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The occurrence of ladybells (*Adenophora liliifolia*) in border meadow Drahos (Drahoše) near Hollóháza (NE Hungary) and Skároš (SE Slovakia)

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Abstract: The ladybells (*Adenophora liliifolia* (L.) Besser) is a glacial relict plant species and is endangered throughout Europe. The species is strictly protected in Hungary and listed in the Habitats Directive of the EU. It is a designating species of the HUBN20085 Északi-Zempléni-hegység Natura 2000 site in Hungary. The occurrence of the species is limited to very few localities both in Hungary and Slovakia. This study was undertaken to characterize the habitats of ladybells from a phytosociological perspective and analyse the structure of its population in Drahos (Drahoše) meadow. Two relevés were sampled, one at each side of the border. The number of individuals was recorded, and selected quantitative variables of the stem, leaves, and inflorescence of each individual were evaluated during eight years of the survey.

Keywords: *Adenophora liliifolia*, endangered species, Drahoše, morphological structure, population dynamics.

Introduction

The ladybells (*Adenophora liliifolia* (L.) Besser) is a vascular plant species of the Campanulaceae family and the only identified species of the genus *Adenophora* in Central Europe. It is a European-South-Siberian geoelement and is threatened with extinction throughout Europe. In Hungary, there were 30 occurrences before 1950,

but presently only six localities are known. The species occurs in the Zemplén Mountains, in the Aggtelek Karst and the Great Hungarian Plain between the rivers Danube and Tisza (Farkas & Vojtkó 2011, 2013).

The distribution of the species was estimated to consist of more than 60 localities in Slovakia, but most localities have not been confirmed in the last ten years. The species can be sporadically found at the foothill of the Carpathians and in the Carpathians from the Strážovske vrchy Mts. through the Malá Fatra Mts. and the Chočské vrchy Mts., to the Central and Lower Hornád Valley. It grows in forests with open canopy, in meadows with scattered shrubs in hilly and mountainous areas. It prefers calcareous or volcanic soils (Kmeťová 2008). Most of the populations are small in size and the number of populations has been gradually decreasing (Mereďa & Hodálová 2011).

The ladybells prefers moderately shaded habitats; in Hungary, the species grows on wet meadows belonging to the *Molinion* alliance, on dry grasslands (class *Festuco-Brometea*), occasionally on mountain hay meadows and in riparian mixed gallery forests (suballiance *Ulmenion*). In the Zemplén Mountains, it inhabits periodically inundated *Molinia* meadows (Farkas & Vojtkó 2011, 2013) (Fig. 1).

The first record of *Adenophora liliifolia* in the Zemplén region was published by Kitaibel from near Telkibánya in 1803, but no herbarium specimen was collected (Gombocz 1945). The species was found near Drahos by Simon (2000, 2005) in the Nagy-Almás-rét. It was one geographical unit with Drahos previously. Other authors used the geographical name Drahos (Lendvai 1999; Simon 2005; Vojtkó 2007).

The occurrence of ladybells has not been published on the Slovak side of Drahoše meadow until now and according to the Standard Data Form of the SKUEV0327 Milič Natura 2000 site, the species is not the subject of protection. Currently, the species is threatened by habitat destruction, grazing of wild animals and climate change. This study aims to describe the stands and habitat of ladybells from phytosociological point of view and investigate population dynamics.

Material and Methods

Study site

The strictly protected Drahos (Drahoše) meadow was studied in the Zemplén Mountains (NE Hungary) and the Slanské vrchy Mts. (SE Slovakia) (Fig. 2). This considerably species-rich meadow is situated at the height of 500–540 m a.s.l., at the border of Slovakia and Hungary (centre of the site coordinates: 48°33'43.11"N, 21°25'15.11"E). The study area is about 20 ha large, but the population is occupying only about 100 m^2. The study site is part of the SKUEV0327 Milič Natura 2000 site in Slovakia and HUBN20085 Északi-Zempléni-hegység Natura 2000 site in Hungary and it is a national protected area (Zempléni Tájvédelmi Körzet), too. The soil type is podsol and clay forest soil; the upper soil layer is semi-acidic and rich in humus. The bedrock consists of rhyolite and andesite. The mean annual temperature is 7.5–8.3 °C. The mean annual precipitation is about 700 mm and the maximum amount of precipitation falls in the summer (Dövényi 2010). The species inhabits periodically

Fig. 1 *Adenophora liliifolia* in Drahoše.

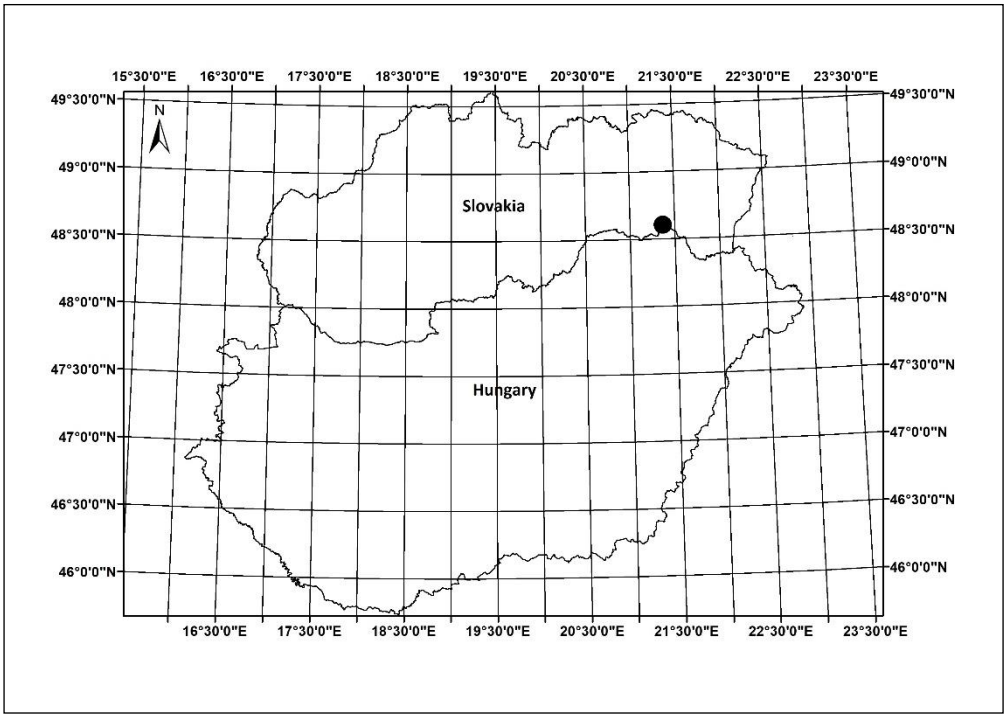

Fig. 2 Map of the studied localities of *Adenophora liliifolia*.

inundated *Molinia* meadow belonging to the association *Nardo-Molinietum hungaricae* (Kovács 1962). Other rare species co-occurring with ladybells in the area include *Achillea ptarmica*, *Gentiana pneumonanthe*, *Gladiolus imbricatus* and *Iris sibirica*.

According to Simon (1977), the meadows in the Zemplén Mountains were formed during the 17th–18th centuries after the clearing of oak forests (*Quercetum petreae-cerris* and *Querco petreae-Carpinetum*). Over the past 200–250 years the meadows have been mowed once a year, usually in July (Paládi-Kovács 1979). Traditional land management has gradually been abandoned since the 1960s. At present, the meadows are mowed only occasionally on the Hungarian side and remain unmanaged on the Slovak side of the locality (Fig. 3).

Methods

The population dynamics and morphological characteristics of the species were studied between 2011 and 2020. Each individual was marked, and the geographical coordinates of the individuals were recorded, too. The following variables were recorded for every individual: the number and height of stems, the surface area of each leaf, the number of flowers and capsules in inflorescence per stem. The individual was defined as stems less than 5 cm apart from each other. The basal leaf was grown directly from the rhizome, having long petiole with cordate to rounded

Fig. 3 Habitat of *Adenophora liliifolia* in Drahoše (Photo: Tünde Farkas, 15.08.2019).

base and coarsely serrate blades. The young plants have got only 1-5 basal leaves and haven't got any stems.

The grazing pressure was tested, too. The complete stem destruction and the partial destruction was taken into account, too.

All parameters were measured during full flowering from 15th to 25th August every year. The capsules were counted in September (between 10th and 20th).

Two 4×4 m plots were used for relevés recording in 15th August 2019, one in the Hungarian site and second in Slovakia. The percentage cover and abundance of all vascular plant species were assessed. Phytosociological relevés were made with the commonly used Braun-Blanquet method. The nomenclature of the species and the plant communities follows Király (2009) and Borhidi (2003), respectively. The coenological classification of the species is based on the system of Borhidi (1993).

Results

The number of individuals and the number of flowering stems showed a high year to year variation (individuals between 44 and 117 and flowering stems between 4 and 32). The highest number of flowering stems was recorded in 2020 (32 in total), and the least flowering stems were recorded in 2012 (Fig. 4 a, c).

The total number of stems ranged between 45 and 119. The number of stems per individual rarely exceeded two (Fig. 4 b).

The number of flowering stems increased markedly between 2011 and 2016 (from 3 to 27), then it was stable between 2017 and 2019 and increased markedly again to 33 in 2020 (Fig. 4 c).

Regarding inter-annual differences, the total number of flowers on the stems varied between 5 and 386. The highest number of flowers was found in 2020 (71 flowers per stem on average). This year the total number of flowers was 386.

In many cases, only a few capsules developed on the stems. The fruit ratio was 22–42 %. The highest capsule production was recorded in 2020, when more than 40 % of the flowers were fertilised and 164 capsules were produced. In other years, even if there were much more flowers, fewer capsules developed. In 2012, there was no capsule developed at all. According to our observations, the number of pollinators and the grazing intensity affected the number of flowers and capsules (Fig. 4 d).

The proportion of stems damaged by grazers was between 6.4 and 40.0 % (15–27 stems per year). That highest grazing rate was observed in 2011 and the lowest in 2019. The grazed stems could bloom and develop capsules, but these fruits did not contain seeds (Fig. 5).

When the mowed (Hungarian side) and non-mowed (Slovakian side) areas were compared, the results showed more young individuals with only basal leaves and more grazed stems but fewer flowers on the mowed areas. The number of old specimens with several flowers was higher on the non-mowed Slovakian side (Fig. 6 a, b).

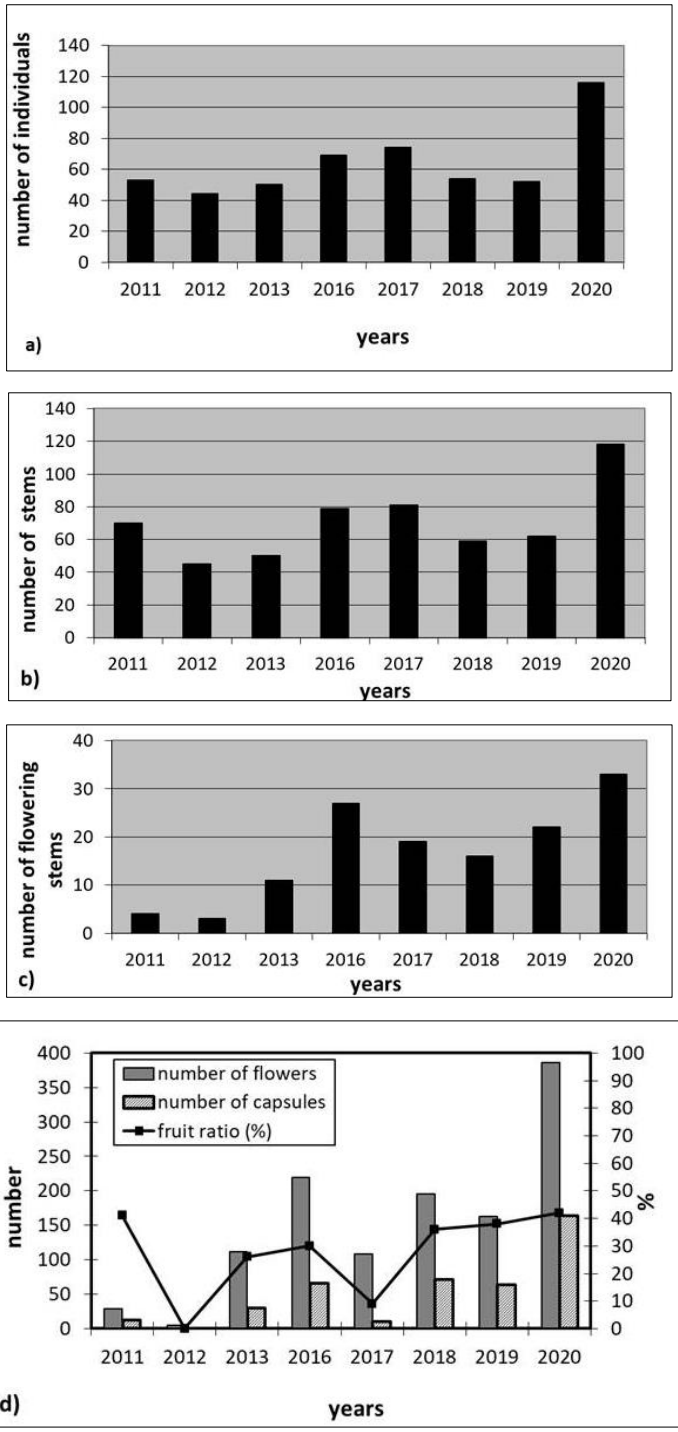

Fig. 4. The population dynamics and reproduction success of *Adenophora liliifolia* population at the locality Drahos (Drahoše) during eight years of survey. a) Number of individuals; b) Number of stems; Number of flowering stems; d) Number of flowers and capsules over the study years and the fruit ratio.

Tab. 1 Statistics of the studied stems of *Adenophora liliifolia* (2019).

Morphological characters	Values		
	mean	minimum	maximum
Number of stems per individual	1.2	1	3
Stem height (cm)	47.4	16	102
Number of leaves per stem	20.3	4	35
Leaf length (cm)	5.2	0.6	9.7
Leaf width (cm)	1.7	0.3	3.0
Number of flowers per stem	2.6	0	38
Number of capsules per stem	1.6	0	16
Leaf surface area (cm^2) per stem	92.9	4.8	383.4

Detailed information is presented about the number of stems per individual, stem height, number of leaves per stem, leaf length, leaf width, number of flowers per stem, number of capsules per stem, leaf surface area from 2019. These statistical data are listed in Tab. 1.

Only 1–3 stems per individual were found 2019. The mean value of the height of flowering plants was 47.4 cm, while the minimum and maximum values were 16.0 and 102.0 cm, respectively. The mean number of leaves was 20.3, and their mean length and width were 5.2 cm, respectively. The number of flowers varied between 0 and 38 per stem. From the 38 flowers only 16 fruits were formed. The total number of flowers was 163 this year. The leaf area per stem was measured, too.

The relationship was examined among stem height, leaf number and the number of flowers. We found that the number of flowers increased with increasing height and leaf number. The first flowers appeared at a 20-leaved stage and at a height of 50 cm, when the leaf surface area was 69.7 cm^2 (Fig. 7).

Comparing the syntaxonomical group spectrum of the species in the coenological relevés on the two sides of the border, we found that the share of the class *Querco–Fagetea* (this group includes: *Querco-Fagetea*, *Fagetalia*, *Quercetalia pubescentis-petraeae*, *Quercion petraeae-cerris* and *Aceri tatarico-Quercion*) elements is high (36–57 %) in the habitat. Corresponding species include *Ajuga reptans*, *Betonica officinalis*, *Carex pallescens*, *Pulmonaria molissima* and *Carpinus betulus*. The share of this group is higher on the Slovakian side than on the Hungarian one. The amount of the class *Molinio–Arrhenatheretea* (this group includes: *Molinietalia*, *Junco-Molinietum* and *Arrhenatheretalia*) elements (e.g. *Achillea ptarmica*, *Cirsium canum*, *Molinia caerulea* and *Sanguisorba officinalis*) and the dry grassland (class *Festuco-Brometea*) elements are higher in Hungary (24 % and 12 %) than in Slovakia (22 % and 0 %), possibly due to shrub clearing in the Hungarian side. In the Hungarian side the proportion of indifferent species, such as *Anthoxanthum odoratum*, *Potentilla erecta* and *Betula pendula*, is also high (28 %). The shrub layer is dominated by *Betula pendula* (coverage 50 %) and *Molinia caerulea* is the most common species in the herb layer (coverage 60–70 %) (Fig. 8). On average 35 plants species per relevé were found. The results of the coenological records are presented in Tab. 2.

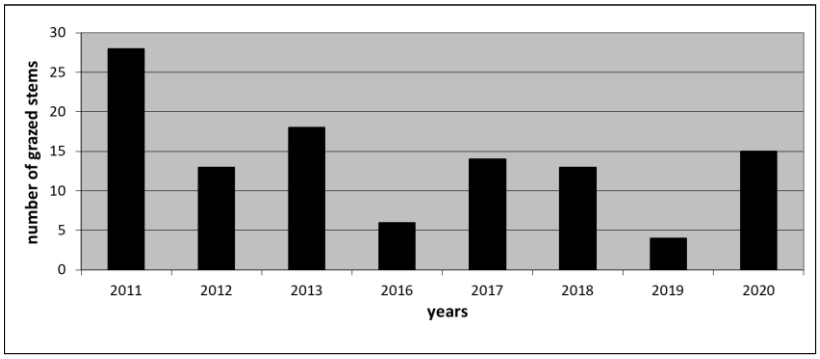

Fig. 5. The grazing pressure on the population of *Adenophora liliifolia* at the locality Drahos (Drahoše) during eight years of survey.

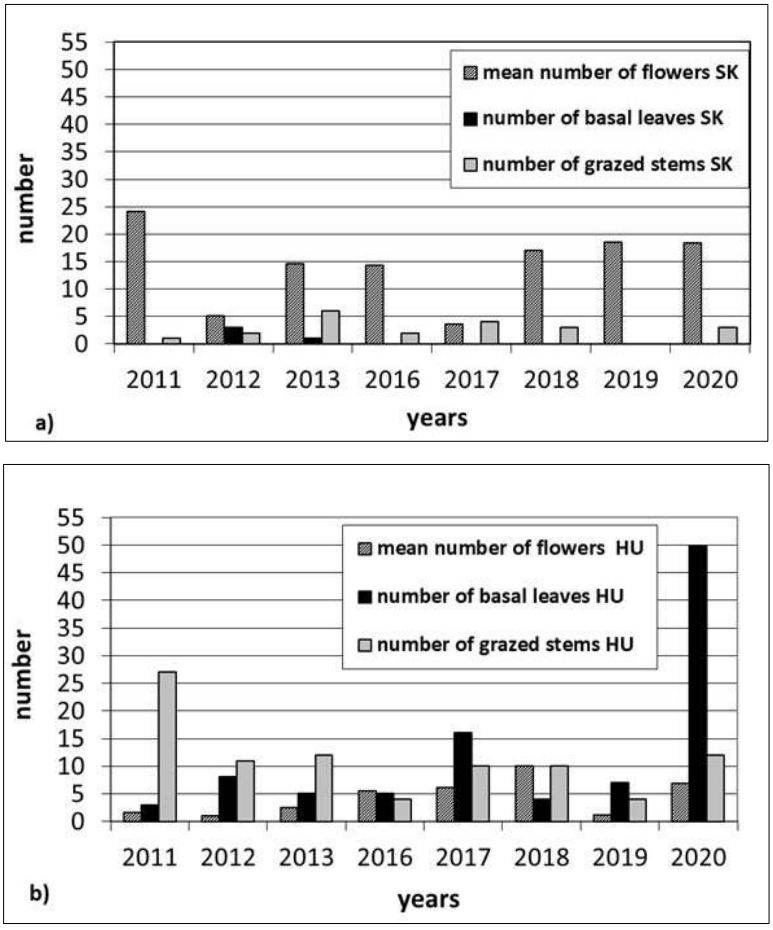

Fig. 6. The comparison of grazing pressure, young individuals with only basal leaves number and mean number of flowers of the Slovak part (unmanaged stand) and Hungarian part (moved stand) of *Adenophora liliifolia* population at the locality Drahos (Drahoše) during eight years of survey. a) Data of the Slovak part; b) Data of the Hungarian part.

Tab. 2 *Adenophora liliifolia* in *Molinia* meadow in Drahoše (coenological relevés) (15.08.2019).

Number of relevé		1	2
Cover of layer (%)			
	a/a1/a2		5
	b	+	55
	c	100	100
Number of species		42	28
Adenophora liliifolia	c	1	+
Querco-Fagetea			
Carpinus betulus	b, c	1	
Crataegus laevigata	c	+	
Populus tremula	b, c		+
Frangula alnus	b, c	+	+
Quercus petraea	c	+	+
Fagus sylvatica	c		2
Betonica officinalis		1	+
Cruciata glabra		1	+
Primula veris		1	
Carex pallescens		2	2
Hypericum montanum		+	+
Veronica chamaedrys		+	+
Convallaria majalis			3
Fagetalia			
Tilia platyphyllos	c	+	
Astrantia major			2
Quercetea pubescenti-petraeae			
Carex montana		3	2
Potentilla alba		3	2
Peucedanum cervaria			1
Pulmonaria mollissima		2	+
Quercion petraeae* and *Aceri tatarico-Quercion			
Campanula cervicaria		2	
Alnetea glutinosae			
Salix cinerea	b		2
Molinio-Juncetea			
Galium boreale		+	
Molinia caerulea		70	60
Succisa pratensis		1	2
Hieracium laevigatum		1	
Inula salicina		+	
Molinietalia			
Achillea ptarmica		+	1
Cnidium dubium		2	+
Molinio-Arrhenatheretea			
Sanguisorba officinalis		1	1
Briza media		2	2
Triseto-Polygonion bistortae			
Gladiolus imbricatus		+	
Festuco-Brometea			
Euphorbia salicifolia		1	

Tab. 2 - cont.

Filipendula vulgaris		+	
Agrostis alba		3	
Prunella grandiflora		2	
Ranunculus auricomus		+	
Indifferent			
Betula pendula	a2, b, c	+	50
Ajuga genevensis		+	
Potentilla erecta		+	+
Serratula tinctoria		2	2
Trifolium montanum		+	
Tussilago farfara		1	
Valeriana officinalis		1	
Vicia tetrasperma		+	
Thalictrum lucidum		+	
Leontodon hispidus		1	+
Solidago virgarea		+	1

(a: upper canopy layer, a2: lower canopy layer, b: shrub layer, c: herb layer, +: sporadic species)

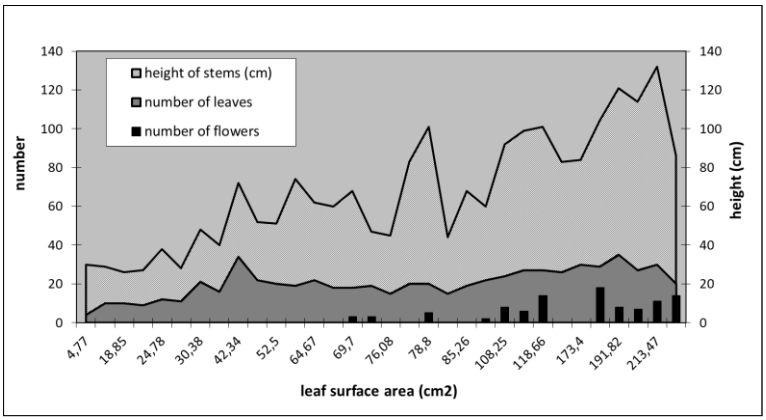

Fig. 7. Comparison of the height of stems, the number of leaves and leaf surface area with the number of flowers of *Adenophora liliifolia* at the locality Drahos (Drahoše) in 2019.

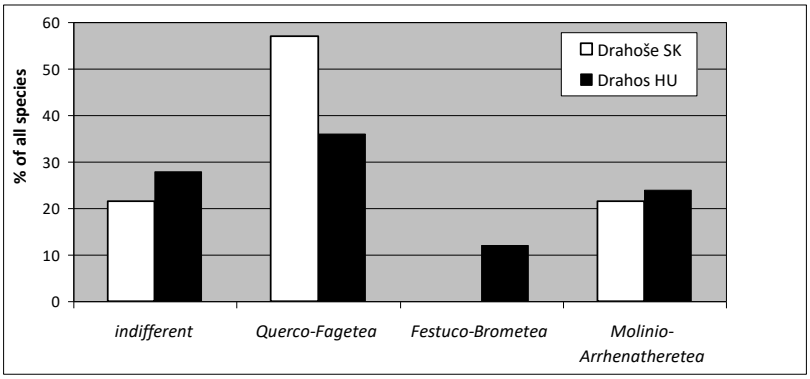

Fig. 8. Syntaxonomical group spectrum of the plant communities hosting the studied *Adenophora liliifolia* stand at the locality Drahos (Drahoše) in 2019.

Discussion

This study provides an overview of a new occurrence of *Adenophora liliifolia* in Drahoše meadow in the border region situated between Slovakia and Hungary. The study demonstrates the morphological structure and population dynamics of the population. The number of the individuals in the population has doubled from 2011 to 2020. The number of stems and the rate of flowering fluctuated year by year, which was probably influenced by the age of the plants and grazing by wild animals.

We found only few young individuals with only basal leaves, but many grazed stems in non-mowed area. The ladybells prefers slightly shaded habitats, the development of young plants requires a more open habitat. At the same time young individuals are more exposed to herbivorous animals.

Similar studies were performed by Ciosek (2006) in the Polish population in a thermophilous oak forest *Potentillo albae-Quercetum*. He found higher values for all parameters of the individuals. For example, the maximum height was 205 cm and the maximum number of flowers was 141. In Drahoše these values were only 102 cm and 38 flowers.

Prausová et al. (2016) studied the population size, genetic variability, site conditions, and vegetation units of *Adenophora liliifolia* in Czech Republic, Slovakia (in Drahoše, too), Hungary, Romania, and Poland. According to that study the species shows a high morphological variability associated with geological bedrock, soil, moisture, and habitat type. The tallest individuals were found in oak-horn-beam and beech forests; the smallest individuals were in meadows. Compared to current conditions, the Karlické valley and Vražba (Czechia) site conditions are close to those in Poland (Kisielany) and Hungary. They showed that there is a similar problem in the Czech Republic as in Drahoše. In the Karlické valley, which is influenced by inappropriate forest management, young ladybells have been overgrown by juvenile trees and shrubs.

We can conclude that the main intervention to maintain the population of *Adenophora liliifolia* in Drahoše should be the suppression of overgrowing woody species at both sides of the border in winter. If shrubs and trees grow again after mowing the area, mowing should be repeated at specific intervals. Manual mowing is also recommended once a year, at the end of September to remove accumulated grass and to suppress *Molinia caerulea*. Grazing pressure by wild animals should also be lowered for example with reduce of the number of the wild animals (deer, boar). It is recommended to list *Adenophora liliifolia* as the species of the subject of protection for SKUEV0327 Milič Natura 2000 Site.

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