Study Of *Impatiens Glandulifera* Competitors Among Native Plant Species And Their Potential For Control Of The Soil Erosion In Riparian Habitats

Plamen S. Glogov*, Mira L. Georgieva

Forest Research Institute – Bulgarian Academy of Sciences, 132 Kliment Ohridski Blvd, Sofia, BULGARIA

***corresponding author e-mail: pglogov@abv.bg**

Abstract

The aim of the present study is to identify among the native plants the main competitors of *Impatiens glandulifera* in an experimental section of the Iskar River gorge with intensive presence of this invasive alien plant and to identify among these species those whose populations would help limit its distribution in natural hygrophilous communities and to reduce the risk of soil erosion in the riparian zone. The investigation was conducted in the period 2019-2020. Sixty Permanent Sample Plots (area 2x2 $m^{2)}$ were set up in representative wetland communities and based on their floristic composition and cover abundance 12 dominant species were identified- *Impatiens glandulifera* Royle, *Urtica dioica* L., *Rubus caesius* L., *Petasites hybridus* (L.) P. Gaertn., B. Mey. & Scherb, *Aegopodium podagraria* L., *Epilobium hirsutum* L., *Scrophularia umbrosa* Dumort, *Carex* sp., *Scirpus sylvaticus* L., *Phalaris arundinacea* L., *Typha angustifolia* L., *Phragmites australis* (Cav.) Trin. ex Steud. The most suitable of the native plants against the Hymalayan balsam are *Phalaris arundinacea* - for localities of flooded and periodically flooded type and *Phragmites autsralis* - for standing waters. In riparian communities with a three- and four-layers structure and high total cover abundance of the tree layer, the shade-tolerant species *Aegopodium podagraria* is the most competitive with *Impatiens glandulifera* and permanently suppresses its populations. The recommendation for optimal use of local competitors is to stimulate their spread in areas not occupied by vegetation along the river under the direct action of the watercourse in order to strengthen the shore and subsequently planting local tree and shrub species (alder, willow and poplar) to build a sustainable vertical structure of the communities and gradually restore the autochthonic wetland forest vegetation.

Key words: invasive alien species, ecological strategy, competiveness, Hymalayan balsam, erosion, wetland vegetation

INTRODUCTION

Competition is one of the main interactions between alien invasive species and native species together with the predation, herbivory, introduction of disease, and resource use. (Keller at al. 2012). Differences in competitive ability may explain the maintenance of existing plant populations and the invasion of new areas by plant species (Bakker, Wilson, 2001). The outcome of competition between the alien invaders and native species is strongly context-dependent as competitive strength varies along environmental gradients, and life stages, and also depends on abundances. (Čuda at al. 2015). The invasion as a function of competition generally reflect on habitat alteration and the loss of biodiversity (Frenot, 2005, Vilà et al. 2006). The low intensities of competition, altered disturbance regimes and low levels of environmental stress, especially high resource availability are factor which thought to render habitats invasible (Alpert at al. 2000). According to Nikolić at. al. (2013) the number of invasive taxa increases with habitat diversity and the level of habitat fragmentation and the species richness positively correlates with the invasive taxa richness. Just as habitat degradation leads to the emergence of invasive species, so the emergence of invasive species can lead to habitat degradation (Hill, J. 2020, Calizza, E at al. 2017).

A typical example in this respect is the highly invasive alien species Hymalayan balsam (*Impatiens glandulifera* Royale) which spreads rapidly throughout Europe, parts of North America and New Zealand, dominate landscapes, and finaly displace native plant species (Global Invasive Species Database, 2021). In species-rich tall herb communities, invasion by *I. glandulifera* causes a considerable change in plant species richness, diversity and evenness. (Kiełtyk, 2019). According to Power, Vilas (2020) the competitive ability of I. *glandulifera*, both in terms of resource exploitation and allelopathy (i.e., the release of biochemicals that may be toxic to neighbouring plants), is considered a key determinant of its success. This and other similar studies of *Impatiens gandulifera's* competitive relationships with native plant species (Gruntman et al., 2013, Pattison at al. 2019, Power, Vilas, 2020) convincingly prove the competitive superiority of this species over most of them and the reasons for it, including, allelopathy, seed dispersal strategy, vegetative propagation, etc.

Bieberich at al., (2021) suggest that I. glandulifera is a "back -seat driver" changes, which is facilitated by previous ecosystem changes (land use change, pollution, nutrient input etc.) but is also a driver of further changes and in this case its is more complicated because the previous changes that facilitated invasion have to be known and countered. One of the negative regulatory role of *Impatiens gladnulifera* in changing the riparian habitats is provoking soil erosion processes such as: 1. the competitive displacement of perennial vegetation by *I. glandulifera* increasesthe risk of erosion during the winter period when live Hymalayan balsam plants are absent (Greenwood at al., 2018); 2.the stems of mature individuals of *I. glandulifera* are disproportionately tall and heavy compared to its shallow root system, which facilitates the easy uprooting of individuals by the river flow along with parts of the soil in their roots (Dawson, Holland, 1999); 3. the dead stems and adventitious roots of *I. glandulifera* can obstruct waterways and wetlands, which can alter ecosystem's hydrology and can lead to increased erosion or flooding (Cao at al., 2021).

In recent years, a number of studies have been conducted in Bulgaria related to the identification of biological agents (Belilov et al., 2020, Zaemdzhikova et al., 2020, Glogov et al., 2020a) and measures for biological control of *I. glandulifera* populations. The relationship between Impatiens glandulifera's competitors among native species and their role in combating the spread of this invasive species and preventing soil erosion has not yet been studied.

Given the strong ecological-coenotic strategy of *Impatiens glandulifera* in order to protect natural habitats from this invasive species, it is important to limit the ability of its populations to penetrate their communities. Even only one individual of Hymalayan balsam can produce and disperse 800–2,500 seeds (Beerling, Perrins, 1993) and its participation in the floristic composition of a natural community hides a danger of exponential growth of its population in it in the coming years. The risk of such a danger and its consequences are especially high for disturbed riparian habitats threatened by erosion processes, which can be catalyzed by the presence of *Impatiens glandulifera* (Greenwood, Kuhn, 2014). For this reason, it is important to find an opportunity for populations of highly competitive native species to act as a natural barrier to the spread of this invasive species in communities of this type of habitat.

The aim of the present study is to identify among the native plants the main competitors of *Impatiens glandulifera* in an experimental section of the Iskar River gorge with intensive presence of this invasive alien plant and to identify among these species those whose populations would help limit its distribution in natural hygrophilous communities and to reduce the risk of soil erosion in the riparian zone.

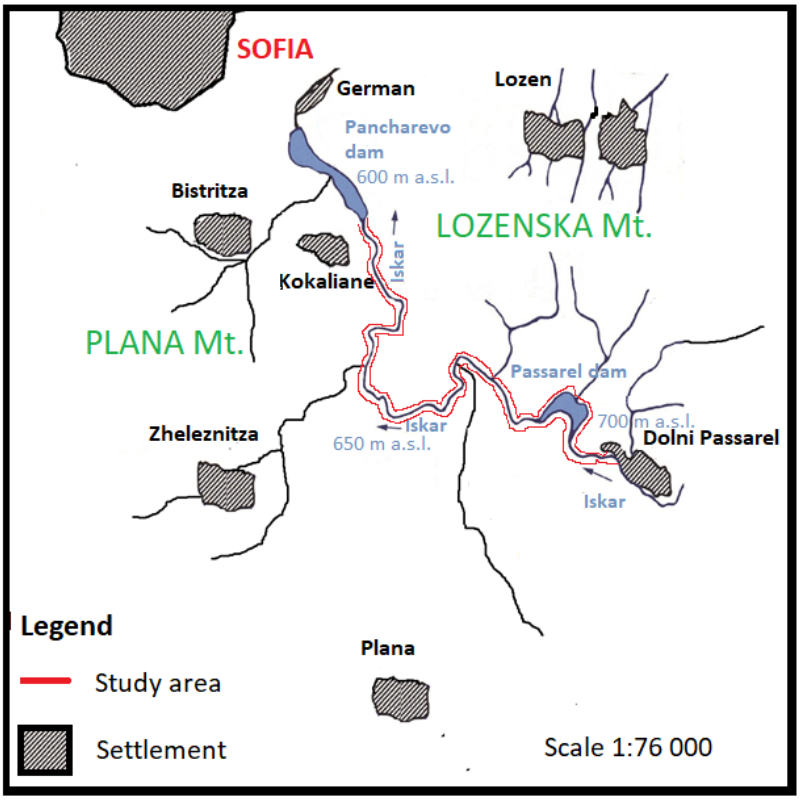
MATERIALS AND METHODS

1. *Study area and object of the study*

The study area is located 10 km from the capital of Bulgaria- Sofia. It covers part of the Iskar river gorge between Plana and Lozenska Mountains (Western Bulgaria). The study area stretches between the villages of Kokalyane and Dolni Pasarel (Sofia municipality) (Fig. 1) and it is about 3 km^2, approximately 30 km long and 0.1 km wide (0.05 km on both sides of the river).

The reasons for choosing the study area is the high participation of *Impatiens glandulifera* - about 5000 m^2 Kachova et al. (2020) in natural hygrophilous communities and the recent studies of this species in the same area related to the specifics of its localities (Glogov et al. 2019, Kachova et al. (2020)), morphological features (Glogov at. al. 2020a) and measures for its distribution (Glogov at. al. 2020b,c, Georgieva, Glogov, 2020) some of which continue at the present stage.

Fig. 1. Map of the study area



The climate data in the study area are as follows: 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 average annual precipitation is 645 mm. (Glogov at al.,2019)

The present study focuses on hygrophilous communities from the following characetristic type of localities according to Kachova et al. (2020): 1- Periodically flooded riparian type, 2 - Constantly flooded by (by river running waters) riparian type; 3- "Swamp" on stagnant water. They are located next to the river and are most vulnerable to erosion processes. Soil type is Fluvisols and Histosols. (Kachova et al.,2020):

The predominant vegetation in the studied area is presented by riparian communities of *Alnus glutinosa* (L.) Gaertn which belong to a habitat subtype of NATURA 2000 habitat 91E0 * Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion*, *Alnion incanae*, *Salicion albae*). (Glogov et al., 2020b, Kavrakova et al., 2009).

The object of study are populations of *Impatiens glandulifera* and native species with predominant cover abundance (dominants) in the grass floor of the hygrophilous communities along the Iskar River. The use of a dominant species as a target plant rather than a random species or one with poor competitive ability, renders our results more general, implying that *I. glandulifera* might exert greater competitive effect on the less robust co-occurring species. (Gruntman et al., 2013).

2. *Vegetation sampling*

2.1. *Species cover abundance measurment*

The investigation was conducted in the period January-November, 2020 in order to trace the length of the growing season in *I. glandulifera* and each of the local competing species.

Following Kiełtyk, Delimat (2019), 60 Permanent samlple plots (PSP) , 2x2 m^2 in size, were set up on both sides of the Iskar river. The leading criteria in the selections of the places for setting up the PSP are:

- Selection of sites in the immediate vicinity of the river, with a high risk of erosion, corresponding to the localities type 1,2 and 3 in the study area acccording to Kachova et al. (2020)
- Selection of representative plant communities with a predominant cover abundance of Impatiens glandulifera and communities dominated by native species in which the Hymalayan balsam has different participation or is absent.
- Even distribution of PSP throughout the river basin in the study area.

In the PSP were determined the total species cover abundance and the cover abundance of the dominant species (including *Impatiens glandulifera*) using 5-degree Braun-Blanquet scale (1964) (Table 1). The determination of plant taxa and the biological types to which they belong is according to Delipavlov, Chesmedjiev (2003).

Table 1. Braun – Blanquet cover abundance scale

Braun – Blanquet Scale	Range of cover
R	< 5%; very few individuals
+	< 5%; few individuals
1	< 5%; numerous individuals
2	5-25%
3	25-50%
4	50-75%
5	75-100%

Based on the number of PSPs in which they meet with a predominant cover abundance, the main dominants among the local species in the hygrophytic communities have been determined. The PSPs are divided into 9 groups:

Group I - PSP with monodominant communities in which the species meets with cover abundance 5

Group II - PSP with monodominant communities in which the species meets with cover abundance 4

Group III - PSP with communities in which the species meets with cover abundance 3 or 4 and is co-dominant with other species.

Group IV- PSP with communities in which the species meets with cover abundance 1-2

Group V- PSP in which the species occurs singly

Group VI - PSP with communities in which the species is absent

Group VII - the species is co-dominant with *Impatens glandulifera*

Group VIII- *Impatiens glandulifera* occurs with low cover abundanceage or singly in communities of this dominant species

Group IX- *Impatiens glandulifera* is absent from communities of this dominant species.

2.2. Density of the populations

The average density (number of individuals per m^2) of the dominant species in both phases- juvenile and maturity was calculated. A comparison was made between the average densities in PSP with a predominance of *Impatiens glandulifera* and that of PSP with a predominance of native species.

2.3. Phenological observations

For each dominant species in PSP, are registered the beginning and the duration of the growing season and flowering period. The beginning and end of the vegetation is considered to be the appearance of the first individual and respectively the death of the last individual from the populations of the dominant species in all sample areas.

2.4. Measurement of the predominant height of the species

The predominant height of individuals in the population was measured during the other studies in the sample plots and in some cases it was used together with cover abundance as an additional indicator of the superiority of a species in the community. Subsequently, data on the predominant heights of individuals of a particular species in all PSPs were averaged

2.5. Floristic diversity in the PSP

After establishing the floristic composition and counting the species in each of the PSPs, the PSP with the most common dominant species were divided into three groups depending on the projective coverage of the dominants: I- *Species dominates in the PSP with cover abundance >75%*; II- *Species dominates in the PSP with cover abundance 50%-70%*; III- *Species co-dominates in the PSP with cover abundance 25% -50%.* In each of the groups the average number of species was determined. A comparison was made between the floristic richness in PSP with a predominance of *Impatiens glandulifera* and that of PSP with a predominance of native species.

Knowing the ecological-coenotic strategies of the dominant native species, the competitiveness of each of them is analyzed and the possibilities with their help to limit the distribution of *Hymalayan balsam* and to reduce the risk of erosion in the investigated localities.

Results

Species cover abundance measurment

During the investigation period 12 dominant species were identified in the communities represented by the PSP, including 1 annual (*Impatiens glandulifera*), 10 perennials and 1 shrub (*Rubus caesius*) (Table 2). *Impatiens glandulifera* is present as dominant in the communities of 41.7% of the PSP, in 28.3% of the PSP it has a lower quantitative share and in 30.0% of the PPP the species has not been identified. The large participation of the species in PSP is related not only to its high competitive ability but also to its ability to resist competitive suppression. In some of the PSP, the species has been isolated by populations of native species and individuals from it that have reached the stage of flowering and fruiting are found to grow on a rotting wood and cracks in the stone foundations of a bridge.

Among the native species with the highest share in PSP are European dewberry (*Rubus caesius*), stinging nettle (*Urtica dioica*) and goutweed (*Aegopodium podagraria*), which, like the invasive alien species *Impatiens glandulifera*, are found in over 50% of PSP. European dewberry and stinging nettle are the predominant species in more than 1/3 of all PPP. After *Impatiens glandulifera* in the studied area goutweed is the species that forms the largest number of monodominant communities, and the stinging nettle is the co-dominant species that participates in the most PSP with polydominant phytocoenoses.

The Hymalayan balsam was not found in the monodominant communities of the Poaceae reresentatives *Phalaris arundinacea* and common reed *Phragmites australis*, and in the communities of sedges (*Carex* sp.), wood clubrush (*Scirpus sylvaticus*) and lesser bulrush (*Typha angustifolia*) individuals with low cover abundance or single ones have been identified.

Apart from those presented in Table 2, other species with regular presence and occurrence, which in some of the PSP reach cover abundance 3 and sometimes assume the role of co-dominants are *Galium aparine* L., *Agrostis stolonifera* L., *Ranunculus repens* L., *Mentha longifolia* (L.) Huds., *Lythrum salicaria* L. and *Lactuca seriola* L.

Table 2. Distribution of PSP by predominant species and groups

Species	Biological type	Distribution of PSP by groups (%)								
		Group I	Group II	Group III	Group IV	Group V	Group VI	Group VII	Group VIII	Group IX
Impatiens glandulifera Royle	annual	8.3	6.7	26.7	26.6	1.7	30.0	0.0	0.0	0.0
Urtica dioica L.	perennial	3.3	3.3	23.3	35.0	13.3	21.7	18.3	5.0	1.7
Rubus caesius L.	schrub	1.7	5.0	10.0	31.7	10.0	41.7	6.7	5.0	1.7

Petasites hybridus (L.) P. Gaertn., B. Mey. & Scherb	perennial	1.7	1.7	5.0	8.3	3.3	80.0	11.7	1.7	1.7
Aegopodium podagraria L.	perennial	5.0	5.0	16.7	18.3	10.0	45.0	10.0	3.3	8.3
Epilobium hirsutum L.	perennial	0.0	1.7	6.7	13.3	10.0	53.3	3.3	1.7	1.7
Scrophularia umbrosa Dumort	perennial	0.0	1.7	6.7	13.3	5.0	73.3	1.7	3.3	1.7
Carex sp.	perennial	1.7	3.3	3.3	16.7	5.0	53.3	3.3	3.3	1.7
Scirpus sylvaticus L.	perennial	0.0	0.0	3.3	1.7	0.0	95.0	1.7	1.7	0.0
Phalaris arundinacea L.	perennial	5.0	0.0	0.0	0.0	0.0	95.0	0.0	0.0	5.0
Typha angustifolia L.	perennial	3.3	0.0	0.0	0.0	0.0	96.7	0.0	1.7	1.7
Phragmites australis *(Cav.) Trin. ex Steud*	perennial	5.0	0.0	0.0	0.0	0.0	95.0	0.0	0.0	5.0

Density of the populations

The average number of individuals in the populations of the most common dominants decreased from the juvenile phase to the maturity phase between 1.4 times and 3.2 times in the monodominant communities and between 1.3 times and 5.6 times in the polydominant communities (Table 3). In both types of communities, the number of individuals decreases most in *Impatiens glandulifera* (3.2 times in monodominant and 5.6 times in polydominant communities), whose populations have the highest number of individuals among the other dominant species. In the monodominant communities the population density decreased the least in *Aegopodium podagraria* (1.4 times) and *Petasites hybridus* (1.6 times), and in the polydominant communities in *Epilobium hirsutum* (1.3 times) and *Petasites hybridus* (2.2 times).

Phenological observations

Most of the dominants which number prevails in the PSP have a long growing season between 9 and 11 months, and for some of them it starts from the beginning of the calendar year (Table 3). The growing season for Hymalayan balsam starts a month later in comparison with the native species. The species with the longest flowering period- 4 months- are *Impatiens glandulifera* and *Urtica dioica*. The flowering period in most native species begins earlier than that of the Hymalayan balsam.

Table 3. Density, heights and phenological data for some of the dominant species in the communities of the study area

Species	Monodominant cmunnities	Polydominant communities	Monodominant cmunnities	Polydominant communities	Beginning of the		Duration

	Average number of individuals in juvenil phase per m^2	Average number of mature individuals per m^2	Average number of individuals in juvenil phase per m^2	Average number of mature individuals per m^2	Predominat height of individuals in juvenil phase (cm^2)	Predominat height of mature individuals (cm^2)	Predominat height of individuals in juvenil phase (cm^2)	Predominat height of матуре individuals (cm^2)	growing season (month, No)	Flowering period (from (month No) to (month No))	of the growing season (number of months)
Impatiens glandulifera	132.6	41.1	96.9	17.2	8.2	193.9	7.7	184.4	IV	VI-IX	8
Urtica dioica	84.6	35.7	56	22.5	9.6	188.5	9.3	182.7	I	VI-IX	11
Rubus caesius	Vegetative propagation	17.2	Vegetative propagation	9.5	Vegetative propagation	144.4	Vegetative propagation	138.6	III	V-VIII	9
Petasites hybridus	27.7	17.0	16.5	7.4	6.1	137.4	5.5	129	III	III-IV	9
Aegopodium podagraria	41	28.3	29.2	11.8	9.2	151.1	8.4	148.6	III	V-VII	9
Epilobium hirsutum	56.3	21.7	22.0	16.5	9.7	142.8	9.5	151.9	II- III	VI-VIII	9
Scrophularia umbrosa	97.2	36.3	44.9	19.7	14.2	114.8	13.5	111.2	I	VI-VII	11

Measurement of the predominant height of the species

Among the more common dominants ocured in PSP, with the highest average predominant height of juvenille plants is *Scrophularia umbrosa*, and the species with the lowest ones- *Petasites hybridus* (Table 3). Among mature individuals the highest are the stems of *Impatiens glandulifera* and *Urtica dioica*, and the lowest -those of *Petasites hybridus*. A comparison between the heights of the species in juvenille phase in the monodominant and polydominant communities shows that in the former the individuals are taller. The difference in heights of the juvenile plants in both type of communities are the following: *Aegopodium podagraria*- 9.8%, *Scrophularia umbrosa*- 8.5%, *Petasites hybridus*- 7.3%, *Impatiens glandulifera*-6.1%, *Urtica dioica* –3.7%, *Epilobium hirsutum*- 2.4%. A similar dependence is observed in the mature plants. The difference in their heights in both type of communities is as follows: *Impatiens glandulifera*- 4.9%, *Epilobium hirsutum*- 4.7%, *Petasites hybridus*- 4.3%, *Urtica dioica* –3.0%, *Rubus caesius*- 3%, *Scrophularia umbrosa*- 1.9%, *Aegopodium podagraria*- 1.3%.

Floristic diversity in the PSP

Data on species richness in PSPs (Table 4) with a dominant share of *Impatiens glandulifera* are close to those in PSPs with a predominance of native species, with the lowest number of species (between 3 and 5 species) in monodominant communities with over 75% abundance of the predominant species. In the PSP where the Hymalayan balsam dominates with a lower abundance (including as a co-dominate species), the diversity is higher than that of the communities with native dominant species. In addition, in some of the PSP with the participation of the *Impatiens glandulifera*, were found another invasive species such as *Acer negundo* L., *Erigeron annuus* (L.) Pers. and *Oenothera biennis* L.

Table 4. Number of species in PSP with different cover abundance of the dominants

Dominat	Mean total species number in PSP

species	Species dominates in the PSP with cover abundance >75%	Species dominates in the PSP with cover abundance 50%-70%	Species co-dominates in the PSP with cover abundance 25% -50%
Impatiens glandulifera	3.1	12.8	12.6
Urtica dioica	4.8	6.4	10
Rubus caesius	3.0	4.9	9.1
Aegopodium podagraria	5.0	8.6	10.4

Discussion

Part of the species in the list of main competitors from the present study coincides with those established by other authors (Vilà, Weiner, 2004, Gruntman at al. 2014, Power and Vilas, 2020). The comparative data from the present study regarding the *density of the populations*, *phenological observations* and variations in *predominant height* of the species did not show significant differences between the Hymalayan balsam and its competitors, moreover they did not show such differences that would be in favor of the competitors. A number of similar studies (Houlahan, Findlay, 2004, Hejda et al., 2009) show that even if better competitor, IAS like *Impatiens glandulifera* could thus have low effects on species diversity of communities previously dominated by highly competitive natives.

Concerning the *cover abundance* and *floristic diversity* the resuts from the present study are close to the findings of Hejda and Pyšek (2006) and did not reveal any effect of invasion on the species composition in terms of species presence but their cover hierarchies changed after the invasion, as *I. glandulifera* became dominant at the expense of tall native nitrophilous dominants. In plant communities inhabited by a low number of species, *I. glandulifera* may not negatively impact species richness and diversity because this type of vegetation is often already dominated by native species, and the invader entering into such communities reduces the qualitative share of these dominant species by taking over their functions (Kiełtyk, 2019). The registered presence of another invasive alien species in the polydominant communities of *Impatiens glandulifera* confirms the findings of Nikolić et al. (2013) and indicates the participation of the Hymalayan balsam in phytocenoses with enhanced dynamics.

According to Bakker, Wilson (2001) and Vilà, Weiner (2004) the formation of monodominant phytocoenoses of the invasive alien species in parallel with the declining populations of native species is an indicator of the strong effect of the competitiveness of this invasive alien species. This conclusion is relevant not only for *Impatiens glandulifera* but also for monodominant coenoses formed by native species such as those found in the present study, most of which are weeds.

Dominant plant species, whether native or invasive exotic, strongly modulate species interactions and community composition (Hillebrand et al. 2008). Maintaining dominant native vegetation at high abundance is thus key to preventing large monospecific

Impatiens glandulifera stands from forming (Pattison et al., 2019). A recent study of Power and Vilas (2020) refutes the notion that a more diverse community may be more resistant to invasion. Therefore, options for assistance from native hygrophytic species in limiting populations of *Impatiens glandulifera* should be sought among those that form monodominant phytocenoses. In the study area such species are *Urtica dioica, Rubus caesius, Aegopodium podagraria, Petasites hybridus, Carex sp., Phalaris arundinacea, Phragmites australis* and *Typha angustifolia.* Although *Scrophularia umbrosa* and *Epilobium hisrustum* are mostly met as co-dominant species in the communities, these plants also demonstrate high competitiveness and ecological-coenotic strategy (PALADIAS, 2020, Van Der Kooi at al., 2015), and they exceed some of the other species by number and height of the individuals in the population. During the study, it was observed in the field how new shoots can grow from frozen last year's stems of *Scrophularia umbrosa*.

Only polydominant communities of *Scirpus sylvaticus* with *Impatiens glandulifera, Epilobium hirsutum*, *Lythrum salicaria* were found in the study area along the Iskar River. Wood clubrush is predominant species in marsh phytocoenoses such as the association *Scirpetum sylvatici* Ralski 1931 (Adriani, Culiţă, 2010).

The two native species with a predominant cover in PSP - *Urtica dioica* and *Rubus caesius* are the most common companions in the communities of *Impatiens glandulifera* and their populations, although with limited quantitative participation, remain until the last in the monodominant plantations of the Hymalayan blasam. Although *U. dioica* has a small seed mass its competitive strategy involves an exceptionally high relative growth rate, which coincides with tall stature, extensive lateral spread and the tendency to accumulate leaf litter, characteristics that facilitate the exclusive occupation of fertile sites. (Thompson, Grime, 1979, Taylor K, 2009, CABI, 2020). The rapid spread of Rubus caesius is mainly due to its vegetative propagation from buds sprouting from the roots and on the creeping stems which lay down on the soil and, in contact with it, they shoot. (Băbuţ, Manea, 2011). *Urtica dioica* and *Rubus caesius* have proven in a number of studies to be strong competitors but insufficiently resistant to competition from *Impatiens glandulifera*, which reduces the biomass of both native species in communities due to resource constraints and allelopathic properties. (Pattison at al. 2019, Power, Vilas, 2020).

A study by Georgieva, Glogov (2020) in which in sample plots with heterogeneous communities of *Urtica dioica*, *Rubus caesius* and *Impatiens glandulifera* after manual eradication at an early age of individuals from *Impatiens glandulifera* and additional planting of individuals from the other two species, the population of Hymalayan balsam restores its number in these communities from late germinating seeds and its individuals manage to reach their normal size.

In the present study, *Impatiens glandulifera* was not found in only 1.7% of the communities involving *Urtica dioica* and *Rubus caesius*, making these species an unsuitable choice for total isolation of the Hymalayan balsam. The result is similar with the distribution of *Impatiens glandulifera* in communities with predominant participation of the butterbur (*Petasites hybridus*) (Hymalayan balsam is absent in 1.7% of its PSP). For this reason like the previous species *P. hybridus* is found unsuitable for strengthening the shores with monodominant coenoses, both due to the easy penetration of *Impatiens glandulifera* into them and due to the fact that the populations of the butterbur also provoke erosion processes (Giversen et al., 2014).

Aegopodium podagraria predominates in the largest number of PSP (8.0%), in which floristic composition I. glandulifera has not been found, but at the same time in 10% of PSPs this species is a co-dominant of Hymalayan balsam. Goutweed is highly competitive in shady habitats (Garske, Schimpf, 2005). Such habitats in the study area are occupied by forest wetland communities where the crowns of trees form two layers - the uppermost of which with edificators *Populus nigra* and *P. deltoides*, and the layer below is dominated by *Alnus glutinosa* and *Salix sp*. The layer of the schrubs is represented by *Cornus mas* L., *Ligustrum vulgare* L., *Euonymus europaeus* L. and others. Only goutweed dominates the grass layer, and *Impatiens glandulifera* is absent. In the study area, most communities of this type are not located next to the river, where there is the greatest risk of erosion. The localities of the communities with predominant participation of goutweed, which are located on the shoreline, are of Periodically flooded riparian type and Constantly flooded riparian type and in them Hymalayan balsam often participates with high cover abundance.

Most of the rest 4 dominant species prefer locality type 3- "Swamp" on standing water. In the communities dominated by *Carex* sp. (incl. *Carex acutiformis* Ehrh., *Carex riparia* Curtis, etc.) and *Typha angustifolia* participated also Hymalayan balsam. A strength in terms of the competitiveness of some hygrophytic *Carex* species is their ability to prioritize resource allocation to organs responsible for acquiring the most limited resources when they are under flood stress (Tan et al., 2020).

In the communities of lesser bulrush is shown a positive connection of *Typha angustifolia* L. and *Impatiens glandulifera* similar to that with *Impatiens capensis* Meerb in tidal freshwater marshes (Hopfensperger, Engelhardt, 2007) where both species respond to environmental gradients the same way without interacting directly.

The only PSP in which not a single participation of *Impatiens glandulifera* was found during the study period were PSP dominated by the representatives of the Poaceae family *Phragmites australis* and *Phalaris arundinacea*. The strong ecological strategy of the reed is mainly due to its extensive rhizome system producing up to 200 stems / m2 (Haslam 1958) and seeds, which are dispersed by wind, water, and adhesion to waterfowl throughout the fall and winter (Quiriuon et al., 2018). Although the species is considered by some scientists to be highly aggressive and therefore harmful to all levels of biodiversity, it is useful for reducing shoreline erosion in marshlands and for carbon storage (Theuerkauf et al., 2017). *Phalaris arundinacea*'s ecological strategy includes clonal growth mechanisms- phalanx and guerilla strategies, rapid expansion, early growth, and the mulching effect of a dense litter layer all interact to facilitate the decline of the other species (including the invasive ones) (Wisconsin Reed Canary Grass Management Working Group, 2009).

With their anti-erosion function and the ability to keep away Hymalayan balsam from their plantations (probably due to their clone system, both species of the Poaceae family are most reliable for limiting the spread of *Impatiens glandulifera* in those communities of the study area located in close vicinity to the water. Populations of *Phalaris arundinacea* are suitable for securing localities type 1 and 2, which are most at risk of soil loss from periodic and permanent flooding, while *Phragmites australis* is more suitable for protection of localities type 3 associated with standing water.

Conclusions

The use of native competing species to limit the spread of the invasive alien species *Impatiens glandulifera* is possible, but requires a compromise between protecting riparian habitats from erosion and preserving their species diversity. Only monodominant coenoses, with high coverage (over 75%) of the predominant native species in the grass floor, are able to limit or stop effectively the invasion of the Hymalayan balsam, but in such communities the species composition is limited.

In the study area, the most suitable of the native plants against the Hymalayan balsam are *Phalaris arundinacea* - for localities of flooded and periodically flooded type and *Phragmites autsralis* - for standing waters. In riparian communities with a three- and four-layers structure and high total cover abundance of the tree layer, the shade-tolerant species *Aegopodium podagraria* is the most competitive with *Impatiens glandulifera* and permanently suppresses its populations.

The recommendation for optimal use of local competitors is to stimulate their spread in areas not occupied by vegetation along the river under the direct action of the watercourse in order to strengthen the shore and subsequently planting local tree and shrub species (alder, willow and poplar) to build a sustainable vertical structure of the communities and gradually restore the autochthonic wetland forest vegetation.

Acknowledgment

The study is part of the implementation of project KP-06-M31/3 of 12.12.2019 "Study of the distribution and impact of the invasive alien species Impatiens glandulifera Royale on natural habitats in the gorge of the Iskar River between Lozenska and Plana Mountains" , funded by the Bulgarian National Science Fund.

References

Adriani, O, S. Culiţă. 2010. Phytocoenotic surveys on some mesotrophic – eutrophic marshes in Eastern Romania. Plant develop. 17 (2010): 75-108.

Alpert, P., E. Bone, C. Holzapfelet. 2000. Invasiveness, invasibility and the role of environmental stress in the spread of non-native plants, Persp. Pl. Ecol. Evol. Syst. (3):52–66.

Băbuţ, C., D. Manea. 2011. Controlling the perennial species Rubus caesius L. – a problem weed in winter wheat and grain maize in the Timişoara area. Research Journal of Agricultural Science . 43(2):8-14.

Bakker, J., S.Wilson. 2001. Competitive abilities of introduced and native grasses. Plant Ecol. 157: 117-125.

Beerling, D., J. Perrins. 1993. Biological Flora of the British Isles. Impatiens glandulifera Royle (Impatiens roylei Walp.). Journal of Ecology. 81 (2) 367—382.

Belilov, S., M. L Georgieva, P. Glogov. 2020. First reports of damage to the leaves of the invasive alien species Hyalayan balsam (*Impatiens glandulifera* Royale) caused by Chrysolina herbacea (Duftschmid) (Coleoptera: Chrysomelidae). Proceedings of the 29th International Scientific Conference for Young Scientists, 24 - 25.09.2020, Blagoevgrad, 378-382.

Bieberich, J., S. Müller, H. Feldhaar, M. Lauerer. 2021. Invasive *Impatiens glandulifera*: A driver of changes in native vegetation? Ecology and Evolution. 1-14. https://doi.org/10.1002/ece3.7135

Braun-Blanquet, J. 1964. Pflanzensociologie: Grundzuge der Vegetationskunde. III Auflage. Vienna, Austria: Springer, 632. (in German)

CABI. 2020. Urtica dioica. https://www.cabi.org/isc/datasheet/55911

Cao, L., L. Berent, A. Fusaro, 2021, Impatiens glandulifera Royle: U.S. Geological Survey, Nonindigenous Aquatic Species Database, Gainesville, FL, and NOAA Great Lakes Aquatic Nonindigenous Species Information System, Ann Arbor, MI, https://nas.er.usgs.gov/queries/GreatLakes/FactSheet.aspx?SpeciesID=2695, Revision Date: 9/23/2012, Access Date: 1/18/2021

Calizza, E., M. Costantini, G. Careddu, L. Rossi 2017. Effect of habitat degradation on competition, carrying capacity, and species assemblage stability
Ecol Evol. 7(15): 5784–5796

Čuda, J., H. Skálová, J. Zdeněk, P. Pyšek 2015. Competition among native and invasive *Impatiens* species: the roles of environmental factors, population density and life stage. AoB PLANTS, 7, plv033, https://doi.org/10.1093/aobpla/plv033

Dawson, F., D. Holland.1999. The distribution in bankside habitats of three alien invasive plants in the U.K. in relation to the development of control strategies. Hydrobiologia 415:193–201.

Delipavlov, D., I. Cheshmedzhiev. (eds). 2003. Key to the Plants in Bulgaria. Agrarian University, Academic Press, Plovdiv, 590 pp. (In Bulgarian).

Frenot Y. 2005. Biological invasions in the Antarctic: extent, impacts and implications. Biol. Rev. 2005;80:45–72.

Garske, S., D. Schimpf. 2005. Fact Sheet: Goutweed. Plant Conservation Alliance's Alien Plant Working Group. https://www.invasive.org/weedcd/pdfs/wgw/goutweed.pdf

Georgieva, M. L., P. Glogov. 2020. Results of the application of manual eradication against the invasive alien species *Impatiens glandulifera* Royale in the Iskar gorge between Plana and Lozenska mountain. Sroceedings of the 8th International scientific conference "Reliability and risk", 15-16.10.2020, Sofia. 139-146. (in Bulgarian)

Giversen, I., L. Brimer, B. Kristiansen. 2014. Danmarks Vilde Lægeplanter Gyldendal A/S. 320p.

Global Invasive Species Database. 2021. Species profile: Impatiens glandulifera. Downloaded from http://www.iucngisd.org/gisd/species.php?sc=942 on 18-01-2021.

Glogov, P., D. Pavlova, M. Georgieva, Y. Dodev, S. Gyudorova. 2019. Survey of invasive alien species in the flora of Lozenska Mountain, Bulgaria. Botanikai Közlemények. 106 (2): 197-216.

Glogov, P., M. L. Georgieva, S. Gudorova, E. Filipova. 2020a. Study of the regenerative abilities of *Impatiens glandulifera* Royale in severe mechanical damage to the stem. Proceedings of the 31st National Scientific and Practical Conference "Quality - for a better life", Sofia, 12-13.11.2020, 241-248. (in Bulgarian)

Glogov, P., M. L. Georgieva. 2020b. Benefits and risks of using for grazing the invasive alien species *Impatiens glandulifera* Royale in the Iskar river gorge between Plana and Lozenska mountain. Proceedings of the 8th International Scientific Conference "Reliability and Risk", 15-16.10.2020, Sofia, 223-227. (in Bulgarian)

Glogov, P., M. L. Georgieva, B. Koychev, D. Pupaki, S. Gudorova, E. Filipova. 2020c. Study of the impact of herbicides on the populations of *Impatiens glandulifera* Royale in the Iskar river gorge Plana and Lozenska mountain. Proceedings of the 29th International Scientific Conference for Young Scientists, 24-25.09.2020, Blagoevgrad, 326-333. (in Bulgarian)

Glogov, P., S. Gudorova, M. Georgieva, M. Bozhilova. 2020d. Updating the classification of potential vegetation in the Iskar River gorge between Plana and Lozenska Mountain. Proceedings of the 29th International Scientific Conference "Management and Quality" for young scientists, Sofia 11-12.06.2020. 83-99. (in Bulgarian)

Greenwood, P., N. Kuhn, N. 2014. Does the invasive plant, Impatiens glandulifera, promote soil erosion along the riparian zone? : An investigation on a small watercourse in northwest Switzerland. Journal of soils and sediments. 14 (3): 637-650.

Gruntman, M., A. Pehl, S. Joshi, K. Tielborger. 2013. Competitive dominance of the invasive plant Impatiens glandulifera: using competitive effect and response with a vigorous neighbour. Biol Invasions. 141–151. DOI 10.1007/s10530-013-0509-9

Haslam, S. 1972. Phragmites communis Trin. (Arundo phragmites L.,? Phragmites australis (Cav.) Trin. ex Steudel). J Ecol 60:585–610

Hejda, M., P. Pyšek. 2006. What is the impact of Impatiens glandulifera on species diversity of invaded riparian vegetation? Biological Conservation 132(2):143-152. DOI: 10.1016/j.biocon.2006.03.025

Hejda, M., P. Pyšek, V. Jarošík. 2009: Impact of invasive plants on the species richness, diversity and composition of invaded communities. Journal of Ecology. 97: 393-403.

Hill, J. 2020. Invasive species: How They Affect the Environment. Environmental science. https://www.environmentalscience.org/invasive-species

Hillebrand, H., D. Bennett, M. Cadotte. 2008. Consequences of dominance: a review of evenness effects on local and regional ecosystem processes. Ecology. 89: 1510–1520.

Hopfensperger, K., K. Engelhardt 2007. Coexistence of Typha angustifolia and Impatiens capensis in a tidal freshwater marsh BioOne Complete. Wetlands. 27(3):561-569.

Houlahan, J., C. Findlay. 2004. Effect of Invasive Plant Species on Temperate. Wetland Plant Diversity. Conservation Biology. 18(4): 1132-1138.

Kachova, V., S. Bogdanov, M. Bozhilova, E. Filipova. 2020. Characteristic localities of the invasive alien species *Impatiens glandulifera* Rolyale in the Iskar River gorge between Plana and Lozenska Mountain. Proceedings of the 31st National Scientific and Practical Conference "Quality - for a Better Life", Sofia, November 12-13, 2020, Avangard Prima, 248-255. (in Bulgarian)

Kavrakova, V., D. Dimova, M. Dimitrov, R. Tsonev, T. Belev, K. Rakovska (ed. team), 2009, 77 Manual for Determination of Habitats of European Importance in Bulgaria. Second, revised and supplemented edition. World Wildlife Fund, the Danube -Carpathian Program and the Green Balkans Federation, Sofia. 132 p. (in Bulgarian).

Keller, P. J. Geist, J. Jeschke, I. Kuëhn. 2012. Invasive species in Europe: ecology, status, and policy, Environ Sci Eur 23 (2011), http://www.enveurope. com/content/23/1/23, Accessed 21 March 2012.

Kiełtyk, P., Delimat, A. 2019. Impact of the alien plant Impatiens glandulifera on species diversity of invaded vegetation in the northern foothills of the Tatra Mountains, Central Europe. Plant Ecol 220, 1–12. https://doi.org/10.1007/s11258-018-0898-z

Nikolić, T., B. Mitića, B. Milašinović, S. Jelaska. 2013. Invasive alien plants in Croatia as a threat to biodiversity of South-Eastern Europe: Distributional patterns and range size Comptes Rendus Biologies Volume 336, Issue 2, February 2013, Pages 109-121

PALADIAS. 2020. ***Scrophularia umbrosa* subsp. *Umbrosa.***
https://pladias.cz/en/taxon/data/Scrophularia%20umbrosa%20subsp.%20umbrosa

Pattison, Z., M. Vallejo-Marín & N. Willby. 2019. Riverbanks as battlegrounds: why does the abundance of native and invasive plants vary?. *Ecosystems*, 22 (3): 578-586. https://doi.org/10.1007/s10021-018-0288-3

Power, J., J.Vilas. 2020. Competition between the invasive Impatiens glandulifera and UK native species: the role of soil conditioning and pre-existing resident communities. Biological Invasions, 22, 1527–1537.

Quirion, B., Z. Simek, A. Dávalos, B. Blossey. 2018. Management of invasive Phragmites australis in the Adirondacks: a cautionary tale about prospects of eradication. Biol Invasions 20, 59–73. https://doi.org/10.1007/s10530-017-1513-2

Shochat, E. S. Lerman, J. Anderies, P. Warren, S. Faeth, C. Nilon. 2010. Invasion, Competition, and Biodiversity Loss in Urban Ecosystems. BioScience, Volume 60, Issue 3, March 2010, Pages 199–208, https://doi.org/10.1525/bio.2010.60.3.6

Theuerkauf, S. B. Puckett, K. Theuerkauf, E. Theuerkauf, D. Eggleston. 2017. Density-dependent role of an invasive marsh grass, Phragmites australis, on ecosystem service provision. *PLOS ONE*. 12 (2): e0173007 DOI: 10.1371/journal.pone.0173007

Tan, W., L. Sun, X. Zhang, Ch. Song. 2020. The Effects of Water Levels and Interspecific Competition on Two Carex Species in a Temperate Wetland of Northeast China. Sustainability 2020, 12, 10654; doi:10.3390/su122410654

Taylor, K. 2009. Biological Flora of the British Isles: Urtica dioica L. Journal of Ecology (Oxford). 97(6):1436-1458. http://www.blackwell-synergy.com/loi/jec

Thompson, K., J. Grime, 1979. Seasonal variation in the seed banks of herbaceous species in 10 contrasting habitats. Journal of Ecology. 67(3): 893-921.

Van Der Kooi, C. J.; Pen, I.; Staal, M.; Stavenga, D. G.; Elzenga, J. T. M. (2015). "Competition for pollinators and intra-communal spectral dissimilarity of flowers". Plant Biology. 18 (1): 56–62. doi:10.1111/plb.12328. PMID 25754608.

Vilà, M., J. Weiner. 2004. Are Invasive Plant Species Better Competitors than Native Plant Species?—Evidence from Pair-Wise Experiments. Oikos. 105: 229-238. http://dx.doi.org/10.1111/j.0030-1299.2004.12682.x

Vilà, M, M. Tessier, CM. Suehs, G. Brundu, L. Carta, A. Galanidis, P. Lambdon, M. Manca , F. Médail F, E. Moragues, A. Travaset, A. Troumbis, P. Hulme P (2006) Local and regional assessments of the impacts of plant invaders on vegetation structure and soil properties of Mediterranean islands. J Biogeogr 33:853–861

Wisconsin Reed Canary Grass Management Working Group. 2009. Reed Canary Grass (*Phalaris arundinacea*) Management Guide: Recommendations for Landowners and Restoration Professionals. 20pp

Zaemdzhikova, G., M. Georgieva, **P. Glogov**, D. Doychev, 2020. *Impatiens glandulifera, a new host of the tortrix Pristerognatha fuligana in Bulgaria*. ZooNotes, 167, 1-4.