First record of the alien species *Mollugo verticillata* (*Molluginaceae*) from Bulgaria

Georgi Kunev

Department of Ecology and Environmental Protection, Sofia University St. Kliment Ohridski, Faculty of Biology, 8 Dragan Tzankov Blvd. 1164 Sofia, Bulgaria,
e-mail: gorokunev@abv.bg

Received: March 12, 2019 ▷ Accepted: August 10, 2019

Abstract. *Mollugo verticillata* L., a new alien species for the Bulgarian flora, was collected from the Valley of River Struma (South) floristic subregion in 2018. The paper presents a concise morphological description of the species, with comparison to the similar *M. cerviana* (L.) Ser. Information on its distribution and ecology in Bulgaria is provided and the species invasive status is commented on.

Key words: alien flora, invasive status, *Mollugo verticillata*

Introduction

During fieldwork along River Struma in 2018, an unknown plant species was collected and subsequently identified as *Mollugo verticillata* L. Apparently, this is the first find of this species from Bulgaria, as well as from the Balkans. *M. verticillata* is considered native to the American tropics, wherefrom it most probably had naturalized across the temperate zones of North America already before the European colonization (Boetsch 2002). According to archaeological evidence, the species was present in the temperate eastern parts of North America 3000 years ago (Chapman & al. 1973). *M. verticillata* is widely distributed as pioneering weed in various types of disturbed areas: roadsides, rail tracks, pavement joints, lawns and gardens (Vincent 2003), although in arid climate it is mostly confined to temporarily wet environments at riversides or banks of lakes and water reservoirs (Sukhorukov & al. 2017). Besides in the Americas, the global distribution of this species as an alien includes Southwest Europe, Tropical West Africa, East Asia (China, Japan, Taiwan, and Korea), and East Australia (Vincent 2003; Uotila 2011; Hassler 2019).

Material and methods

The plant collected by the author from the new locality was subsequently divided into two vouchers and deposited in the Herbarium of Sofia University (SO 107 997) and Herbarium of the Institute of Biodiversity and Ecosystem Research (SOM 176 678). It was compared for similarities with a specimen of *Mollugo verticillata* (USA, Middlesex County, town of Weston, 7.09.1981, D. E. Boufford & E. W. Wood; SOM 145 343). Furthermore, herbarium material of *M. cerviana* has been checked both in SO and SOM. The species description is based on characters observed in the collected material and data from relevant literature (Bogle 1970; Tutin 1993; Boetsch 2002; Vincent 2003; Sukhorukov & Kushunina 2017). Ecological features of the habitat are presented according to personal observations. Geographical distribution is recorded from references and online databases. The invasive status of the species is given according to Richardson & al. (2000).

Results and discussion

Mollugo verticillata L. Sp. Pl. 1: 89. 1753 (Figs. 1-3a)

Annual, prostrate or decumbent, forming circular patches (carpets, mats) 15–40(-60) cm in diameter. Leaves in whorls of 3–8, exstipulate, linear to narrowly spatulate or obovate, 4–25 mm long, 0.5–3(-8) mm wide, smooth, mostly light-green in color, with a reddish tinge at late phenological stages (Fig. 2); basal rosette present or disappearing with plant maturing. Flowers 2–6 in axillary clusters, pedicellate, pedicels 0.5–4 mm, glabrous or sparsely glandular pubescent. Sepals 5, spreading at anthesis, oblong-elliptic, 1.5–2.5 × 0.5–1.2 mm, with 3 green veins on the outer surface, margins hyaline. Petals absent. Stamens 3(-5), alternate with carpels. Ovary syncarpous, 3-loculate, ovules numerous. Fruit capsule ovoid-ellipsoid, 1.8–3.5 × 1.2–2 mm; seeds numerous, reniform, 0.5–0.6 × 0.35–0.5 mm, with 3–7 curved ridges on the sides or smooth, dark or reddish-brown, lustrous. 2n = 64 (Bogle 1970).

So far, only one species of the genus, *Mollugo cerviana* (L.) Ser. is known from Bulgaria (Georgieff 1966). In Europe, *M. cerviana* occurs mainly in the Mediterranean and Pontic regions (Uotila 2011). In Bulgaria, it has scattered distribution confined to the coastal and riverine sands. Although *M. verticillata* is morphologically very variable and appears in similar habitats as *M. cerviana,* both taxa can be easily distinguished by a number of characters (Table 1).

Recent studies focused on molecular phylogenetics and morphology and anatomy of the seeds have revealed some drastic changes in the taxonomy of *Molluginaceae*. *Mollugo cerviana* is now regarded as a member of *Hypertelis* E.Mey. ex Fenzl – *H. cerviana* (L.) Thulin (Thulin & al. 2016). *M. verticillata* is described as a morphologically and phylogenetically heterogeneous group of taxa needing further studies in order of defining the species boundaries (Christin & al. 2011; Sukhorukov & Kushunina 2017).

Fig. 1. *Mollugo verticillata* at River Struma, 11.09.2018. (Photograph G. Kunev).

Location in Bulgaria

Only one specimen of *Mollugo verticillata* was found in 2018 from Blagoevgrad district, Petrich Municipality, westwards of Marikostinovo village, on a mid-channel river bar of River Struma, 41°25'43.66"N, 23°18'23.37"E, alt. 85 m. The plant was in late flowering and fruiting stage, with many fruit capsules open and the seeds already dispersed. A new field inventory was made on 4th October 2018, in order to see whether the species might grow in more locations. The banks of River Struma were examined approximately 1 km upstream and downstream from the first spot. However, only one more specimen was found a few meters from the location of the first one. The second individual was in the same phenological phase as the first find.

Phenology

Mollugo verticillata is a fast-growing ephemeral, germinating from seed to fading within 30 to 45 days

Table 1. Key characters of the Bulgarian species of *Mollugo*.

Character	*M. verticillata*	*M. cerviana*
Habitus	Prostrate or decumbent	Erect or ascending
Leaves	Spatulate or obovate, width 0.5–3(-8) mm, seldom glaucous green	Narrow linear, width 0.8–1.1 mm, glaucous green
Sepals (see Fig. 3)	Oblong-elliptic, 1.5–2.5 × 0.5–1.2 mm, with 3 green veins on the outer surface	Elliptic to obovate, 1–1.5 × 1–1.6 mm, with a single broad vein or anastomosing network of veins on the outer surface
Capsules (see Fig. 3)	Cylindrical to ovoid, 1.8–3.5 × 1.2–2 mm, exceeding sepals at maturity	Globose, 1.5–1.8 × 1.5–1.9 mm, not exceeding sepals at maturity
Seeds	Reniform, with 3–7 ridges on the sides or smooth, 0.5–0.6 × 0.35–0.5 mm	Asymmetrically hemi-oval (D-shaped), finely reticulate, 0.3–0.4 × 0.3–0.4 mm

Fig. 2. *Mollugo verticillata* terminal inflorescence. (Photograph G. Kunev).

(Bogle 1970, Hereford & al. 2017). In the spring high-water period, the Bulgarian location is probably flooded by the high waters, thus the flowering and fruiting periods of the species are depending on the water level and most likely are from June to October.

Habitat

In Bulgaria, *Mollugo verticillata* grows in exposed, sunny, temporarily wet environments, on sandy to gravelly substrate. The vegetation can be affiliated to the alliance *Bidention tripartitae* Nordh. 1940. The communities are dominated by *Echinochloa crus-galli* (L.) P. Beauv., *Xanthium italicum* Moretti and *Persicaria lapathifolia* (L.) Gray. Accompanying species are: *Bidens frondosus* L., *Cyperus fuscus* L., *C. hamulosus* M. Bieb, *Chenopodium* spp., *Portulaca oleracea* L., *Euphorbia maculata* L., *Lindernia dubia* (L.), and *Corrigiola litoralis* L. The substrate and vegetation are moderately disturbed by livestock trampling and grazing. A sand and gravel extraction facility located at a short distance most likely also affects the water level and silt accumulation in that stretch of the river.

European distribution

Most of the European records are reported from more or less drained substrates at riversides, lake margins and various types of anthropogenic habitats. On the

Fig. 3. Comparison of sepals and fruit capsules between **a** – *Mollugo verticillata* and **b** – *M. cerviana*. (Photograph G. Kunev)..

continent, *Mollugo verticillata* is distributed primarily in its southwestern parts. The first European find of the species was probably recorded in 1887 (as pavement weed at a railway station) in Belgium (Verloove 2013). So far, the species has been reported from France, Spain, the Azores, and continental Portugal and Italy (Corillion 1958; Gonçalves 1990; Almeida & Freitas 2006; Celesti-Grapow & al. 2009; Uotila 2011), where it is considered as naturalized, and from Sweden, Hungary and Belgium (Verloove 2004, Balogh & al. 2004; Verloove 2013), were it was found occasionally and thus regarded as a casual alien.

Invasive status

Judging by the location of the species and the number of individuals at River Struma, it is impossible to assume with certainty how and when this species has been introduced in Bulgaria. The plant produces numerous small seeds that could be easily transferred by humans as contaminant of crop-seeds, by road or rail traffic, or accidentally by birds. These probabilities should be taken into account, especially when a major motorway and a railroad run close to the site, and greenhouse vegetable production is very well established in the region. Wind dispersal of the seeds has been also reported (Bogle 1970), although, in the author's opinion, it could be observed only at a relatively short distance, since the seeds have no specific structural adaptation for wind dispersal. Because a large number of locations of *M. verticillata* are associated with river or lake margins, it could be assumed that its seeds are well adapted for transportation by water. On the one hand, considering the fact that only two plant individuals were found after a thorough examination of the region, it could presumed that the species has been recently introduced and there no persistent seedbank has accumulated yet. Therefore, the current invasive status of *M. verticillata* on the territory of Bulgaria should be determined as a casual alien. On the other hand, the found plants seem to have been well adjusted to the local environment, flowering and producing seeds, and thus more locations could be expected along River Struma between Kresna town (Bulgaria) and Lake Kerkini (North Greece). Further field researches along the river and lake surroundings at these areas are required, in order to understand whether or how the species has been established and to assess accurately its invasive status.

Acknowledgments: The author is grateful to Assoc. Prof. Rosen Tzonev, PhD and Chief Assist. Kalina Pachedjieva, PhD from the Department of Ecology and Environmental Protection of Sofia University St. Kliment Ohridski, as well to the anonymous reviewer for the valuable comments on the early version of the manuscript.

References:

Almeida, J.D. & Freitas, H. 2006. Exotic flora of continental Portugal: A reassesment. – Bot. Complut., **30**: 117-130.

Balogh, L., Dancza, I. & Király, G. 2004. Actual list of neophytes in Hungary and their classification according to their success. – In: **Mihály, B. & Botta-Dukát, Z.** (eds), Biological Invasions in Hungary: Invasive Plants, pp. 61-92. Budapest (in Hungarian).

Boetsch, J.R. 2002. The *Aizoaceae* and *Molluginaceae* of the Southeastern United States. – Castanea, **67**(1): 42-53. https://www.jstor.org/stable/pdf/4034315.pdf

Bogle, A.L. 1970. The genera of *Molluginaceae* and *Aizoaceae* in the southeastern United States. – J.Arnold Arb., **51**(4): 431-462.

Celesti-Grapow, L., Alessandrini, A., Arrigoni P.V., Banfi, E, Bernardo, L., Bovio, M., Brundu, G., Cagiotti, M.R., Camarda, I., Carli, E., Conti, F., Fascetti, S., Galasso, G., Gubellini, L., Lavalva, V., Lucchese, F., Marchiori, S., Mazzola, P., Peccenini, S., Poldini, L., Pretto, F, Prosser, F., Siniscalco, C., Villani, M.C., Viegi, L., Wilhalm, T & Blasi, C. 2009. Inventory of the non-native flora of Italy. – Pl. Biosystems, **143**(2): 386-430.

Chapman, J., Stewart, R.B. & Yarnell, R.A. 1973. Archaeological evidence for pre-Columbian introduction of *Portulaca oleracea* and *Mollugo verticillata* into Eastern North America. – Econ. Bot., **28**(4): 411-412. https://doi.org/10.1007/BF02862857

Christin, P-A., Sage, T.L., Edwards, E.J., Ogburn, R.M., Khoshravesh, R. & Sage, R.F. 2011. Complex evolutionary transitions and the significance of C3–C4 intermediate forms of photosynthesis in *Molluginaceae*. – Evolution, **65**: 643-660. http://dx.doi.org/10.1111/j.1558-5646.2010.01168.x

Corillion, R. 1958. Sur la présence du *Mollugo verticillata* L. (Aizoacée), à l'état spontané, dans le Val de Loire. – Bull. Soc. Bot. France, **105**(1-2): 51-52. https://doi.org/10.1080/00378941.1958.10837850

Georgieff, T. 1966. *Molluginaceae* Weight. – In: **Jordanov, D.** (ed.). Fl. Reipubl. Popularis Bulgaricae. Vol. **3**, pp. 265-269. In Aedibus Acad. Sci. Bulgaricae, Serdicae (in Bulgarian).

Gonçalves, M.L. 1990. *Mollugo* L. – In: **Castroviejo, S.** (ed.) Flora Iberica 2. *Platanaceae-Plumbaginaceae*: 93-95. Real Jardín Botánico, CSIC, Madrid.

Hassler M. 2019. World Plants: Synonymic Checklists of the Vascular Plants of the World (version Apr 2018). – In: **Roskov, Y., Ower, G., Orrell, T., Nicolson, D., Bailly, N., Kirk, P.M., Bourgoin, T., DeWalt, R.E., Decock, W., Nieukerken, E. van, Zarucchi, J. & Penev L.** (eds), Species 2000 & ITIS Catalogue of Life, 29th January 2019. Digital resource at www.catalogueoflife.org/col. Species 2000: Naturalis, Leiden, the Netherlands. ISSN 2405-8858. http://www.catalogueoflife.org/annual-checklist/2018/details/species/id/919790eb49595cac397e813692152788 (accessed 18.02.2019)

Hereford, J., Scmitt, J., & Ackerly, D. D. 2017. The seasonal climate niche predicts phenology and distribution of an ephemeral annual plant, *Mollugo verticillata*. – J. Ecol., **105**(5): 1323-1334.

Richardson, D.M., Pyšek, P., Rejmánek, M., Barbour, M.G., Panetta, F.D. & West, C.J. 2000. Naturalization and invasion of alien plants: concepts and definitions. – Diversity & Distributions, **6**(2): 93-107.

Sukhorukov, A.P. & Kushunina, M. 2017. Taxonomic significance of seed morphology in the genus *Mollugo* s.l. (*Molluginaceae*). – Israel J. Pl. Sci., **64**: 31-47. h

Sukhorukov, A.P., Verloove, F., Alonso, M.A., Belyaeva, I.V., Chapano, C., Crespo, M.B., El Aouni, M.H., El Mokni, R., Maroyi, A., Shekede, M.D., Vicente, A., Dreyer, A. & Kushunina, M. 2017. Chorological and taxonomic notes on African plants, 2. – Botany Letters, **164**: 135-153.

Thulin, M., Moore, A.J., El-Seedi, H., Larsson, A., Christin, P-A. & Edwards E.J. 2016. Phylogeny and generic delimitation in *Molluginaceae*, new pigment data in *Caryophyllales*, and the new family *Corbichoniaceae*. – Taxon, **65**(4): 775-793.

Tutin T. G. 1993. *Mollugo* L. In: **Tutin T.G. & al.** (eds.), Flora Europaea, vol. **1** (2nd ed.). Cambridge Univ. Press: 137.

Uotila, P. (2011): *Molluginaceae*. – In: Euro+Med Plantbase. Published on the Internet http://ww2.bgbm.org/EuroPlusMed/ (accessed 18.02.2019).

Verloove F. 2004. *Mollugo verticillata*, an obligatory railroad additive in Belgium. – Dumortiera, **82**: 7-9.

Verloove F. 2013. *Mollugo verticillata* L. – In: Manual of the Alien Plants of Belgium, http://alienplantsbelgium.be/content/mollugo-verticillata (accessed 18.02.2019).

Vincent, M.A. 2003. *Molluginaceae*. – In: Flora of North America, North of Mexico, Flora of North America Editorial Committee, vol. **4**, New York & Oxford: Oxford Univ. Press. http://www.efloras.org/