Research Article

First record of *Eriochloa villosa* (Thunb.) Kunth in Austria and notes on its distribution and agricultural impact in Central Europe

Swen Follak[1,*], Michael Schwarz[2] and Franz Essl[3]

[1]*Institute for Sustainable Plant Production, Austrian Agency for Health and Food Safety, Vienna, Austria*
[2]*Data, Statistics and Risk Assessment, Austrian Agency for Health and Food Safety, Vienna, Austria*
[3]*Division of Conservation Biology, Vegetation and Landscape Ecology, University of Vienna, Vienna, Austria*

Author e-mails: *swen.follak@ages.at (SF), michael.schwarz@ages.at (MS), franz.essl@univie.ac.at (FE)*

**Corresponding author*

Citation: Follak S, Schwarz M, Essl F (2020) First record of *Eriochloa villosa* (Thunb.) Kunth in Austria and notes on its distribution and agricultural impact in Central Europe. *BioInvasions Records* 9(1): 8–16, https://doi.org/10.3391/bir.2020.9.1.02

Received: 6 September 2019
Accepted: 28 November 2019
Published: 21 February 2020

Handling editor: Quentin Groom
Thematic editor: Stelios Katsanevakis

Abstract

Eriochloa villosa is native to temperate Eastern Asia and is an emerging weed in Central Europe. Its current distribution in Central Europe was analyzed using distribution data from the literature and data collected during field trips. In 2019, *E. villosa* was recorded for the first time in Austria. It was found in a crop field in Unterretzbach in Lower Austria (Eastern Austria). So far, the abundance of *E. villosa* in the weed communities in Austria and the neighboring Czech Republic is low and thus, its present agricultural impact can be considered limited. However, in Romania and Hungary, the number of records of *E. villosa* has increased in recent years and it has locally become a troublesome weed. Thus, it is of importance to further monitor *E. villosa* and to raise awareness among farmers and agricultural advisors.

Key words: agriculture, alien species, emerging weed, fields, Poaceae

Introduction

The introduction of new alien plants in agricultural areas has become a major issue for farmers in Central Europe (Weber and Gut 2005; Follak et al. 2017). A substantial number of alien plants is already commonly found in crop fields, while others are considered to be at an early stage of invasion ("emerging weeds") and are expected to become problematic in the future (Follak et al. 2017; EPPO 2019a).

One of these emerging weed species is *Eriochloa villosa* (Thunb.) Kunth (woolly cupgrass), which is a tall annual grass native to temperate Eastern Asia (mostly China, Russia only in the Far Eastern Federal District) (Darbyshire et al. 2003). It can be a competitive weed in crops because of its vigorous axillary branching, shoot production and tillering (Darbyshire et al. 2003). This species is difficult to control due to its early, prolonged and variable seedling emergence and flexible growth habit as well as its tolerance to several herbicides regularly used to control annual grass weeds (Darbyshire et al. 2003; Szilágyi et al. 2015).

Eriochloa villosa thrives well as a crop weed in the mid-western United States and, since its first introduction in 2000, in agricultural areas of

southern Quebec/Canada (Darbyshire et al. 2003; Simard et al. 2015). In Western Europe (Belgium, France, Great Britain), only a few casual records from ruderal sites have been published so far (Verloove 2019), while a noticeable and increasing number of records was recently made in crop fields in Central and Eastern Europe (e.g., Mikhajlovich et al. 2015; Szatmari 2016). In this paper, the first record of *E. villosa* in Austria as well as its phytosociological affiliation is presented. Further, the current distribution of *E. villosa* in Central Europe is synthesized and discussed and notes on its agricultural impact are provided.

Materials and methods

Study species

Eriochloa villosa is a loosely tufted grass with a C_4 photosynthetic pathway. Stems are erect, basally decumbent and (30)50 to 100 cm in height. It also produces stolons with adventitious roots at the nodes, and thus the species branches extensively. The most characteristic features are the inflorescence that consists of "… 2 to 12 stout racemic (spike-like) branches borne one per node are held mostly to one side of the inflorescence axis" and "the cup-like callus at the base of the spikelet" (Darbyshire et al. 2003; Figure 2). According to field observations in Central Europe, *E. villosa* starts to germinate in mid-April, begins to flower in mid-July and seeds ripen from early August to September. *Eriochloa villosa* is a prolific seed producer and it is assumed that seeds fall close to the parent plant (barochory), however dispersal by water, mammals and insects is also suggested (Darbyshire et al. 2003). According to the climatic conditions in its introduced range in Central Europe, the species prefers a continental climate with a mean annual temperature and precipitation of 9.0 °C to 11.0 °C and 450 to 600 mm, respectively. Photos can be retrieved from the EPPO Global Database (EPPO 2019b) and a detailed description of *E. villosa* and its biology and ecology can be found in Darbyshire et al. (2003).

Data sources and analysis

Eriochloa villosa was monitored during field trips that were conducted in 2017 (2017-07-13 and 2017-09-07) and 2019 (2019-07-17 and 2019-08-06) in the municipalities of Retzbach/Lower Austria and Šatov/Jihomoravský kraj (Czech Republic). This area was chosen because *E. villosa* has already been found in this area on the territory of the Czech Republic (Paulič and Němec 2014). The study area (c. 6.5 km^2) is dominated by agriculture and viticulture. Phytosociological relevés were recorded according to Braun-Blanquet (1964) to characterize the floristic composition of invaded weed communities and infestation levels. Nomenclature and taxonomy follow Fischer et al. (2008).

For analyzing the distribution in Central Europe, records of *E. villosa* were collated from 2006 (first occurrence in the study area, i.e. Romania)

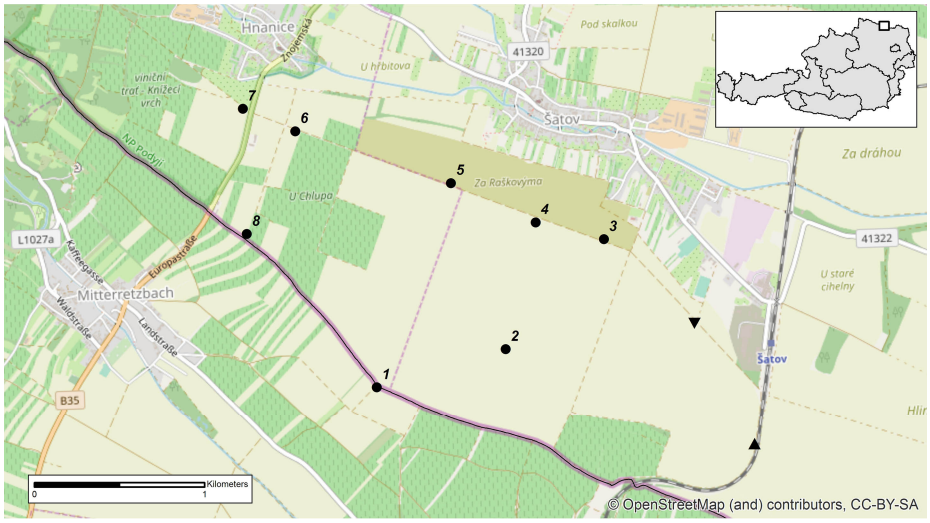

Figure 1. Map of the investigated area showing the presence of *Eriochloa villosa* in the border area of Austria and the Czech Republic (boundary line is in purple); (●) observations in 2019, numbers correspond to the phytosociological relevés (see Table 1); (▼) observation in 2017; (▲) first record in 2013 (Paulič and Němec 2014).

Figure 2. *Eriochloa villosa* in sugar beet in Unterretzbach/Austria (left) and inflorescence of *E. villosa* (right). Photos by Swen Follak.

until 2019 from the floristic literature and weed science publications (Paulič and Němec 2014; Takács et al. 2014; Szatmari 2016; Szilágyi et al. 2016, 2019). These data were supplemented by observations of the first and last author made during field trips in Hungary (2017-08-26 and 2019-07-13) and the Czech Republic (see above). All records were assigned to a grid cell (5 × 3 geographic minutes, ~ 33 km^2) of the Floristic Mapping Project of Central Europe (Niklfeld 1999). A map showing the spatial distribution of the study species was created based on the grid cells occupied. All maps were produced in ArcMap 10.2.2 (ESRI).

Results

Distribution in the border area of Austria and the Czech Republic

Eriochloa villosa was detected for the first time on the territory of Austria close to the border of the Czech Republic (Figures 1 and 2, Supplementary material Table S1). The species was found in Unterretzbach (48.778972N; 15.993917E, 279 m a.s.l.) in sugar beet (field edge) directly at the boundary

stone VIII 36 on the 2019-07-17. The site is located in one of the driest areas of Austria (442.4 mm, 9.2 °C, 1971–2000; ZAMG 2019). In the wider surroundings of this locality (c. 500 m away from the border), no further populations of the species were found on the Austrian side. In the Czech Republic, *E. villosa* was detected for the first time in 2013 in a maize field almost 2.5 km away from the Austrian population (Paulič and Němec 2014). Recent observations showed a local spread of *E. villosa* in this area (Follak and Essl *pers. obs*. 2017, 2019; Figure 1). In 2019, the species has invaded crop fields distributed across an area of c. 4.0 km^2 in the Czech Republic.

Phytosociological affiliation and habitat preferences

So far, *E. villosa* is restricted to crop fields cultivated with summer crops (maize, sunflower, oil-pumpkin, sugar beet) in Austria and the Czech Republic (Table S1). The phytosociological affiliation in the study area was documented with eight phytosociological relevés (Table 1). The invaded weed vegetation belongs to the association *Echinochloo-Setarietum pumilae* Felföldy 1942, which is the most widespread weed vegetation in summer crops in Central Europe (Mucina et al. 1993). The most abundant co-occurring species in the relevés are other Poaceae (*Setaria pumila, Echinochloa crus-galli*) together with further thermophilic and common weed species (e.g. *Amaranthus powellii*, *Chenopodium album*, *Polygonum aviculare*).

Distribution in Central Europe

At present, apart from Austria and the Czech Republic, *E. villosa* is known from two other countries in Central Europe, i.e. Romania and Hungary. The species was found in a total of 52 grid cells (Figure 3; Austria: 1, Czech Republic: 1, Hungary: 13, Romania: 37). In Romania, *E. villosa* has already been found for the first time in 2006 in both the Satu Mare (town of Livada) and Timiș County (Pișchia, Gătaia) (Ciocârlan and Sike 2006; Fărcăşescu et al. 2007). Later, its presence was also indicated for the Arad County (Vinga, Peregul Mic) in 2008 (Ardelean et al. 2009). Since then, *E. villosa* has spread throughout the Western Romanian Plain and Hills as detailed by Szatmari (2016). Figure 3 indicates a current wide, but somewhat scattered distribution of *E. villosa*, only in Timiș County, there seems to be a more coherent distribution as indicated by the contiguous occupied grid cells. In this respect, Szatmari (2016) mentioned that the presence of this species is probably much more extensive throughout the counties. In Hungary, there are currently three independently located occurrences of *E. villosa* (Figure 3). The species was first found in 2007 in a maize field near the town of Gesztely (Borsod-Abaúj-Zemplén County, NE Hungary, Figure 3) (Partosfalvi et al. 2008). Then, the species was observed in 2011 in Debrecen (Hajdú-Bihar County, E Hungary) and in 2013 in Szentborbás (Somogy County, SW Hungary) (Takács et al. 2014; Szilágyi et al. 2019).

Table 1. Phytosociological relevés with occurrences of *Eriochloa villosa* in Austria and the Czech Republic. For information on locality and site characteristics, see Supplementary material Table S1.

Species	Relevé							
	1	2	3	4	5	6	7	8
***Eriochloa villosa* (Thunb.) Kunth**	+	**1**	+	**1**	+	**1**	+	+
Beta vulgaris L.	4		+	+				
Chenopodium album L.	2		+	1	2	+	r	+
Setaria pumila (Poir.) Roem. & Schult.	3	2	2	3	1	2	2	+
Setaria viridis (L.) P.Beauv.	+							
Chenopodium hybridum L.	1							
Mercurialis annua L.	1	1			1			
Echinochloa crus-galli (L.) P.Beauv.	+			+	+	2	+	2
Solanum nigrum L.	r							
Anagallis arvensis L. forma *azurea*	+							
Convolvulus arvensis L.	2	1	+		1	2	1	1
Viola arvensis Murray	+							
Fallopia convolvulus (L.) Á.Löve	1	2	1	2				
Amaranthus powellii S.Watson	r		1	1	+		r	3
Carduus acanthoides L.	+							
Datura stramonium L.	+		r					
Reseda lutea L.	1							
Anagallis arvensis L. forma *arvensis*	+							
Lepidium draba	+							
Helianthus annuus L.		4	3	4				
Stellaria media (L.) Vill.		r						
Polygonum aviculare L.			1	1	3	+	+	
Atriplex oblongifolia Waldst. & Kit.			1		1			
Arctium tomentosum Mill.			r			+		
Elymus repens (L.) Gould			r					r
Panicum miliaceum L. ssp. *ruderale*				+				
Zea mays L.					3	3	4	
Daucus carota L.					+			
Avena fatua L.					+			
Lolium perenne L.					r	+	+	
Bromus sterilis L.					+			
Bromus tectorum L.						+		
Persicaria lapathifolium (L.) Delarbre						1		
Tripleurospermum inodorum (L.) Sch.Bip.						+	+	
Falcaria vulgaris Bernh.						+		
Consolida regalis Gray						r		
Cucurbita pepo L.								4
Atriplex patula L.								1
Amaranthus retroflexus L.								2
Cirsium arvense (L.) Scop.							1	
Lathyrus tuberosus L.							+	+

Eriochloa villosa has also been found in the forest-steppe and northern steppe subzones of European Russia (Eastern Europe). The first record was made in 2000 (Voronezh province) (Sukhorukov 2011). Recent floristic investigations showed further local occurrences of the species in other districts of this area (Sukhorukov 2011; Mikhajlovich et al. 2015). Here, it appears that *E. villosa* invades more ruderal habitats (railway tracks, roadsides) than crop fields (Mikhajlovich et al. 2015).

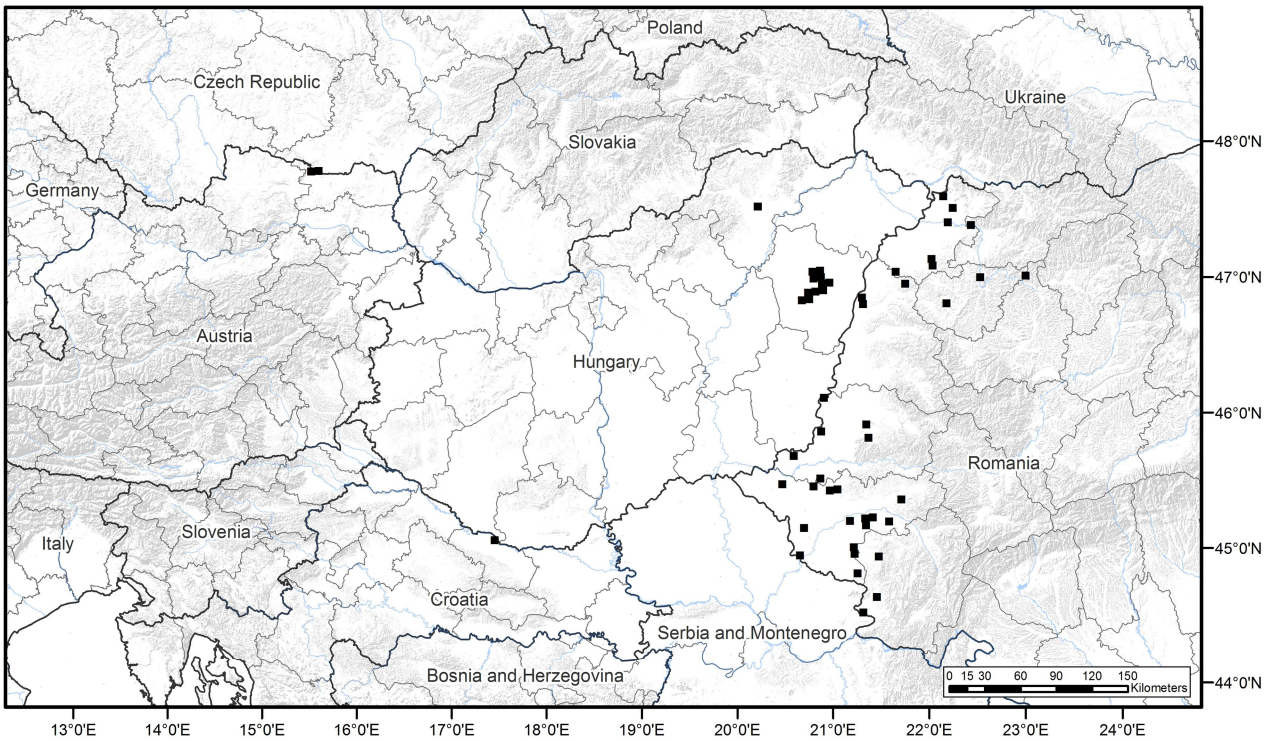

Figure 3. Distribution map of *Eriochloa villosa* in Central Europe (Austria, Czech Republic, Hungary, Romania) based on the grid cells of the Floristic Mapping of Central Europe (cell size: 5 × 3 geographic minutes, ~ 33 km^2). Records are from the following sources: Paulič and Němec (2014); Takács et al. (2014); Szatmari (2016); Szilágyi et al. (2016, 2019); Follak and Essl (*unpub. records* 2017, 2019).

Discussion

Distribution and spread pattern

The occurrence of *E. villosa* on the Austrian territory was to be expected as the species is already established within a few kilometers across the border in the Czech Republic (Paulič and Němec 2014; Follak *pers. obs.* 2017). Local spread of *E. villosa* is typically attributed to the movement of seeds attached to agricultural machinery (i.e., harvesters, soil cultivation equipment). Seeds of *E. villosa* may have reached the Austrian territory by cross-border use of agricultural machinery or even by natural dispersal as suggested by the close proximity to the populations on the other side of the border. The species has a high seed production (Darbyshire et al. 2003) that leads to a large soil seedbank and consequently, to high population sizes if conditions are favorable. This in turn promotes high propagule pressure and increases the probability of spread to other fields by e.g. agricultural machinery. The phytosociological relevés of Szatmari (2016) clearly show that *E. villosa* can develop high densities in crop fields and along field margins. So far, the abundance of *E. villosa* in Austria and the Czech Republic is rather low as documented by relevés (Table 1).

In Hungary, *E. villosa* has already undergone a compact local range expansion as indicated by Szilágyi et al. (2019) and by the cluster of occupied grid cells around the city of Debrecen (E Hungary, Figure 3). In Romania, Szatmari (2016) showed the rapid expansion of *E. villosa* on the

local scale in an agricultural area (Pir/Satu Mare County), where the species was noted at 4 km distance from the initial point of infestation within three years. This underlines that its spread was most likely fostered by frequent unintentional human-mediated seed dispersal from field to field. Introduction to new areas and long-distance spread may occur with movement of contaminated seeds for planting or with the unintentional contamination of seed, grain, or also with agricultural machinery. As for many other invasive weed species (Essl et al. 2009), the spread pattern of *E. villosa* corresponds to stratified dispersal processes consisting of long-distance movements and local, radial diffusion. In this respect, *E. villosa* can be expected to occur in Serbia soon, as it has already been found close to the Serbian-Romanian border (Szatmari 2016; Figure 3).

Phytosociological affiliation and habitat preferences

In Austria and the Czech Republic, *E. villosa* currently is limited to weed communities in summer crop fields. As occurrences of the species in other Central European countries are also mostly reported from summer crops (Ardelean et al. 2009; Szatmari 2016), the phytosociological affiliation and the most-abundant co-occurring species are similar to the ones reported for Austria and the Czech Republic. However, occurrences of *E. villosa* have rarely been reported from other habitats such as dry grasslands (Ardelean et al. 2009), ruderal habitats like roadsides (Szatmari 2016) and disturbed wetlands (Otves et al. 2014) in Romania. Thus, it is likely that the future spread of *E. villosa* in Austria and the Czech Republic will be most likely confined to crop fields, although spread to other habitats (roadsides, ruderal habitats) seems possible. Other alien weed species such as *Ambrosia artemisiifolia* (common ragweed) have shown to expand their niches during successful invasion (e.g. Essl et al. 2009).

Agricultural impact

At present, *E. villosa* is most troublesome in parts of eastern Hungary and western Romania (Szatmari 2016; Szilágyi et al. 2019). The species reaches high abundances and invades many crop types. *Eriochloa villosa* is particularly competitive (in terms of aboveground biomass) when it emerges at the same time as the crop, while late emerging individuals are considered less competitive, but they can still produce seeds (Mickelson and Harvey 1999). Although interference studies under Central European conditions are lacking, there is little doubt that the impact of *E. villosa* on crop yields can be significant. It can be expected that *E. villosa* is similarly problematic in crop fields, as for example the related *Panicum* and *Digitaria* species. However, in Austria and the Czech Republic, the abundance of *E. villosa* in the weed communities is comparably low and thus, its present agricultural impact can be considered low.

In summary, *E. villosa* is an example of a weed that is still rare in Central Europe. However, the number of records has increased rapidly in recent years and local spread is gaining importance in particular in Romania and Hungary. It can be assumed that the species will most likely expand its range in Austria and in other Central European countries. Thus, it is of importance to further monitor *E. villosa* and to observe its appearance in new areas. However, studies are also necessary at assessing the specific impact of the species on crop yield in Central Europe.

Acknowledgements

FE acknowledges support by the BiodivERsA-Belmont Forum Project "AlienScenarios" (FWF project no I 4011-B32). The suggestions and comments of two anonymous reviewers and of the Handling Editor Q. Groom are greatly appreciated.

References

Ardelean A, Karacsonyi K, Negrean G (2009) *Eriochloa villosa* - a new alien graminaceae species for Arad County (Romania). *Studia Universitatis "Vasile Goldiş", Seria Ştiinţele Vieţii* 19: 281–282

Braun-Blanquet J (1964) Pflanzensoziologie - Grundzüge der Vegetationskunde. 3. Auflage. Springer, Vienna - New York, 634 pp, https://doi.org/10.1007/978-3-7091-8110-2

Ciocârlan V, Sike M (2006) *Eriochloa villosa* (Thunb.) Kunth (Poaceae) in the Romanian flora. *Journal of Plant Development* 13: 105–107

Darbyshire SJ, Wilson CE, Allison K (2003) The Biology of invasive alien plants in Canada. 1. *Eriochloa villosa* (Thunb.) Kunth. *Canadian Journal of Plant Science* 83: 987–999, https://doi.org/10.4141/P03-016

EPPO (2019a) European and Mediterranean Plant Protection Organization. http://www.eppo.int/INVASIVE_PLANTS/ias_lists.htm#A1A2Lists (accessed 18 March 2019)

EPPO (2019b) EPPO Global Database - *Eriochloa villosa*. https://gd.eppo.int/taxon/ERBVI (accessed 16 August 2019)

Essl F, Dullinger S, Kleinbauer I (2009) Changes in the spatio-temporal patterns and habitat preferences of *Ambrosia artemisiifolia* during its invasion of Austria. *Preslia* 81: 119–133

Fărcăşescu AM, Arsene G-G, Neacşu A-G (2007) *Eriochloa villosa* (Thunb.) Kunth: A new species for the Banat flora. *Research Journal of Agricultural Science* 39: 483–488

Fischer MA, Oswald K, Adler W (2008) Exkursionsflora für Österreich, Liechtenstein und Südtirol. Biologiezentrum der Oberösterreichischen Landesmuseen, 1392 pp

Follak S, Schleicher C, Schwarz, M, Essl F (2017) Major emerging alien plants in Austrian crop fields. *Weed Research* 57: 406–416, https://doi.org/10.1111/wre.12272

Mickelson JA, Harvey RG (1999) Effects of *Eriochloa villosa* density and time of emergence on growth and seed production in *Zea mays*. *Weed Science* 47: 687–692, https://doi.org/10.1017/S0043174500091347

Mikhajlovich VV, Sukhorukov AP, Aleksandrovna KM (2015) Contributions to the alien flora of the European Russia. *Phytodiversity of Eastern Europe* 4: 120–128 [in Russian]

Mucina L, Grabherr G, Ellmauer T (eds) (1993) Die Pflanzengesellschaften Österreichs. Teil I: Anthropogene Vegetation. Gustav Fischer Verlag, Jena, 1454 pp

Niklfeld H (1999) Mapping the flora of Austria and the eastern Alps. *Revue Valdôtaine d'histoire Naturelle* 51(Suppl.): 53–62

Otves C, Neacşu A, Arsene G-G (2014) Invasive and potentially invasive plant species in wetlands area of Banat. *Research Journal of Agricultural Science* 46: 146-161

Partosfalvi P, Madarász J, Dancza I (2008) Occurrence of *Eriochloa villosa* (Thunb.) Kunth in Hungary. *Növényvédelem* 44: 297–304

Paulič R, Němec R (2014) Chlupatka srstnatá (*Eriochloa villosa*) nový druh flóry České republiky. *Thayensia, Znojmo* 11: 135–138

Simard M-J, Nurse RE, Darbyshire SJ (2015) Emergence pattern and seed production of a Canadian woolly cupgrass (*Erichloa villosa*) population in legume forage. *Canadian Journal of Plant Science* 95: 539–548, https://doi.org/10.4141/cjps-2014-317

Sukhorukov AP (2011) New invasive alien plant species in the forest-steppe and northern steppe subzones of European Russia: secondary range patterns, ecology and causes of fragmentary distribution. *Feddes Repertorium* 122: 287–304, https://doi.org/10.1002/fedr.201100004

Szatmari P-M (2016) Monitoring invasive woolly cupgrass *Eriochloa villosa* in the Pir village area, Satu Mare County, Romania, and its impact on segetal flora. *Acta Horti Botanici Bucurestiensis* 43: 41–55

Szilágyi A, Balogh Z, Dávid I, Szabó L, Radócz L (2015) Woolly cupgrass (*Eriochloa villosa* /Thunb./Kunth), a recently occurred invasive weed in Trans-Tisza Region and a trial for control in maize. *Journal of Agricultural Sciences* 66: 53–57, https://doi.org/10.34101/actaagrar/66/1892

Szilágyi A, Tamás T, Radócz L (2016) Az ázsiai gyapjúfű (*Eriochloa villosa* [Thunb.] Kunth) új előfordulása a Hajdúság kistérség területén. *Agrártudományi* 71: 51–54, https://doi.org/10.34101/actaagrar/71/1572

Szilágyi A, Tamás T, Radócz L (2019) Az ázsiai gyapjúfű (*Eriochloa villosa* [Thunb.] Kunth) újabb előfordulásai a Hajdúság kistérség területén. *Georgikon for Agriculture* 23: 70–75

Takács A, Nagy T, Molnár V (2014) Apró közlemények. *Kitaibelia* 19: 173–176

Verloove F (2019) *Eriochloa villosa*. In: Manual of the Alien Plants of Belgium. Botanic Garden Meise, Belgium. http://alienplantsbelgium.be/content/eriochloa-villosa (accessed 29 July 2019)

Weber E, Gut D (2005) A survey of weeds that are increasingly spreading in Europe. *Agronomy for Sustainable Development* 25: 109–121, https://doi.org/10.1051/agro:2004061

ZAMG (2019) Klimadaten von Österreich 1971-2000 - Retz, Niederösterreich. http://www.zamg.ac.at (accessed 26 August 2019)

Supplementary material

The following supplementary material is available for this article:

Table S1. Recording date, habitat (crop), altitude (m a.s.l.), vegetation cover (in %), country where the plot was located (each 50 m^2 in size), and coordinates (latitude, longitude).

This material is available as part of online article from:
http://www.reabic.net/journals/bir/2020/Supplements/BIR_2020_Follak_etal_Table_S1.xlsx