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ORIGINAL PAPER

The estimation of population size and density of Hungarian crocus, *Colchicum hungaricum*, on its *locus classicus* (South Hungary)

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Abstract

Hungarian crocus, *Colchicum hungaricum* Janka is relict plant species of the Carpathian Basin, where it is known only from its *locus classicus*, Szársomlyó Hill in southern Hungary. Despite its limited distribution, data on its population have remained scarce. The previous assessments have been conducted with a different methodological approach without detailed explanations; therefore, the results are incomparable. The aim of our study was to reveal the current local distribution range of the species and to estimate its population size and density. Surveys carried out in January 2022 and 2023 revealed that the species occupies a 0.34 km^2 area on the southern slope of Szársomlyó Hill. Population size was estimated based on counts of plants in 100 randomly selected 4 m^2 plots, with values extrapolated to the total occupied area. To improve estimation accuracy, we applied a representative sampling design covering 0.12% of the species' local range, combined with generalized linear models assuming quasi-Poisson error distribution and a bootstrap resampling approach. The estimated population size was higher than in previous estimations, exceeded 3.2 million individuals in 2022 and 3.4 million in 2023. Plant density ranged from 0–5 to 120–130 individuals/m^2. We suggest that the results gained by this method provides a reliable base for future monitoring of Hungarian crocus, offering valuable insights into its population dynamics and trends.

Keywords Area of occupancy · Colchicaceae · Extrapolation · Monitoring · Permanent plot

Introduction

Hungarian crocus, *Colchicum hungaricum* Janka is a species of the Colchicaceae family (Goaverts and Persson 2025), first discovered by Viktor Janka on the southern slope of Szársomlyó Hill in the Villány Mountains (Janka 1867; Brickell 1980). This site is the *locus classicus* and the northernmost point of the species' distribution range. The species is considered to be an Illyrian-West Balkan floristic element, native to Hungary (Csapody 1982), as well as Croatia (Milović 2017), Bosnia and Herzegovina (Maslo and Boškailo 2018), Montenegro (Hadžiablahović 2018), Kosovo (Millaku et al. 2011; Berisha et al. 2014), and Albania (Demiri 1983; Barina et al. 2018). Hungarian crocus is a Tertiary relict species that flowers in winter and is synanthous i.e., flowers and leaves develop simultaneously (Oganezova 2019). Its closest relatives are found in Mediterranean and southern Russian regions (Csapody 1982; Persson 2007; Persson et al. 2011). In Hungary it is endangered and strictly protected (Király 2007; Erdős 2025), yet its population size has not been precisely assessed, prompting

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the need for more thorough research, since for the conservation of rare and relict species, it is essential to understand both the size and trends of their populations (Hutchings 1991; Kiss et al. 2024).

The first estimate of population size of this species was carried out in 2007 by the employees of the Duna-Drava National Park Directorate, although the methodology of this survey was not published nor properly documented (Fenyősi 2021). The next assessment took place in 2010, based on the recommendations of the National Biodiversity Monitoring System (Török 1997; Bata et al. 2011). In that survey, 24 evenly spaced 10 m × 10 m plots were placed within the local distribution area, and the flowering and vegetative individuals were counted, and the total population size was estimated through extrapolation. In subsequent assessments (2013, 2016 and 2019), the members of the National Park Directorate applied the so-called microarea mapping methodology. This comprised the mapping of the boundary of the local plant population, the subsequent counting of individuals in 55 semi-randomly selected 2 × 2 m plots for plant counts, and an estimation of total population size through extrapolation. In 2021, the estimation was based on 100 randomly selected 1 × 1 m plots (Fenyősi 2021). Across these six assessments, both the sampling methods, survey timing, and estimated area of occupancy differed significantly. Precise spatial delimitation of the population is essential for comparability across surveys and reliable detection of population changes (Bullock et al. 2006). Since this criterion was not always fulfilled in earlier studies, the results of estimations are not comparable. Thus, we cannot determine whether observed differences reflect real changes in population size or variations caused by using different methods. Moreover, earlier assessments did not provide confidence intervals for the population size estimations making it impossible to account for variation due to chance. Consequently, there is a need to introduce a more reliable estimation method suitable for the long-term monitoring of Hungarian crocus.

The aim of our study was to: 1) delimitate the local distribution area of Hungarian crocus on the southern slope of Szársomlyó Hill, and within this area, 2) estimate the population size by introducing an improved method, and 3) assess the spatial distribution of individual density.

Materials and methods

Study area

Szársomlyó is a 442 m high hill belonging to the Villány Mts., situated near the southern border of Hungary (Fig. 1). Its bedrock is composed of white and grey limestone formed during the Triassic period, while loess deposits cover the foothills (Lovász 1977). The southern slope is characterized by stony, skeletal soils and rendzina rich in black and red clay, whereas humus-carbonate soils have developed at the foot of the hill (Lehmann 1979, 1995). The area has been inhabited for more than two thousand years, during which the local communities used the landscape for pasturing sheep, goats, pigs, and cattle. Significant landscape transformations began in the Roman period, including the creation of vineyard terraces on the southern slope, which continued by planting new vineyards in the recent times (Dénes 2000). The climate is moderately warm and moderately dry, with the annual mean temperature of 10.8 °C (in the period 1971–2000), while in the past decade it has fluctuated between 12.0 and 13.2 °C. The average temperature in the coldest month (January) is − 0.5 °C, and in the warmest month (July), it reaches 22.5 °C. The average annual precipitation in this region is 680 mm (Czigány et al. 2020; OMSZ 2024).

Szársomlyó Hill has been under strict nature protection since 1944 and has been part of the Natura 2000 network (code: HUDD20006) since 2004 (European Environmental Agency 2025). The Villány Mts. belong to the *Sopianicum* floristic district within the *Praeillyricum* region of southern Transdanubia, where European floristic elements are dominant, followed by Mediterranean taxa, e.g. *Asperula taurina* L. subsp. *leucanthera* (Beck) Hayek in Hegi, *Colchicum hungaricum* Janka, *Festuca dalmatica* (Hack.) K. Richt., *Helleborus odorus* Waldst. et Kit., *Trigonella gladiata* Steven (Lehmann 1975; Borhidi et al. 2013). Szársomlyó Hill is Hungary's richest sites of Mediterranean flora and due to its unique geological and climatic features, hosts numerous rare plant and animal species. More than 75 protected plant species have been recorded here, including 5 strictly protected species species occur in this location in Hungary. The northern slopes are primarily covered by mesophilous forests, while the southern slopes support xerophilous forests and grasslands (Dénes 2000; Erdős et al. 2011). The Hungarian crocus grows in open limestone rocky grasslands (*Sedo sopianae–Festucetum dalmaticae* Simon 1964, *Chrysopogono–Festucetum dalmaticae* Dénes in Borhidi et Dénes 1997) and stony slope steppe habitats (Fig. 2). Characteristic species of these communities include *Bothriochloa ischaemum* (L.) Keng, *Cleistogenes serotina* (L.) Keng, *Elymus hispidus* (Opiz) Melderis and *Festuca rupicola* Heuff. (Dénes 1998, Bölöni et al. 2011). Individuals of Hungarian crocus may also be found on the ground layer of secondary shrublands, which mostly consists of *Fraxinus ornus* L., *Ligustrum vulgare* L., and *Rosa canina* L. The area covered by xerophilous grasslands on the southern slope is gradually shrinking due to the encroachment of shrub vegetation advancing from the foothills (Erdős et al. 2012).

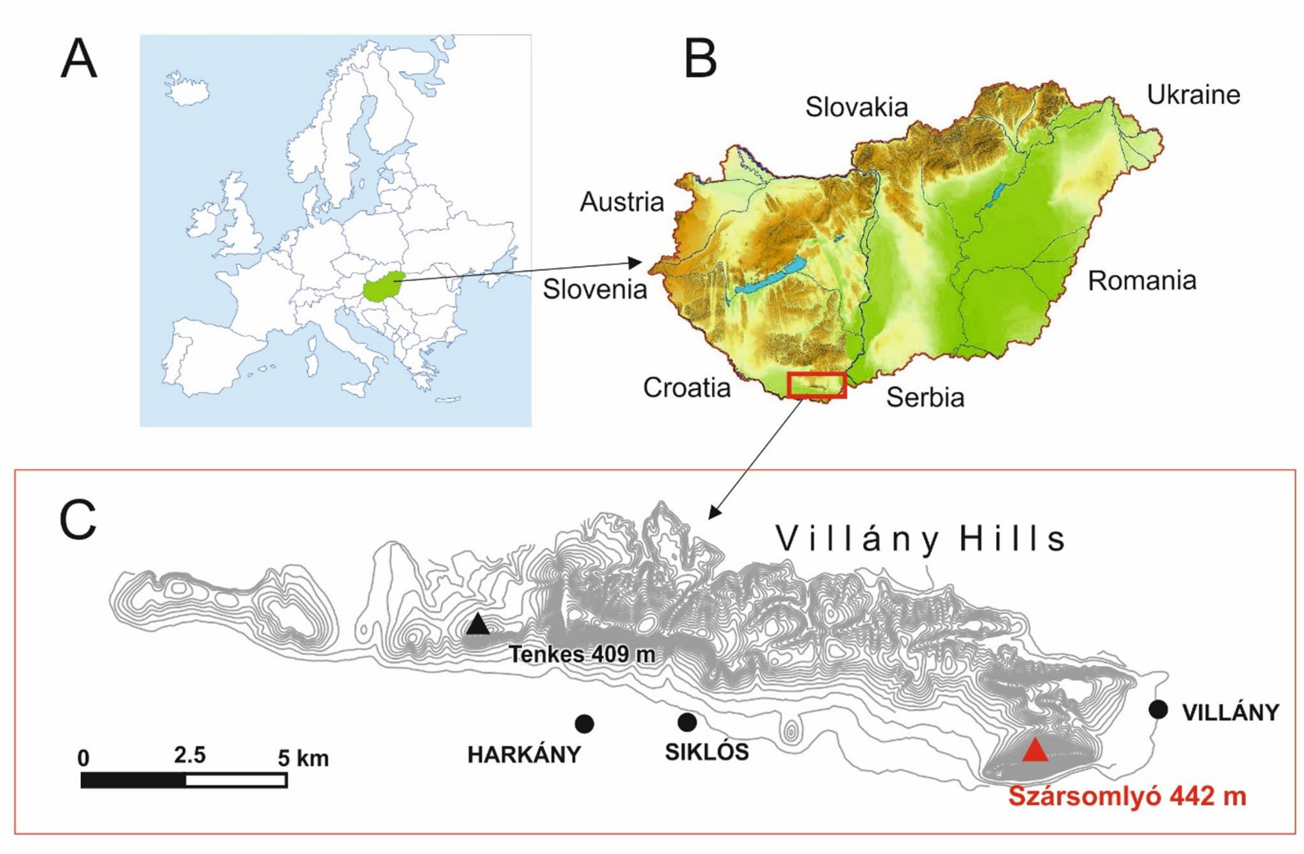

Fig. 1 Location of the study area: Europe (**A**), Hungary (**B**), Villány Hills with Szársomlyó (**C**). (Map by Z. Ujvári)

Delimitation of the local distribution area

A systematic search was implemented to enhance the precise delimitation of local distribution of Hungarian crocus, its area of occupancy (AOO) which measures the physical space where the plant occurs, excluding unsuitable habitats. Searches were conducted in parallel 25 m wide transects, during which the GPS coordinates of each occurrence point of Hungarian crocus were recorded. Patches inhabited by Hungarian crocus were considered separate if the target species was absent within a distance of at least 50 m between them.

The outermost individuals of each subpopulation were georeferenced using a GPS device, and their coordinates were used to delineate the discontinuous local distribution area of Hungarian crocus patches using a geographic information system software (Quantum GIS Development Team 2013). The boundaries of each patch were mapped onto a high-resolution (1:2000) base map for precise spatial definition.

Designation of sampling plot locations

Sampling plots were randomly selected to ensure that each potential sampling unit had an equal probability of inclusion in the study (Sutherland 2006). In 2022, within the local distribution area of Hungarian crocus, 100 random points were generated using QGIS, representing the north-western corners of the 4 m^2 sampling plots (Quantum GIS Development Team 2013) (Fig. 3). The survey was repeated in 2023.

The size of sampling plots

The appropriate size of sampling plots is crucial for the accurate determination of frequency values, as plots that are too large or too small may bias sensitivity to population changes (Elzinga et al. 1998). The primary consideration in selecting the plot size was that individuals could be easily counted within the given area (Török, 1997). Therefore, 100 sampling plots measuring 2×2 m were designated covering a total of 0.12% of the local distribution area of the studied species. To minimize detection errors, each plot was subdivided into four 1 m^2 subplots, thereby reducing the likelihood of missing detectable individuals during counting.

Fig. 2 Habitat of *Colchicum hungaricum* on the southern slope of Szársomlyó Hill (Photo by J.J. Purger)

Fig. 3 Study area with delimitated local occupancy (red line) and randomly assigned 2 × 2 m sampling plots (yellow dots)

Counting both non-flowering and flowering individuals of Hungarian crocus within a 4 m^2 plot usually required less than 30 min.

Total population size estimation

We used 100 random sample plots to estimate the population size with confidence intervals. Since the variance in the observed data substantially exceeded the mean, the assumption of the Poisson distribution—that the mean and variance are of similar magnitude—was not met. Therefore, we used generalized linear models with quasi-Poisson error distribution and applied bootstrap estimation to assess the total population size.

Population density (individuals m^{-2})

To assess the density of Hungarian crocus individuals we used the same 100 sampling plots applied for total population size estimation. Each 4 m^2 plot was first divided into four 1 m^2 subplots, from which one subplot per plot was randomly selected. We used the count data from these 1 m^2 subplots to analyse density. Based on the data obtained from the 100 subplots across the two survey years, we evaluated the individual density of Hungarian crocus and visualized the density values using spatial mapping software (Quantum GIS Development Team 2013).

Survey timing

The developmental stage of plants influences their detectability, thereby affecting the accuracy of population estimates (Alexander et al. 2012). Consequently, our surveys were conducted during the period when individuals were most easily detectable, during flowering, and all individuals were recorded regardless of their developmental stage (including juvenile and non-flowering plants). Counting only flowering individuals would clearly result in underestimation of the population (Hutchings 1991). We counted the individuals in the 100 sampling plots between 15th January and 15th March 2022. The same units were re-examined in the period between 5th January and 27th February 2023. During survey campaigns, the variations in flowering times among subpopulations were took in consideration, therefore the sampling was started in exposed, sunny units where previous observations indicated that the flowering began earliest and continued in plots less exposed to sunlight.

Results

Determination of the local distribution area

On the southern slope of Szársomlyó Hill, the area occupied by Hungarian crocus consisted of 20 patches in 2022 and 25 patches in 2023 (Fig. 4). In previous survey years (2010, 2013, 2016, 2019, 2021), fewer or only a single large

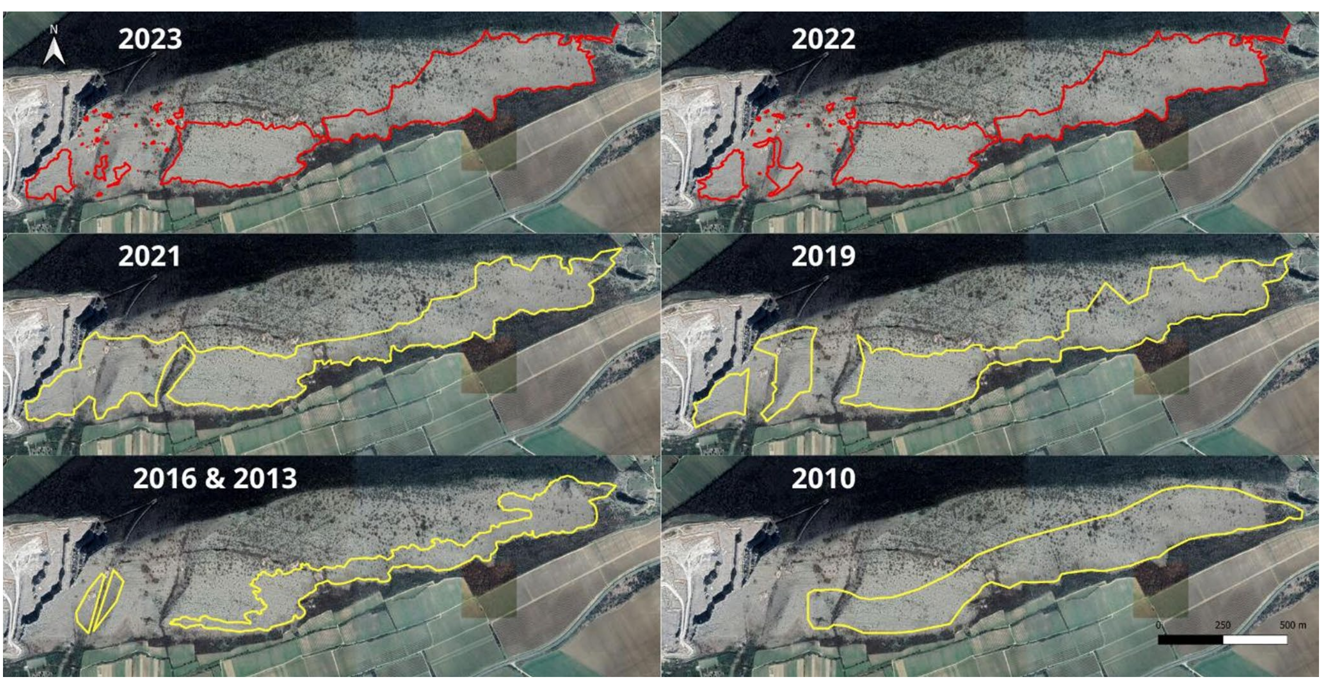

Fig. 4 Delimitation of the local distribution area of *Colchicum hungaricum* on the southern slope of Szársomlyó Hill in our survey (2022–2023) compared with the results of the previous studies performed by Fenyősi (2021) for 2021, and Duna-Drava National Park Directorate for other years

Table 1 Results of the total population size estimation of *Colchicum hungaricum* on Szársomlyó Hill (NA: Not available, DDNPD: Database of the Duna-Drava National Park Directorate)

Year	Range km^2	Flowering	Juvenile	Total	Source
2023	0.340	2 867 727	571 328	3 439 056	Present study
2022	0.341	2 466 092	734 200	3 200 292	Present study
2021	0.388	NA	NA	2 898 596	Fenyősi 2021
2019	0.316	1 280 000	NA	1 280 000	DDNPD
2016	0.183	1 160 000	NA	1 160 000	DDNPD
2013	0.191	1 346 354	NA	1 346 354	DDNPD
2010	0.350	509 720	180 652	690 372	DDNPD
2007	NA	NA	NA	600 000	DDNPD

patch was identified within the established distribution area (Table 1).

Estimation of the population size

The quasi-Poisson distribution and the bootstrap method produced comparable estimates for the total population size and 95% confidence intervals. The estimated population sizes were 3.2 [Cl 95%: 2.2–4.3] million in 2022 and 3.4 [Cl 95%: 2.3–4.6] million in 2023 (The values in brackets represent the 95% confidence intervals for the estimated population sizes, indicating the range within which the true population size is likely to fall). The proportion of flowering individuals at the time of the surveys was 77% in 2022 and 83% in 2023 (Table 1). Most previous surveys reported smaller estimated population sizes (Table 1); however, the estimation in 2021 fell within the confidence intervals based on the censuses in 2022 and 2023.

Distribution of density

The density of Hungarian crocus varied within its local distribution area (Fig. 5). In the low-density areas (sometimes covering larger areas) individual density ranged from 0 to 5 individuals/m^2, while in high-density areas it reached values of 120–130 individuals m^{-2} (Fig. 5).

Discussion

This survey assessed the local distribution patterns of Hungarian crocus. The occurrence of individuals on the southern slope of Szársomlyó Hill was recorded in more than 20 patches, the local area of occupancy covering approximately 0.34 km^2 in January 2022 and 2023. In the previous surveys, the local distribution area appeared less fragmented, even though the occupied area exceeded our recorded value in two cases (2010 and 2021). These notable differences are primarily due to methodological differences. To our knowledge, during the delimitation in 2013 and 2016, the side of the hill facing the quarry was not surveyed, which explains the smaller extent of the local area of occupancy reported in those years. Several factors complicate the precise delimitation of the population, including the species' large local range, high number of individuals, dense surrounding vegetation, and the fact that individuals are small and difficult to detect in vegetative state (Elzinga et al. 1998). Additionally, the number of surveyors and their detection skills also influence accuracy (Klimeš et al 2001; Alexander et al. 2012).

Fig. 5 The density of *Colchicum hungaricum* based on the sampling plots surveyed in 2022 and 2023 (the intensity of the red colour is proportional to the density of individuals, ind. m^{-2})

Small teams (3–4 surveyors) generally detect 90–99% of the patches (Elzinga et al. 1998).

In this study, we estimate the total population size to be between 2 and 4 million individuals, most likely slightly above 3 million. This estimation is supported by the surveys conducted in both 2022 and 2023. Earlier surveys repeated every three years between 2007 and 2019 followed different methodology, covered smaller area, and thus estimated consistently smaller population sizes (600,000–1,280,000). In contrast, the estimated population size from the survey in 2021 was similar to our current estimates. Monitoring of three life cycle stages (flowering, growing, fruiting) of the spring meadow saffron, *Colchicum bulbocodium* Ker-Gawl., in permanent plots for six consecutive years showed that life cycle was strongly related to weather parameters and dormancy; moreover, population estimation based on the number of flowering individuals in a single year can underestimate population size by 40–83% (Kiss et al. 2024). The life cycle of the Hungarian crocus, including its dormancy, is not known, therefore the population size we estimated only upon above-ground shoots.

The appropriate size of sampling plots depends on the characteristics of the species under study, and the sampling units are considered suitable when frequency values fall between 30 and 70%, at least in the first year (Elzinga et al. 1998). With our method (using 4 m^2 plots), frequency values remained within the range suggested by Elzinga et al. (1998), thus ensuring sensitivity to changes in frequency. Using excessively large sampling plots can also bias estimation results, as their survey requires considerably more time. For this reason, it is recommended that the duration of surveying a single plot should not exceed 30 min, to avoid fatigue and declining concentration of the surveyors (Archaux et al. 2006).

In 2022 and 2023, a total of 100 randomly selected 4 m^2 sampling units were surveyed, covering 0.12% of the species' local distribution area. This represents a substantial increase compared to the 2021 survey, which used 1 m^2 sampling units and covered only 0.025% of the area (Fenyősi 2021). The highest recorded density during our surveys was 130 individuals/m^2, slightly exceeding the maximum of 120 individuals/m^2 observed in 2021 (Fenyősi 2021). The total population estimates in large local distribution areas are often underestimated due to detection errors (Keith 2000). Our results indicated that sampling-based methods using larger and more representative plots are preferable for estimating the population size of abundant species (Reisch et al. 2018). However, it should be noted that habitat changes were not assessed in this study, despite their potential importance for long-term population viability (Balmford et al. 2003).

Conclusion for future biology

For the long-term conservation of Hungarian crocus, it is essential to monitor its population in a consistent and comparable method. The sampling method applied in this study-based on randomly selected plots, model-based extrapolation, and the quantification of confidence intervals-appears theoretically more robust than previous approaches. However, its practical reliability and advantages cannot be fully confirmed without comparative studies using different methods on the same population, or without knowledge of the true population size. Therefore, while we abstain from making a definitive methodological recommendation at this stage, our findings suggest that data collection based on representative sampling units combined with extrapolation may be a promising approach for estimating population sizes in species with large local distributions. Future studies should aim to collect demographic data and assess habitat changes, as these factors are likely to play a critical role in the long-term viability of the species.

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Author contributions Field data were collected by ZF and DP. ZF and AL analysed and interpreted the data. The article was drafted by ZF, DP, JJP and revised by all authors. All authors gave final approval for publication and agree to be held accountable for this work.

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Data availability The data sets supporting this article are available at the first author.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval Research permit: Baranya County Government Office, Department of Environmental Protection, Nature Conservation and Waste Management, Nature Conservation Department, Registration number: 263-4/2022.

References

Alexander HM, Reed AW, Kettle WD, Slade NA, Bodbyl Roels SA, Collins CD, Salisbury V (2012) Detection and plant monitoring programs: lessons from an intensive survey of *Asclepias meadii* with five observers. PLoS ONE 7:e52762. https://doi.org/10.1371/journal.pone.0052762

Archaux F, Gosselin F, Berges L, Chevalier R (2006) Effects of sampling time, species richness and observer on the exhaustiveness of plant censuses. J Vegetation Sci 17:299–306. https://doi.org/10.1111/j.1654-1103.2006.tb02449.x

Balmford A, Green RE, Jenkins M (2003) Measuring the changing state of nature. Trends Ecol Evol 18:326–330. https://doi.org/10.1016/S0169-5347(03)00067-3

Barina Z, Somogyi G, Pifkó D, Rakaj M (2018) Checklist of vascular plants of Albania. Phytotaxa 378:1–339 https://doi.org/10.11646/phytotaxa.378.1.1

Bata K, Varga I, Takács G (2011) Védett edényes növényfajok monitorozása (Monitoring of protected vascular plant species). Nature Conservation Information System. Central protocol, Budapest. 10 p. (in Hungarian) https://termeszetvedelem.hu/_user/browser/File/NBmR/N%C3%B6v%C3%A9nyfajok/TIR%20NBmR%20V%C3%A9dett%20ed%C3%A9nyes%20n%C3%B6v%C3%A9nyfajok%20monitoroz%C3%A1sa_protokoll_jelent%C3%A9smint%C3%A1val_2011_05_19.pdf

Berisha N, Millaku F, Krasniqi E, Gashi B (2014) Rare and endangered geophyte plant species in serpentine of Kosovo. Ecol Balk 6:67–74 http://web.uni-plovdiv.bg/mollov/EB/2014_vol6_iss2/067-074__eb.14118.pdf

Bölöni J, Molnár Z, Kun A (eds) (2011) Magyarország élőhelyei: vegetációtípusok leírása és határozója; ÁNÉR 2011 (Habitats of Hungary. Description and determinant of vegetation types in Hungary). Hungarian Academy of Sciences, Institute of Ecology and Botany, Budapest https://www.researchgate.net/publication/271833851_Magyarorszag_elohelyei_A_hazai_vegetaciotipusok_leirasa_es_hatarozoja_ANER_2011_Habitats_of_Hungary_Description_and_determinant_of_vegetation_types_in_Hungary#fullTextFileContent

Borhidi A, Kevey B, Lendvai G (2013) Plant communities of Hungary. Akadémiai Kiadó, Budapest

Brickell CD (1980) *Colchicum* L. In: Tutin TG, Heywood VH, Burges NA, Moore DM, Valentine DH, Walters SM, Webb DA (eds) Flora Europaea, Vol. 5: Alismataceae to Orchidaceae (Monocotyledones). Cambridge University Press, Cambridge, pp 21–25 https://zenodo.org/records/293845

Bullock JM, Shea K, Skarpaas O (2006) Measuring plant dispersal: an introduction to field methods and experimental design. Plant Ecol 186:217–234. https://doi.org/10.1007/s11258-006-9124-5

Csapody I (1982) Védett növényeink (Our protected plants). Gondolat Kiadó, Budapest, 346 p

Czigány S, Novák TJ, Pirkhoffer E, Nagy G, Lóczy D, Dezső J, Fábián SA, Świtoniak M, Charzyński P (2020) Application of a topographic pedosequence in the Villány Hills for terroir characterization. Hung Geogr Bull 69:245–261 https://doi.org/10.15201/hungeobull.69.3.2

Demiri M (1983) Flora ekskursioniste e Shqipërisë (Excursion flora of Albania). Shtëpia Botuese e Librit Shkollor, Tiranë, 985 p

Dénes A (2000) A Villányi-hegység flóra- és vegetációkutatásának története, eredményeinek összefoglalása, különös tekintettel a védett és ritka fajok előfordulására (History of research on flora and vegetation in the Villány Hills;a summary of results, with special regard to the occurrence of rare and protected species). Dunántúli Dolg Term Tud Sorozat 10:47–77

Dénes A (1998) A Villányi-hegység Chrysopogono-Festucion dalmaticae társulásai. (Chrysopogono-Festucion dalmaticae associations of the Villány Mountains) In: Csontos P (ed) Sziklagyepek szünbotanikai kutatása. (Syntaxonomical research of rock grasslands). Scientia Kiadó, Budapest, pp 57–76

Elzinga CL, Salzer DW, Willoughby JW (1998) Measuring & monitoring plant populations. US Dept of the Interior, Bureau of Land Management, Chapter 8, 168 p

Erdős L, Gallé R, Bátori Z, Papp M, Körmöczi L (2011) Properties of shrubforest edges: a case study from South Hungary. Cent Eur J Biol 6:639–658. https://doi.org/10.2478/s11535-011-0041-9

Erdős L, Dénes A, Morschhauser T, Bátori Z, Tóth V, Körmöczi L (2012) Actual vegetation of the Villány Mts based on north-south facing vegetation gradients. Bot Közlem 99:47–63

Erdős L (2025) Magyar kikerics *Colchicum hungaricum* Janka (Hungarian crocus *Colchicum hungaricum* Janka). In: Takács A et al (eds) Magyarország védett hajtásos növényei. (Protected vascular plants of Hungary). University of Debrecen Faculty of Natural Sciences and Technology, Debrecen, Hungarian National Museum Public Collection Center, Hungarian Natural History Museum, Budapest, 278 p.

European Environmental Agency (2025) Szársomlyó Natura 2000 site (code HUDD20006). Available online: https://eunis.eea.europa.eu/sites/HUDD20006 (Accessed 15 August 2025)

Fenyősi Z (2021) Védett növényfajokat veszélyeztető tényezők és rovarkártevőik a Szársomlyón (Threatening factors of protected plants and their herbivores on Szársomlyó). MSc Thesis, Department of Plant Systematics, Ecology and Theoretical Biology, Institute of Biology, Faculty of Science, Eötvös Loránd University, Budapest, 37 p. https://doi.org/10.13140/RG.2.2.22605.29929

Goaverts R, Persson K (2025) World Checklist of Colchicaceae. Facilitated by the Royal Botanic Gardens, Kew. http://apps.kew.org/wcsp/ (Accessed 18 November 2025)

Hadžiablahović S (2018) The diversity of the flora and vegetation of Lake Skadar/Shkodra. In: Pešić V, Karaman G, Kostianoy A (eds) The Skadar/Shkodra Lake Environment. Handbook of Environmental Chemistry, Vol. 80. Springer, Cham https://doi.org/10.1007/698_2018_236

Hutchings MJ (1991) Monitoring plant populations: census as an aid to conservation. In: Goldsmith FB (ed) Monitoring for conservation and ecology. Chapman & Hall, New York, pp 61–76

Janka V (1867) Zwei ungarische, für die Flora der österreichischen Monarchie neue Pflanzenarten. Osterr Bot Z 17:101–104. https://doi.org/10.1007/BF01665799

Keith DA (2000) Sampling designs, field techniques and analytical methods for systematic plant population surveys. Ecol Manag Restor 1:125–139. https://doi.org/10.1046/j.1442-8903.2000.00034.x

Király G ed (2007) Vörös Lista. A magyarországi edényes flóra veszélyeztetett fajai (Red list of the vascular flora of Hungary). Private edition, Sopron, 73 p

Kiss R, Lukács K, Godó L, Tóth Á, Miglécz T, Szél L, Demeter L, Deák B, Valkó U (2024) Understanding the effects of weather parameters on the population dynamics of an endangered geophyte supports monitoring efficiency. Sci Rep 14:25974. https://doi.org/10.1038/s41598-024-76942-5

Klimeš L, Dancák M, Hájek M, Jongepierová I, Kucera T (2001) Scale-dependent biases in species counts in a grassland. J Veg Sci 12:699–704. https://doi.org/10.2307/3236910

Lehmann A (1975) A nagyharsányi Szársomlyó-hegy és növényzete (The Szársomlyó Hill in Nagyharsány and its vegetation). MTA Dunántúli Tud Int Közl 20:1–185 (in Hungarian)

Lehmann A (1979) A Villányi-hegység földrajzi jellemzői (Geographical characteristics of the Villány Mountains). Földr Közl 4:276–281 (in Hungarian)

Lehmann A (1995) Földrajzi tanulmányutak a Mecseken és környékén (Geographical study trips in Mecsek Mts and surrounding). 2nd ed. Janus Pannonius Tudományegyetem, Pécs, 147 p (in Hungarian)

Lovász G (1977) Geomorfológiai körzetek. (Geomorphological regions) In: Lovász G (ed) Baranya megye természeti földrajza. (Natural geography of Baranya County). Baranya County Archives, Pécs, pp 70–75

Maslo S, Boškailo A (2018) Vascular flora of the old town of Počitelj and its surrounding area (South Bosnia and Herzegovina). Glas Zemalj Muz Bosne Herceg (PN) NS 37:19–45

Millaku F, Krasniqi E, Rexepi F (2011) The Association *Stipeto-Convolvuletum compacti* ass. nova in Kosovo. Hacquetia 10:137–147. https://doi.org/10.2478/v10028-011-0008-4

Milović M (2017) The genus Colchicum L. (Colchicaceae) in the flora of Croatia. (In Croatian) Glas Hrvat Bot Druš 5:20–31 https://hrcak.srce.hr/179243

Oganezova GG (2019) The problems of the genus Colchicum L.: Colchicum sensu lato or Colchicum sensu stricto in terms of categories of discontinuity and continuity (In Russian). Gitutyun Publishing House. Yerevan

OMSZ (2024) Országos Meteorológiai Szolgálat adattára (Hungarian Meteorological Service database) (Accessed 7 September 2024). https://www.met.hu/rolunk/tevekenysegek/adattar/index.php

Persson K (2007) Nomenclatural synopsis of the genus Colchicum (Colchicaceae), with some new species and combinations. Bot Jahrb Syst 127:165–242. https://doi.org/10.1127/0006-8152/2007/0127-0165

Persson K, Petersen G, del Hoyo A, Seberg O, Jørgensen T (2011) A phylogenetic analysis of the genus *Colchicum* L. (Colchicaceae) based on sequences from six plastid regions. Taxon 60:1349–1365. https://doi.org/10.1002/tax.605011

Quantum GIS Development Team (2013) Quantum GIS Geographic Information System. Open Source Geospatial Foundation Project. Version 2.12. http://www.qgis.org/

Reisch C, Schmid C, Hartig F (2018) A comparison of methods for estimating plant population size. Biodivers Conserv 27:2021–2028. https://doi.org/10.1007/s10531-018-1522-1

Sutherland WJ (ed) (2006) Ecological census techniques: a handbook. Cambridge University Press, Chapter 4, pp 189–194

Török K (ed) (1997) Nemzeti Biodiverzitás-monitorozó Rendszer IV. Növényfajok (National Biodiversity Monitoring System IV. Plant species). Hungarian Natural History Museum, Budapest, 135 p (in Hungarian) https://termeszetvedelem.hu/_user/downloads/biomon/IV.%20N%C3%B6v%C3%A9nyfajok.pdf