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AUTECOLOGY OF *IMPATIENS PARVIFLORA* DC. IN NATURAL FOREST COMMUNITIES

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ABSTRACT. In three neighbouring regions situated in southern Poland, differing in land use, soils, and type of forest vegetation, autecological studies on one of the most invasive alien species of the country, small balsam *Impatiens parviflora*, were conducted. The habitat requirements of *I. parviflora* were estimated in 139 permanent plots, randomly distributed in various forest communities and varying in the abundance of the examined species. The forest stands were located either in nature reserves (Kraków-Częstochowa Upland, Silesian Upland) or in old growth forests (Głubczyce Plateau). The physical and chemical properties of soils (soil reaction, mineral and granulometric composition of substratum), litter depth, slope, and aspect were gathered and showed on ecodiagrams. The study shows that small balsam is a species with a wide ecological amplitude, what probably contributes to its invasiveness and enables success in colonizing and persisting in forest ground vegetation.

KEY WORDS: *Impatiens parviflora*, ecological tolerance, habitat requirements

INTRODUCTION

The success of invasion of specific species depends on its set of traits, called invasiveness, and the vulnerability of occupied habitats to invasion – invasibility (Lonsdale 1999). A wide ecological tolerance to biotopic factors, apart from competitiveness, resource allocation, and release from natural enemies, play a crucial role in the invasion of plants (Rejmánek et al. 2005). Small balsam, *Impatiens parviflora* DC., is one of the most invasive species in the country (Tokarska-Guzik 2005). It is an annual from the Balsaminaceae family, native to Central Asia. In the 1830s it was introduced to Europe and ca. 20 years later was observed for the first time in Poland (Trepl 1984). Small balsam is a rare case of an alien plant invading forest communities. Its invasion success, apart from human-induced changes in forest ecosystems, is a result of its high phenotypic plasticity in various shady conditions, high reproduction capacity, long-term flowering, efficient seed-dispersal mechanisms, lower nutrient requirements, the small number of parasites and herbivores (Eliáš 1999) as well as dynamic co-existence with components of ground flora (Piskorz and Klimko 2007). According to Ellenberg et al. (1992), small balsam is indifferent in relation only to soil reaction. Concerning the other ecological indicator values, the species is assigned intermediate values. In this study we focused on soil conditions in forests from regions differing from each other, but all invaded by this species.

MATERIAL AND METHODS

Study area

The study area encompasses three adjacent geographical regions located in Southern Poland (Kondracki 1988) (Fig. 1). The Głubczyce Plateau, the first geographical unit, is a typical agricultural region, where the Polish part covers an area of ca. 1700 km^2. Due to fertile soils, only 4% of the area is covered by forest vegetation, the former woodlands having been converted to arable lands. The majority of the soils are of loess origin as brown and black soils. According to the literature, including the historic maps of Wieland-Schubart dating from the years 1722-1750, forests of this region are the remnants of ancient woodlands, but are currently highly fragmented (Orczewska 2003).

The Silesian Upland is a physical-geographical region, covering an area ca. of 4000 km^2 (Fig. 1). It is characterized by a differentiated relief and geological structure, with a central part built of Carboniferous formations. The region is known due to the occurrence of important mineral resources: hard coal, zinc and lead ores, sand, gravel, dolomite, and iron ores. Mineral resource exploitation commenced at the beginning of the Mid-

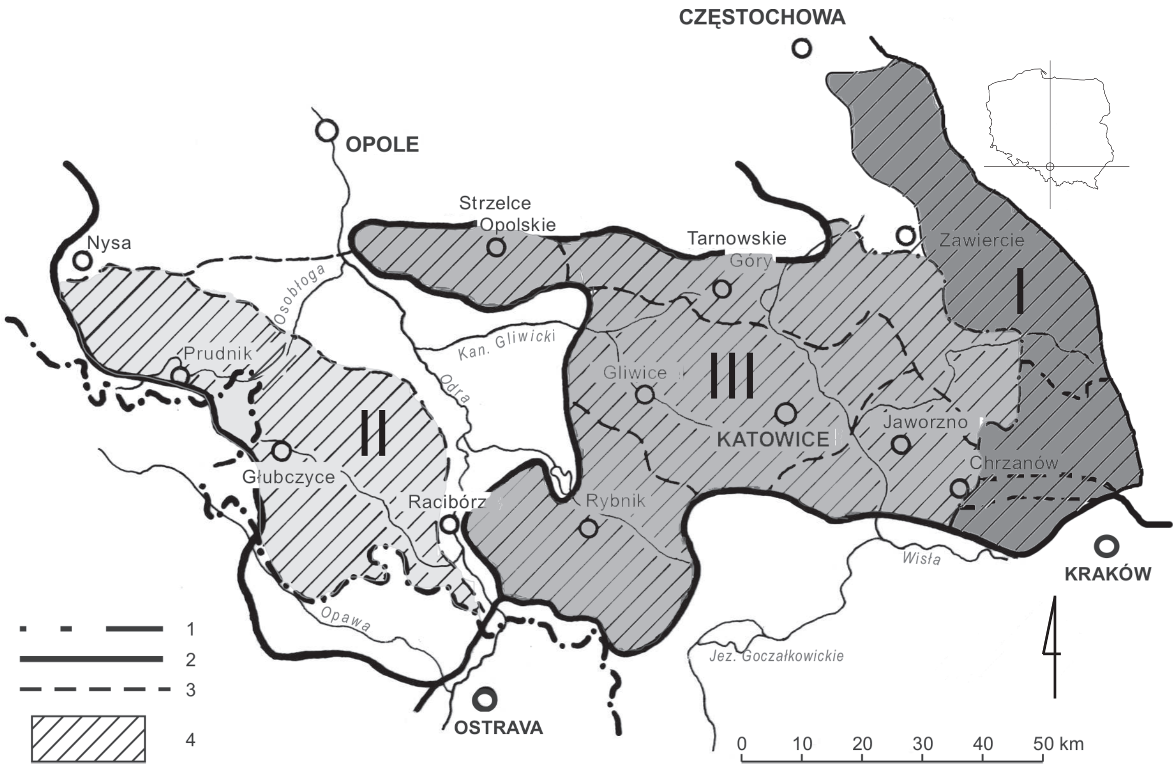

Fig. 1. Location of the study area. 1 – the border of the state, 2 – the border of the study area, 3 – the borders of the mesoregions, 4 – the study area with regions analysed: I – Kraków-Częstochowa Upland, II – Głubczyce Plateau, III – Silesian Upland

dle Ages, and intensified in the last half of 18th century due to changes in economic activity, technical-scientific progress, and urbanization. The plant and soil cover has been substantially altered as a result of human impact, basically the coal-mining and metallurgy industries (Kozyreva et al. 2004). Forest and brushwood communities are represented by deciduous forest and secondary pinewoods, and less frequently, by disturbed oak-hornbeam forests, riparian forests or alder carrs. There are some remnants of ancient forests owing to habitat continuity, but they have been exploited by forestry. The prevailing soil types are podzolic, brown, calcareous and alluvial soils.

The Kraków-Częstochowa Upland (Jurrasic Upland) is a macroregion covering 2615 km^2. The soils of the area are rather poor; about 60% are podzolic soils; however, brown soils also occupy a large area. This region is rich in vascular flora, both of lowlands and of mountains. Broadleaved woodlands, such as fertile beechwoods and oak-hornbeam forests prevail in lower grounds, and pine forests reign on poor sandy soils in depressions. The forest vegetation depicts considerable diversity, and therefore there are many nature reserves and landscape parks.

Data source

The studies were conducted in (semi-)natural deciduous and mixed forest communities and habitats of the *Querco-Fagetea* class laid out and randomly distributed in forest reserves both in the Silesian Upland and the Jurrasic Upland and in well-preserved woodland islands of ancient forests in the Głubczyce Plateau. In total 139 sites were randomly selected for autecological studies differing in the percentage cover of *I. parviflora* beneath the dense forest canopy. Habitat requirements: soils conditions, litter depth, slope and the aspect of patches with *I. parviflora* were estimated in permanent plots 10 m × 10 m. Four soil sub-samples were collected from 0 to 10 cm depth and mixed into one composite sample.

In total 566 sub-samples of soil from 139 stands of *I. parviflora* in distinct types of forest communities were collected. In laboratory analyses basic, ecologically important for growth and development of plants physical and chemical soil properties were taken into account.

Air-dry samples were analysed for:

1) and 2) pH (in aqueous solution and in KCl solution),
3) organic carbon by the Tiurin method,
4) loss on ignition,
5) N_T – total nitrogen (PN-ISO 11261),
6) available phosphorus P (PN-R-04023),
7) Mg – available magnesium (PN-R-04020),
8) sodium Na and potassium K,
9) were detected using flame photometry,
10) Ca by spectrophotometry in 1 N ammonium acetate,
11) $CaCO_3$ by Scheibler method.

The results of analyses were presented on figures in the form of ecodiagrams (Zarzycki et al. 2002) which show the percentage of the occurrence of *I. parviflora* at distinguished classes of slopes, aspect, soil properties, and litter depth and other soil variables were listed in table. The scales of available nutrient contents (P, K, M), pH in water and KCl solution as well as C/N ratio were adopted after Piękoś-Mirkowa et al. (1996) and literature cited there. However, scale of organic carbon, total nitrogen and scale of slope follow Węglarski (1991). The 7-degree scale of percentage of floatable fraction and division of soils into groups, due to granulometric composition, were employed according to Kuźnicki et al. (1979). The 5-degree scale of litter depth were used after Obmiński (1977).

RESULTS

The study shows that small balsam occurred the most frequently at flat sites (ca. 41% of total studied sites) (Fig. 2). Amongst the sites situated on slopes the species was the most frequent in stands associated with north and western scoring 25, 20, 13, and 7% of frequency for N, W, NE and N respectively. The southern slopes with the presence of the species studied were the rarest – ca. 7% (Fig. 2).

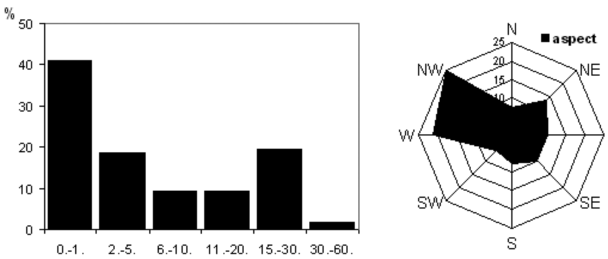

Fig. 2. The slope and aspect of sites with *I. parviflora*

Taking into account granulometric composition of soils it should be noted that majority (ca. 65%) of soils are heavy soils i.e. percentage of floatable fraction is higher than 35% (Fig. 3). However, 20% of total are light soils more frequently when compared with moderate soils.

Small balsam occupied soils with thin layer of litter (more than 50% of total forest stands); also the species grew on bare ground or litter thinner than 1 cm (Fig. 3).

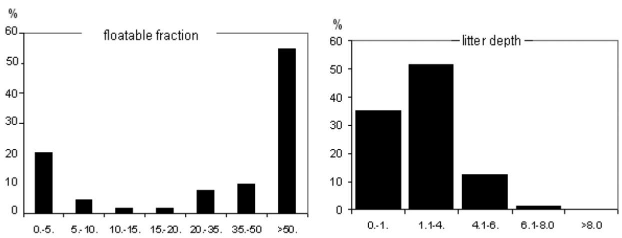

Fig. 3. The share of floatable fraction in soils and litter depth in sites with *I. parviflora*

Almost 50% of total stands are located on very strongly and strongly acid soils (Fig. 4). Surprisingly the species reveals two optima; the second is associated with neutral soils where it is more frequent than on slightly acid and alkaline soils.

In respect to available phosphorus, *I. parviflora* occupied mainly soils where the content of this nutrient was low i.e. less than 3 mg per 100 g of soil. Generally the species showed decreasing gradient of the frequency along the increase of phosphorus concentration. The examined soil samples exhibiting similar frequency for available magnesium and potassium. The contents of

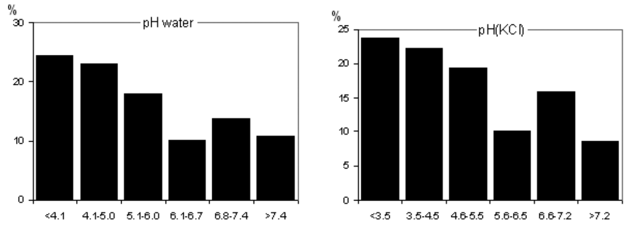

Fig. 4. The soil range of sites with *I. parviflora*

total nitrogen in 46% and 44% of the examined soil samples vary between 0.1-025 and 0.26-0.50% respectively i.e. indicate very poor and poor as well as mean rich in nitrogen soils (Fig. 5).

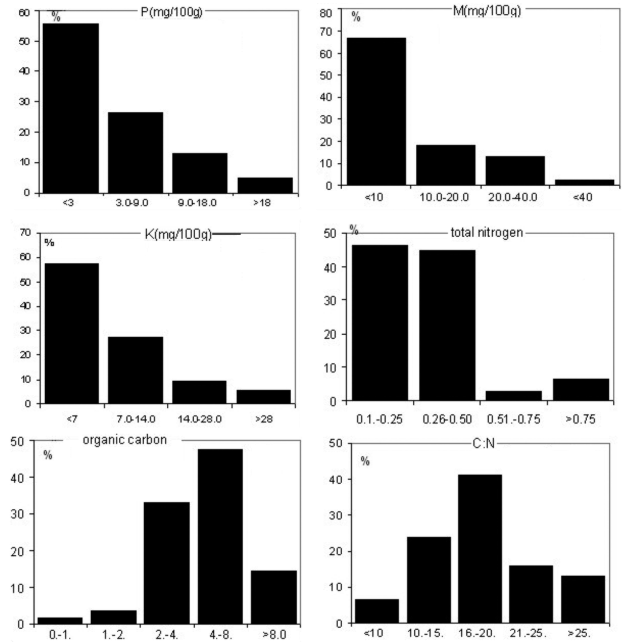

Fig. 5. The ecodiagrams of the chemical properties of the soils studied

Soils, on which small balsam grew, are rich in organic carbon. Approximately 47% of them contain from 4.1 to 8% – the highest class in Lazar's scale (1976). It is worthy mentioning that more than 14% are characterized by values above 8%. The maximum recorded value amounted to 27%. This result is concordant with percentage of loss on ignition (Table 1). As humus regards, the soils where C and N ratio varied 16-20 were the most frequent, next soils with 10-15 interval (Fig. 5). In relation to remaining soil properties it was noted that concentration of calcium

Table 1. Descriptive statistics of calcium, sodium and calcium carbonate and loss on ignition of the soils studied

	Ca (mg/100 g)	Na (mg/100 g)	$CaCO_3$ (%)	Loss on ignition (%)
Mean	387.67	3.31	1.54	12.44
SD	338.33	1.17	5.29	6.99
Min	20.61	0.73	0	0.81
Max	1 463.35	10	31.9	51

is very high and very differentiated in analysed soils samples (Table 1) but the content of calcium carbonate is lower and in many cases it was absent. As sodium, its content is lower compared to other exchangeable cations.

DISCUSSION

In previous research by other authors some information can be found on autecological characteristics of small balsam. As the role of the slope and aspect are concerned the species is considered to occur more abundantly on northern slopes in less shaded sites (Coombe 1956). Ling and Ashmore (1999) found that *I. parviflora* occurred more abundantly on steeper slopes but with high light requirements and more cover of bare ground. In this study we found that *I. parviflora* occurred more frequently on slopes directed to north-west what supported general pattern observed by other researchers. Litter depth of sites occupied by *I. parviflora* varies among analysed regions. It is a result of degree of forest management practices. The smallest litter depth was observed in the most disturbed and managed forests in the Silesian Upland. Nevertheless it does not affect the establishment of small balsam. The species was more frequent on thin layer of litter than on bare ground. However, the latter is believed as factor enhancing its penetration into forest floor (Obidziński and Symonides 2000). According to Węglarski (1991) roots of *I. parviflora* can grow down to a depth of 12 cm what can suggest that roots of the species can grow through litter layer.

Coombe (1956) in his review work, within biological flora of British Isles, claimed that *I. parviflora* grew on wide range of mineral soils also diversified with respect to soil reaction (pH range from 4.5 to 7.6). The pH range of observed sites in the present study was 2.75-8.5 i.e. much wider than observed in the Great Britain, despite that soil samples were taken from a narrower range of habitats. Taking into account assigned "x" score, by Ellenberg et al. (1992) of indicator of soil reaction (R-indicator), small balsam is an indifferent species. According to the scheme proposed by Ewald (2003) the species studied can not be classified both as "acidophilous" (R = 1-6) or "calciphilous" (R = 7-9). However, Lawesson (2003), using large pH datasets for Danish forests and statistical modelling, believed that *I. parviflora* has optimum at pH = 4.4. Following the division by Gough et al. (2000) *I. parviflora* can be treated as acidophytic species (pH < 5.5). Also according to Węglarski (1991) small balsam is a good indicator of weakly acid and acid soils. The present study shows that in two of three regions *I. parviflora* occupied little acid soils (medians of pH (water): 4.1-5.1 and pH (KCL) 3.45-4.66), but in forests of the Silesian Upland occurred on neutral substratum (medians of pH: 6.9-7.0). However, in the study by Csontos (1984) no correlation between soil acidity and abundance of *I. parviflora* was observed. The study of ours confirmed that *I. parviflora* is mainly confined to acid soils but the range of pH of soils, occupied by this species, is wide (Fig. 3). Csontos (1984) also did not confirm relations of the species with water supply and temperature. Coombe (1956) gave information that small balsam grew on open-textured, retentive of moisture but not waterlogged soils. We did not analyse moisture but on the basis of soil granulometric composition and its vulnerability to store a water and field observations one can expect that species prefers fresh soils and avoids both dry and waterlogged substratum. Węglarski (1991) reported that *I. parviflora* is confined to soils enriched with phosphorus, magnesium and potassium. Our study showed that *I. parviflora* occurred more frequently on soils poor in nutrients (Fig. 5). This discrepancy can result from large area and higher heterogeneity of habitats studied in the present research but not from differences between populations from the Wielkopolski National Park and analysed regions in the paper. Our study indicates typical humus of forest type, which is characterized by large ratio of C:N. According to Duchaufour (1970) after Piękoś-Mirkowa et al. (1996) the forest mull most often ranges from 12 to 15 and for moder it varies from 15 to 25. These intervals are the most frequent in the soil samples studied (Fig. 4). Taking into account that small balsam can easily colonize fallen trees both fallen logs and their vicinity (Piskorz and Klimko 2001) content of humus, nitrogen and organic carbon could be very high. The highest obtained C:N was more than 39 and percentage of organic carbon amounted to 50.8% in neighbourhood of decaying dead wood Chmura (2006). Węglarski (1991) also claimed that *I. parviflora* is an indicator of strongly decaying soils (large ration C:N).

CONCLUSIONS

The study shows that small balsam is a species with a wide ecological breadth, which enhances its success in colonizing and persisting in different forest communities, regardless of the physical and chemical properties of the soils. The differentiation of analysed variables result from various habitat conditions occurring in woodlands of three regions, varied in geological structure and substratum, but not from differences in ecotypes of *I. parviflora*. Quite small number of samples does not permit to state something certain about biotopic preferences, especially about association of the species to specific chemical properties of soils and about differences between the regions studied or relationship between abundance of the species and environmetal gradients.

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