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Occurrence and dynamics of *Impatiens parviflora* depending on various environmental conditions in the protected areas in Slovakia

Lenka Bobuľská[1], Dagmar Macková[1], Radovan Malina[2], Lenka Demková[1]

[1]Department of Ecology, Faculty of Humanities and Natural Sciences, University of Prešov, 17. Novembra 1, 080 01 Prešov, Slovakia
Corresponding author, E-mail: bobulska.lenka@gmail.com

[2]Department of Biology and Ecology, Faculty of Natural Sciences, Matej Bel University, Tajovského 40, 974 01 Banska Bystrica, Slovakia

ABSTRACT

Biological invasion as one of the main threats to natural ecosystems has big economic impact on conservation of nature. Studies of the population biology of invasive species may allow more precise focus on specific plant and soil characteristics involved in invasiveness. The aim of the study was to investigate the relationship between selected biological population characteristics of *Impatiens parviflora* and a few chosen chemical and physical soil features. Sites were selected because of the poor mapping of invasive plants in the protected natural areas and their interactions with specific soil characteristics. Research on *I. parviflora* was realised during a vegetation season in three forest nature reserves in Prešov district, Slovakia. Some population biological characteristics of *I. parviflora* as one of the most invasive plant species in Slovakia and Central Europe were surveyed. The correlation between the numbers of plants was analysed, as well as select population biological characteristics of *I. parviflora* (plant height, width of the largest leaf and the number of flowers/fruits) on some select chemical and physical soil attributes (soil pH, bulk density, porosity and soil moisture) were analysed. The results suggest that biological characteristics of *I. parviflora* in three different microhabitats – a meadow (a habitat without tree vegetation), a habitat close to the stumps and a habitat under dense tree vegetation seemed to influence the selected soil parameters. Our results showed that *I. parviflora* prefers acidic and non-compacted soil conditions. Sunlight and soil moisture do not show statistically significant differences on any biological characteristic of the population. The results also suggest that the autecology of *I. parviflora* in Western and Central Europe is not very well known and deserves further study.

KEYWORDS

Impatiens parviflora, North-Eastern Slovakia, Soil variables, Population biological characteristics

INTRODUCTION

Biological invasions are one of the main threats to natural ecosystems that reduce native biodiversity and change the functioning of the invaded ecosystems. The impact of invasive plant species on native species, communities, ecosystems and soil biota has been widely recognised over the last decades (Lodge 1993; Simberloff 1996; Liao et al. 2011; Vilà et al. 2011; Renčo & Balezentiene 2015), and invasive species are now viewed as a significant component of global change (Vitousek et al. 1996). Economic impact of these species is evident. The costs of invasive species are estimated to range from millions to billions of dollars annually and the success of invasive species has been attributed to their biological and ecological trails (tall statue, high biomass, high growth rate, etc.) (Pimentel et al. 2000; Duda et al. 2003; Čuda et al. 2014). The negative impact of the invaded species on ecosystems is evident; but, several authors have shown some positive features of invasive plant species (Dudek et al. 2016; Petillon et al. 2005). Nature reserves act as a suitable laboratory environment for studying the factors that determine the distribution of non-native plants and also provide the knowledge of the barriers that subsequently become invasive (Richardson et al. 2000). Knowledge about these factors can be mainly used in the management and control of invasive plant species, but they are also important from a general point of view, especially for understanding the fundamental issues of adaptive capacity of individual plant species. Studies of the population biology of invasive species may allow more precise focus on specific plant and soil characteristics involved in invasiveness (Crawley 1986; Sakai et al. 2001; Balezentiene & Renčo 2014). Few reports indicated that exotic plant species might alter soil conditions such as nutrient availability, microbial activity and composition, as well as other physical and chemical characteristics of the soil. The changed soil conditions in some invaded ecosystems, in turn, might promote further

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invasion (Duda et al. 2003; Kourtev et al. 2003). While many published studies report increased soil nutrient stock and/or their availability in invasive plant species compared to uninvaded ecosystems (Duda et al. 2003; Dassonville et al. 2008; Liao et al. 2008), other studies show the opposite pattern (Christian & Wilson 1999; Leary et al. 2006). In addition, the same species may have different impacts on many soil parameters, depending on local conditions (Dassonville et al. 2008; Čuda et al. 2014).

Impatiens parviflora DC. (Balsaminaceae), a therophyte, is a native species to Central and Eastern Asia. It was introduced in the 19th century to Central and Western Europe (Trepl 1984) where it could grow on a wide range of mineral soils (Coombe 1956) and in many different plant communities, such as *Querco-Fagetea, Quercion, Alnetea glutinosae, Galio-Alliarietalia, Artemisietalia* (Trepl 1984). *I. parvilora* is an invasive species, which, due to its mass occurrence, disturbs the natural vegetation composition in many localities (Dostálek 1997; Čuda et al. 2014). According to Slovak legislation, *I. parviflora* is non-invasive species, but its character and environmental influence on native biodiversity, through changes in community structure, nutrient cycles, trophic levels, hydrology, competition and others is invasive and may even cause high economic losses by promoting allergic reaction or altering the natural environment (Medvecká et al. 2012). It has been found that there is a relationship between the floristic and structural degradation of the herbaceous layer in the forest ecosystems and its resistance to the invasion of *I. parviflora* (Obidzinski & Symonides 2000; Chmura & Sierka 2007; Łysik 2008). Actions for its eradication have been reported in Poland (Adamowski & Keczynski 1999) and in Hungary (Csontos 1986). It included that all individuals of this species found in the protected area were carefully removed, which led to almost complete extirpation of *I. parviflora* population. Short life cycle, presence of cleistogamic and chasmogamic flowers, production of a large number of easily germinating seeds, rapid growth of seedlings and shade tolerance may allow *I. parviflora* to compete successfully with native components of the ground layer even if the disturbance of the phytocoenosis is minor (Perrins et al. 1993).

The aim of this study, being a part of a broader research on the ecology of *I. parviflora,* was to investigate the relationship between selected biological population characteristics of this species and some chosen chemical and physical soil features.

1. MATERIAL AND METHODS

1.1. Study area

The research was carried out during a vegetation season (July–August) in three protected areas of North-Eastern Slovakia in the National Nature Reserve (NNR) Šarišský hradný vrch (49° 03´06,74´´, 21° 10´36,59´´), National Nature Reserve (NNR) Kokošovská dubina (48° 57´22,13“, 21° 22´55,19´´) and Nature Reserve (NR) Fintické svahy (49° 04´07,08´´, 21° 17´28,87´´) in 2014 (Figure 1). From the pedology point of view, mostly moderate Cambisols are typical in all researched areas (Šály & Jurina 2002) in warm, medium wet climatic regions with cold winter (Lapin et al. 2002). NNR Šarišský hradný vrch belongs to *Carpineto-Aceretum*, *Fageto-Quercetum*, *Fageto-Quercetum* versus *Fagetum pauper* habitat with the dominant vegetation of *Acer platanoides*, *Fagus sylvatica* and *Quercus petrea*. NNR Kokošovská dubina and NR Fintické svahy belong to *Fageto-Quercetum* habitat where *Quercus robur*, *Quercus petraea*, *Acer campestre* and *Acer platanoides* are the predominant

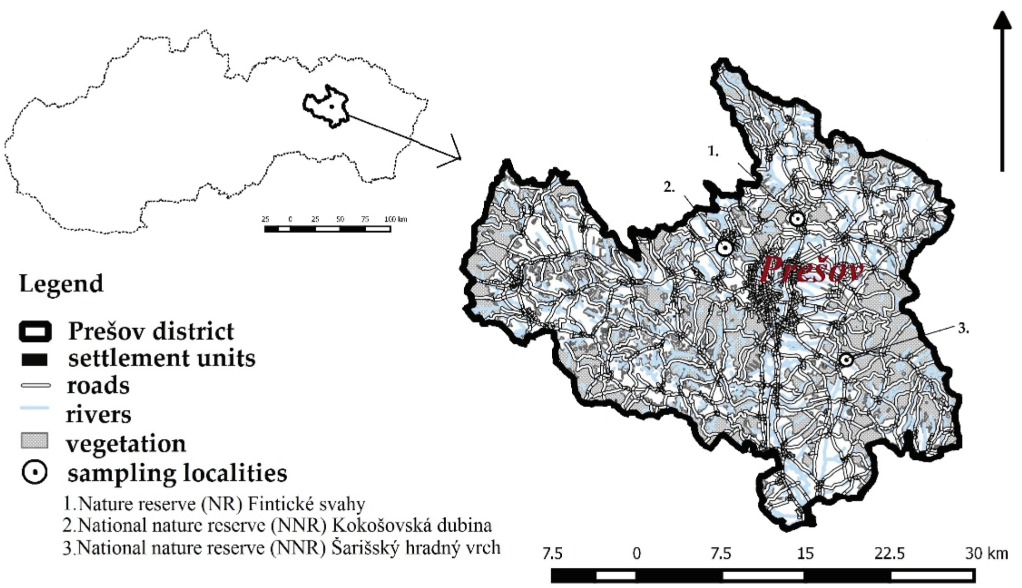

Figure 1. Study area of I. parviflora *in a protected area*

species in NNR Kokošovská dubina and *Acer campestre*, *Carpinus betulus*, *Crataegus monogyna*, *Quercus petraea* and invasive species *Robinia pseudoacacia* dominate in NR Fintické svahy (Maglocký 2002).

1.2. Data analysis

Three permanent plots (5 × 5m) were selected in each nature reserve for each microhabitat (9 measurements for each reserve). Selected population biological characteristics of *I. parviflora* were surveyed, such as the number of plants, the height of the plant, width of the largest leaf and the number of flowers/fruits in three different microhabitats – meadows (a habitat without tree vegetation), a habitat close to the stumps (as the bottom part of a tree left) and a habitat under dense tree vegetation, in each natural reserve. Flora diversity was evaluated according to the Braun–Blanquet's (Braun-Blanquet 1964) seven-number scale (5 – cover of 75–100%; 4 – cover of 50–75%; 3 – cover of 25–50%; 2 – cover of 5–25%; 1- cover less than 5%; + - negligible cover, r – occasionally), which describe the frequency and cover of species population.

At the same time, the soil was also sampled in all the three different microhabitats. Soil samples were taken in triplicates from all the sites to ensure high homogeneity of the measured data. The sampling of the soil was provided during one weekend with no rainfalls; thus, the sampling parameters can be considered the same. The soil samples were determined for chemical and physical properties: soil pH, bulk density, soil porosity and soil moisture. Soil acidity (pH/H_2O) was measured in distilled water (10 g of air-dry soil in 50 ml of H_2O), shaken for 1 hour and the soil reaction was measured using the pH electrode. Bulk density [$t.m^{-3}$] and porosity [%] of the soil were evaluated in a Kopecky physical cylinder with a capacity of 100 cm^3 (Fiala et al. 1999). Soil water content [%] was determined gravimetrically by oven-drying fresh soil at 105°C for 24 h.

The correlation between the number of plants were analysed, as well as selected population biological characteristics of *I. parviflora* (plant height, width of the largest leaf and the number of flowers/fruits) on detected soil properties were studied. The dependence of the population's biological characteristics and soil properties was evaluated using a linear regression program in PASW Statistics 18 (Zvára 2006).

2. RESULTS AND DISCUSSION

In all cases, the areas were located in the forest biotopes. According to presented observations, the forest types can be mostly classified as the Carpathian oak and horn-beam forest or acidophilus beech wood (Appendices 1–3).

The most individual occurrences of *I. parviflora* were recorded on meadow microhabitats in all three localities (Table 1). The number of individual occurrences in the microhabitats ranged from 67 to 145. The height of plants ranged from 5 to 51 cm. The highest individual specimens were found in the stump habitats. Therefore, it can be assumed that in course of the subtilisation process, the number of plants in meadows (as well as in other locations) decreases, while the size of plants increases in the course of the vegetation period. Generally, the largest leaf of this species was observed in NR Fintické svahy and the smallest one in NNR Šarišský hradný vrch. The research also showed that the number of flowers/fruits was the highest in the stumps microhabitats in all three localities mentioned above.

These results do not correspond with those reported by Chmura (2006), where the highest individual specimens occurred in the ecotone between alder forest and oak-hornbeam

Table 1. Population biological characteristics of I. parviflora *in three microhabitats in nature reserves*

Natural reserves	Microhabitats	Number of individuals	Height of individuals [cm]	Width of the biggest leaf [cm]	Number of flowers/fruits
NNR Šarišský hradný vrch	Meadow	145	11.9±5.7	4.9±1.3	15.3±4.8
	Habitat under tree vegetat.	110	11.5±3.7	4.8±1.2	15.4±5.0
	Stumps habitat	98	13.3±4.7	4.8±1.2	20.2±6.2
NNR Kokošovská dubina	Meadow	86	15.3±5.7	5.0±1.3	14.6±3.3
	Habitat under tree vegetat.	79	16.0±5.8	4.8±0.9	14.0±3.8
	Stumps habitat	67	18.4±7.9	5.1±1.1	15.7±5.8
NR Fintické svahy	Meadow	115	22.8±9.9	5.9±1.2	15.4±3.9
	Habitat under tree vegetat.	110	21.5±7.3	5.2±1.1	15.6±3.3
	Stumps habitat	108	24.9±7.4	5.0±0.8	19.2±5.9

forest and the smallest plants were encountered on grassland and meadows. The height of plants he found ranged from 4 to 152 cm. When examining its phenology, Piskorz (2005) found out that the location with the highest *I. parviflora* was in a habitat under tree vegetation in comparison with those that were growing under compact and dense tree vegetation. Kujawa-Pawlaczyk (1991) also found the smallest individuals located in shadowy parts of the woods (the size from 1 to 20 cm) along with the highest individuals (the size exceeding 70 cm) located in the sunny places, e.g. older oak and horn-beam woods *Tilio-Carpinetum* in Bialowieźsky Woods (Poland). According several authors, under different environmental conditions, the length of generative development varied (Piskorz 2005; Leishman et al. 2014; Gallagher et al. 2015). Generally, moderate shade condition balsam distinctly shortens the time of flowering and fruiting. Plants developing in strongly shaded sites had the smallest fruits, whereas the largest were observed in plants, which were growing on sunny areas. That explains why the number of flowers/fruit and as well as average high of individuals were highest in the stump microhabitat not shadowed by tree vegetation.

The results shown in Table 1 were evaluated by ANOVA and subsequently by the Tukey-Kramer test. The statistically significant differences in height of the individuals were found between plants growing in stumps habitat and under trees in the localities of NNR Šarišský hradný vrch (p=0.0208) and NR Fintické svahy (p=0.0028). In the parameter of the largest leaf width, statistically significant differences were only found in NR Fintické svahy. The greatest number of wide leaves was found in the meadow microhabitat. From the viewpoint of the number of flowers/fruits, statistically significant differences (p=0.001) were found in localities NNR Šarišský hradný vrch and NR Fintické svahy. In both localities, more flowers or fruits were found in the stump habitats.

Soil pH is an important factor of soil health and quality despite of the fact that its value changes dynamically depending on so-called internal and external factors (Fazekašová et al. 2012; Bobuľská et al. 2015). Table 2 shows that the most acidic microhabitats were found in NR Fintické svahy. Jurko (1990) and Chmura (2006) stated that *I. parviflora* prefers acidic pH but according to Coombe (1956), *I. parviflora* prefers soil pH 4.5–7.6. In our studied areas, *I. parviflora* shows a significant preference for acidic and not compacted soil condition, which was represented by higher individuals (Fig 2). Chmura (2006) found out the highest influence of chemical soil features, e.g. the organic carbon content, nitrogen content and soil pH, on *I. parviflora* growing near the stump habitats. As the value of pH increased, the morphometric values of *I. parviflora* increased accordingly (Chmura & Gucwa-Przepióra 2012). The length and width of all leaves correlated with the height of the individuals. Soil pH has a positive influence on the height of plants whereas C/N has a negative influence (Chmura et al. 2007). The results in relation to the soil pH were according to the conclusions obtained by Godefroid & Koedam (2010) and by Jurko (1990). Coombe (1956) implies that this species grows on a large scale of mineral soils, yet its occurrence is strictly influenced by soil reaction (pH varies from 4.5 to 7.6). According to the scheme recommended by Ewald (2003), the species cannot be classified as both acidophillous (R=1–6) and calciphile (R=7–9).

Despite this statement, Lawesson (2003) made use of a large pH dataset in wooden vegetation located in Denmark and, for statistic models, he assigned *I. parviflora* with a pH of 4.4. Gough et al. (2000) defines *I. parviflora* as an acidophilous species with pH < 5.5. Similarly, according to Węglarski (1991), *I. parviflora* could be a good indicator of moderate acidic and acid soils.

Soil physical characteristics are indicators of soil ability to absorb and maintain water. The principal physical parameters of soil are porosity, bulk density and soil moisture. Soil moisture is considered to be one of the essential factors impacting soil respiration. The presence of water in soil is defined in a percentage value (Hraško & Bedrna 1988) and the highest soil moisture was measured in NR Fintické svahy, especially in the stump habitats (Table 2). Soil moisture, as one of the examined soil parameter, did not show any statistically significant influence on population biological characteristics of the individual specimens (Table 3). Badano et al. (2005) and Sternberg & Shoshnay (2001) found higher species diversity compared to our study, which can be explained by lower inter-species competition as a result of lower number of species and intra-species competition regarding light and higher humidity in plant layers. Coombe (1956) states that *I. parviflora* grows on structured soils maintained humidity except for flooded locations. Csontos (1984), Schmidtz & Dericks (2010) also did not prove any relationship between the content of water in soil and average air temperature. Bulk density is closely interconnected with the total porosity of the soil. In NR Fintické svahy, the presented research encountered both; the highest porosity and the lowest bulk density of soil. Table 3 indicates the occurrence of the highest species in this locality. Kraczewski (2007) compared the influence of soil features on structural parameters of the species. He proved that the species growing in the woods were twice as high as the plants growing near highways.

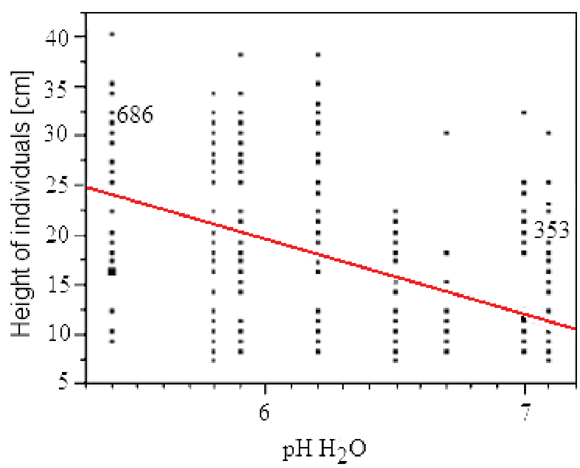

Figure 2. Influence of soil reaction on the height of individual I. parviflora *plants (regression axis indicated in red)*

Table 2. Soil characteristics of three microhabitats in nature reserves

Natural reserves	Microhabitats	pH/H_2O	Bulk density [t.m^{-3}]	Porosity [%]	Soil moisture [%]
NNR Šarišský hradný vrch	Meadow	6.7	1.33	49.81	26.2
	Habitat under tree vegetation	6.5	1.15	56.60	35.8
	Stumps habitat	7.1	0.94	64.53	34.9
NNR Kokošovská dubina	Meadow	6.2	1.12	57.54	30.7
	Habitat under tree vegetation	7.0	0.95	64.15	35.8
	Stumps habitat	6.2	1.11	58.11	36.9
NR Fintické svahy	Meadow	5.9	0.86	67.55	33.0
	Habitat under tree vegetation	5.8	0.87	67.17	40.3
	Stumps habitat	5.4	0.62	76.60	54.8

Table 3. Relationship between the population biological characteristics and soil properties

Population biology characteristics of *I. parviflora*	Soil moisture [%]	pH/H_2O	Porosity [%]	Bulk density [t.m^{-3}]
Number of individuals	X	X	X	X
Height of individuals	X	Rsquare=0.27	Rsquare=0.27	Rsquare=0.26
Width of the biggest leaf	X	X	X	X
Number of flowers/ fruits	X	X	X	X

The presented results point to the preference of *I. parviflora* towards to the dense soils (Fig 3). The results show the positive correlation of soil porosity and height of plants, as well as negative correlation between bulk density and height of plants (Fig. 4). These results does not correspond with the observations of Godefroid & Koedam (2010). The examined soil features (pH, porosity, bulk density) had a statistically significant influence only on the size of plants (Table 3).

3. CONCLUSION

In the summary, *I. parviflora* shows preferences towards low base soils and non-compacted soils. It easily penetrates non-ruderal communities and dense ground layers. *I. parviflora* had a positive growth response with the increasing compaction and behaved as a shade plant. These results suggest that the autecology of *I. parviflora* in Western and Central Europe is highly variable, not yet very well known and deserves further studies.

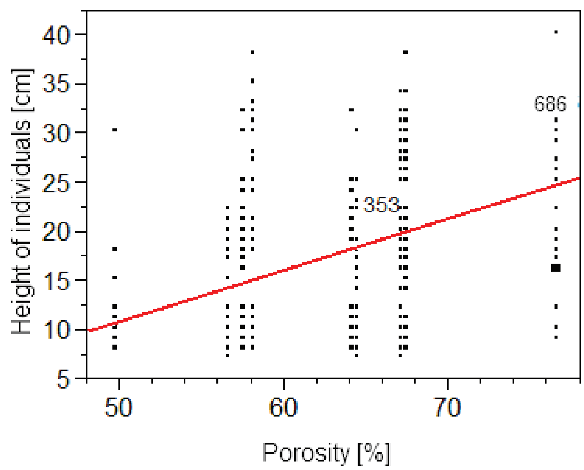

Figure 3.Influence of soil porosity on the height of individual I. parviflora *plants (regression axis indicated in red)*

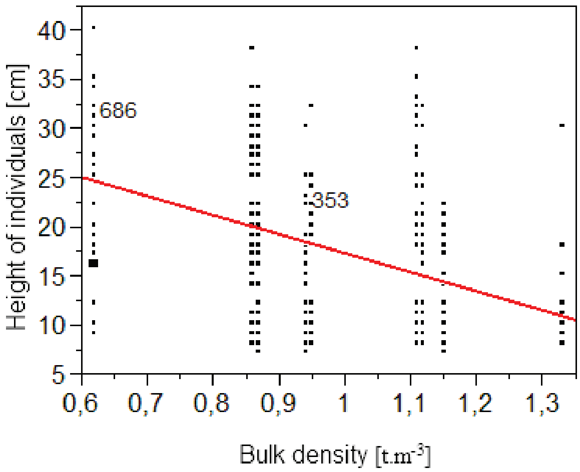

Figure 4.Influence of bulk density on the height of individual I. parviflora *plants (regression axis indicated in red)*

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