Botanikai Közlemények 106(2): 197–216 (2019)
DOI: 10.17716/BotKozlem.2019.106.2.197

Survey of invasive alien species in the flora of Lozenska Mountain, Bulgaria

Plamen GLOGOV[1]*, Dolja PAVLOVA[2], Mira GEORGIEVA[3], Yonko DODEV[1] and Stela GYUDOROVA[1]

[1]Department of Silviculture, Forest Research Institute, Bulgarian Academy of Sciences, 132 St. Kliment Ohridski Blvd., 1756 Sofia, Bulgaria; pglogov@abv.bg, ionkododev@abv.bg, stella_gjudorova@abv.bg
[2]Department of Botany, Faculty of Biology, University of Sofia, 8 Dragan Tzankov Blvd., 1164 Sofia, Bulgaria; dolja_pavlova@abv.bg
[3]Department of Forest Genetics, Physiology and Plantations, Forest Research Institute, Bulgarian Academy of Sciences, 132 St. Kliment Ohridski Blvd., 1756 Sofia, Bulgaria; mirageorgieva@abv.bg

Accepted: 1 August 2019

Key words: abundance, distribution, ecological strategy, frequency, invasive plants.

Abstract: This study explores the invasive alien flora of Lozenska Mountain, southwestern Bulgaria (maximum height 1190 m, area 80 km^2). The aims were to (i) describe the taxonomic and ecological structure of the invasive alien flora in Lozenska Mountain, and (ii) provide data on the local distribution of the globally most widespread invasive species. Ten transects of different lengths (from 4 to 12 km) in different parts of the mountain covering the most characteristic habitats were surveyed between April 2017 and October 2018. Altogether, 27 invasive alien species (IAS) and 4 potentially invasive alien species (PIAS) belonging to 17 families of flowering plants were encountered. These represent 3.46% of the flora of Lozenska Mountain, and 45% of all the IAS in Bulgaria. Seven species (*Acer negundo*, *Ailanthus altissima*, *Amorpha fruticosa*, *Bidens frondosus*, *Fallopia* × *bohemica*, *Opuntia humifusa* and *Robinia pseudoacacia*) are highly aggressive. In the biological spectrum of IAS, therophytes predominate (29%), followed by hemicryptophytes (19.4%). The majority of IAS originates from America (65.6%) and Asia (19.5%). 64.5% of the IAS were deliberately introduced. The established invasive species on the territory of the mountain are predominantly heliophytes (90.3%); microthermophytes (71.0%); high humidity species (38.7%); mesophytes (54.8%), mesooligotrophs (58.1%) and basophilic species (80.6%).
The most widespread species are *Robinia pseudoacacia*, *Erigeron canadensis* and *Xanthium italicum*. Most of the IAS were found in one transect only. The highest percentage of species cover (over 80%) was reached by plants adapted to specific habitats: aquatic (*Elodea canadensis*), riparian (*Impatiens glandulifera*, *Fallopia* × *bohemica*) and anthropogenically heavily disturbed terrains (*Sorghum halepense*). There is a substantial threat of IAS irruption on the territory of Lozenska Mountain for the following habitat types (reference codes according to Annex I of the Directive 92/43/EEC): 3150 (Natural eutrophic lakes with Magnopotamion or Hydrocharition vegetation) and 3270 (Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation) included in Natura 2000.

* Corresponding author

A map of IAS occurrences in the mountain was prepared and it was found that IAS predominantly appear in areas around rivers with permanent water regime such as Iskar, Rakita and Gabra, and near urbanized areas adjacent to settlements, along roads and in abandoned mines. The populations of the species *Amaranthus hybridus*, *A. retroflexus*, *Elodea canadensis*, *Erigeron annuus*, *E. canadensis*, *Fallopia* × *bohemica*, *Impatiens glandulifera*, *Oenothera biennis*, *Opuntia humifusa*, *Robinia pseudoacacia*, *Solidago gigantea*, *Sorghum halepense* and *Xanthium italicum* occur in certain parts of Lozenska Mountain. Other IAS have so far formed small populations only being accessorial elements in natural plant communities.

Introduction

The problem with the spread of Invasive Alien Species (IAS) is global in scope and requires international cooperation to supplement the actions of governments, economic sectors and individuals at national and local levels. These species are causing enormous damage to biodiversity and the valuable natural agricultural systems upon which we depend (McNeely et al. 2001). IAS are included in the National Biodiversity Conservation Strategy of Bulgaria (formulated in 1998) as one of the threats to the biodiversity of the country. The Biodiversity Strategy 2020 of the European Union (EU) requires detailed information about the distribution of these species as a step towards their isolation, elimination and control over their introduction. In addition, regular studies on the IAS composition and distribution are essential to track the dynamics of the alien flora on the territory of the country (Petrova and Vladimirov 2007, 2012).

The project Delivering Alien Invasive Species Inventories for Europe (DAISIE 2009) funded by the European Union led to the compilation and update of alien plant species inventories for many countries such as Serbia (Lazarević et al. 2012), Romania (Sîrbu and Oprea 2011), Czech republic (Pyšek et al. 2012), Slovakia (Medvecká et al. 2012), Montenegro (Stešević and Petrović 2010). A list of invasive alien species in Bulgaria was prepared and edited by Petrova et al. (2013). It summarized regional data for the chorology of new alien species found on the territory of Bulgaria and for well-known ones already included in the volumes of Flora of the Republic of Bulgaria. Recently, surveys of the invasive alien flora for local regions in Bulgaria were conducted (Asenov and Dimitrov 2013, Aneva et al. 2018). An updated chorological information about the alien species distributed in Bulgaria was also provided (Kalníková and Palpurina 2015, Petrova 2017). Only complete lists of alien species, presented for separate regions, can provide a robust basis for analyses of regional levels of invasions and underlying driving forces (Pyšek et al. 2018, Vinogradova et al. 2018). Such analyses are important not only for a better understanding of the factors determining local invasions, but also for obtaining a more complete picture of global alien species richness (van Kleunen et al. 2015, Pyšek et al. 2017, Vinogradova et al. 2018).

Because of its proximity to the capital and great economic and recreational potential, Lozenska Mountain is subject to a strong anthropogenic impact. As a result, a number of degradation processes are taking place on its territory which reduce the autochthonous vegetation and open niches for new species, including invasive ones. Part of the mountain territory (14.3%) is included in Natura 2000, and falls under special management regimes that require the identification of potential threats for the habitats. Glogov and Delkov (2016) have recorded 11 IAS (1.26% of the whole floristical composition of the mountain) during their floristic survey on the territory of Lozenska Mountain. The present study is focused on the IAS of Lozenska Mountain and constitutes part of the ongoing inventory of the invasive plant species distributed on the territory of the country. It is accepted that an "alien species" is a species occurring outside its natural distribution while an "invasive alien species" is an exotic species which becomes established with high abundance in natural or semi-natural habitats. Such plants are agents of change and threaten native biological diversity (Williamson 1996, IUCN 2000, Shine et al. 2000, McNeely et al. 2001).

The aims of this study are to (1) provide a list of invasive alien plant species on the territory of Lozenska Mountain, (2) explore the taxonomical structure, biogeographical and ecological characteristics, and distribution of the invasive alien species, and (3) elucidate the level of invasion in the territory of the mountain. The results of this study could serve as a basis for future monitoring and analyses of the threat by invasive alien species to the native flora and biodiversity of the mountain.

Material and methods

Geographical characteristics of the studied area

Lozenska Mountain is the westernmost part of Ihtimanska Sredna Gora Mts, located in the southwestern part of Bulgaria. Its area is about 80 km^2 and its maximum height is 1190 m (Nikolov and Yordanova 2002). The mountain is composed of various bedrocks of different age. These are mainly slate on the southern slopes and sandstones on the northern slopes. Part of the ridge of the mountain is limestone. The soils are mostly Chromic Luvisols and transitional to Dystric, Dystric Cambisols and Dystric-Eutric Cambisols in the higher parts (Ganchev 1961, Ninov 1997).

Climatically, Lozenska Mountain belongs to the Transitional Climatic Zone of Bulgaria (Velev 1997). The mountain is characterized by a small number of days without sunshine (61 days per year). The average monthly air humidity is the lowest in July (63%) and the highest in December and January (85%). The average monthly temperature is the highest in July, 21.5 °C and the lowest in January, –2.5 °C. The prevailing wind direction is northwest, and winter winds are the strongest from December to March. The average annual precipitation is not much different from the average value for the country (645 mm). The maximum rainfall is in May, and the minimum is in December. A second maximum is observed in June and a second minimum in August. The average annual number of days with snowfall is 23.5.

The rivers and streams of the mountain, especially on the northern slopes have short length and most of them dry up in midsummer. Unlike the fluctuating hydrological regime inside the mountain, it is bordered by several water bodies: Pancharevo Dam (northwest border), Iskar River and Pasarel Dam (west and southwest borders), and Gabra Lake (southeast border).

Lozenska Mountain is part of the floristical region Sredna Gora, subregion Western Sredna Gora. The vascular flora of the mountain consists of 875 species from 379 genera and 91 families (Glogov and Delkov 2016). The vegetation is dominated by broadleaved deciduous forests and shrubs. The vegetation type is represented by xerothermic oak forests (including communities from the alliance Quercion frainetto), mesophytic oak forests (Quercion roburis petreae), hornbean forests (Carpinion betuli moesiacum) and beach forests (Fagion moesiacus). Shrub communities belong to alliances Syringo-Carpinion orientalis and Crataego-Corylion (Ganchev 1961, Dimitrov and Glogov 2003). Herbaceous communities of secondary origin replace the forests that were destroyed in the past (Ganchev 1961, Pedashenko et al. 2009).

Methods

The study period covers two growing seasons from the beginning of April 2017 until the end of October 2018. The transect method was applied in order to cover maximum area and to compare the distribution of the invasive species in the northwestern and southeastern parts of the mountain which division was proposed by Danov (1964). Based on the previous floristic investigation of Lozenska Mountain (Glogov and Delkov 2016), ten transects with different length (from 4 to 12 km) were set up (Table 1, Fig. 1). 30 site visits were carried out during the study period (3 for each transect) in spring, summer and autumn. Additional visits were made in 4 of the transects due to the length and high diversity of species in their area. The transects correspond to part of the routes set up in Glogov and Delkov (2016) field surveys. Sample plots were laid out in each locality of the IAS found along the transects. These represent the most common

Table 1. Transect data. Habitat Code 3150: Natural eutrophic lakes with Magnopotamion or Hydrocharition-type vegetation; 3270: Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation; 40A0: Subcontinental peri-Pannonic scrub; 6110: Rupicolous calcareous or basophilic grasslands of the Alysso-Sedion albi; 6210: Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia); 6510: Lowland hay meadows (*Alopecurus pratensis*, *Sanguisorba officinalis*); 6520: Mountain hay meadows; 8210: Calcareous rocky slopes with chasmophytic vegetation; 91M0: Pannonian-Balkanic turkey oak –sessile oak forests; 9130: *Asperulo-Fagetum* beach forests; 9170: *Galio-Carpinetum* oak-hornbeam forests.

Transect №	Length (km)	Elevation (m)		Basic geographical locations	Natura 2000 habitat	Habitats under risk of IAS irruption	Reasons for IAS threat
		Min	Max				
1	6.69	615	672	Kokalyane – a monument of Trudovaka (along the river Iskar)	3150,3270	3151, 3270	Invasion of *Impatiens glandulifera*
2	8.49	595	694	German village – Kokalyane village	40AO, 6110, 6210, 8210, 91MO	6210	Invasion of *Opuntia sp.*
3	8.46	646	984	German village – German monastery – German meadows	91MO, 9130, 9170, 6510, 6520	no substantial threats	n.a
4	4.63	698	823	Passarel village – Passarel Dam	3150, 3270	3151, 3270, 3151	Invasion of *Solidago gigantea*
5	4.21	712	811	Passarel village – Passarel monastery	3150, 3270, 91MO,	no substantial threats	n.a
6	12.4	712	1165	Lozen Red Cross Center – Lozen Monastery – Polovrak peak – Passarel village	6110, 6210, 6510, 6520, 8210, 91MO, 9130, 9170	no substantial threats	n.a
7	8.59	643	789	Dolni Lozen village – Gorni Lozen village – German village – Dolni Lozen – Gorni Lozen village – German village	6210, 6510, 6520, 91MO	no substantial threats	n.a
8	12.6	698	918	The highway near the village of Novi Han – Gabra	91MO	no substantial threats	n.a
9	6.55	929	957	Gabra – Tarattorsko (Upper Gabrene) Lake	3150, 3270	no substantial threats	n.a
10	4.14	837	989	Gabra village – Chukurovo mine	91MO	no substantial threats	n.a

paths of alien plants invasion on the territory of the mountain. Transects pass close to settlements, wetlands, inland areas influenced to a small scale by human activities, areas under severe anthropogenic impact, and main forest roads. The geographical coordinates of each of the IAS populations, found on the transects, were collected by GPS in order to include their localities in the national GIS database for IAS distribution.

Sample plots were set up for the estimation of species abundance. The size of the sample plots was 10 m^2 for grasslands and 100 m^2 for woodlands and shrublands, according to the standard plot sizes suggested by Chytrý and Otýpková (2003) and Pavlov (2006). Species abundance is measured by plant cover (%) in a sample plot (Braun-Blanquet 1964). The average species cover is calculated as the sum of the covers of a species in a transect divided by the number of transects in which this species occurs (Pavlov 2006).

Frequency (F) (scale from 0 to 10) of the IAS is calculated as F = T/N, where T is the number of transects where the target invasive species occur, and N is the total number of transects (10).

The stages of naturalization and invasion for each IAS were determined according to Richardson et al. (2000). Naturalization starts when abiotic and

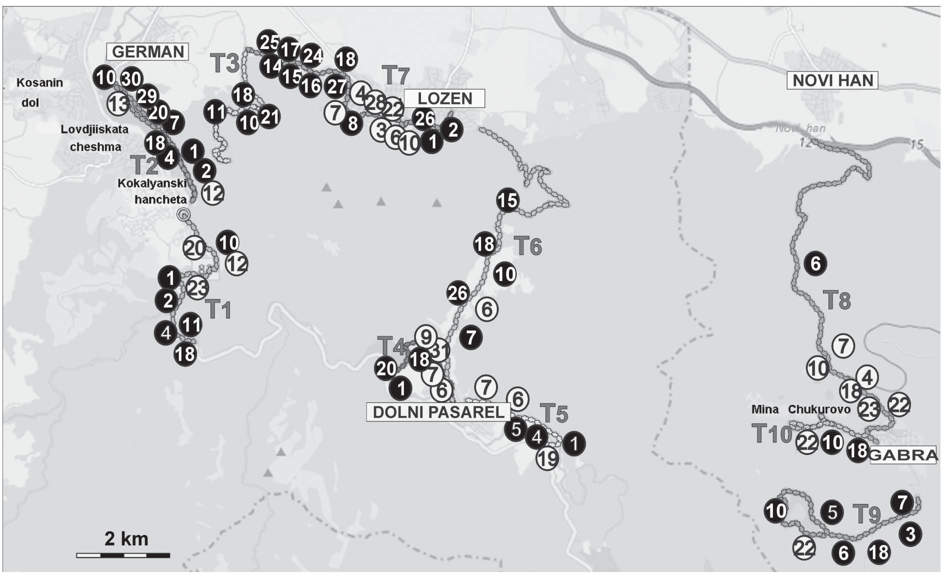

Fig. 1. Distribution map of invasive alien species (IAS) and potentially invasive alien species (PIAS) on the territory of Lozenska Mountain. For the numbering of transects and species see Table 2. ❶ = species is not dominant in the communities where it occurs (< 50% coverage); ① = species is dominant in the communities where it occurs (> 50% coverage). The species numbers correspond to those presented in Table 2.

biotic barriers to survival are surmounted and when various barriers to regular reproduction are overcome. (Richardson et al. 2000). Invasion further requires that introduced plants produce reproductive offsprings in areas distant from sites of introduction. The invasive plant species following their main route of introduction to the mountain were distinguished according to Petrova et al. (2013) as follows: 1) deliberately introduced (species intentionally imported for cultivation, ornamental purposes, afforestation, wood production or other economic interests); 2) unintentionally introduced (species imported unconsciously by humans as uncleaned seeds of vegetable, forestry and other crops for sowing).

The taxonomic nomenclature of the plants follows Delipavlov and Cheshmedzhiev (2003). The Plant List (2010) was used to standardize the scientific names. The life forms are defined according to Pavlov (2006) and the determination of the floristical elements is after Assyov and Petrova (2012). The ecological groups are defined according to Pavlov (1998) and Tela Botanica (1901). Data on the origin of species follows Assyov and Petrova (2012), Petrova et al. (2013), and Flora of Republic of Bulgaria (Stoyanov et al. 1966–1967, Jordanov 1963–1979, Velchev 1982–1989, Kozhuharov 1995, Peev 2012). For the analyses, the established alien species were classified into two groups: 1) invasive alien species (IAS, Petrova et al. 2013); and 2) potentially invasive alien species (PIAS, species listed in the European Network on Invasive Species (NOBANIS)). Due to the small number of PIAS and the high degree of their invasibility, the two groups IAS and PIAS were treated as one group. Herbarium specimens collected during the study were deposited in the Herbarium of Sofia University (SO). The geographical coordinates of each IAS locality, including those with single specimen presence, were specified.

Data analysis

Cluster analysis using Euclidean distance and the unweighted pair group mean average method (UPGMA) was used as the computational criteria to express the similarities between studied transects based on the number of species and the number of populations found, their life forms, and requirements according ecological factors like light, humidity and temperature. The purpose of this comparative analysis between the transects was i) to understand better the distribution paths of IAS on the territory of the mountain; ii) to discern some common rules of the IAS dissemination and their adaptability to the specific climatic and geographic conditions of the investigated area; and iii) to get more information about the competition between the invasive species and the coexisting resident flora. Statistical analyses were carried out by using the StatSoft Inc. 7.0 (2004) software.

Results

Taxonomic and ecological structure, life forms, origin and type of introduction

As a result of our survey, altogether 27 IAS and 4 PIAS belonging to 17 families of flowering plants were encountered on the territory of Lozenska Mountain. The species found belong to 25 genera, most of them are representatives of Magnoliopsida, and only one belongs to Liliopsida. The potentially invasive species belong to 4 genera and 3 families, all of them representatives of Magnoliopsida. The families with the highest number of species and genera are Asteraceae (7 IAS), followed by Fabaceae (4 IAS and 1 PIAS). Other families with more significant presence are Cactaceae (1 IAS and 2 PIAS), Balsaminaceae (1 IAS and 1 PIAS) and Amaranthaceae (2 IAS).

Phanerophytes, hemicryptophytes and therophytes have the same participation in the biological spectrum of IAS, each with 29%. In the first group of life forms, microphanerophytes predominate with 16.1% over the mesophanerophytes (9.7%) and macrophanerophytes (3.2%). The group of chamaephytes is not represented (Table 2). Differences were found in the representation of life forms among the transects. Therophytes were dominant in all transects followed by microphanerophytes or mesophanerophytes. The most frequent invasive alien species in the studied area is the mesophanerophyte *Robinia pseudoacacia*. Other frequently found mesophanerophytes are *Acer negundo* and *Ailanthus altissima*.

The majority of IAS originates from America (64.5%) and 54.8% of them are North American. The invasive species of Asian origin represent 12.9% followed by the European-Asian (9.7%), cosmopolitan (6.5%), Submediterranean-Asian (3.2%) and European elements (3.2%).

According to the type of their introduction on the territory of the country, 64.5% of the IAS are deliberately introduced while the unintentionally introduced species make up 35.5% (Table 2). Only the 4 PIAS species are considered as being in the stage of naturalization on the territory of the mountain while the 27 IAS are in the stage of invasion.

The distribution of the established IAS on the territory of Lozenska Mountain by climatic ecological factors – sunlight, temperature and atmospheric humidity – shows predominance of the ecological of groups of heliophytes, microthermophytes and the group of species requiring high air humidity (Fig. 2A–C). With regard to the soil factors, moisture, nutrients and acidity the predominant ecological groups are mesophytes, mesooligotrophs and basophilic species (Fig. 2D–F).

As a result of this study, 10 of the established IAS are confirmed as new for the Sredna Gora floristical region according to Glogov et al. (2018): *Bidens fron-*

dosus, *Buddleja davidii*, *Chenopodium ambrosioides*, *Elodea canadensis*, *Fallopia × bohemica*, *Gleditsia triacanthos*, *Helianthus tuberosus*, *Koelreuteria paniculata*, *Laburnum anagyroides* and *Solidago gigantea,* while twenty are new species for the flora of Lozenska Mountain.

Diversity and distribution of invasive alien species

The diversity and distribution of IAS along each transect of the surveyed area are presented in Table 2. The species ranking in each of them shows that the most common IAS on the territory of the mountain are not the same as the ones with

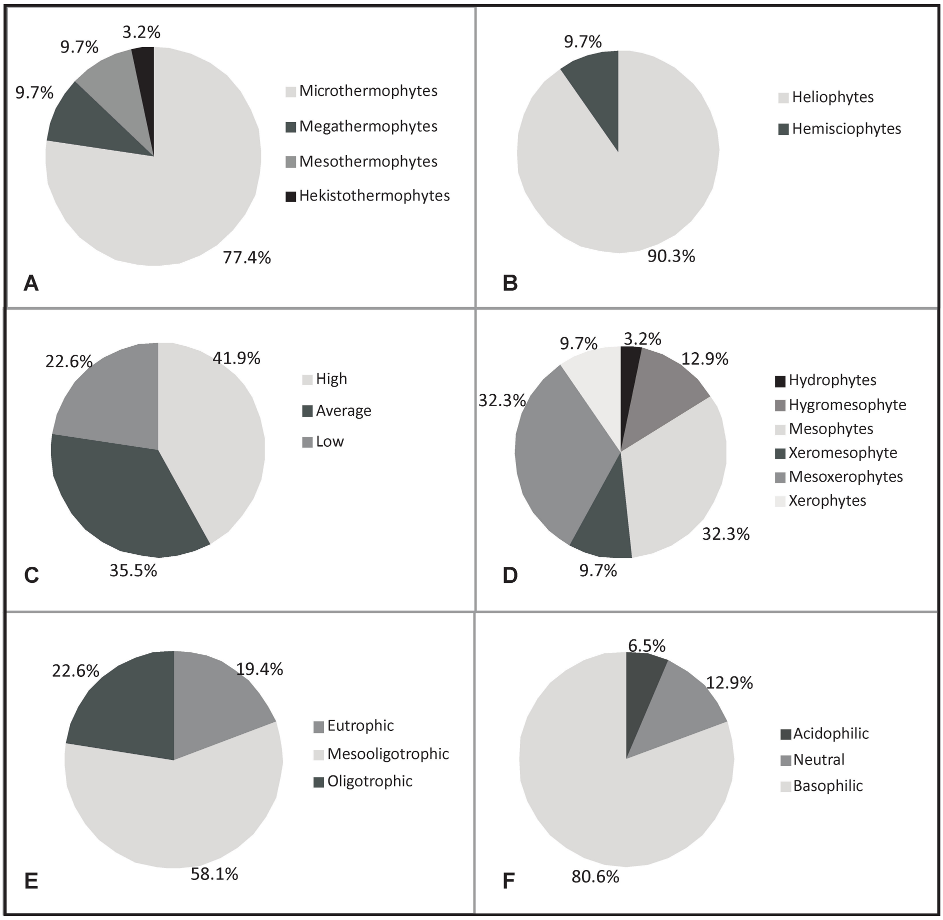

Fig. 2. Distribution of IAS according to their ecological requirements: A = air temperature; B = light; C = air humidity; D = soil moisture; E = soil nutrients; F = soil acidity.

Table 2. Biological spectrum, origin and distribution of the IAS on the territory of the Lozenska Mountain. Abbreviations used: MaPh: macrophanerophyte; MePh: mesophanerophyte; MiPh: microphanerophyte; Ch: chamaephyte; H: hemicryptophyte; Th: therophytes; Am: American, As: Asian, Eur: European, Ch: China, Cos: cosmopolitan, N: North, S: South, E: East, W: West, Sub: subregion; Int: intentionally; Unint: unintentionally; I: invasion, N: naturalization.

№	Species	Life forms	Phytogeo-graphical elements	Number of the localities of the IAS in each transect (T)										Fre-quency (T/N)	Average species cover (%)	Type of intro-duction	Stage of natural-ization or invasion
				T1	T2	T3	T4	T5	T6	T7	T8	T9	T10				
	Invasive Alien Species (IAS)																
1	*Acer negundo* L.	MePh	NAm	5	1	0	1	1	0	1	0	0	0	0.5	28.0	Int	I
2	*Ailanthus altissima* Swingle	MePh	Ch	6	2	0	0	0	0	1	0	0	0	0.3	30.0	Int	I
3	*Amaranthus hybridus* L.	Th	SAm	0	0	1	0	0	0	19	0	1	0	0.3	57.5	Unint	I
4	*Amaranthus retroflexus* L.	Th	Cos	1	1	1	0	5	0	8	6	0	0	0.6	55.8	Unint	I
5	*Bidens frondosa* L.	Th	Nam	0	0	0	0	1	0	0	0	6	0	0.2	16.7	Unint	I
6	*Erigeron annuus* (L.) Pers.	Th-H	NAm	0	0	0	42	1	8	7	2	2	0	0.6	31.7	Unint	I
7	*Erigeron canadensis* (L.) Cronquist	Th	NAm	0	2	1	4	17	6	13	5	5	0	0.8	52.5	Unint	I
8	*Helianthus tuberosus* L.	H	NAm	0	0	0	0	0	0	2	0	0	0	0.2	20.0	Int	I
9	*Solidago gigantea* Ait.	H	NAm	1	0	0	23	0	0	0	0	0	0	0.2	65.0	Int	I
10	*Xanthium italicum* Moretti	Th	NAm	1	2	1	0	0	3	16	2	1	2	0.8	28.8	Unint	I
11	*Xanthium spinosum* L.	Th	Kos	1	0	1	0	0	0	0	0	0	0	0.2	5.0	Unint	I
12	*Impatiens glandulifera* Royle	Th	As	46	1	0	0	0	0	1	0	0	0	0.3	83.3	Int	I
13	*Opuntia humifusa* (Raf.) Raf.	H	NAm	0	3	0	0	0	0	0	0	0	0	0.1	50.0	Int	I
14	*Chenopodium ambrosioides* L.	Th-H	Am	0	0	0	4	0	0	0	0	0	0	0.1	35.0	Int	I
15	*Amorpha fruticosa* L.	MiPh	NAm	0	0	0	0	2	1	2	0	0	0	0.3	13.3	Int	I
16	*Gleditsia triacanthos* L.	MaPh	NAm	0	0	0	0	0	0	3	0	0	0	0.1	20.0	Int	I
17	*Laburnum anagyroides* Medik.	MiPh	Eur	0	0	0	0	0	0	1	0	0	0	0.1	5.0	Int	N

Table 2. (cont.)

№	Species	Life forms	Phytogeo-graphical elements	Number of the localities of the IAS in each transect (T)										Fre-quency (T/N)	Average species cover (%)	Type of intro-duction	Stage of natural-ization or invasion
				T1	T2	T3	T4	T5	T6	T7	T8	T9	T10				
18	*Robinia pseudoaccacia* L.	MePh	NAm	50	50	50	50	50	50	50	50	50	50	1.0	24.5	Int	I
19	*Elodea canadensis* Michx.	H	NAm	0	0	0	0	1	0	0	0	0	0	0.1	80.0	Int	I
20	*Oenothera biennis* L.	H	NAm	11	1	0	0	0	0	1	0	0	0	0.3	36.7	Int	I
21	*Oxalis corniculata* L.	Th-H	Eur-As	0	0	1	0	0	0	0	0	0	0	0.1	7.5	Unint	I
22	*Sorghum halepense* (L.) Pers.	H	subMed-As	0	0	0	0	0	0	1	2	3	12	0.4	92.5	Unint	I
23	*Fallopia x bohemica* (Chrtek et Chrtkova) J. P. Balley	Ch-H	EAs	1	0	0	0	0	0	0	2	0	0	0.2	90.0	Int	I
24	*Koelreuteria paniculata* Laxm.	MiPh	EAs	0	0	0	0	0	0	1	0	0	0	0,1	5.0	Int	N
25	*Buddleja davidii* Franch.	MiPh	Ch	0	0	0	0	0	0	1	0	0	0	0.1	5.0	Int	N
26	*Datura stramonium* L.	Th	Am	0	0	0	0	0	1	6	0	0	0	0.2	7.5	Int	I
27	*Parthenocissus quinquefolia* (L.) Planch.	MiPh	NAm	0	0	0	0	0	0	2	0	0	0	0.1	5.0	Int	N
				Potentially Invasive Alien Species (PIAS)													
29	*Opuntia tortispina* Engelm.	H	NAm	0	2	0	0	0	0	0	0	0	0	0.1	25.0	Int	I
30	*Impatiens balfourii* Hook. f.	Th	As	0	0	0	0	0	0	1	0	0	0	0.1	60.0	Int	I
31	*Lupinus polyphyllus* Lindl.	H	NAm	0	0	0	3	0	0	0	0	0	0	0.1	75.0	Int	I

the highest species cover. Only 6 of the IAS (19.4%) occur in more than half of the transects. The highest percentage (45.2%) is the IAS found in one transect only.

From the 11 natural habitats included in Natura 2000 (Table 1) for the territory of Lozenska Mountain, substantial threat of IAS irruption appears for habitat types 3150 (Natural eutrophic lakes with Magnopotamion or Hydrocharition vegetation) and 3270 (Rivers with muddy banks with Chenopodion rubri and Bidention vegetation). These two habitats are located on the periphery of the mountain near the Iskar River and the Pancherevo, Gabrensko and Pasarelsko Lakes and Dams, and substantial threat for them are the populations of *Impatiens glandulifera* and *Solidago gigantea*. Potential risk also exists for the habitat type 6210 Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia) located in transect 2 because of the slow but massive invasion of the species from genus *Opuntia* there. The rest of the habitats occupy areas with forests (91M0, 9130, 9170), shrublands (40A0) and grasslands on specific and in most cases undisturbed terrains (6110, 6210) in the interior of the mountain where the presence of the IAS species is low and these are not competitive to the natural flora.

As a result of the cluster analysis (Fig. 3), five clusters (A–E) are formed at a linkage distance of around 20. Transects 1, 2, 4 and 7 are separated from the other transects due to the higher number of species found and specific distribution of some of the IAS, for example *Opuntia humifusa* and *Impatiens glandulifera* in transect 2; *Chenopodium ambrosioides* only in transect 4; *Buddleja davidii* in transect 7. These transects are in the periphery of the mountain where the flora and vegetation are highly influenced by people. Along these transects are encountered certain unintentionally introduced IAS, such as *Xanthium italicum* and *X. spinosum* and also intentionally introduced ones like *Robinia pseudoacacia*, *Gleditsia triacanthos*, *Laburnum anagyroides*, *Amorpha fruticosa*, *Opuntia humifusa*. Some of the intentionally introduced species are naturalized in the flora of the mountain (*Acer negundo*, *Ailanthus altissima*, *Amorpha fruticosa*), while others are considered "escaped" from gardens (*Impatiens balfourii*, *Lupinus polyphyllus*, *Oenothera biennis*, *Parthenocissus quinquefolia*).

The rest of the transects belong to cluster C. These are inside the mountain where the number of IAS is lower. Most of the IAS found there are ruderals or unintentionally introduced, such as *Amaranthus hybridus*, *A. retroflexus*, *Bidens frondosus*, *Datura stramonium*, *Erigeron annuus*, and *Sorghum halepense*. Transects 8 and 9 have the lowest linkage distance and the similarity between them is the highest. Close to these are transects 6 and 3. These have equal number of species but different number of populations which is the reason for their separation in sub-clusters. These four transects are related to transect 10 (linkage distance about 15) characterized by the abundant distribution of *Sorghum halepense* and transect 5 (linkage distance about 20) characterized by the population of *Elodea canadensis*.

Discussion

The number of IAS on the territory of Lozenska Mountain is relatively high. These species represent 45% of all reported IAS for the flora of Bulgaria (Petrova et al. 2013) and 3.46% of the floristic composition of the Lozenska mountain (Glogov and Delkov 2016). The abundance of species from Asteraceae and Fabaceae found fits well to the data presented for the invasive alien flora of Bulgaria (Petrova et al. 2005, 2013). The family Asteraceae was the richest in IAS in the Lozenska Mountain, and the same was reported previously in a number of other regional studies (Dimitraşcu et al. 2011, Pyšek et al. 2017, Vinogradova et al. 2018). This is probably associated with the taxonomical structure of alien floras in the temperate zone (Vinogradova et al. 2018). Although Asteraceae is the family with the biggest number of IAS, the highest species cover of alien plants belongs to species from Fabaceae (*Robinia pseudoacacia*), Poaceae (*Sorghum halepense*) and Polygonaceae (*Fallopia* × *bohemica*).

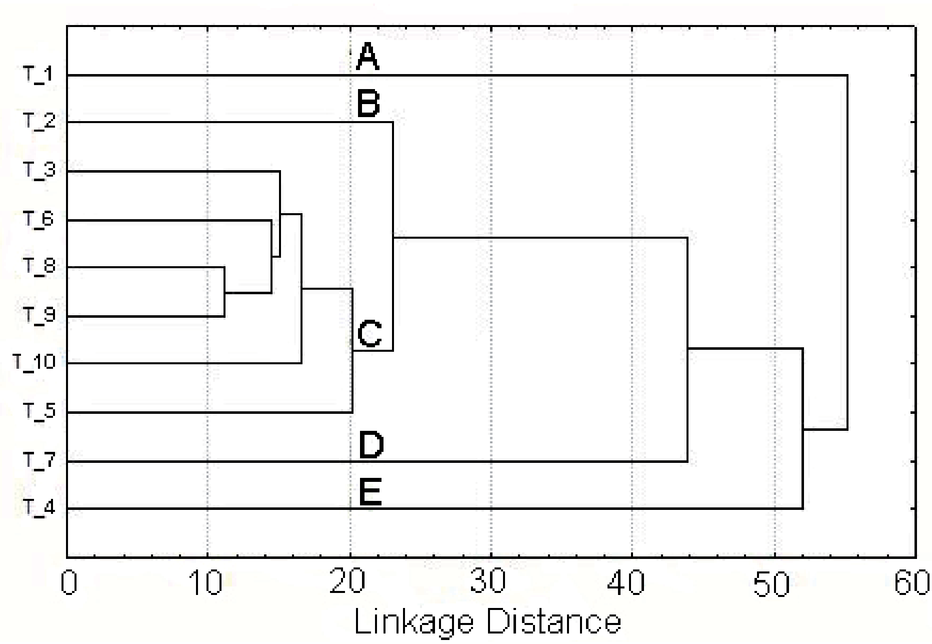

Fig. 3. The similarity between the transects based on cluster analysis (UPGMA). T_1 to T_10 correspond to transect number.

The analysis of the biological spectrum of IAS shows equal presence of the three main life forms. The high percentage of therophytes conforms with data reported by Petrova et al. (2013) for our country, and in terms of alien plant species numbers on a global scale (Podda et al. 2011, Maslo 2016). The high presence of the phanerophytes found in this survey is not in contrast to the data presented by Wagner et al. (2017) for the European woodlands where phanerophytes are dominant. According to Wagner et al. (2017), the higher number of alien phanerophytes reflects the stronger introduction pressure of trees since the 17th century, the facilitation of alien tree spread through deliberate and massive planting, and human management practices and landscape fragmentation. The distribution of woody alien species is related to climatic conditions and in areas with harsh climate their establishment and growth is low (Vinogradova et al. 2018).

The distribution of phytogeographical elements is in agreement with the data presented by Petrova et al. (2013) where the majority of the species are of American origin. The most frequently found alien species with Asiatic origin is the therophyte *Impatiens glandulifera*. The same conclusion was presented by Wagner et al. (2017) who considered its successful distribution and frequency in European woodlands linked to its wide habitat niche, high shade tolerance, seed production and long flowering period.

The increased presence of IAS on the periphery of Lozenska Mountain and their absence in its interior is fully in line with their prevailing environmental requirements. Forest and shrubland communities predominate in the mountain, and most of the IAS thrive in full sun and prefer open spaces. In terms of soil nutrients, the IAS of the more extreme regimes, such as eutrophs (growing in nutrient rich habitats, e.g. *Impatiens glandulifera, Erigeron annuus, Elodea canadensis, Solidago giganeta*) and oligotrophs (preferring nutrient poor soils, e.g. *Opuntia humifusa*) are competitively superior to local species. They occupy specific habitats and are dominant there. The distribution of the IAS on the territory of the mountain is quite similar to the data presented for European forests (Wagner et al. 2017).

Seven species in this study (*Acer negundo*, *Ailanthus altissima*, *Amorpha fruticosa*, *Bidens frondosus*, *Fallopia* × *bohemica*, *Opuntia humifusa* and *Robinia pseudoacacia*) are highly aggressive and represent the greatest threat to biodiversity, nature and man (Pyšek et al. 2009, Petrova et al. 2013). These plants are widely distributed in Bulgaria and Europe and are included into the list of 10 most significant species with negative impact (Petrova et al. 2013). Black locust (*Robinia pseudoacacia*), with dominant coverage in all transects, was artificially propagated in the Lozenska Mountain in the form of stands with anti-erosion function in the 1990s. This introduced tree is considered to be one of the most promising species in the establishment of intensive forest plantations for the production of biomass and the restoration of degraded lands (Dimitrova 2012). On the other hand, a side-effect of planting this nitrogen-fixing pioneer tree, very tolerant to the nature of the substrate, is its propagation and spread, which pose a problem for nature conservation (Vítková et al. 2017). Solitary individuals of this species occur very often in all parts of the mountain near settlements or along forest roads and paths. This result confirms Wagner et al. (2017) that ongoing land-use change, abandoned fields, and urban periphery could continue to provide habiat and dispersal corridors for alien phanerophytes, such as *Robinia pseudoacacia* and to a lesser degree *Acer negundo*. According to the same authors, *Robinia pseudoacacia* can colonize fallow land and urban wastelands as well. The high frequency of *Robinia pseudoacacia* in the mountain can also be linked to different habitats, a fact previously mentioned by Campos et al. (2013), and the possibility of the species to reproduce vegetatively, which render it competitive in specific habitats.

Certain invasive tree species were registered with a more limited distribution on the territory of Lozenska Mountain. Among these, *Amorpha fruticosa* was found more commonly in the interior of the mountain forming small groups along forest paths. The remaining species occur sporadically in mixed communities with *Robinia pseudoacacia*, *Fraxinus ornus* and others along the Iskar River and roads near settlements.

Species, having high frequency and species cover similarly to black locust are *Amaranthus retroflexus*, *Erigeron canadensis*, *E. annuus* and *Xanthium italicum*, which belong to the group of ruderals distributed in the immediate vicinity of settlements (dumps, abandoned construction sites, agricultural fields). *Erigeron canadensis* (distributed in 95.9% of the European countries according to Petrova et al. 2013) shows a higher degree of plasticity compared to other ruderals in terms of their distribution on the territory of the mountain. This species colonizes clearcut areas, on the place of natural landslides and wilderness in the interior of the mountain. *Chenopodium ambrosioides*, *Datura stramonium*, *Oxalis corniculata*, and *Xanthium spinosum* have relatively small populations (usually counting less than 10 individuals) and a small number of localities in the immediate vicinity of settlements.

The group of species with high frequency in a small number of transects (≤ 2) includes *Elodea canadensis*, *Impatiens glandulifera*, *Solidago gigantea*, and *Sorghum halepense*. These species dominate in a particular habitat type that is best suited to the successful implementation of their ecological strategy. *Sorghum halepense*, for example, uses mycorrhiza and endophytic nitrogen-fixing bacteria, which allows it to dominate on nutrient poor soils (Erin 2008). The natural advantages of *Impatiens glandulifera* and *Solidago gigantea* are their high productivity and rapid growth (Andrews et al. 2009, Grime 1979).

The frequency depends on the ecological plasticity of the species and the coverage of its higher adaptability to a particular type of habitat. Low-frequency IAS (occurring only in one transect) but with high coverage as the cacti occupy habitats with extreme environmental conditions. Their population is located in the western part of the mountain above Pancharevo Dam, on a relatively small area (about 1000 m^2) next to an oak forest. Because of the morphological features of the cacti and their ability to quickly disperse, they pose a potential threat to adjacent natural communities. The low occurrence and coverage of the majority of the other IAS in natural communities of the Lozenska Mountain are due to their still low naturalization, relatively low level of invasion, as for ornamental species such as *Koelreuteria paniculata* and *Buddleja davidii* located adjacent to gardens and backyards in the periphery of the settlements from where they have spread.

The analysis of the distribution of the IAS on the territory of Lozenska Mountain shows their predominant presence in areas around rivers with permanent water regime (Iskar, Rakita and Gabra) or such located in the immediate vicinity of settlements. High levels of invasion in riparian habitats are well documented for Europe and regions outside Europe (Wagner et al. 2017). We confirm Vinogradova et al. (2018) affirmation that the richness of IAS correlates positively to human population density and the percentage of urban population in the studied region. The small number of IAS in the forest habitats can be explained by their ecological preferences and also by the low suitability of the shade-adapted and slow-growing woodland herbs (Wagner et al. 2017). The proximity to water bodies with constant hydrological status for some of the IAS (*Bidens frondosus*, *Impatiens glandulifera*) and the presence of disturbed terrains for species such as *Sorghum halepense* (Chukurovo mines, eroded slopes, and landslides) are prerequisites for the formation of large monodominant communities of these plants.

On the basis of the results of this study, we consider appropriate to carry out certain practical measures to limit the populations of IAS in the territory of Lozenska Mountain. Using the IAS control methods described by Korda (2015), we believe that at the current stage of the mountain conditions the non-chemical methods are more applicable. These methods include manual uprooting, mowing, forestry mulching for the herbs like *Fallopia* × *bohemica*, *Impatiens glandulifera*, *Solidago gigantea* and other methods used for trees and shrubs like girding, felling, cut of the root collar and sprout control.

References

ANDREWS M., MAULE H., HODGE S., CHERRILL A., RAVEN J. 2009: Seed dormancy, nitrogen nutrition and shade acclimation of *Impatiens glandulifera*: implications for successful invasion of deciduous woodland. Plant Ecology and Diversity 2: 145–153. https://doi.org/10.1080/17550870903186256

ANEVA I., ZHELEV P., STOYANOV S. 2018: Alien species as a part of plant composition in the periphery of agricultural fields. Acta Zoologica Bulgarica, Suppl. 11: 173–176.

ASENOV A, DIMITROV D. 2013: The anthropophyte and invasive flora of Mountain Zemenska, West Bulgaria. Proceedings and Abstracts. Seminar of Ecology, 25-26 April 2013 Sofia, pp. 204–211.

ASSYOV B., PETROVA A. (eds) 2012: Conspectus of the Bulgarian vascular flora. Distribution maps and floristic elements. 4th edition. Bulgarian Biodiversity Foundation, Sofia. Bulgarian Academy of Sciences, Sofia, 490 pp.

BRAUN-BLANQUET J. 1964. Pflanzensoziologie, Grundzüge der Vegetationskunde. 3rd Edition, Springer-Verlag, Berlin, 631 pp. http://dx.doi.org/10.1007/978-3-7091-8110-2

CAMPOS J. A., BIURRUN I., GARCÍA-MIJANGOS I., LOIDI J., HERRERA M. 2013: Assessing the level of plant invasion: A multi-scale approach based on vegetation plots. Plant Biosystems 147: 1148–1162. https://doi.org/10.1080/11263504.2013.861538

CHYTRÝ M., OTÝPKOVÁ Z. 2003: Plot sizes used for phytosociological sampling of European vegetation. Journal of Vegetation Science 14(4): 563–570. https://doi.org/10.1111/j.1654-1103.2003.tb02183.x

DANOV G. 1964: Lozenska Mountain. Medicine and Physical Education, Sofia, 55 pp. (In Bulgarian)

DELIPAVLOV D., CHESHMEDZHIEV I. (eds) 2003: Key to the plants of Bulgaria. Agrarian University Press, Plovdiv, 591 pp. (In Bulgarian)

DIMITROV M., GLOGOV P. 2003: Characteristic syntaxa of forest phytocenoses in Lozenska Mountain. In: KOSTOV G. (ed.): Collection of Scientific Reports "50 Years University of Forestry, Forest Management and Landscape Architecture". University of Forestry, Sofia, pp: 15–20. (In Bulgarian)

DIMITROVA P. 2012: Assessment of the introduction of black locust (*Robinia pseudoacacia* L.) to Bulgaria. Nauka za Gorata (Forest Science, Sofia) 48(1-2): 71–82. (In Bulgarian)

DIMITRAŞCU M., GRIGORESCU I., KUCSICSA G., DRAGOT G-S, NĂSTASE M. 2011: Non-native and native invasive terrestrial plant species in Comana Natural Park. Case-studies: *Amorpha fruticosa* and *Crataegus monogyna*. Rev. Roumanian Géography/Romanian Journal of Geography 55(2): 81–89.

ERIN M. 2008: The invasive *Sorghum halepense* harbors endophytic N_2-fixing bacteria and alters soil biogeochemistry. Plant and Soil 315(1): 163–172. https://doi.org/10.1007/s11104-008-9740-z.

GANCHEV I. 1961. The vegetation of the Lozenska Mountain and peculiarities in its development. Publishing House Bulg. Acad. Sci., Sofia, 193 pp. (In Bulgarian).

GLOGOV P., DELKOV A. 2016: Results from investigation of vascular flora on the territory of Lozen mountain. Nauka za Gorata (Forest Science, Sofia) 52(1–2): 5–46. (In Bulgarian)

GLOGOV P., GEORGIEVA M. L., PAVLOVA D. 2018: Reports 130–141. In: VLADIMIROV V., AYBEKE M., TAN K. (eds): New floristic records in the Balkans: 37. Phytologia Balcanica 24(3): 412–415.

GRIME J. 1979: Plant strategies and vegetation processes. John Wiley and Sons, Ltd., Chichester-New York-Brisbane-Toronto, 222 pp.

IUCN – The World Conservation Union 2000: IUCN Guidelines for the Prevention of Biodiversity Loss due to Biological Invasion (Approved by the IUCN Council, February, 2000). 25 pp.
Jordanov D. (ed.) 1963–1979: Flora of NR Bulgaria. vols I–VII. BAS, Sofia. (in Bulgarian)
Kalníková V., Palpurina S. 2015: *Epilobium adenocaulon* and *Oenothera glazioviana* (Onagraceae): new alien species for the Bulgarian flora. Phytologia Balcanica 21(1): 21–27.
Korda M. 2015: A brief overview of technologies used for controlling invasive alien plant species. In: Csiszár Á., Korda M. (eds): Practical Experiences in Invasive Alien Plant Control. Rosalia Handbooks. Duna–Ipoly National Park Directorate, Budapest, pp. 37–42.
Kozhuharov S. (ed.) 1995. Flora of Bulgaria. vol. X. BAS. Sofia, 428 pp. (in Bulgarian)
Lazarević P., Stojanović V., Jelić I., Perić R., Krsteski B., Ajtić R., Sekulić N., Branković S., Sekulić G., Bjedov V. 2012: Preliminarni spisak invazivnih vrsta u Republici Srbiji sa opštim merama kontrole i suzbijanja kao potpora budućim zakonskim aktima. Zaštita Prirode 62(1): 5–31.
Maslo S. 2016: Preliminary list of invasive alien plant species (IAS) in Bosnia and Herzegovina. Herbologia 16(1): 1–14. https://doi.org/10.5644/herb.16.1.01
McNeely J. A., Mooney H. A., Neville L. E., Schei P., Waage J. K. (eds) 2001: A global strategy on invasive alien species. IUCN Gland, Switzerland, and Cambridge, UK, 50 pp.
Medvecká J., Kliment J., Májeková J., Halada L., Zaliberová M., Gojdičová E., Feráková V., Jarolímek I. 2012: Inventory of the alien flora of Slovakia. Preslia 84: 257–310.
Nikolov V., Yordanova M. 2002: Mountains in Bulgaria. Academic Publishing House Professor Marin Drinov, 432 pp. (In Bulgarian).
Ninov N. 1997: Soils. In: Galabov G. (ed.): Geography of Bulgaria. Physical Geography. BAS, Sofia, 1: 225–257 (In Bulgarian).
NOBANIS (European Network on Invasive Alien Species) 2013. Gateway to information on Invasive Alien species in North and Central Europe. http://www.nobanis.org/Search.asp
Pavlov D. 1998: Ecological foundations of forest typology in Bulgaria. Dissertation, Sofia, pp. 96–245. (In Bulgarian)
Pavlov D. 2006: Phytocenology. University of Forestry. Sofia, 256 pp. (In Bulgarian)
Pedashenko H., Meshinev T., Apostolova I. 2009: Herbaceous vegetation on carbonate terrains in Mt Lozen. Phytologia Balcanica 15(2): 245–253.
Peev D. (ed.) 2012. Flora Republicae Bulgaricae. vol. 11. Serdica: Aedibus Acad. Sci. Bulgaricae, 527 pp. (In Bulgarian)
Petrova A. 2017: On the identity and distribution of the alien *Acalypha* species (Euphorbiaceae) in Bulgaria. Phytologia Balcanica 23(1): 31–34.
Petrova A., Vladimirov V. 2007: Recent (1994–2004) taxonomic studies on the Bulgarian flora. Bocconea 21: 7–25.
Petrova A., Vladimirov V. 2012: A contribution to the alien flora of Bulgaria. Proceedings of the Bulgarian Academy of Sciences 65(6): 771–778.
Petrova A., Vladimirov V., Georgiev V. 2005: Distribution of foreign and invasive plant species reported to Bulgaria over the last 20 years (1991-2011). Reports VIII National Botany Conference, Sofia, 21-30 September 2005, Sofia, pp. 339–348. (In Bulgarian)
Petrova A., Vladimirov V., Georgiev V. 2013: Invasive alien species of vascular plants in Bulgaria, IBER – BAS, Sofia, 320 pp.
Podda L., Fraga I, Arguimbau P., Mascia F., Mayoral García-Berlanga O, Bacchetta G. 2011: Comparison of the invasive alien flora in continental islands: Sardinia (Italy) and Balearic Islands (Spain). Rendiconti Lincei 22(1): 31–45. https://doi.org/10.1007/s12210-010-0112-2
Pyšek P., Danihelka J., Sadlo J., Chrtek J. Jr., Chytry M., Jarošik V., Kaplan Z., Krahulec F., Moravcova L., Pergl J., Štajerova K., Tichy L. 2012: Catalogue of alien plants

of the Czech Republic (2nd edition): checklist update, taxonomic diversity and invasion patterns. Preslia 84: 155–255.

Pyšek P., Lambdon P. W., Arianoutsou M., Kühn I., Pino J., Winter M. 2009: Alien vascular plants of Europe. In: DAISIE Handbook of alien species in Europe. Springer, Dordrecht, pp. 43–61.

Pyšek P., Meyerson L.A., Simberloff D. 2018: Introducing "Alien Floras and Faunas", a new series in biological invasions. Biological Invasions 20(6): 1375–1376. https://doi.org/10.1007/s10530-017-1648-1

Pyšek P., Pergl J., Essl F., Lenzner B., Dawson W., Kreft H., Weigelt P., Winter M., Kartesz J., Nishino M., Antonova L. A., Barcelona J. F., Cabezas F. J., Ca´rdenas D., Ca´rdenas-Toro J., Castano N., Chacon E., Chatelain C., Dullinger S., Ebel A. L., Figueiredo E., Fuentes N., Genovesi P., Groom Q. J., Henderson L., Inderjit N., Kupriyanov A., Masciadri S., Maurel N., Meerman J., Morozova O., Moser D., Nickrent D., Nowak P. M., Pagad S., Patzelt A., Pelser P. B., Schulze M., Seebens H., Shu W., Thomas J., Velayos M., Weber E., Wieringa J. J., Baptiste M. P., van Kleunen M. 2017: Naturalized and invasive flora of the world: species diversity, taxonomic and phylogenetic patterns, geographic distribution and global hotspots of plant invasion. Preslia 89: 203–274.

Richardson D. M., Pyšek P., Rejmánek M., Michael G. B., Panetta F. D., West C. J. 2000: Naturalization and invasion of alien plants: concepts and definitions. Diversity and Distributions 6: 93–107. https://doi.org/10.1046/j.1472-4642.2000.00083.x

Shine C., Williams N., Gundling L. 2000: A guide to designing legal and institutional frameworks on alien invasive species. IUCN, Gland, Switzerland Cambridge and Bonn, 138 pp.

Sîrbu C., Oprea A. 2011: Plante adventive în flora României. Editura Ion Ionescu de la Brad, Iasi, pp. 657–721.

StatSoft Inc. "Statistica". 2004: Data Analysis Software System, version 7.0. Tulsa. OK USA.

Stešević D., Petrović D. 2010: Preliminary list of plant invaders in Montenegro. Biologica Nyssana 1(1–2): 35–42.

Stoyanov N., Stefanov B., Kitanov B. 1966–1967: Flora of Bulgaria. vols I, II. Art and Sciences. Sofia, 1367 p. (in Bulgarian)

The Plant List 2010: Version 1. Published on the Internet; http://www.theplantlist.org/ (accessed 1 January 2019).

Tela Botanica 1901: Published on the Internet: https://www.tela-botanica.org/

van Kleunen M., Dawson W., Essl F., Pergl J., Winter M., Weber E., Kreft H., Weigelt P., Kartesz J., Nishino M., Antonova L. A., Barcelona J.F., Cabezas F. J., Cárdenas D., Cárdenas-Toro J., Castano N., Chacón E., Chatelain C., Ebel A. L. Figueiredo E., Fuentes N., Groom Q. J., Henderson L., Kupriyanov A., Masciadri S., Meerman J., Morozova O., Moser D., Nickrent D. L., Patzelt A., Pelser P. B., Baptiste M. P., Poopath M., Schulze M., Seebens H., Shu W., Thomas J., Velayos M., Wieringa J. J., Pyšek P. 2015: Global exchange and accumulation of non-native plants. Nature 525: 100–103. https://doi.org/10.1038/nature14910

Velchev V. (ed.) 1982–1989: Flora of NR Bulgaria. vol. VIII, IX. BAS. Sofia. 519 pp. (in Bulgarian)

Velev S. 1997: Climate zoning of Bulgaria. In: Yordanova M., Donchev D. (eds): Geography of Bulgaria. Publishing House Bulg. Acad. Sci., Sofia, pp. 127-130. (In Bulgarian)

Vinogradova Y., Pergl J., Essl F., Hejda M., van Kleunen M., Pyšek P. 2018: Invasive alien plants of Russia: insights from regional Inventories. Biological Invasions 20(8): 1931–1943. https://doi.org/10.1007/s10530-018-1686-3

Vítková M., Müllerová J.,Sádlo J., Pergl J., Pyšek P. 2017: Black locust (*Robinia pseudoacacia*) beloved and despised: A story of an invasive tree in Central Europe. Forest Ecology and Management 384: 287–302. https://doi.org/10.1016/j.foreco.2016.10.057
Wagner V., Chytrý M., Jiménez-Alfaro B., Pergl J. 2017: Alien plant invasions in European woodlands. Diversity and distributions 23: 969–981. https://doi.org/10.1111/ddi.12592
Williamson M. 1996: Biological Invasions. Chapman & Hall, London, 256 pp.