species in the phytocoenoses are wetland species, such as *Bolboschoenus glaucus* (Lam.) S.G. Sm., *Butomus umbellatus* L., *Crypsis alopecuroides* (Piller & Mitterp.) Schrad., *Cyperus fuscus* L., *C. glomeratus* L., *C. michelianus* (L.) Delile, *Echinochloa crus-galli* (L.) P. Beauv., *Lythrum salicaria* L., *Persicaria lapathifolia* (L.) Delarbre, *P. maculosa* Gray, *Phalaris arundinacea* L., etc. Some alien species have been also found in the species composition, such as *Bidens frondosa* L., *Cyperus odoratus* L., *Eclipta prostrata* (L.) L., *Erigeron annuus* (L.) Desf., *Panicum capillare* L., *P. dichotomiflorum* Michx., *Paspalum distichum* L., *Sicyos angulatus* L., *Sagittaria latifolia* Willd., and *Symphyotrichum novi-belgii* agg.

Cyperus esculentus is partly distributed in the phytocoenoses of EU Habitats Directive's wetland habitats 3130 Oligotrophic to mesotrophic standing waters, with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea,* and 3270 Rivers with muddy banks with *Chenopodion rubri* p.p. and *Bidention* p.p. vegetation. According to EUNIS classification, it has been found in three habitats: Q51 Tall-helophyte bed, Q52 Small-helophyte bed and V34 Trampled xeric grassland with annuals.

Fig. 2. Comparison of inflorescences: **A**, *Cyperus rotundus*; **B**, *C. esculentus*; **C**, *C. odoratus*.

Fig. 3. Comparison of spikes: **A**, *Cyperus rotundus*; **B**, *C. esculentus*; **C**, *C. odoratus*.

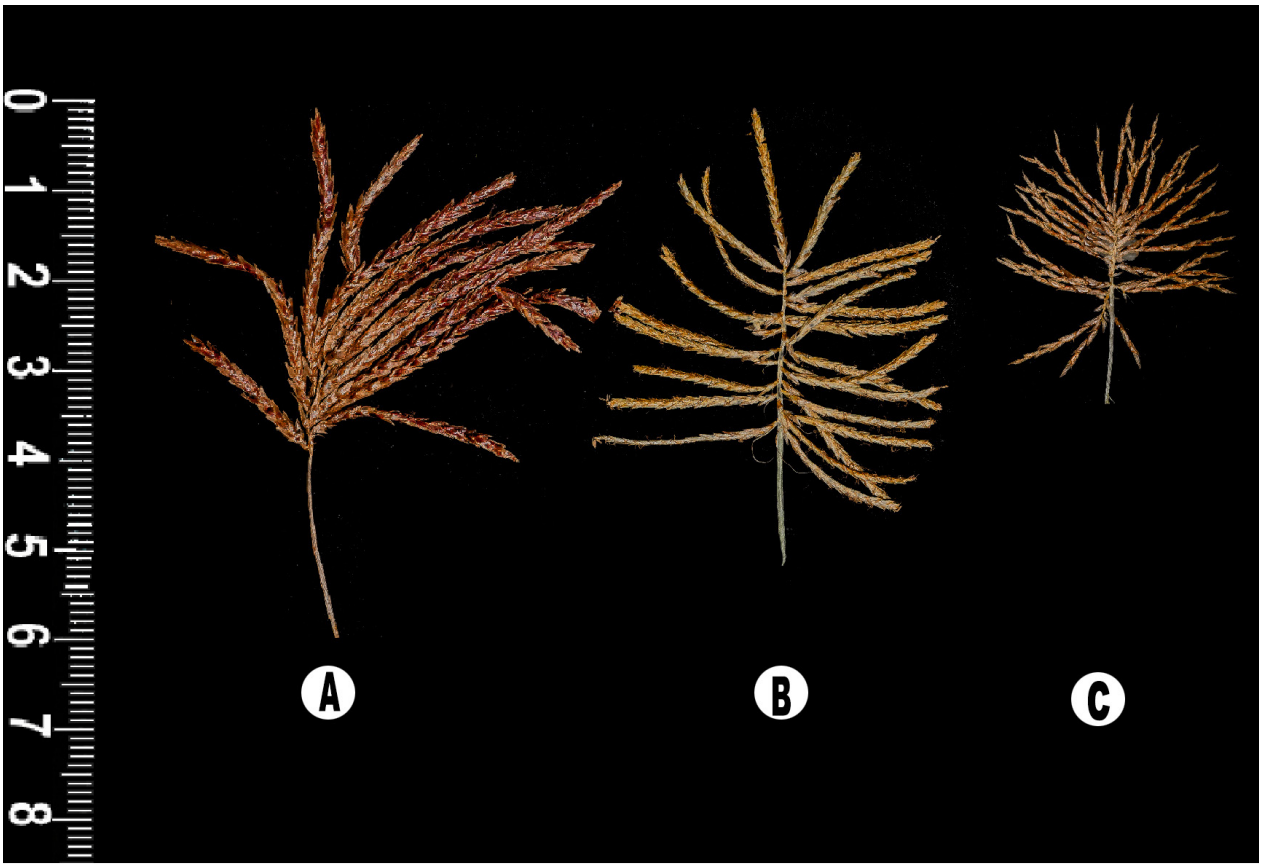
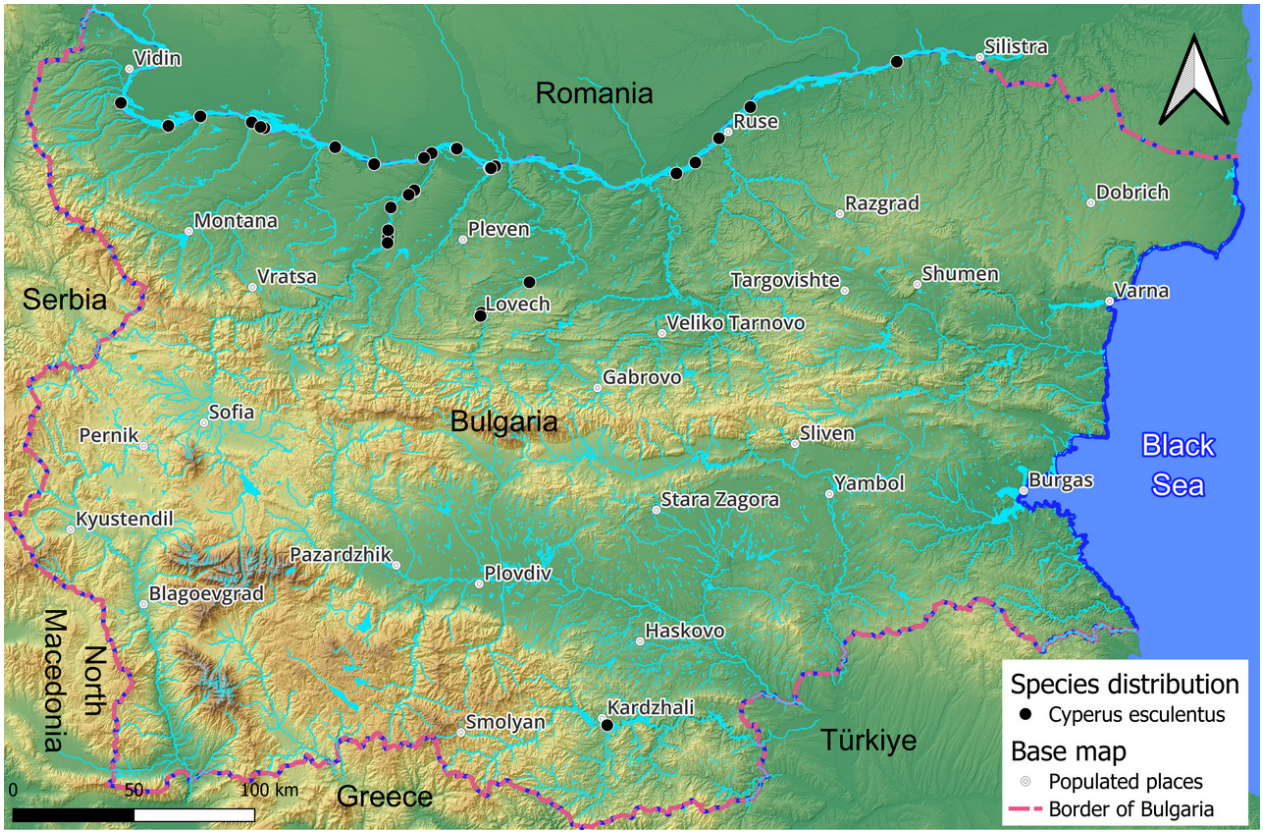


Fig. 4. Comparison of spikelets: **A**, Cyperus *rotundus*; **B**, *C. esculentus*; **C**, *C. odoratus*.

Fig. 5. Solitary terminal tubers of *Cyperus esculentus* (photo: S. Tsoneva).

Fig. 6. Distribution map of *Cyperus esculentus* (black solid circles) in Bulgaria.



Habitat affiliation in the European context. On the European scale, *C. esculentus* is primarily associated with cultivated land, where it represents a major agricultural weed, while colonization of ruderal and semi-natural habitats, including pioneer riverine communities and wetland vegetation, remains comparatively infrequent and is usually associated with disturbed sites (Follak & al. 2015, 2016). The current distribution and habitat affiliation of the species in Bulgaria fall within the range of patterns observed across Europe.

Genome size. The genome size of a plant collected in September 2025 from the Northeast Bulgaria floristic region, along the bank of the Danube River in Marten Town, Ruse District, was estimated to 1C = 0.26 pg. This is the first report of the nuclear DNA content of the species from a Bulgarian accession. The result is congruent with an earlier estimation of the genome size from elsewhere by Zhao & al. (2023), who reported 225.6 Mb which equals approximately 1C = 0.23 pg (1 pg DNA = 0.978×10^9 base pairs, Doležel & al. 2003).

Alien status. *Cyperus esculentus* is regarded as an alien species in some parts of Europe, where it has been documented as invasive, particularly in agricultural landscapes (Vreš & Šilc 2021). Studies from Central Europe document a pronounced increase in the spread of the species, particularly after 2005, and highlight its major economic importance as a weed in arable land, where it causes substantial yield losses and is difficult to control (Follak & al. 2015, 2016).

In a number of taxonomic sources (e.g. DeFilipps 1980; Jiménez-Mejías & Luceño 2011+; POWO 2025), *C. esculentus* is listed as naturally distributed in Bulgaria, most likely based on its presence in the first editions of *Flora of Bulgaria* (Stojanov & Stefanov 1924, 1933, 1948). However, taking into account the fact that all collections of the species from the first half of the 20th century actually turned out to be *C. rotundus*, as well as the fact that the correctly identified materials were all collected after 2000, then it can be assumed that *C. esculentus* has an alien status in the Bulgarian flora. Presently, the species occurs mainly in riparian and other disturbed wet habitats, where it may attain locally high cover (up to 65%) and displaces the native plant species. In this context, continued monitoring is essential so as to assess any future changes in its distribution and habitat affiliation, including potential expansion into agricultural landscapes.

The tubers of the species are available in Bulgaria on a number of web sites, as well as in some stores, and are easily accessible. Their use is mainly related to angling, as bait for fish, largely carp. They are also advertised as a valuable food and medicinal plant. It could be assumed that the tubers have been obtained from *C. esculentus* var. *sativa*, but contamination by wild-growing types is not excluded. However, whether the spread of the species in Bulgaria is related to that commercial product should be subject to further research. Such a pathway of entry into the country's water bodies could be presumed, especially as bait for fish, but at the moment it has not been studied and is only subject to speculation.

List of specimens and observations

Authors-collected data. **Northeast Bulgaria**: N of Marten town, Ruse District, on the muddy banks of Danube River, 15 m, 43.92836°N, 26.07647°E, 21.09.2019, *S. Stoyanov* (SOM 176794, 176795); on the muddy bank of Danube Rier near Prista locality, W of Ruse town, *ca.* 15 m, 43.81059°N, 25.91702°E, 05.10.2019, *V. Vladimirov* obs. (photos); on the muddy banks of Danube River at the port of village Malak Preslavets, Silistra District, 12 m, 44.100476°N, 26.831128°E, 09.09.2021, *S. Tsoneva* & *V. Georgiev* obs. (photos); NE of Batin village, Ruse District, on the muddy banks of Danube River, in riparian communities of *Paspalum distichum*, 15 m, 43.67778°N, 25.70098°E, 03.10.2021, *K. Vassilev* (SOM 177830); on the bank of Danube River near Mechka village, Ruse District, *ca.* 20 m, 43.71912°N, 25.79732°E, 04.10.2025, *V. Vladimirov* (SOM 179575). **Danubian Plain**: on the sandy banks of Danube River on Malak Bliznak Island, Vidin District, 26 m, 43.871451°N, 22.835255°E, 03.10.2012, *S. Tsoneva* & *V. Georgiev*, herb. *S. Tsoneva* & *V. Georgiev*; on the sandy banks of Danube River on Tsibritsa Island, Montana District, 28 m, 43.806125°N, 23.558604°E, 15.10.2012, *S. Tsoneva* & *V. Georgiev*, herb. *S. Tsoneva* & *V. Georgiev*; on the sandy banks of Danube River on Kicha Island, Montana District, 23 m, 43.802423°N, 23.578289°E, 15.10.2012, *S. Tsoneva* & *V. Georgiev*, herb. *S. Tsoneva* & *V. Georgiev*; on the muddy and sandy substrate on the banks of Danube River at the mouth of river Vit, Pleven District, 20 m, 43.682460°N, 24.748362°E, 21.10.2016, *S. Tsoneva* & *V. Georgiev* obs. (photos); on the sandy banks of Danube River at the port of village Zagrazhden, Pleven District, 22 m, 43.751247°N, 24.570753°E, 10.08.2021, *S. Tsoneva* & *V. Georgiev* obs. (photos); on the muddy and sandy substrate on the banks of Danube River at the mouth of river Vit, Pleven District, 20 m, 43.681348°N, 24.744024°E, 26.08.2021, *S. Tsoneva* & *V. Georgiev* obs. (photos); N of Lom town, Montana District, on the bank of the wastewater channel flowing into the Danube River, on the muddy substrates, 25 m, 43.83549°N, 23.24720°E, 01.10.2021, *S. Stoyanov, V. Vladimirov* & *S. Bancheva* (SOM 178473, 178474); SW of Iskar town, Pleven District, at the western end of a small island in river Iskar, in riparian communities of *Sagittaria latifolia*, 60 m, 43.43998°N, 24.23184°E, 27.09.2023, *K. Vassilev* (SOM 179248); E of Glava village, Pleven District, on the left bank of river Iskar, in riparian communities of *Phalaris arundinacea*, 60 m, 43.39291°N, 24.23089°E, 27.09.2023, *K. Vassilev* (SOM 179249); E of Dolni Lukovit village, Pleven District, on the left bank of river Iskar, in riparian communities of *Phalaris arundinacea*, 50 m, 43.52490°N, 24.24147°E, 28.09.2023, *K. Vassilev* (SOM 179250); E of Bregare village, Pleven District,

on the left bank of river Iskar, in riparian communities of *Salix alba*, 35 m, 43.59186°N, 24.35881°E, 28.09.2023, *K. Vassilev* (SOM 179251); S of Bregare village, Pleven District, on the left bank of river Iskar, in phytocoenoses of *Chenopodion rubri* p.p. and *Bidention* p.p. vegetation, 40 m, 43.57446°N, 24.33091°E, 01.10.2023, *K. Vassilev* (SOM 179252); E of Aleksandrovo village, Lovech District, at the southern end of a small island in river Osam, in phytocoenoses of *Persicaria lapathifolia*, 85 m, 43.26211°N, 24.96019°E, 17.10.2023, *K. Vassilev* (SOM 179253); W of Somovit village, Pleven District, on the muddy banks of Danube River, near the mouth of river Vit, 25 m, 43.68192°N, 24.74697°E, 29.08.2024, *K. Vassilev* (SOM 179375); N of Zagrazhden village, Pleven District, on the muddy banks of Danube River, 25 m, 43.75125°N, 24.56856°E, 15.09.2024, *K. Vassilev* (SOM 179376); on the muddy banks of Danube River at the port of village Ostrov, Vratsa District, 24 m, 43.683955°N, 24.148763°E, 09.10.2025, *S. Tsoneva* & *V. Georgiev* obs. (photos); on the muddy and sandy substrate on the banks of Danube River at the port of village Baykal, Pleven District, 20 m, 43.712863°N, 24.403408°E, 09.10.2025, *S. Tsoneva* & *V. Georgiev* obs. (photos); on the muddy banks of Danube River at the port of Somovit village, Pleven District, 19 m, 43.690077°N, 24.770196°E, 09.10.2025, *S. Tsoneva* & *V. Georgiev* obs. (photos); on the muddy banks of Danube River at the port of Dolni Tsibar village, Montana District, 30 m, 43.822040°N, 23.5123060°E, 10.10.2025, *S. Tsoneva* & *V. Georgie*v obs. (photos); on the muddy banks of Danube River at the port of Dolni Tsibar village, Montana District, 30 m, 43.822040°N, 23.5123060°E, 10.10.2025, *S. Tsoneva* & *V. Georgie*v obs. (photos); NW of Oryahovo town, on the muddy banks of Danube River, 30 m, 43.74174°N, 23.94581°E, 24.10.2025, *K. Vassilev* (SOM 179576); N of Orsoya village, Lom District, on the muddy banks of Danube River, 25 m, 43.79472°N, 23.08487°E, 03.11.2025, *K. Vassilev* obs. (photos). **Forebalkan (*Eastern*):** Lovech town, on the left bank of river Osam, *ca.* 160 m, 43.14418°N, 24.71999°E, 20.08.2025, *V. Vladimirov* (SOM 179577); Lovech town, on the banks of river Osam, *ca.* 165 m, 43.13182°N, 24.71590°E, 20.08.2025, *V. Vladimirov* obs. (photos); **Rhodopi Mts (*Eastern*)**: E of Kardzhali town, valley of Arda River, on the muddy banks of Studen Kladenets Reservoir, 220 m, 41.62085°N, 25.39737°E, 28.09.2024, *K. Vassilev* (SOM 179254); on the sandy deposits at the bottom of the dried-up Studen Kladenets Reservoir, 218 m, 41.620451°N, 25.399408°E, 11.10.2024, *S. Tsoneva* & *V. Georgiev* obs. (photos).

Revised specimens. The here-listed specimens have been misidentified as *C. strigosus*. **Danubian Plain**: at the mouth of river Iskar near Gigen village, Pleven District, 09.2000, *R. Tzonev* (SO 100679); at Pisarevo village, Pleven District, near river Iskar, 23.09.2006, *R. Tzonev* (SO 104291), 05.2013, revised by *F. Verloove* as *C. odoratus*; on the left bank of river Iskar, near the bridge at Orehovitsa village, 05.07.2007, *D. Dimitrov* (SO 104803, SOM 164024).

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