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Contribution to the knowledge of class *Sisymbrietea* Gutte et Hilbig 1975 in Bulgaria through newly established synanthropic associations

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Abstract

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This research aimed to contribute the knowledge on the syntaxonomy and ecology of class *Sisymbrietea* Gutte et Hilbig 1975 on the territory of Bulgaria. During the period 2018–2023, 297 phytocoenological relevés with a plot size of 10–16 m^2 following the Braun-Blanquet approach were collected. All relevés were contributed to the Balkan Vegetation Database (EU-00-013) and nomenclature of species was standardized according to the Euro+Med PlantBase. The hierarchical clustering was performed using the PC-ORD software package using Bray-Curtis dissimilarity and flexible beta clustering algorithm. The diagnostic species were determined by calculating the Phi-coefficient and only the statistically significant values, evaluated by Fisher's exact test ($P < 0.05$), were considered.

As a result of investigation were found four new ruderal associations (*Descurainietum sophiae*, *Hordeo murini-Brometum sterilis*, *Linario-Brometum tectorum* and *Aegilopsietum cylindricae*) for Bulgarian vegetation. *Descurainietum sophiae* association is typical for areas with nitrophilization, while the other three associations occur within agrocoenoses, other anthropogenic territories or in altered grasslands.

Keywords: ecology; new associations; syntaxonomy; ruderal vegetation

Introduction

The *Sisymbrietea* Gutte et Hilbig 1975 class (syn.: *Onopordo-Sisymbrietea* Görs 1966 p.p.; *Stellarietea mediae* Tüxen et al. ex von Rochow 1951 p.p.) unites zoo-anthropogenic, moderately to strongly nitrophilous ruderal plant communities of disturbed sites, such as animal shelters, agricultural fields, gardens, and wastelands across the cool- and cold-temperate regions of Eurasia (Ellenberg, 1988; Rodwell et. al., 2002; Lososová et al., 2009; Mucina et al., 2016). It is mesic to dry vegetation consisting mainly of therophytes, formed on open ground in or near urban areas, beside railway lines, landfills, embankments and wastelands, and in sand and gravel pits also (Dengler and Wollert, 2004; Ninot et al., 2010). The habitats represent early-successional, mostly annual anthropogenic herba-

ceous vegetation, established on poorly or well developed mesotrophic to eutrophic soils (Mucina et al., 2016; Chytrý et al., 2024).

At European level, the *Sisymbrietea* class is represented by two orders: *Sisymbrietalia sophiae* with four alliances – *Atriplicion*, *Cannabidion sativae*, *Malvion neglectae*, *Sisymbrion officinalis*, and *Hackelio deflexae-Blitetalia foliosi* with one alliance only – *Erysimo wittmannii-Hackelion* (Mucina et al., 2016; Chytrý et al., 2024). Diagnostic species at class level are *Sisymbrium officinale*, *S. orientale*, *S. irio*, *S. loeselii*, *S. polyceratium*, *S. altissimum*, *Bromus squarrosus*, *B. tectorum*, *B. sterilis*, *Avena barbata*, *Lactuca serriola*, *Chenopodium murale*, *Amaranthus albus*, *A. retroflexus*, *Conyza canadensis*, *Diplotaxis muralis* (Dengler and Wollert, 2004; Foucault, 2012). Such vegetation could be assigned to *Stellarietea mediae* class (Čarni, 2005; Jarolímek et al., 2008; 1997; Lososová et al., 2009) or *Chenopodietea* class (Mucina, 1982; Oberdorfer, 1993; Stančić, 2014) also.

While some studies of *Sisymbrietea* class have been conducted in Bulgaria (Tzonev & al. 2009; Apostolova 2023), they were sporadic and a significant knowledge gap still exists regarding this neglected vegetation type. New ruderal plant communities related to *Sisymbrietalia* order were described from four localities along the Bulgarian Black Sea coast (Glogov and Georgieva, 2021).

This paper aims to explore the floristic composition, syntaxonomy and distribution patterns of the ruderal vegetation of *Sisymbrietea* class in whole area of Bulgaria.

Material and Methods

Study area

Plant communities of the class *Sysymbrietea* are located in different geographical areas throughout the country. The majority of them are distributed in the Thracian Valley, the Forebalkan, the Danubian Plain, the valleys of Sofia and Struma River, and the Eastern Rhodopes. They offer an ample diversity from geological, geomorphological, climatic, water and soil point of view. The majority of the communities are distributed along the Transitional Climate Zone (Velev, 2010). The rivers are represented by Maritsa, Osam, Yantra, Rositza and Struma (Hristova, 2012). Soils are mainly Fluvisols, Phaeozems, Chernozems, Vertisols, Cambisols (Ninov, 2002).

Data collection and statistical analysis

Two hundred and ninety seven vegetation plots (relevés) during 2018–2023 years representing phytocoenoses of *Descurania sophia*, *Aegilops cylindrica*, *Bromus tectorum* and *Anisantha sterillis*, which are classified to the *Sisymbrietea* class from the territory of Bulgaria, following the Braun-Blanquet approach (Westhoff & van der Maarel, 1973) were sampled. The sample plots were square-shaped with size in the range 10–16 m^2 (Chytrý and Otýpková, 2003). Altitude, slope, inclination and location were measured by Garmin eTrex Vista device for all relevés, whereas the slope aspect was determined by a compass. For each relevé full species list was recorded, as well as the total vegetation cover and the cover of the herb layer. All of the relevés were stored in the Balkan Vegetation Database (Vassilev et al., 2020). The selected relevés were analyzed using PC-ORD (McCune & Mefford, 1999) and JUICE 7.0 (Tichý, 2002) software packages. Bray-Curtis was used as a distance measure and dissimmilarity was calculated by the flexible beta clustering method. The clusters obtained were standardized to equal size. The diagnostic species were determined by calculating the Phi-coefficient. Only the statistically significant Phi-coefficient values, evaluated by Fisher's exact test (*$P < 0.05$) were considered. In the synoptic table the threshold value for a species to be considered a diagnostic one was set up at Phi-coefficient ≥ 0.3 (multiplied by 100). They were ordered by decreasing of their fidelity value (Table 1). The diagnostic role of the species was also considered on the basis of the available literature sources. Two values were assigned to each species in the synoptic table: "Fidelity" – expressed as a Phi-coefficient and "Frequency" expressed in percentage. Species with a coverage of above 50% in at least in 20% of the relevés in any cluster were considered as dominants, whereas constant species were those having at least 50% presence in a cluster. Detrended Correspondence Analysis (DCA) was used as indirect ordination technique using the CANOCO 4.5 software package (ter Braak & Šmilauer, 2002) to reveal the major environmental gradients determining vegetation distribution. Square root transformation and downweighting of the rare species were applied.

The nomenclature of the vascular plants followed Delipavlov & Cheshmedzhiev (2003) and was subsequently standardized according to the Euro+Med PlantBase (September 2024). The nomenclature of the high-rank syntaxa was harmonized with Mucina et al. (2016). We also merged the following taxa into broadly defined aggregates: *Carduus nutans* agg. (C*arduus nutans*, *C. nutans subsp. leiophyllus*), *Heracleum sphondylium* agg. (*Heracleum sphondylium*, *Heracleum sphondylium* subsp. *sibiricum*), *Lamium purpureum* agg. (*Lamium purpureum*, *Lamium purpureum* var. *hybridu*m), *Poa trivialis* agg. (*Poa trivialis*, *Poa trivialis* subsp. *sylvicola*), *Vicia sativa* agg. (*Vicia sativa*, *Vicia sativa* subsp. *cordata*, *Vicia sativa* subsp. *nigra*).

Results and Discussion

Based on numerical analysis, the relevés from Bulgaria belonging to the class *Sisymbrietea* are classified to 1 order, 2 alliances and 4 associations. All of the associations have been studied for the first time in the whole country. The proposed syntaxonomical scheme is:

Cl. *Sisymbrietea* Gutte et Hilbig 1975
Ord. *Sisymbrietalia sophiae* J. Tx. ex Görs 1966
All. *Atriplicion* Passarge 1978
Ass. *Descurainietum sophiae* Kreh 1935
All. *Sisymbrion officinalis* Tx. & al. ex von Rochow 1951
Ass. *Aegilopsietum cylindricae* Buia et al. 1959
Ass. *Hordeo murini-Brometum sterilis* Lohmeyer ex von Rochow 1951
Ass. *Linario-Brometum tectorum* Knapp 1961

Syntaxa description

Ass. *Linario-Brometum* tectorum Knapp 1961 (Table 1, Cluster 1-LB)

Constant species: *Convolvulus arvensis*; Dominant species: *Bromus tectorum*

Distribution and ecology: The association was typical for areas with southern exposition between 41 and 705 m a.s.l. (204 m a.s.l. in average) on flat or slightly inclined terrains up to 5 degrees. Soils were moderately deep, normally with sandy structure. This ruderal vegetation occurs in abandoned agricultural lands, near ditches, roads and other anthropogenic infrastructure and is developed predominantly in May and June.

Vegetation description and syntaxonomy: The phytocoenoses of the association had semi-open to closed horizontal structure (total coverage is 93% in average). Sporadic shrubby species, such as *Crataegus monogyna*, *Ulmus minor*, *Prunus spinosa*, *Rubus* spp., occurred here, as well. *Bromus tectorum* is the dominant species, having a coverage of 60–85%. The species of *Convolvulus arvensis*, *Hypecoum pendulum*, *Anthemis ruthenica*, *Lolium perenne* have a projective coverage of 10–15% in some of the plots. The species diversity is between 4 and 32 species (17 on average).

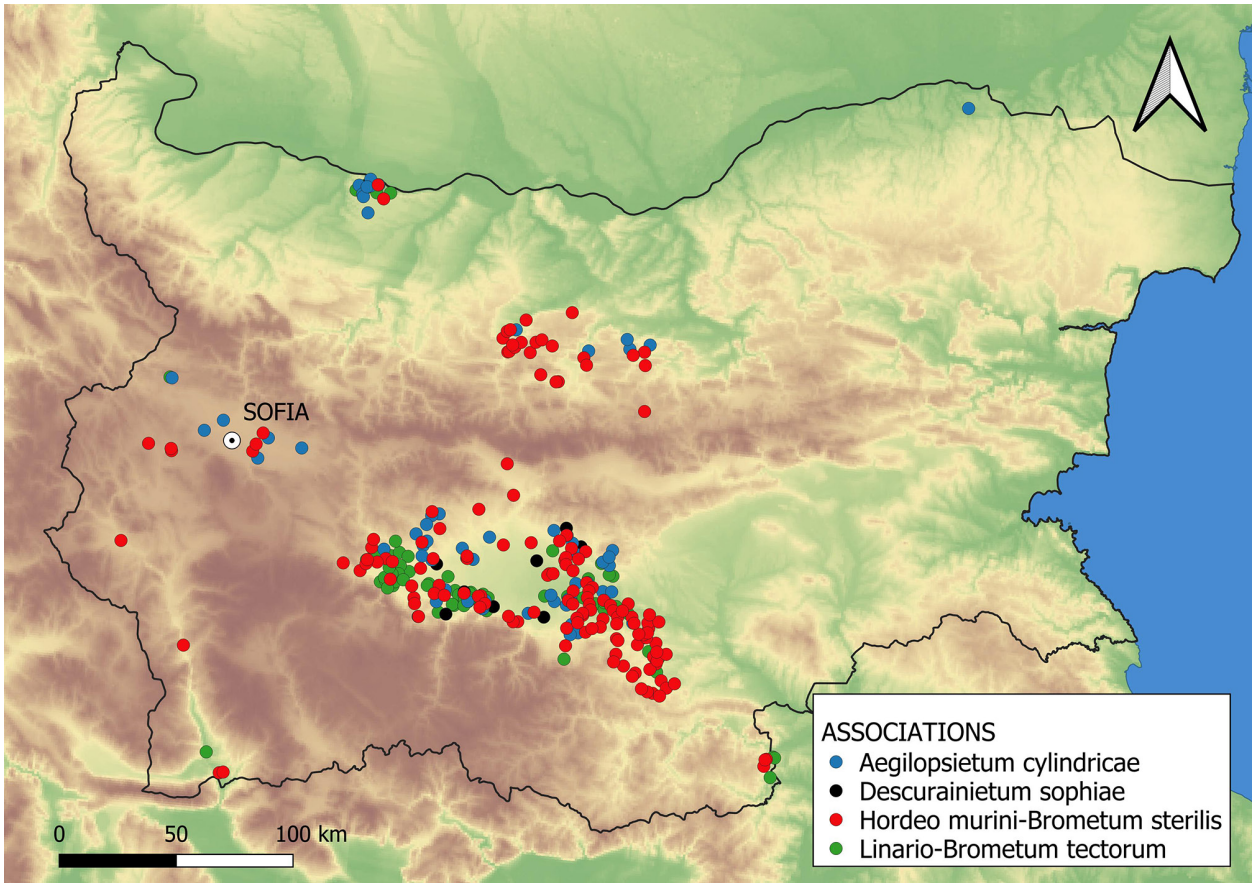

Fig. 1. Distribution of the studied associations in Bulgaria

Ass. *Descurainietum sophiae* Kreh 1935 (Table 1, Cluster 2-DS)

Constant species: *Capsella bursa-pastoris*, *Geranium pusillum*; Dominant species: *Descurainia sophia*

Distribution and ecology: The maximum of this vegetation was typically during the months of May and June. The stands were restricted to sites with substrates rich in nitrates with southern exposition (dump sites, embankments, ditches, etc.), and were typical for the Thracian and the Danubian Plains (Fig. 1). Terrains were generally flat, with few exceptions where there was slight inclination up to 3 degrees. Soils were moderately deep, covered with a fallow mass from previous years.

Vegetation description and syntaxonomy: The phytocoenoses of the association were with a closed horizontal structure with a total cover of 95–100%. They had two layers: higher and lower. The higher was dominated by *Descurainia sophia*, while *Malva sylvestris*, *Stellaria media*, *Lamium purpureum* agg., *Geranium pusillum*, etc. occurred in the lower. The species composition included 8 to 24 species (15 in average). Some diagnostic species of the cl. *Papaveretea rhoaeadis*, such as *Stellaria media*, *Lamium purpureum* agg., *Veronica hederifolia*, etc. and cl. *Artemisietea vulgaris*, such as *Onopordon acanthium*, *Ballota nigra*, *Lepidium draba*, *Asperugo procumbens*, etc. occurred as well.

This association is well-known from the Czech Republic (Lososová et al., 2009).

Ass. *Aegilopsietum cylindricae* Buia et al. 1959 (Table 1, Cluster 3-AC)

Constant species: *Convolvulus arvensis*, *Capsella bursa-pastoris*; Dominant species: *Aegilops cylindrica*

Distribution and ecology: This association had wide distribution in the country but still was locally investigated in Thracian plain, Dabubian plain, Forebalkan, Sofia lowland, Western Sredna gora Mts and North-Eastern Bulgaria. It represented ruderal vegetation, typical for agricultural areas. It formed bands between agricultural roads. Typically, it was well developed in May and June, still there were cases when this process occurred in the first half of July in warmer places. It was found between 31 and 709 m a.s.l. Terrains were flat, the soils were moderately-deep, sometimes shallow, dry mostly during the entire vegetation season. The phytocoenoses were often trampled.

Vegetation description and syntaxonomy: The phytocoenoses had mainly closed horizontal structure and with total cover of 85–100% (average 95%). Species richness was between 6 and 38 (16 on average). The vegetation dominated by *Aegilops cyindrica*, having cover of 65–95%. Other species with a cover above 10% were *Lolium perenne, Poa angustifolia*, *Polygonum aviculare*, *Convolvulus arvensis*, *Lepidium draba*, *Achillea millefolium*, *Sclerochloa dura*. Some diagnostic species for cl. *Polygono-Poetea annuae* (such as *Lolium perenne*, *Polygonum aviculare*, *Sclerochloa dura*), cl. *Papaveretea rhoaeadis* (such as *Matricaria chamomilla*, *Poa bulbosa*, *Avena fatua*) and *Digitario sanguinalis-Eragrostietea minoris* (such as *Cynodon dactylon*, *Convolvulus arvensis*) were found too.

Ass. *Hordeo murini-Brometum sterilis* Lohmeyer ex von Rochow 1951 (Table 1, Cluster 4-HB)

Constant species: *Convolvulus arvensis*, *Galium aparine*; Dominant species: *Anisantha sterillis*

Distribution and ecology: This vegetation type was widespread in the warmer parts of the country (Thracian Plain, Sofia Valley, Danubian Plain) and on slopes with southern exposition of semi-mountainous areas (Forebalkan, Eastern Balkan Range). Typically, it was found close to agricultural areas, roads and road ditches. This vegetation occurred between 31 and 752 m a.s.l. on flat or slightly inclined terrains with an inclination of up to 5 degrees. Soils were sandy, moderately deep.

Vegetation description and syntaxonomy: The phytocoenoses of this association were characterized with semi-open to closed horizontal structure with total cover in the range 75–100%. Species composition was represented by 4 to 35 taxa (17 on average). These phytocoenoses were monodominant – *Anisantha sterillis* had cover between 50% and 90%. Other typical species with cover of 10–20% were *Convolvulus arvensis*, *Torilis nodosa*, *Lepidium draba*, *Veronica hederifolia*, *Geranium pusillum*, *Avena fatua* and *Cota austriaca*. Ruderal species, such as *Rumex crispus*, *Torilis arvensis* and *Lactuca serriola* were present also. Some species from the neighbouring xerothermic phytocoenoses, like *Agrimonia eupatoria* and *Poa angustifolia* occurred as well.

The species composition and vegetation structure of the association found in Bulgaria are similar to those described in other European countries (Lososová et al., 2009).

Vegetation–environment relationships

The examined associations are clearly distinguished within the ordination space, reflecting the underlying ecological gradients (Fig. 2). Trampling is prevalent in the plots of the first association, where anthropogenic activities are notably intense. The *Aegilopsietum cylindricae* association thrives in these disturbed habitats, in contrast to the other associations, which exhibit minimal human impact. Nitrification is particularly pronounced in the second association. The *Descurainietum sophiae* association is typically found near dump sites filled with manure or animal pens. The re-

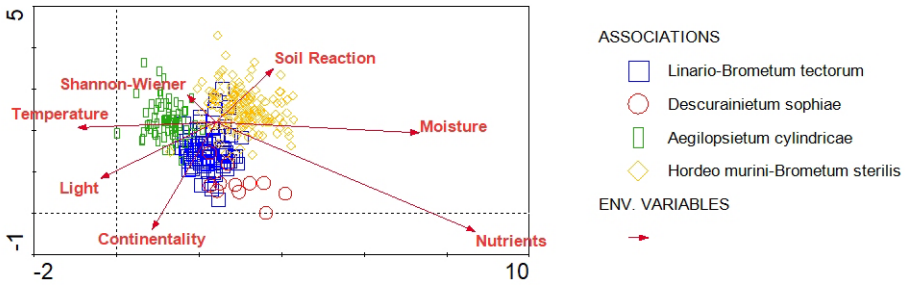

Fig. 2. Ordination diagram of the analyzed data set along the first two axes. Variables (Shannon-Wiener Index, Ellenberg Indicator Values) passively projected onto the ordination space

Table 1. Shortened synoptic table of class *Sisymbrietea*. Fidelity is given as Phi, whereas Percentage frequency is given as PF

Number of cluster	1		2		3		4	
Syntaxa	LB		DS		AC		HB	
Number of relevés	73		11		66		147	
Phi/PF	Phi/PF		Phi/PF		Phi/PF		Phi/PF	
Diagnostic species for ass. *Linario-Brometum tectorum*								
Bromus tectorum[2]	76.4	100	---	27	---	17	---	1
Anthemis ruthenica	47.1	38	---	0	---	5	---	5
Hypecoum pendulum	31.9	15	---	0	---	0	---	1
Diagnostic species for ass. *Descurainietum sophiae*								
Descurainia sophia[1]	---	14	88.9	100	---	2	---	3
Malva sylvestris	---	4	65.1	64	---	3	---	6
Stellaria media	---	19	31.7	45	---	3	---	22
Onopordum acanthium	---	8	31.1	27	---	3	---	4
Diagnostic species for ass. *Aegilopsietum cylindricae*								
Aegilops cylindrica[2]	---	3	---	9	88.2	100	---	8
Polygonum aviculare	---	3	---	0	45.4	32	---	2
Plantago lanceolata	---	14	---	0	45.2	48	---	11
Lolium perenne	---	16	---	18	42.9	58	---	9
Cynodon dactylon	---	22	---	9	40.8	55	---	12
Poa bulbosa	---	14	---	0	40.5	38	---	3
Matricaria chamomilla[2]	---	11	---	0	36.2	36	---	10
Bromus arvensis	---	1	---	0	35.4	23	---	4
Cichorium intybus	---	8	---	0	31.5	36	---	20
Diagnostic species for ass. *Hordeo murini-Brometum sterilis*								
Anisantha sterilis[2]	---	10	---	18	---	24	73.7	100
Rumex crispus	---	14	---	0	---	3	32.9	30
Diagnostic species for ord. *Sisymbrietalia sophiae* & cl. *Sisymbrietea*								
Capsella bursa-pastoris	---	49	23.4	73	4.1	56	---	32
Hordeum bulbosum	---	1	---	0	---	2	22.5	10
Convolvulus arvensis	---	58	---	45	---	73	17.1	78
Cirsium arvense	---	1	---	0	---	2	13.6	5
Geranium pusillum	7.3	38	27.2	55	---	15	---	22
Sisymbrium orientale	---	11	29.6	27	---	2	---	5

Table 1. Continued

Vicia villosa	13.2	16	---	9	---	9	---	4
Erodium cicutarium	14.8	27	---	18	---	17	---	8
Tordylium maximum	---	5	---	0	---	5	17.8	13
Bromus hordeaceus	---	8	---	0	---	8	---	8
Lactuca serriola	---	18	---	27	---	21	7.9	30
Geranium dissectum	---	8	---	9	---	21	---	17
Hordeum murinum	---	29	---	36	---	29	---	23
Diagnostic species for cl. *Epilobietea angustifoliae*								
Galium aparine	---	37	---	27	---	5	28.3	53
Anthriscus cerefolium	---	0	---	0	---	2	17.8	6
Sambucus ebulus	---	0	---	0	---	2	16.4	5
Anthriscus caucalis	---	0	26.4	9	---	0	---	0
Cota altissima	---	0	26.4	9	---	0	---	0
Dasypyrum villosum	---	8	---	27	29.3	45	---	14
Cerastium glomeratum	---	14	---	9	---	11	---	10
Vicia sativa agg.	---	23	---	0	---	17	---	15
Diagnostic species for cl. *Papaveretea rhoeadis*								
Vicia pannonica	---	1	---	0	---	15	27.9	25
Torilis arvensis	---	12	---	0	---	3	25.6	22
Thlaspi alliaceum	---	3	---	0	---	0	16.7	7
Cephalaria transsylvanica	---	12	---	9	---	9	16,5	23
Fallopia convolvulus	---	5	---	0	---	2	15.7	10
Lamium purpureum agg.	---	15	---	36	---	3	14.5	32
Veronica hederifolia	---	0	---	9	---	2	8.2	7
Camelina sativa	1	7	27.7	18	---	0	---	1
Neslia paniculata	---	0	26.4	9	---	0	---	0
Lamium amplexicaule	13.6	22	---	18	---	8	---	7
Papaver rhoeas	14	42	---	45	---	9	---	28
Veronica arvensis	17.7	45	---	18	12.4	41	---	20
Viola arvensis	18.3	25	---	0	---	17	---	14
Alopecurus myosuroides	---	15	---	9	---	20	---	22
Cota austriaca	---	16	---	18	---	9	---	20
Diagnostic species for cl. *Artemisietea vulgaris*								
Linaria vulgaris	---	1	---	0	---	0	15.2	5
Conium maculatum	---	3	---	27	---	0	11.9	19
Lepidium draba	---	12	---	18	---	17	11.3	26
Ballota nigra	---	5	---	27	---	6	9.9	21
Rumex patientia	---	0	26.4	9	---	0	---	0
Asperugo procumbens	---	4	28.4	18	---	0	---	3
Centaurea solstitialis	---	12	---	9	19.9	33	---	24
Chondrilla juncea	23.2	32	---	9	---	12	---	14
Carduus acanthoides	---	11	---	18	---	6	---	11
Diagnostic species for cl. *Festuco-Brometea*								
Poa angustifolia	---	10	---	0	---	29	23.2	33
Agrimonia eupatoria	---	1	---	0	---	2	22.5	10

Abbreviations used for syntaxa: LB – ass. *Linario-Brometum tectorum*; DS – ass. *Descurainietum sophiae*; AC – ass. *Aegilopsietum cylindricae*; HB – ass. *Hordeo murini-Brometum sterilis*. Legend: 1 – Diagnostic species for all. *Atriplicion*, ord. *Sisymbrietalia sophiae* & cl. *Sisymbrietea*; 2 – Diagnostic species for all. *Sisymbrion officinalis*, ord. *Sisymbrietalia sophiae* & cl. *Sisymbrietea*.

maining associations represent ruderal phytocoenoses or altered grassland habitats.

The ecology and floristic composition of established syntaxa are similar to those of the associations that are distributed in the Southeastern and the Central Europe (Lososová et al., 2009), The phytocoenoses of the *Sisymbrietea* class are located in termophylic and sunny habitats and present different stages of succession of ruderal vegetation.

Conclusions

This study provides a comprehensive evaluation of the syntaxonomical diversity of the cl. Sisymbrietea in Bulgaria, highlighting the first documentation of four associations from this region, namely: *Descurainietum sophiae*, *Hordeo murini-Brometum sterilis, Linario-Brometum tectorum*, and *Aegilopsietum cylindricae*. All identified associations are characterized by monodominance of certain species, and their phenological optimum is from spring to summer seasons. Notably, the *Descurainietum sophiae* association is associated with nitrophilous conditions, while the other associations predominantly occur in agrocoenoses and other anthropogenically influenced areas. A distinctive feature of the *Aegilopsietum cylindricae* association is its adaptation to trampling. This research contributes valuable insights into the ecological dynamics of these associations and their response to anthropogenic influences in Bulgaria.

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