

Distribution and habitats of fast spreading perennial weed *Sorghum halepense* (L.) Pers. in Slovakia

Rozšírenie a biotopy rýchlo sa šíriacej trvacej buriny *Sorghum halepense* (L.) Pers. na Slovensku

Nikola KOTLÁROVÁ, Ľuba ĎURIŠOVÁ, Samuel KŠIŇAN, Lenka TOMOVIČOVÁ, Pavol ELIÁŠ Jr. (✉)

Institute of Plant and Environmental Sciences, Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, 949 76 Nitra, Slovak Republic

✉ Corresponding author: pavol.elias1@uniag.sk

Received: January 10, 2025; accepted: March 21, 2025

ABSTRACT

Sorghum halepense (L.) Pers. is an extensively distributed alien weed species that poses a potential threat to agricultural agrosystems. Infested crops experience large yield losses with secondary problems due to the impact of *Sorghum halepense* as an alternative host for diseases and pests. The paper aimed to process the historical and current distribution and habitats of *Sorghum halepense* in Slovakia. The results showed that until the 1950s, this weed grass was rare; localities were found only in southwestern Slovakia. With the intensification of agriculture and the import of contaminated seeds, *Sorghum halepense* began to gradually spread, while initially the type of habitats colonised by it was relatively balanced (fields, ruderal stands and railways and harbours). From the mid-1970s, it established itself mainly in harbours and railways, and after 2000 mainly on the edges of roads. Currently, it is spreading intensively to the north, and the first localities in the Carpathians have been recorded. Its intensive spread represents a significant risk for agriculture in Slovakia.

Keywords: alien species, central Europe, occurrence, *Poaceae*, stands

ABSTRAKT

Sorghum halepense (L.) Pers. je hojne rozšírený nepôvodný druh buriny, ktorý predstavuje potenciálnu hrozbu pre poľnohospodárske agrosystémy. Pri napadnutých plodinách dochádza k veľkým stratám úrody a sekundárnym problémom v dôsledku vplyvu ciroku alepského ako alternatívneho hostiteľa pre choroby a škodcov. Cieľom príspevku bolo spracovať historické a súčasné rozšírenie a biotopy *Sorghum halepense* na Slovensku. Z výsledkov vyplýva, že až do 50-tych rokov sa táto burina vyskytovala vzácné najmä v oblasti juhozápadného Slovenska. Intenzifikáciou poľnohospodárstva a dovozom kontaminovaného osiva sa *Sorghum halepense* začal postupne šíriť, pričom spočiatku bol typ ním osídľovaných biotopov relatívne vyrovnaný (polia, ruderálne miesta a železničné stanice a prístavy), od polovice 70-tych rokov sa presadil najmä v prístavoch a na železničiach a po roku 2000 predovšetkým na okrajoch ciest. V súčasnosti sa takto intenzívne šíri na sever a boli zaznamenané aj prvé lokality v Karpatoch. Jeho intenzívne šírenie predstavuje významné riziko pre poľnohospodárstvo na Slovensku.

Kľúčové slová: nepôvodný druh, stredná Európa, výskyt, *Poaceae*, stanovišťa

INTRODUCTION

Sorghum (Poaceae) is a relatively small genus including around 30 species of agricultural importance, both cultivated cereals and forage plants as well as weeds (Barkworth, 2003; Shouliang and Phillips, 2006; The Plant List, 2024). *Sorghum halepense* (L.) Pers., Johnsongrass, is one of the most widely distributed weed species, posing a potential threat to agrosystems worldwide. It is native to the Mediterranean regions of Africa, the eastern Mediterranean, the Black Sea region, and Asia Minor, making it well adapted to warmer habitat conditions (Peerzada et al., 2017; Klein and Smith, 2020). Recently, the species has been more or less successfully naturalised in Europe, Central and South Africa, Southwest Asia, South and North America, and Australia (Groves, 1991; Jehlík, 1998).

Johnsongrass is a robust, competitive, strong perennial herb. Mature plants are up to 2.5 metres tall, and the stems are 0.5 – 2.0 cm in diameter. The leaves have veins with a prominent midvein and can be up to 60 cm in length. *Sorghum halepense* flowers 46 days after emergence and can produce up to 80,000 grains per plant in one season. They then remain viable in the soil for up to 10 years (Shouliang and Phillips, 2006; Klein and Smith, 2020).

Sorghum halepense can effectively colonise new areas, but it reduces species diversity, and poor germination occurs in some crops due to toxic exudates from *S. halepense* roots or decomposing vegetation (Travlos et al., 2019). In Central Europe, the species is considered a neophyte, most often invasive (Medvecká et al. 2012; Follak and Essl 2012; Csiky et al. 2023), more rarely casual (Pyšek et al. 2022). In Slovakia, it has been found rare in the past (first data Reuss 1853), but the number of localities is increasing, and further research is needed (Jehlík, 1998; Májeková and Zaliberová, 2008; Kropáč and Mochnacký, 2009). So, detailed analyses of the occurrence and habitat preferences of *S. halepense* have not yet been carried out in Slovakia. The goals of this study were to (a) present the current and historical distribution, (b) characterise its typical habitats in Slovakia in different time periods and

(c) estimate ways of its future spreading as a risk factor for both agroecosystems and natural habitats.

MATERIAL AND METHODS

This research was conducted between 2022 and 2024. We compiled a dataset of historical and recent localities for *Sorghum halepense* by studying herbarium collections, extracting data from published sources, and conducting field research. We revised herbarium specimens in 15 public herbaria in Slovakia (BRA, KO, LTM, NI, PMK, SAV, SLO, SMBB, TTM, ZV) and Czechia (BRNM, BRNU, PR, PRA, PRC), referring to the abbreviations used by Thiers (2024) and Vozárová and Sutorý (2001).

The methodology of *S. halepense* mapping is according to Dudáš and Eliáš (2021) to publish comparable data. Data on *Sorghum halepense* occurrence and habitat preferences were collected for 25-year intervals, except for the period prior to 1900, due to data scarcity. These intervals were selected to coincide with major historical events in (Czecho) Slovakia (World War I and II, collectivisation during the socialist era, and the dissolution of agricultural cooperatives after 1990), which may have influenced the distribution of species. Habitat data were gathered from published works and herbarium label information.

The maps follow the grid template described by Niklfeld (1971) and were created in CoreIDRAW. The work of Futák (1980) was accepted for the phytogeographical division of Slovakia. Vascular plant nomenclature follows Marhold and Hindák (1998).

RESULTS

Sorghum halepense in Slovakia

S. halepense has occurred mainly in the areas of the Pannonian xerothermic flora, especially in the Podunajská nížina Lowland and partially also in the Východoslovenská nížina Lowland, as well as the Ipel' Basin. It rarely penetrated into some adjacent areas of the lower Carpathians – the Poľana Mts, the Slanské vrchy

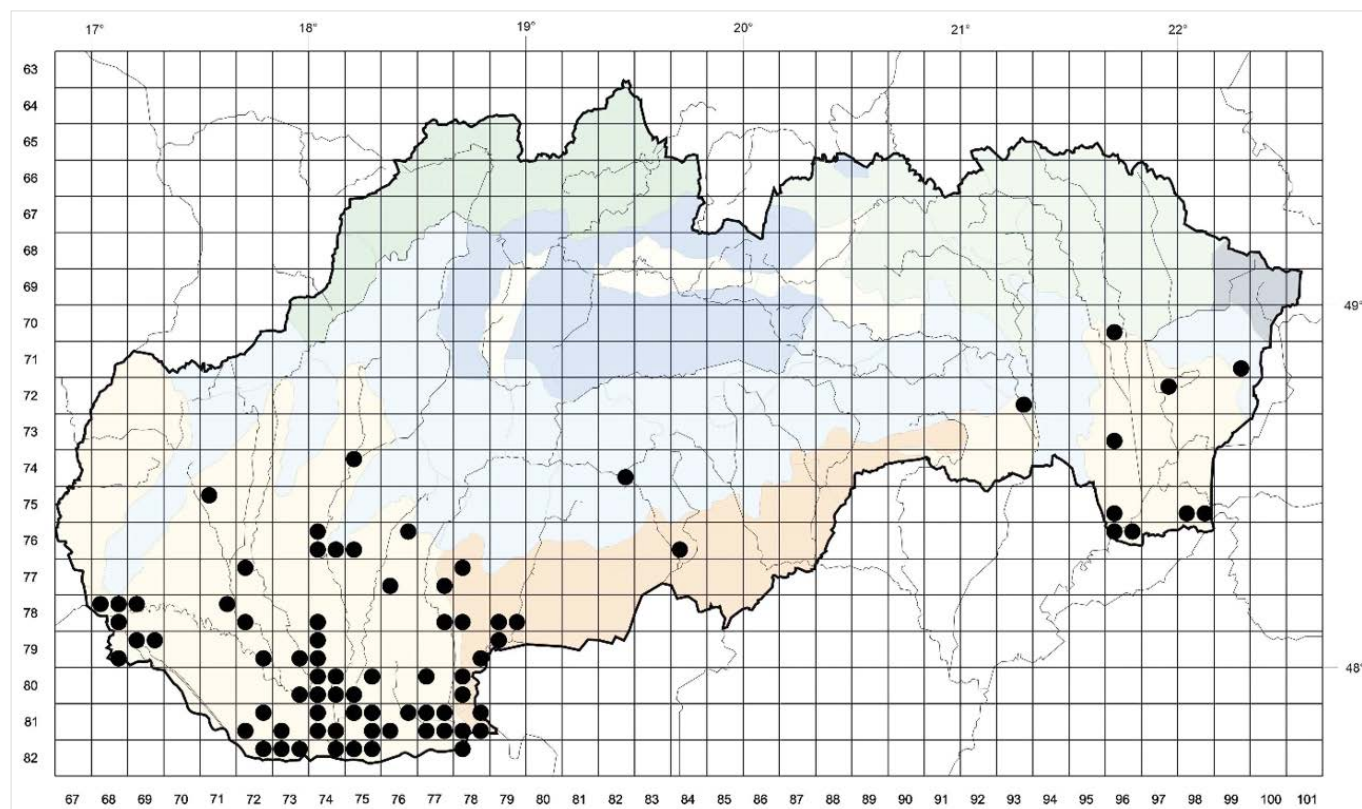
hills, the Vihorlat hills, and the Nízke Beskydy Mts (Figure 1, Appendix 1). In total, it was recorded at 166 localities (Figure 2), 93% of *S. halepense* occurrences are located at an altitude of up to 200 m.

Comparing the occurrence in individual 25-year intervals (Figure 2), we found very rare (before 1900 and in the period 1926 – 1950) or no *S. halepense* presence (in the period 1900 – 1925) until the period shortly after World War II. Since the 1950s, a gradual, but still slow, increase in the number of localities in the southwestern part of Slovakia has begun. An extreme increase in localities was recorded after 2000 (Figure 3). The spatial trend of *S. halepense* spreading from south to north is also clearly visible, with the first occurrences in the Carpathian region being recorded only recently in settlements of Kriváň (Central Slovakia), Košické Olšany, Podčičva and Podhorod' (E Slovakia) (Appendix 1).

Habitats of *Sorghum halepense*

Before 1900, *Sorghum halepense* was recorded at only one site in a corn field in SW Slovakia (Komárno). Later, during the period 1926 – 1950, it was found in the field margin near Komárno (Figure 2, Appendix 1). Even these sporadic finds indicated what types of habitats it may have inhabited.

In the first phase of its spreading in Slovakia in 1951 – 1975, *S. halepense* occupied more or less evenly ruderal areas (4 records), fields (6 records) and railways + harbours (4 records), and was also found on road edges, but more rarely (2 localities). In the following period (1976 – 2000), the species was most frequently found in railways + harbours (28 records), and significant field localities were also recorded (18 sites). After 2000, a sharp increase in *S. halepense* on roadsides was found (78 localities), which is now also the most frequent vector of fast *S. halepense* spreading to new regions.



Yellow and orange colours represent the warm Pannonian region, other colours represent the mountains and basins of the Carpathians

Figure 1. Map of the overall distribution of *Sorghum halepense* in Slovakia in phytogeographical units (according to Futák, 1980)

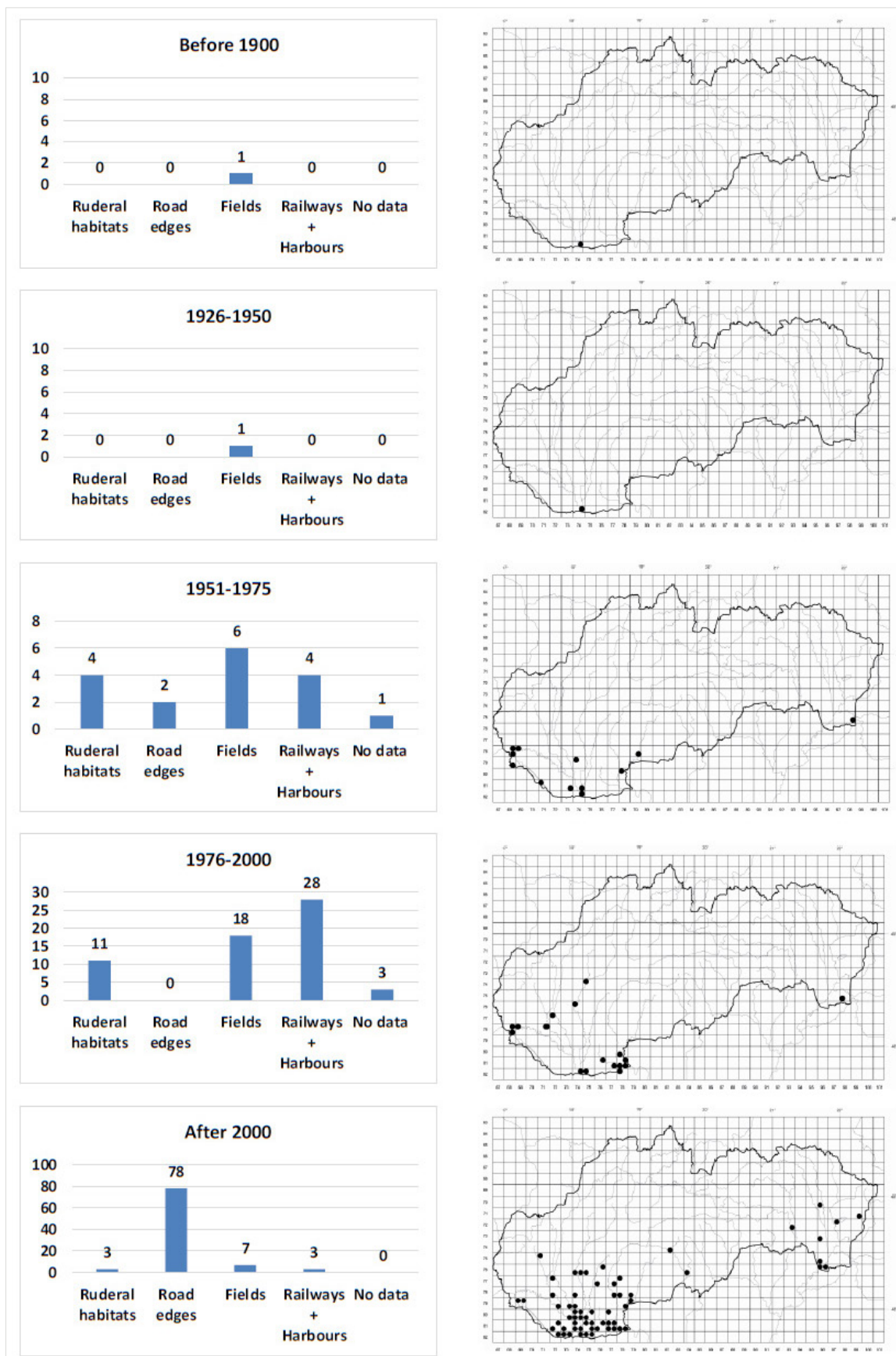


Figure 2. Number of new localities per habitats occupied and distribution of *Sorghum halepense* during the 25-year time periods in Slovakia

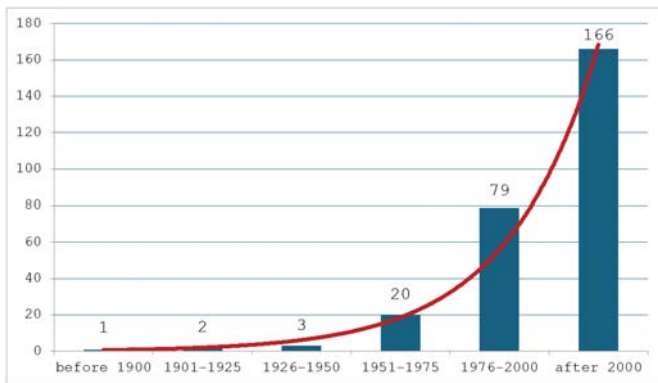


Figure 3. Cumulative numbers of *Sorghum halepense* localities in Slovakia

Compared to road edges, the occurrence of *S. halepense* in fields (7 localities), ruderal areas (3 localities) and railways + harbours (3 localities) was only accessory. By evaluating the typical habitats of the species, it is clear that the main current vector of *S. halepense* spread in Slovakia is along roads.

DISCUSSION

In Slovakia, *Sorghum halepense* was documented first in the second half of the 19th century as a weed and probably an ornamental plant in gardens (Reuss, 1853; Schiller, 1865). The next occurrence was recorded more than 70 years later. We can therefore conclude that its occurrence before World War II was only very sporadic; it is not mentioned even in significant review works examining the weed flora just after World War II (e.g. Opluštilová, 1953). The species began to spread more intensively along the Pannonian and eastern weed migration routes only in the mid-20th century in connection with the import of cereals from North America and the former Soviet Union (Jehlík, 1998; Jehlík and Dostálek, 2008). Later, from the mid-1970s, the species spread intensified, it was most frequently recorded at railway stations and harbours in southwestern Slovakia, from where it also penetrated into its surroundings (Eliáš, 1985; Svobodová, 1989, 1991). Jehlík (1998) believed the increase in sites could have been related to the termination of DDT (dichlorodiphenyltrichloroethane) application in former Czechoslovakia. Recently, *S. halepense* has spread exponentially in Slovakia. As far as Europe is concerned, in recent years, more and more researchers have pointed

to an increasing tendency of *Sorghum halepense* spread. It is frequently found in agricultural fields across almost all of Europe, where it is established as a serious weed (Weber and Gut, 2005; Travlos et al., 2019). In Austria, studies show that habitat affiliation is changing and only recently has the distribution of *Sorghum halepense* increased (Follak and Essl, 2012). A study conducted by researchers in Romania reports that the species is found almost throughout the country, attacking vegetable crops as well as vine and fruit tree plantations (Ramona et al., 2008). In Hungary, the species spread rapidly in the 1960s and became one of the most commonly occurring weeds in the country (Novák et al., 2009). Also, in the Americas, the species was easily naturalised and spread to the majority of North America. It occurs in both agricultural and non-agricultural habitats (Paterson et al., 2020). Binemelis et al. (2009) reported that the species was cultivated in the early 20th century for forage purposes but was banned for agricultural purposes in 1936 due to its high invasiveness. Initially, it was found only in the north of Argentina, but nowadays it is found in almost every agricultural region of the country. Parsons and Cuthbertson (1992) pointed out that *Sorghum halepense* occurs in Australia as an invasive weed in crops and was first cultivated as a forage plant in the Adelaide Botanic Gardens in 1871. In recent years, the weed has become a serious environmental threat to some parts of Australia.

Spatio-temporal patterns of *S. halepense* spread showed a clear south-north direction from the warm Pannonian region to the foothills of the Carpathians, e.g. very similar to another notable neophyte weed, *Ambrosia artemisiifolia*, which has now been recorded in the most northern regions of Slovakia (Hrabovský and Mičieta, 2014, 2018; Hrabovský et al., 2016). On the contrary, data published by Follak and Essl (2012) indicated *S. halepense* spreading in the direction east-west in northern Austria according to suitable environmental conditions in the Vienna Basin and Northern Alpine and Carpathian Foreland. The expansion is usually attributed to global climate change (Travlos et al., 2019), although exact data has been published in Europe sparsely (e.g. Kleinbauer et al., 2010). However, we can support this claim with

data from North America. Based on climate change and thus increasing temperatures, models predict that the distribution of *Sorghum halepense* will expand poleward by 200–600 km by 2100 in the USA (McDonald et al., 2009). Reduced rainfall, as another impact of climate change, can also affect some control methods, such as herbicide use (Zhai et al., 2024).

Comparing distribution data on a time-temporal scale, different habitat affiliation was found. In the first 50 years of the invasion, *S. halepense* dominated in habitats of fields and railway stations; recently, it has been successfully and massively spreading along roadsides, representing more than 90% of all localities. This phenomenon has also been observed in Austria, where the *S. halepense* records outside fields account for 68% of all records (Follak and Essl, 2012). The species has a high genetic diversity, which helps its spread (Squires et al., 2021). Sezen et al. (2016) indicate that the species has spread to agricultural habitats from its original non-agricultural habitat and shows phenotypically and genotypically different behaviour in this new environment. Kigel and Rubin (1985) reported that the western part USA mainly contains slender plants with small inflorescences and narrow leaves, while the eastern part contains more robust plants. In northern latitudes, *S. halepense* plants have earlier flowering, which avoids damage from autumn frosts during reproductive development. It is therefore clear that *S. halepense* has a significant ecological valence that allows it to successfully colonise new types of habitats. We believe that the transfer of the species from fields and railways to semi-ruderal stands (edges of the roads, i.e., the opposite of what is stated by Sezen et al., 2016) had two reasons in Slovakia. First, *S. halepense* successfully avoided the application of herbicides, and second, it occupied an ecological niche to which it has adapted very well. Road edges represent a very specific man-made habitat affected by dust and traffic deposits, as well as disturbance of road maintenance (Šerá, 2010), including regular mowing and the absence of herbicide application. Perennial grasses are usually well adapted to grazing

and mowing and have strong competitive skills (Stanley, 1999; Linder et al., 2018). *S. halepense* belongs to a typical competitor-life strategy plant with clonal spreading (Klein and Smith, 2020). Rhizomes store carbohydrates and thus increase the chances of survival in mild cold spells and tropical dry periods (Paterson et al., 2020). Outside fields, it spreads circularly with no preferential direction of growth (Horowitz, 1973). Mowing machines help to spread rhizomes and promote colonisation of new areas (Andújar et al., 2012). *S. halepense* has regenerated rapidly even from small fragments of underground outcrops; the potential for successful control is severely limited (Follak and Essl, 2012). Therefore, we believe that the spread of *S. halepense* along roadsides will continue in Slovakia, which poses a great risk of surrounding field crops in the future, either directly as a weed or secondarily as an alternative host for diseases and pests.

CONCLUSION

Sorghum halepense is spreading intensively in Slovakia, most likely due to climate change. Most of the localities were recorded mainly in the Podunajská nížina Lowland, while it is gradually becoming established also in the Východoslovenská nížina Lowland and some adjacent regions of the Carpathians. Although the species is capable of inhabiting various types of man-made habitats, road edges are the most common type of habitat recently in Slovakia, which is probably also a form of dispersal due to insufficient mowing, thus leaving rhizomes in the soil and creating additional new populations. In the future, we foresee an increasing tendency for *Sorghum halepense* to also occur in fields, which may have a negative impact on crop yields and overall crop quality.

ACKNOWLEDGMENT

We are indebted to the curators of the visited herbarium collections for allowing the study of *Sorghum halepense* specimens. The research was funded by a grant project VEGA No. 1/0359/22.

REFERENCES

- Andújar, D., Barroso, J., Fernández-Quintanilla, B. C., Dorado, J. (2012) Spatial and temporal dynamics of *Sorghum halepense* patches in maize crops. *Weed Research*, 52 (5), 411-420.
DOI: <https://doi.org/10.1111/j.1365-3180.2012.00937.x>
- Barkworth, M. (2003) *Sorghum* Moench. In: Flora of North America Vol 25, Poaceae, Part 2. New York: Oxford University Press, pp. 626-630.
- Binemelis, R., Pengue, W., Monterroso, I. (2009) "Transgenic treadmill": Responses to the emergence and spread of glyphosate-resistant Johnsongrass in Argentina. *Geoforum*, 40 (4), 623-633.
DOI: <https://doi.org/10.1016/j.geoforum.2009.03.009>
- Csiky, J., Balogh, L., Dancza, I., Gyulai, F., Jakab, B., Király, G., Lehoczky, É., Mesterházy, A., Pósa, P., Wirth, T. (2023) Checklist of alien vascular plants in Hungary and their invasion biological characteristics. *Acta Botanica Hungarica*, 65, 53-72.
DOI: <https://doi.org/10.1556/034.65.2023.1-2.3>
- Dudáš, M., Eliáš, P. Jr. (2021) Alien weed *Xanthium spinosum* in Slovakia I: distribution and habitats. *Journal of Central European Agriculture*, 22 (2), 305-316. DOI: <https://doi.org/10.5513/JCEA01/22.2.3083>
- Eliáš, P. (1985) Flora of the river harbour in Bratislava. *Zprávy Československé botanické společnosti*, 20 (3), 227-228. (in Slovak)
- Follak, S., Essl, S. (2012) Spread dynamics and agricultural impact of *Sorghum halepense*, an emerging invasive species in Central Europe. *Weed Research*, 53 (1), 53-60.
DOI: <https://doi.org/10.1111/j.1365-3180.2012.00952.x>
- Futák, J. (1980) Fytogeografické členenie / Phytogeographical division (1: 1 000 000). In: Mazúr, E., ed. Atlas Slovenskej socialistickej republiky, mapa VII/14. Bratislava: Slovenské pedagogické nakladateľstvo, p. 88. (in Slovak)
- Groves, R. H. (1991) Weeds of tropical Australia. In: Baker, F. W. G., Terry, P. J., eds. *Tropical Grassy Weeds*. Wallingford: CASAFA. Report Series No. 2, pp. 189-196.
- Horowitz, M. (1973) Spatial growth of *Sorghum halepense* (L.) Pers. *Weed Research*, 13 (2), 200-208.
DOI: <https://doi.org/10.1111/j.1365-3180.1973.tb01264.x>
- Hrabovský, M., Mičieta, K. (2014) The occurrence of an invasive species *Ambrosia artemisiifolia* in Slovakia in the years 2008-2014. *Acta Botanica Universitatis Comenianae*, 49, 9-12.
- Hrabovský, M., Mičieta, K. (2018) New findings of the common ragweed (*Ambrosia artemisiifolia*) in Slovakia in the year 2017. *Acta Botanica Universitatis Comenianae*, 53, 25-27.
- Hrabovský, M., Ščevková, J., Mičieta, K., Lafférová, J., Dušička, J. (2016) Expansion and aerobiology of *Ambrosia artemisiifolia* L. in Slovakia. *Annals of Agricultural and Environmental Medicine*, 23 (1), 64-70.
DOI: <https://doi.org/doi/10.5604/12321966.1196854>
- Jehlík, V., ed. (1998) Alien invasive weeds of the Czech Republic and the Slovak Republic. Praha: Academia. (in Czech)
- Jehlík, V., Dostálek, J. (2008) Influence of railway transport in the South-East of Slovakia on formation of adventive flora in Central Europe. *Biodiversity: Research and Conservation*, 11-12, 27-32.
DOI: <https://doi.org/10.14746/biorc.2008.11-12.4>
- Kigel, J., Rubin, B. (1985) *Sorghum halepense*. In: Halevy, A. H., ed. *Handbook of Flowering*. IV. Boca Raton, FL, USA: CRC Press, pp. 367-375.
- Klein, P., Smith, Ch. M. (2020) Invasive Johnsongrass, a threat to native grasslands and agriculture. *Biologia*, 76, 413-420.
DOI: <https://doi.org/10.2478/s11756-020-00625-5>
- Kleinbauer, I., Dullinger, S., Klingenstein, F., May, R., Nehring, S., Essl, F. (2010) Ausbreitungspotenzial ausgewählter neophytischer Gefäßpflanzen unter Klimawandel in Deutschland und Österreich. *BfN-Skripten* 275.
- Kropáč, Z., Mochňák, S. (2009) Contribution to the segetal communities of Slovakia. *Thaiszia*, 19/2, 145-211.
- Linder, H. P., Lehmann, C. E. R., Archibald, S., Osborne, C. P., Richardson, D. M. (2018) Global grass (Poaceae) success underpinned by traits facilitating colonization, persistence and habitat transformation. *Biological Reviews*, 93 (2), 1125-1144.
DOI: <https://doi.org/10.1111/brv.12388>
- Májeková, J., Zaliberová, M. (2008) Invasive and expansive plant species in Slovakian agrocenoses. *Biodiversity: Research and Conservation*, 9-10, 51-56. DOI: <https://doi.org/10.14746/biorc.2008.9-10.7>
- Marhold, K., Hindák, F., eds. (1998) Checklist of non-vascular and vascular plants of Slovakia. Bratislava: Veda.
- McDonald, A., Riha, S., DiTommaso, A., DeGaetano, A. (2009) Climate change and the geography of weed damage: Analysis of U.S. maize systems suggests the potential for significant range transformations. *Agriculture, Ecosystems & Environment*, 130 (3-4), 131-140.
DOI: <https://doi.org/10.1016/j.agee.2008.12.007>
- Medvecká, J., Kliment, J., Májeková, J., Halada, L., Zaliberová, M., Gojdičová, E., Feráková, V., Jarolímek, I. (2012) Inventory of alien species of Slovakia. *Preslia*, 84, 257-309.
- Niklfeld, H. (1971) Bericht über die Kartierung der Flora Mitteleuropas. *Taxon*, 20, 545-571. DOI: <https://doi.org/10.2307/1218258>
- Novák, R., Dancza, I., Szentey, L., Karamán, J., Béres, I., Kazinczi, G., Gólya, G. (2009) Arable Weeds of Hungary. Fifth National Weed Survey (2007-2008). Budapest: Ministry of Agriculture and Rural Development.
- Opluštilová, T. (1953) *Ekológia burín v obilninách*. Bratislava: Vydavateľstvo SAV. (in Slovak)
- Parsons, W. T., Cuthbertson, E. G. (1992) *Noxious Weeds of Australia*. Melbourne: Inkata Press.
- Paterson, A. H., Kong, W., Johnston, R. M., Nabukalu, P., Wu, G., Poehlmán, W. L., Goff, V. H., Isaacs, K., Lee, T. H., Guo, H., Zhang, D., Sezen, U. U., Kennedy, M., Bauer, D., Feltus, F. A., Weltzien, E., Rattunde, H. F., Barney, J. N., Barry, K., Cox, T. S., Scanlon, M. J. (2020) The Evolution of an Invasive Plant, *Sorghum halepense* L. ('Johnsongrass'). *Frontiers in Genetics*, 11, 317.
DOI: <https://doi.org/10.3389/fgene.2020.00317>
- Peerzada, A. M., Ali, H. H., Hanif, Z., Bajwa, A. A., Kebaso, L., Frimpong, D., Iqbal, N., Namubiru, H., Hashim, S., Rasool, G., Manalil, S., van der Meulen, A., Chauhan, B. S. (2017) Eco-biology, impact, and management of *Sorghum halepense* (L.) Pers. *Biological Invasions*, 25, 955-973. DOI: <https://doi.org/10.1007/s10530-017-1410-8>
- Pyšek P., Sádlo, J., Chrtek, J. Jr., Chytrý, M., Kaplan, Z., Pergl, J., Pokorná, A., Axmanová, I., Čuda, J., Doležal, J., Dřevojan, P., Hejda, M., Kočár, P., Körtz, A., Lososová, Z., Lustyk, P., Skálová, H., Štajerová, K., Večeřa, M., Vítková, M., Wild, J., Danihelka, J. (2022) Catalogue of alien plants of the Czech Republic (3rd edition): species richness, status, distributions, habitats, regional invasion levels, introduction pathways and impacts. *Preslia*, 94, 477-577.
- Ramona, S., Grozea, I., Șarpe, N., Lauer, K. F. (2008) Control of *Sorghum halepense* (L.) species in Western part of Romania. *Communications in Agricultural and Applied Biological Sciences*, 73, 959-964.
- Reuss, G. (1853) *Května Slovenska*. Banská Štiavnica. (in Slovak)

- Sezen, U. U., Barney, J. N., Atwater, D. Z., Pederson, G. A., Pederson, J. F., Chandler, J. M. et al. (2016) Multi-Phase US Spread and Habitat Switching of a Post-Columbian Invasive, *Sorghum halepense*. *PLoS ONE*, 11 (10), e0164584. DOI: <https://doi.org/10.1371/journal.pone.0164584>
- Schiller, S. (1865) Aus Oberungarn. *Österreichische Botanische Zeitschrift*, 15, 378-383.
- Shouliang, C., Phillips, S. M. (2006) *Sorghum* Moench. In: Zhengyi, W., Raven, P. H., eds. *Flora of China* 22, 201-602. Available at: <http://flora.huh.harvard.edu/china/PDF/PDF22/Sorghum.pdf> [Accessed 26 November 2024]
- Stanley, K. E. (1999) Evolutionary Trends in the Grasses (Poaceae): A Review. *The Michigan Botanist*, 38 (1), 3-12. DOI: <http://hdl.handle.net/2027/spo.0497763.0038.101>
- Svobodová, Z. (1989) New findings of vascular plants in Slovakia II. *Bulletin Slovenskej botanickej spoločnosti*, 11, 16-24. (in Slovak)
- Svobodová, Z. (1991) Floristic contribution from southern Slovakia. *Bulletin Slovenskej botanickej spoločnosti*, 13, 51-54. (in Slovak)
- Squires, C. C., Walsh, M. J. (2021) Chapter 18 - *Sorghum halepense*. *Biology and Management of Problematic Crop Weed Species*, 391-405. DOI: <https://doi.org/10.1016/B978-0-12-822917-0.00012-4>
- Šerá, B. (2010) Roadside herbaceous vegetation: life history groups and habitat preferences. *Polish Journal of Ecology*, 58, 69-79. Available at: https://www.miiiz.waw.pl/pliki/article/ar58_1_06.pdf [Accessed 10 January 2025].
- The Plant List (2024) Version 1.1. [Online] Available at: <http://www.theplantlist.org> [Accessed 29 November 2024].
- Thiers, B. (2024) Index Herbariorum: A global directory of public herbaria and associated staff. New York Botanical Garden's Virtual Herbarium. New York. [Online] Available at: <http://sweetgum.nybg.org/ih/> [Accessed 20 October 2024].
- Travlos, I. S., Montull, J. M., Kukorelli, G., Malidza, G., Dogan, M. N., Cheimona, N., Antonopoulos, N., Kanatas, P. J., Zannopoulos, S., Peteinatos, G. (2019) Key Aspects on the Biology, Ecology and Impacts of Johnsongrass [*Sorghum halepense* (L.) Pers] and the Role of Glyphosate and Non-Chemical Alternative Practices for the Management of This Weed in Europe. *Agronomy*, 9(11), 717. DOI: <https://doi.org/10.3390/agronomy9110717>
- Vozárová, M., Sutorý, K., eds. (2001) Index herbariorum Reipublicae bohemicae et Reipublicae slovacae. *Bulletin Slovenskej botanickej spoločnosti*, Suppl. 7, 1-95. (in Slovak)
- Weber, E., Gut, D. (2005) A survey of weeds that are increasingly spreading in Europe. *Agronomy Sustainable Development*, 25 (1), 109-121. DOI: <https://doi.org/10.1051/agro:2004061>
- Zhai, L., Duell, E. B., Zhang, B. (2024) Drought impacts on the efficacy of invasive grass control by clipping: A study on Johnsongrass (*Sorghum halepense*). *Biological Conservation*, 296, 110-724. DOI: <https://doi.org/10.1016/j.biocon.2024.110724>

APPENDIX

Appendix 1. List of localities of *Sorghum halepense* in Slovakia (the records are arranged according to the phytogeographical division of Slovakia published by Futák, 1980). The localities are arranged in a west-east direction. The data for each site is listed in the following order: settlement, elevation, description of site, habitat.

Pannonian region (Pannonicum)

1. **Burda Hills:** Kamenica nad Hronom, 113 m, on the slope below the railway station to Chĺaba (Svobodová 1987 NI; Svobodová 1989: 22). – Kamenica nad Hronom, 129 m, road edge (Eliáš jun. 2012 NI; Kotlárová et Tomovičová 2024 ined.). – Kováčov, 105 m, along the road to Chĺaba, near the hospice (Eliáš jun. 2014 NI). – Chĺaba, 117 m, along the road on the western outskirts of the village, extensive stands (Eliáš jun. 2007 NI; Kotlárová et Tomovičová 2024 ined.).
2. **Ipeľsko-rimavská brázda Region:** between the villages Čata and Zalaba, 119 m, in the fields (Hostička et Zelený 1957 PRC). – Kamenín, 113 m, corn field on the left bank of the Perc River (Eliáš jun. 2023 NI). – Salka, 105 m, corn field (Svobodová 1987, 1988 NI). – Sikenička, 117 m, fallow under the vineyards (Svobodová 1983 NI; Svobodová 1989: 22). – Lučenec, 179 m, in the railway station (Hrivnák 2012, herb. Hrivnák). – Kmet'ovce, 231 m, road No. 51 to Levice, south-western outskirts of the village, by the road (Kotlárová et Eliáš jun. 2024 NI). – Levice, 156 m, road No. 51 near the military training ground, by the road (Eliáš jun. 2023 ined.). – Jur nad Hronom, 149 m, road No. 76, by the road (Eliáš jun. 2024 ined.). – Hontianska Vrbica, 150 m, road No. 75 from the crossroads to Zbrojníky to the western edge of the village of Demandice, by the road (Eliáš jun. 2024 ined.). – Dolné Semerovce, 152 m, road No. 75 at the crossroads to the village, by the road (Eliáš jun. 2024 ined.). – Hrkovce, 117 m, road No. 66 on the north-western outskirts of the village, by the road (Eliáš jun. 2024 ined.). – Ipeľský Sokolec, 117 m, by the road (Kotlárová et Tomovičová 2024 ined.). – Horné Semerovce, 134 m, north of the village, junction of roads No. 66 and 75 (Eliáš jun. 2012 NI). – Dolné Túrovce, 141 m, northwest of Šahy, southern foot of the Regijské hegy hill (Chrtek et Soják 1957 PRC).
6. **Podunajská nížina Lowland:** Bratislava, 131 m, the Nivy city part, the old Danube harbour (Feráková 1972 SLO; Jehlík 1973; Eliáš 1979 SAV; Eliáš 1985 SAV; Jehlík 1986 PR; Jehlík 1979 – 1981, 1985, 1986, 1988, 1990, 1991 PRA). – Bratislava, 134 m, street on Trnávka city part (Feráková et Schwarzová 1974: 42). – Bratislava, 134 m, Tomášikova street (Feráková 1973, 1974 SLO; Jehlík 1973 PRA). – Bratislava, 133 m, Rožňavská street (Jarolímek 1980 SAV). – Bratislava, 132 m, Vajnorská street (Feráková et Májovský et al. 1976: 14). – Bratislava, 133 m, construction site near the swimming pool Delfín (Jarolímek 1981 SAV). – Bratislava, 146 m, Račianska street on the railway siding from the railway station Bratislava - Predmestie near the oilseed processing factory Palma (Jehlík 1980 PRA; Jehlík et al. 1984, 1985, 1988, 1990, 1991 PRA). – Bratislava, 145 m, Račianska street, near the J. Dimitrov Chemical Plant (Jarolímek 1980 SAV). – Bratislava, 145 m, Račianska street, yard at the mill Union (Dostálek et Jehlík 1985 in Jehlík 1998). – Bratislava, 136 m, Petržalka city part, yards, ruderal on building site (Feráková, Drábová et Halada 1984 SLO; Drábová-Kochjarová 1987: 42). – Bratislava, 139 m, ruderal areas around the ice rink (Jehlík 1986, 1987 PRA; Svobodová 1989: 22). – Bratislava, 130 m, nature reserve Topoľové hony, in a meadow after the end of field cultivation (Eliáš jun. et Galvánec 2021 NI). – Rusovce, 130 m, road near the state border (Votavová et Májovský 1971 SLO). – Gabčíkovo, 112 m, field edge (Jos. Dvořák 1975 BRA). – Sereď, 126 m, railway station

(Dostálek et Jehlík 1983 in Jehlík 1998). – Sládkovičovo, 119 m, in the area of the sugar factory (Feráková 1986 SLO). – Okoč, on the southwestern outskirts of the village, edge of the dirt road (Eliáš jun. 2016 NI). – Komárno, 107 m, field edge (Reuss 1853: 454; Ferd. Weber 1936 BRA). – Komárno, 106 m, Danube harbour (Jehlík 1986, 1988, 1990 – 1992 PRA). – Komárno, 108 m, on the road to Chotín (Dostál 1955 PR). – Komárno, 105 m, Ďulov dvor, west of the Komárno – Chotín road, in the corn field (Svobodová, Svobodová et Kropáč 1989 NI; Jehlík et Svobodová 1990 NI; Svobodová 1991: 53). – between Komárno and Chotín, 106 m, corn field (Svobodová et Kropáč 1989 in Jehlík 1998). – Komárno, 108 m, road No. 63 near the west side of the town, edge of the road (Eliáš jun. 2012 NI). – Komárno, 108 m, west of the village in front of Nová Stráž, road No. 63, edge of the road (Eliáš jun. 2024 ined.). – Komárno – Lándor, 109 m, road No. 1463 about 0.5 km south of the settlement, edge of the road (Eliáš jun. 2024 ined.). – Hliník near the village of Martovce, 106 m, corn field (Dostál 1954 PR). – Hurbanovo, 110 m, near Hliník, in corn field (Osvačilová 1954 NI). – Hurbanovo, 113 m, (cultivated?) in gardens (Schiller 1865: 383). – Hurbanovo, 108 m, part of Zelený Háj, road No. 63 on the northern outskirts of the village, edge of the road (Eliáš jun. 2024 ined.). – Hurbanovo, Zelený Háj, 107 m, southern outskirts of the village, field of pea and edge of the road (Eliáš jun. 2024 ined.). – Hurbanovo, 123 m, south-eastern edge of the village, edge of the road to Svätý Peter (Eliáš jun. 2013 NI; Eliáš jun. 2024 ined.). – Svätý Peter, 118 m, western outskirts of the village, edge of the road No. 1467 (Eliáš jun. 2024 NI). – Zbehy, 151 m, railway station (Dostálek et Jehlík 1985 PRA, PR). – Malé Čiky, 114 m, farmstead near the village of Palárikovo (Ferd. Weber 1971 PR). – Jatov, 113 m, southern outskirt of the village, edge of the road ditch No. 75 (Eliáš jun. 2018 NI; Eliáš jun. 2024

ined.). – Kolárovo, 108 m, Sady settlement, field by the shore of the Listové jazero lake (Eliáš jun. 2020 NI). – Kolárovo, 109 m, edge of the road by the cemetery (Eliáš jun. 2013 NI). – Gbelce, 123 m, on the road to the village of Šarkan, in a field (Eliáš jun. et Sirbu 2012 NI). – Gbelce, 128 m, edge of the road behind the railway viaduct (Eliáš jun. et Sirbu 2012 NI; Kotlárová et Tomovičová 2024 ined.). – Dunajská Lužná, 130 m, road No. 63 (Eliáš jun. 2012 NI). – Kolárovo, 109 m, road No. 573 to the south, on the outskirts of the town, edge of the road (Eliáš jun. 2012 NI). – Kameničná, 111 m, Balvany farmstead, road No. 573 south of the settlement, edge of the road (Eliáš jun. 2015 NI). – Kameničná, 107 m, Balvany farmstead, field north of the old graveyard (Eliáš jun. 2014 NI). – Trstice, 109 m, road No. 651 on the eastern edge of the village, edge of the road (Eliáš jun. 2015 NI). – Trávník, 112 m, edge of the road (Eliáš jun. 2015 NI). – Čičov, 110 m, edge of the road on the northern outskirts of the village (Eliáš jun. 2015 NI). – Komoča, 109 m, road No. 563 on the southern outskirts of the village, edge of the road (Eliáš jun. 2015 NI). – Topoľčany, 173 m, railway station (Dostálek et Jehlík 1983 in Jehlík 1998). – Komoča, 109 m, southern outskirts of the village near the road to Kolárovo (Eliáš jun. 2013 NI). – Komoča, 113 m, road No. 563, east of the village near the Jewish, edge of the road (Eliáš jun. 2024 ined.). – Nitra, 139 m, Topoľová Street opposite the Topoľová Primary School on the area after the tree was cut down (Eliáš jun. 2016 NI). – Nitra, 150 m, edge of the road by the cemetery (Eliáš jun. 2022 NI). – Nitra, 140 m, edge of the road at the intersection of Dlhá and Spišská streets (Eliáš jun. 2020 NI). – Pohranice, 213 m, road No. 65 before the junction with the road to Koliňanský vrch hill, edge of the road (Kotlárová et Eliáš jun. 2023 ined.). – Vlčany, 112 m, northern outskirts of the village near the road No. 573 to Šaľa, edge of the road (Eliáš jun. 2015 NI). – Kuraľany, 150 m, by the

road to Farná (Eliáš jun. 2014 NI). – Dvory nad Žitavou, 120 m, on the road to Kolta (Eliáš jun. 2014 NI). – Keť, 150 m, by the road to Bíňa (Eliáš jun. 2014 NI). – Kamenný Most, 111 m (Deyl 1976 BRA). – Vozokany (near Dunajská Streda), 116 m, edge of the bank of the Čierna voda stream, waste dump (Eliáš jun. 2012 NI). – Belá, 215 m, edge of the road ditch on the northern outskirts of the village (Eliáš jun. 2020 NI). – Chotín, 108 m, on the southern outskirts of the village near the farm, edge of the road (Eliáš jun. 2020 NI). – Boleráz, 167 m, part of Klčovany, road No 51, southern outskirts of the village, edge of the road (Eliáš jun. 2018 NI). – Veľký Meder, 110 m, crossroads of roads E575 (No. 15) and Ižop Pusta, edge of the road (Eliáš jun. 2019 NI). – Medveďov, 112 m, road No. E575 by the Slovnaft petrol station, edge of the road (Eliáš jun. 2019 NI). – Kolárovo, 109 m, road No. 1455 near the Částa farmstead (Částa-Bokoň), edge of the road (Eliáš jun. 2019 NI). – Telince, 153 m, southern edge of the road (Eliáš jun. 2022 NI). – Okánikovo, 108 m, at the crossroads of roads No. 63 and 1458 (Eliáš jun. 2024 ined.). – Zlatná na Ostrove, 108 m, road No. 63 at the junction with the road to the Horná Zlatná lighthouse, edge of the road (Eliáš jun. 2024 ined.). – Nové Zámky, 119 m, road No. 75, edge of the road (Eliáš jun. 2024 ined.). – Nové Zámky, 109 m, road No. 563 near the gardening settlement Tekvičné pole, edge of the road (Eliáš jun. 2024 ined.). – Čalovec, 109 m (Michalko 1951 SLO). – Čalovec, 109 m, road edges in the settlement (Eliáš jun. 2024 ined.). – Jatov, 111 m, Kendereš lighthouse, edge of the road (Eliáš jun. 2024 ined.). – Zlaté Moravce, 211 m, road No. 65 to the settlement of Olichov, edge of the road (Eliáš jun. 2024 ined.). – Dulovce, 161 m, southern outskirts of the village, edge of the road (Eliáš jun. 2024 ined.). – Dulovce, 164 m, eastern edge of the village, edge of the road (Eliáš jun. 2024 ined.). – Pribeta, 130 m, west of the village, edge of road No. 509 (Eliáš jun. 2024 ined.).

– Bajč, Chrasť farmstead, 123 m, road No. 509, edge of the road (Eliáš jun. 2024 ined.). – Palárikovo-Ľudovítov, 116 m, road No. 75, edge of the road (Eliáš jun. 2024 ined.). – Nová Vieska, 139 m, edge of the road (Kotlárová et Tomovičová 2024 ined.). – Bátorové Kosihy, 131 m, edge of the road (Kotlárová et Tomovičová 2024 ined.). – Šrobárová, 118 m, edge of the road (Kotlárová et Tomovičová 2024 ined.). – Marcelová, 120 m, edge of the road (Kotlárová et Tomovičová 2024 ined.). – Nesvady, 112 m, edge of the road (Kotlárová et Tomovičová 2024 ined.). – Holanovo, 108 m, edge of the road (Kotlárová et Tomovičová 2024 ined.). – Mužla, 125 m, road No. 509 opposite to Dankov vrch hill, corn field (Eliáš jun. 2013 NI). – Štúrovo, Belianske kopce hills, 257 m, fallow, fields and orchards (Svobodová 1981, 1982, 1985 NI; Svobodová et Řehořek 1987 NI; Svobodová 1989: 22). – Štúrovo, 117 m, railway station (Jehlík 1976 PRA). – Štúrovo, 122 m (Svobodová 1982 in Jehlík 1998 Cizí expanzivní plevelé České republiky a Slovenské republiky).

8. Východoslovenská nížina Lowland: Slovenské Nové Mesto, 109 m, north of the OMW chopping station (road No. 79), edge of the road (Dudáš 2020 KO; Eliáš jun. 2020 NI; Kotlárová, Tomovičová et Eliáš jun. 2024 ined.). – between Nový Ruskov and Trebišov, 116 m (Kotlárová, Tomovičová et Eliáš jun. 2024 ined.). – Borša, 107 m, northern outskirts of the village (Kotlárová, Tomovičová et Eliáš jun. 2024 ined.). – Trebišov, 109 m, southwestern outskirts of the village near the road No. 79 (Kotlárová et Eliáš jun. 2024 NI). – Somotor, 96 m, edge of the road by the railway crossing, south of the village (Eliáš jun. 2015 NI). – between Zalužice and Lúčky 111 m (Kotlárová, Tomovičová et Eliáš jun. 2024 ined.). – Dobrá, 100 m, grain transshipment site (Jehlík 1977 PRA). – Čierna nad Tisou, 100 m, railway transfer station (Jehlík et Krippelová 1966 PR, PRA, SAV; Jehlík 1968 PRA).

Carpathian region (Carpaticum)

- 10 Malé Karpaty:** Bratislava, 280 m, near Lamačská cesta road (Opluštilová PRC).
- 14d. Poľana Mts:** Podkriváň, 427 m, road No. 16 and 526, edge of the road (Kotlárová, Tomovičová et Eliáš jun. 2024 ined.).
- 19. Slanské vrchy hills:** Košické Olšany, 189 m, edge of traffic roundabout west from the village (Kotlárová, Tomovičová et Eliáš jun. 2024 ined.).
- 20. Vihorlat hills:** Podhorod', 322 m, near the fence of the border police building, edge of the road (Eliáš jun. 2007 NI).
- 30c. Nízke Beskydy Mts:** Podčičva, part Čičva, 128 m, in the village, edge of the road (Kotlárová, Tomovičová et Eliáš jun. 2024 NI).

Unclear data

- 6. Podunajská nížina Lowland:** Komárno – Tôň – Klížska Nemá (Májovský 1951 SLO). The herbarium label does not provide further information, so it is not clear whether these are separate localities or the area between these settlements.