

THE CAUSES OF DISAPPEARANCE OF SWORD LILY *GLADIOLUS IMBRICATUS* L. FROM NATURAL STANDS- SYNTHESIS OF CURRENT STATE OF KNOWLEDGE

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Abstract

*The sword lily *Gladiolus imbricatus* L. is a clonal plant covering Central and Eastern Europe, the Mediterranean, Caucasia and West Siberia. The aforementioned species is included in numerous national Red Books or Lists due to the progressive decrease of stands. The present paper reviews the factors threatening the occurrence and condition of *Gladiolus imbricatus* populations in natural localities. The largest threat is connected with transformation of meadows and expansion of urban areas.*

Keywords: *Sword lily; Natural localities; Population abundance; Threatened species; Molinion.*

Introduction

Progressive anthropopressure is leading to huge changes in the natural environment, which are recognised at various levels of its organisation: they are both global and also locally recognised by changes in the areas covered by particular types of ecosystems, extinction of species and expansion or invasion of new species for a given area. Trends in the contemporary approach to nature conservation as well as the so-called sustainable development are aimed at preserving biodiversity for future generations.

Understanding the causes and mechanisms of the disappearance of plant species is very important because it can enable the taking of appropriate action before a population will reach a critical size. Reductions in the populations of meadow plant species may be the result of changes in the environmental conditions [1-3]; very often it is a consequence of abandoning traditional farming methods [4-6]. Abandonment of traditional use could start a chain of events resulting in stronger competition for various environmental resources or lack of gaps for seeds germinating [7-8]. The occurrence of the species could be also influenced by interaction between plants caused by allelopathins [9]. In addition, plants that have become rare are more susceptible to the interactions that decrease plant fitness, e.g. herbivory, a lack of pollinators etc. The loss of seeds as a result of pre-dispersal seed predation may be a potential threat for the plant population

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maintenance [10-11]. In general, the main reason for the lower population growth rate in rare species is the higher sensitivity to sexual reproduction [12].

Belonging to the group of plant species with a noticed gradual decrease in the number of population is *Gladiolus imbricatus*. It has become a legally protected species in numerous countries inter alia in Poland [13]. Moreover, it is included in the Red Lists or Books of Vascular Plants of many countries such as Belarus [14], the Czech Republic [15], Estonia [16], France [17], Hungary [18], Latvia [19], Switzerland [20], as well as Ukraine [21]. Furthermore, the sword lily is included in 'The Red List of Eastern and Central Europe' [22], as well as 'The Red List of Vascular Plants of the Carpathians' [23].

The present paper reviews several studies on the factors threatening the occurrence and condition of *Gladiolus imbricatus* populations in natural localities. The specific aims were: (i) the survey of natural localities of populations and (ii) the assessment of causes of diminished abundance and performance of individuals.

Material and methods

Plant species

The sword lily *Gladiolus imbricatus* L. is a clonal plant creating underground tubers performing the role of storage and regenerative organs of shoot origin. Leaves, usually three, the lowest 16-35cm×15mm, are obtuse, the cauline up to 5mm wide and subulate. The adult generative individuals form 30-80cm tall, leaved stalks, bearing one-sided inflorescence containing usually from several to a dozen or so purple flowers, blooming from June to July [24]. According to C. Skrypiec and A. Odintsova [25], protandry and herkogamy are revealed as the adaptations for cross-pollination. Pollination is realised as melittophily (by bees *Apis mellifera*) at the beginning of anthesis, and mostly as autophily at the end of anthesis. The fruit is a slightly inflated capsule containing numerous seeds dispersing in the auto-, ballisto- and anemochorous ways [26]. Detailed studies covering the shape of the seeds, presence and disposition of the wing, level of the periclinal cell walls of the seed coat and types of relief were carried out by S.L. Zhygalova et al. [27]. E. Racosy-Tican et al. [28] pointed out that the leaves of the sword lily contain vitamin C and minerals. Furthermore, A.S. Kravnych et al. [29] argued that *Gladiolus imbricatus* - when used as an anesthetic and lactogenic agent in ethnomedicine - has tonic and sedative actions.

The area of distribution of *Gladiolus imbricatus* L. (Fig. 1) covers Central and Eastern Europe, the Mediterranean, Caucasia and West Siberia [30].



Fig. 1. The inflorescence of *Gladiolus imbricatus* L.

Publication search

For this review, a systematic approach for synthesising information through a dedicated step-wise process for selecting available peer-reviewed literature sources was applied. We searched for peer-reviewed articles of causes of disappearance of *Gladiolus imbricatus* populations using the ISI Web of Science (All Databases) and Scopus-indexed publications. These search engines were selected as they provide a comprehensive all-encompassing database for various interdisciplinary domains, including environmental sciences. The review focused on peer-reviewed literature documenting the disappearance of *Gladiolus imbricatus* localities published over the time interval from the years 1950 to 2018. Moreover, publications were searched for by browsing the Google Scholar internet search engine. We used factorial combinations of the following keywords in the searches: ("*Gladiolus imbricatus*", "sword lily", "marsh gladiolus") and ("locality", "land abandonment", "fertilisation", "drainage", "urbanisation", "succession", "transformation of vegetation", "anthropopresion", "herbivore", "pathogen"). The selection terms were examined from the title, abstract, and keywords of the articles. The results included 11 hits from the ISI Web of Science (All Databases), 17 hits from Scopus and 1470 from the Google Scholar internet search engine on 19 October 2018. After the removal of grey literature (master theses, dissertations, reports, conference proceedings and notes) from the lists of searches, we selected books and articles based on the scope which led to 2 articles through the ISI Web of Science, 6 through Scopus and 131 from the Google Scholar internet search engine. Following the removal of duplicates and an initial review of abstracts from all searches, a final total of 80 studies were selected to be reviewed.

Results

The survey of natural localities of Gladiolus imbricatus

The majority of populations of *Gladiolus imbricatus* L. occur in meadows. They were observed particularly in humid lowland meadows [31-53], montane hay-meadows [54-62], tall herb meadows [63-66], as well as flooded meadows [67, 68]. Moreover, populations of *Gladiolus imbricatus* were found in peat bogs [69-70]. Many researchers noticed populations in forests, especially oak forests [71-75], hornbeam forests [34], riparian forests [76], alder forests [77], as well as burn-over and clear cut forests [78]. Other authors noted individuals of sword lily in oats and barley fields [79-84], as well as phytocoenoses dominated by *Calamagrostis epigejos* and *Carex brizoides* [50, 85].

The survey of causes of the disappearance of Gladiolus imbricatus from natural localities

The gathered articles enabled dividing the major causes of the disappearance of *Gladiolus imbricatus* from natural localities into the following: the lack of use of semi-natural communities, the inappropriate agricultural use of *Molinion caeruleae* meadows, the expansion of urbanisation and the damage of *Gladiolus imbricatus* individuals by herbivores and pathogens.

The lack of use of semi-natural communities

The abandonment of *Molinia* meadows promoting rapid secondary succession and habitat fragmentation reversion of many wet meadows into *Carex* or *Phragmites* swamps, *Salix* or *Alnus* thickets, as well as woodlands has contributed to reduction of population abundance of sword lily. The diminishing abundance of *Gladiolus imbricatus* as a result of secondary succession in *Molinia* meadows was observed inter alia by D. Michalska-Hejduk and D. Kopeć [86], T. Wójcik and M. Janicka [87] as well as M. Ziąja and T. Wójcik [88]. Other authors have also noticed the decreasing share of juvenile individuals in overgrown patches [89, 90]. Such a phenomenon is caused by lack of gaps in the continuous plant cover and litter layer considered as safe sites for seedling recruitment. The successful seedling recruitment in openings with different size and

origin was observed by several authors [91-94]. *P. Kubíková and M. Zeidler* [40], has proven that mowing in patches of *Molinion caeruleae* contributes to the appearance of juvenile individuals and to an increase in population abundance. On the other hand, the sowing experiment of *Ü. Jõgar and M. Moora* [95] produced evidence that mulching contributes to greater seedling recruitment than mowing. In light of the above-mentioned studies, it might be concluded that the opportunity of seedling recruitment beneath the litter layer could contribute to the persistence of *Gladiolus imbricatus* populations even in overgrown sites. Additionally, *O. Valkó et al.* [96] noted the lack of *Gladiolus imbricatus* seedlings emerging from soil samples taken in early spring from *Molinion* meadows.

Populations of *Gladiolus imbricatus* occurring in *Potentillo albae-Quercetum* forests are endangered by the expansion of shrubs as an effect of lack of management [73]. The detailed observations of *A.J. Kwiatkowska et al.* [97] showed that the number of *Gladiolus imbricatus* individuals from the forest floor in thermophilous oak forests is negatively correlated with density and size of *Carpinus betulus* saplings. Also, *S. Hänel and F. Müller* [34] pointed out that the increasing shade in woodland habitats, as a consequence of the abandoning of coppice, and middle-storey management, is one of main causes of the disappearance of sword lily populations.

The inappropriate agricultural use of Molinion caeruleae meadows

Patches of *Molinion caeruleae* have suffered from intensive agricultural use. In the last few decades a decrease of abundance of individuals of *Gladiolus imbricatus* due to fertilizer application was discovered by *B. Gryzielec* [98]. The important factor for maintaining purple moor-grass meadows is seasonal variability of the moisture regime caused by fluctuations of the groundwater table (it is higher in spring and autumn and lower in summer). Therefore, the serious threat for the above-mentioned plant communities is drainage affecting the lowering of the groundwater table and the transformation of patches into highly productive meadows from the alliance *Arrhenatherion*. In effect, the most sensitive species such as *Gladiolus imbricatus* are disappearing [99]. *T. Nowak et al.* [100] pointed to periodic burning off as being another factor threatening its populations. The sowing experiments of *Ü. Jõgar and M. Moora* [95] showed weak recruitment of seedlings *Gladiolus imbricatus* in burnt locations.

The expansion of urbanisation

Several authors [100,101] have pointed out that another factor threatening populations is the expansion of urbanisation and the proximity of many communication routes combined with the devastation of land by cross-country vehicles.

The localities of *Gladiolus imbricatus* are threatened due to anthropogenic impact and excessive penetration of the sites. The shoots bearing ornamental inflorescences are exposed to picking by tourists and flower-sellers. Also, whole individuals of sword lily are frequently dug out from natural localities and transplanted into garden cultivations. These frequently occurring phenomena contributes to the destruction of populations.

The individual reasons

The individual reasons might be connected inter alia with susceptibility to activity of herbivores or pathogens. A very serious threat to populations of *Gladiolus imbricatus* is the physical damage to the tubers observed by *M. Cantor and T. Tolety* [102]. The aforementioned authors argue that the tubers of the species from the gender *Gladiolus* are a highly nutritious food for rodents. According to *C. Nicolae-Dănescu* [103] and *N.W. Ellis* [104] and literature cited therein], individuals of *Gladiolus imbricatus* might be infested by *Puccinia gladioli* and *Urocystis gladiolicola*. Furthermore, *A.E. Protsenko* [105] found aster yellows virus in homogenates of parts of *Gladiolus imbricatus*. Moreover, the aboveground parts of the sword lily might be damaged by livestock animals. Monitoring of populations under different management regimes showed that sheep damage significantly more shoots than cattle [106].

The decrease of abundance of sword lily populations might be result of individual causes connected with generative reproduction such as low pollen viability. *M.A. Chertkova* [107]

observed, that pollen of *Gladiolus imbricatus* germinates neither on artificial media nor on the stigma of flower pistil.

Discussion

Although *Gladiolus imbricatus* might occur in numerous plant communities, the abundance of populations has been declining in recent decades. Similarly, it should be pointed out, that the aforementioned environmental factors (transformations of vegetation on unmanaged lands), anthropogenic agents (inappropriate meadow management, expansion of urbanisation, depletion of population resources) as well as individual causes might be also considered as serious threats for other meadow taxa.

Land abandonment might bring disastrous consequences for semi-natural communities such as *Molinion caeruleae* meadows [4, 86,108-112]. The unmanaged patches are subjected to secondary succession, leading to gradual encroachment of native and alien tall-growing macroforbs (e.g. *Filipendula ulmaria*, *Lysimachia vulgaris*, *Solidago canadensis*), tall growing rhizomatous grasses (e.g. *Phragmites australis*), large-tussock grasses and sedges (e.g. *Deschampsia caespitosa*, *Molinia caerulea*), as well as shrubs and trees (e.g. *Betula pendula*, *Salix cinerea*, *S. rosmarinifolia*), that contributes to habitat fragmentation. The disappearance of rare species from meadows as a result of successional changes was observed in numerous localities [1]. The detailed observations showed the reduction of population abundance and plant performance in *Gentiana pneumonanthe* [113-115], *Dianthus superbus* [116], *Iris sibirica* [117, 118] and *Trollius europaeus* [119-121]. The aforementioned authors highlighted the increased trend toward senilisation of populations along the gradient of meadow overgrowing and vegetation height due to successional closure of plant cover, preventing seedling recruitment.

In addition, the deterioration of the population state of the aforementioned species in effect of too intensive meadow drainage [122-126]. *D. Van der Hoek and K.W. Sykora* [127] added that it may trigger a shift into drier and more nutrient-poor plant communities. *C.J.F. Ter Braak and J. Wiertz* [128] found that drainage and acidification of *Molinion caeruleae* patches contributes to decrease of abundance of rare species such as *Parnassia palustris*, *Selinum carvifolia* and *Ophioglossum vulgatum*. At the same time, the deterioration of condition of population of numerous meadow species has been observed in effect of intensive mowing and/or fertilizer addition [98, 123, 129].

Similarly, the depletion of population resources of several plant species (e.g. *Gentiana pneumonanthe*, *Iris sibirica*, *Dianthus superbus*) in effect of expansion of urbanisation [102,126], as well as stem cutting or removal of individuals [118, 130-134] was frequently noticed.

Moreover, it is worth mentioning that the aforementioned species (similarly to *Gladiolus imbricatus*) are prone to pathogen and herbivore activity. Their species-specific influence was repeatedly recorded. Most frequently the attack of herbivores and pathogens results in damage to flowers, fruits and diaspores and the decrease of the germination process. Such a phenomenon was observed in, *Trollius europaeus* [135,136], *Gentiana pneumonanthe* [137], as well as *Dianthus superbus* [138-140]. Also, the damage of vegetative parts of individuals of the aforementioned taxa was often observed [141-145].

Conclusions

Performed survey of publications confirmed the variability of habitat conditions suitable for development of populations of sword lily. Populations have been found in considerable range of habitats: from meadows via forests to arable fields. Moreover, the conducted literature review showed that populations of *Gladiolus imbricatus* are threatened by transformations of vegetation as an effect of land abandonment or its too intensive use. Less frequently mentioned threats are

the expansion of urbanisation, herbivorous animals' activity and pathogen infestation, as well as low pollen viability. The removal of environmental and anthropogenic threats will contribute to more effective protection of populations of sword lily and other endangered meadow species with similar habitat requirements.

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