

The differences in the invasiveness of some alien plant species between continental and coastal part of Croatia

Razlike u invazivnosti nekih stranih biljnih vrsta između kontinentalnog i obalnog dijela Hrvatske

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THE DIFFERENCES IN THE INVASIVENESS OF SOME ALIEN PLANT SPECIES BETWEEN CONTINENTAL AND COASTAL PART OF CROATIA

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Stručni članak

SUMMARY

Croatia is a small but heterogeneous country with different pedo-climatic conditions in its parts. In the continental region, mountain region excluded, the climate is moderate continental and in the coastal region Mediterranean and sub-Mediterranean. The aim of this study was to explore the presence, prevalence and level of aggressiveness of some invasive alien plants between continental and coastal part of Croatia. *Amorpha fruticosa* L., *Reynoutria japonica* Houtt. and *Solidago gigantea* Ait. are widespread and very aggressive in the continental and rarely present in coastal part of Croatia. *Ailanthus altissima* (Mill.) Swingle is present in each Croatian county but it shows greater aggressiveness in the coastal region, including islands and some protected areas.

Key-words: Croatia, invasive alien plants, invasiveness, islands, protected areas

INTRODUCTION

Invasive alien (non-native) species are globally marked as the second greatest threat to biodiversity (Council of Europe, 2007). Invasive alien plants are intentionally or unintentionally introduced into areas outside their natural range. In new areas they show rapid adaptation to new environmental conditions and exceptional ability for rapid reproduction, resulting in their high number and density (Weber, 2005; Novak and Novak, 2017). It is clear that environmental conditions play a crucial role in their successful adaptation.

According to EPPO Climatic Zones the Republic of Croatia is located among Maritime, South-East and Mediterranean part of Europe (EPPO Bulletin, 2014). It is a small but heterogeneous country with different pedo-climatic conditions in its parts. In the Croatian inland climate there is moderately hot humid with warm summers while at higher altitudes climate moderately hot humid with warm summers and wet boreal climate. In the coastal region climate is Mediterranean with hot summer and Mediterranean with warm summer (Šegota and Filipčić, 2003). According to Husnjak et al. (2009) in the area of Panonic lowland (continental part of Croatia) the type of soil is Endogleyic, Luvic Stagnosol (Albic, Epidystric,

Endoeutric, Episiltic, Endoclayic, Ruptic), in the area of mountain region of Gorski kotar the type of soil is Entic Podzol (Endoskeletal) and in the Mediterranean coastal region it is Endostagnic Anthrosol (Eutric, Clayic).

The authors classified those soils according to WRB Classification. Therefore, there is a large difference in soil composition and percentage of organic matter (up to 3%) across Croatia (Rašić et al., 2011). Karst areas represent 48.9% of the land area of Croatia (Bogunović and Bensa, 2006).

According to many literary sources, tree of heaven (*Ailanthus altissima* (Mill.) Swingle), indigo bush (*Amorpha fruticosa* L.), Japanese knotweed (*Reynoutria japonica* Houtt) and giant goldenrod (*Solidago gigantea* Ait), e.g. species included in this study, are considered significant invasive species (Kowarik and Säumel, 2007; Kovačić et al., 2008; Idžojtić et al., 2009). All four species are included on Preliminary check-list of invasive alien plant species (IAS) in Croatia (Boršić et al., 2008) and were on the EPPO List of invasive alien plants at the time this research was conducted. Preliminary check-

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list of invasive alien plant species in Croatia consists of 64 species. According to the DAISIE database, two species included in this research, tree of heaven and Japanese knotweed, are classified among the 100 of the world's worst invasive species. Nikolić et al. (2014) consider all four plant species included in this investigation as significant invasive plants in Croatian flora.

Tree of heaven is a deciduous ornamental tree native to China. It was introduced in Europe in the late 1700s as an ornamental species (Kovačić et al., 2008). Nowadays, the species is spread across all continents except Antarctica, and it is one of the most invasive trees in the world (Kowarik and Säumel, 2007). It can grow rapidly up to 27-30 m in moderate climatic areas and 18-20 m in other climatic areas (Kovačić et al., 2008). Idžojić and Zebec (2006) consider it the most invasive wooden species in Croatia. Indigo bush is a deciduous shrub native to North America. Where native, the species is found in riparian habitats, open rich woods, and in floodplain forests. In places, where invasive, it forms extensive stands due to its dense growth habit, altering the vegetation structure and replacing native species (Weber, 2005). In Croatia it appeared in the early 20th century (Idžojić et al., 2009) and was mentioned already in 1938 as a common and dangerous weed in forestry (Liović, 2009). Japanese knotweed is herbaceous perennial ornamental plant native to Japan. The dense foliage and the vegetative growth lead to dense and tall thickets that completely shade out all other vegetation, degrading native plant and wildlife habitats, thus, eliminating native species. Fragments and rhizomes easily resprout and are carried by streams (Weber, 1997). Giant goldenrod is a perennial herbaceous ornamental and bee plant native in North America. Shoot densities may exceed 300 shoots per m². The species spreads mainly by rhizomes which easily break off and are carried by streams to new sites (Weber, 1997).

The objective of this study was, due to heterogeneous characteristics of the country and well known features of these four invasive alien plants, to investigate differences in their distribution and invasiveness.

MATERIAL AND METHODS

Monitoring of invasive alien plants was conducted in the period 2007-2014. City of Zagreb and all 20 Croatian counties, including 22 islands (Cres, Lošinj, Krk, Ugljan, Pašman, Dugi otok, Olib, Silba, Premuda, Ist, Murter, Kaprije, Žirje, Prvić, Zlarin, Brač, Čiovo, Hvar, Vis, Mljet, Lopud and Lokrum) and peninsula Pelješac, were covered by the survey. Determining the presence and distribution of invasive alien plants was conducted by expert's visual check two to three times during the growing season (spring and late summer or spring-summer-autumn) in two to three counties annually. The size of infested areas, most common habitat and growing conditions of the species, size and vigour of the populations and the impact on native species were visually evaluated directly on the site by experts included in this investigation. The plant height was measured using the

meter. The approximate height of the higher plant that couldn't be measured in this way, was estimated by the expert's assessment. The plant density was measured by numbering the plants on 1 m² on several sites for each location. The sizes of smaller infested areas were measured using the meter and the sizes of larger infested areas were estimated by the expert's assessment directly on the site. Estimations of larger infested areas were made during the flowering of the species. In some cases, the car distance meter was used where it was possible, depending on the situation in the field. Comparison of invasiveness in continental (excluding mountains) and coastal part of Croatia was made for tree of heaven, indigo bush, Japanese knotweed and giant goldenrod.

RESULTS AND DISCUSSION

Species included in this study showed a different level of invasiveness in different parts of Croatia.

Tree of Heaven (*Ailanthus altissima* (Mill.) Swingle)

According to our observations, tree of heaven is present in the whole country (as shown in Table 1). It has been recorded in the City of Zagreb and all 20 Croatian counties. The results are in line with those reported by Idžojić and Zebec (2006) who consider the tree of heaven the most aggressive invasive tree species in Croatia. It was found out that the species correspond devastated and abandoned habitats such as house ruins, industrial yards, etc., that invades much faster than other species. It is most commonly recorded as a species that is a "companion of man" and is mostly located at the entrances to settlements and in populated places. Tree of heaven is a serious threat to autochthon species and biodiversity, especially in the Mediterranean region of Croatia.

In continental part of Croatia it has expanded in limited areas and does not pose a direct threat. However, in several locations in the eastern Croatia (Vukovar-Srijem County), strong populations with high trees, an abundance of seeds and young shoots were observed. In these areas, tree of heaven forms dense monocultures, suppresses native vegetation and shows a further tendency spread. In some locations in Virovitica-Podravina County, it has exhibited a high degree of aggressiveness in humid habitats along the Drava River.

Due to the high level of resistance to long-lasting droughts and high temperatures, tree of heaven was recorded as a very aggressive species in constant and almost visible expansion in the coastal part of Croatia. Monocultures are larger and denser in coastal part where they often occupy several hectares (as shown in Table 1).

Tree of heaven is also present in some protected areas in Mediterranean region and on many Croatian islands which are especially vulnerable due to their isolated ecosystems. Spreading of tree of heaven was observed on some localities in Krka National Park which

is also reported in the literature (Novak and Novak, 2017). Its communities were recorded on Kornati National Park, Brijuni National Park, Biokovo Nature Park, Telašćica Nature Park, Vučina Protected area and on 19 from 22 islands inspected. It was not recorded only on three islands - Ist, Lopud and Lokrum. On some islands, locations of findings are related to the human activity and its prevalence is limited. However, on some locations the species completely devastated natural ecosystems.

The conducted monitoring showed that tree of heaven possesses maximum adaptability to the surrounding environment. The obtained results for this species are in line with the results from other studies (Kovačić et al., 2008; Petrova et al., 2013; Novak and Kravarščan, 2014).

Indigo Bush (*Amorpha fruticosa* L.)

Indigo bush habitats are not so diverse. The results of indigo bush distribution by Croatian counties are presented in Table 1.

On some locations in continental region, it suppresses native vegetation and forms dense monocultures. The largest and "the strongest" populations exist on

humid habitats where this species is a serious threat to biodiversity. Obtained results are in line with Anastasiu and Negrean (2006) and Blagojević et al. (2015) who also claim that species prefer humid habitats and it is mostly present near irrigation channels and river banks, especially in alluvial or marshy areas. Large areas some of which protected wetland areas in continental region (Lonjsko polje in Sisak-Moslavina County and Kopački rit in Osijek-Baranja County) are seriously infested with monocultures of this species being not in the line with results reported by Sărățeanu (2010). The author states that indigo bush occurs on poor, degraded, dry and sandy soils.

In the coastal part of Croatia, it is present only sporadically with individual plants (Figure 6) or small populations that occupying 10-20 m² on few locations being in line with Pedashenko et al. (2012). The authors state that cover of indigo bush in Bulgaria is higher on the mainland than on islands. Its invasiveness shows only in the city of Omiš on the banks of the river Cetina in Split-Dalmatia County. On the other parts of Mediterranean region of Croatia it is not a direct threat to native species. This species is not very competitive in long-lasting drought common in coastal part of Croatia.

Table 1. Distribution of *Ailanthus altissima* (Mill.) Swingle and *Amorpha fruticosa* L. by Croatian counties

Tablica 1. Rasprostranjenost vrsta *Ailanthus altissima* (Mill.) Swingle i *Amorpha fruticosa* L. po hrvatskim županijama

	County Županija	Year of monitoring Godina monitoringa	No. of findings Broj nalaza		Max. infected area per finding (m ² or ha) Maks. zaraženo područje po nalazu (m ² or ha)		Max. height (m) and density of plants m ⁻² Maks. visina (m) i gustoća biljaka (m ⁻²)	
			<i>Ailanthus</i>	<i>Amorpha</i>	<i>Ailanthus</i>	<i>Amorpha</i>	<i>Ailanthus</i>	<i>Amorpha</i>
Continental part	City of Zagreb and Zagreb County	2007	67	-	5000 m ²	-	25/60	-
	Varaždin County	2007	12	-	1500 m ²	-	15/30	-
	Koprivnica-Križevci County	2008	9	5	3000 m ²	1 ha	20/25	3/5
	Krapina-Zagorje County	2008	6	1	500 m ²	100 m ²	15/20	-
	Međimurje County	2008	7	-	5000 m ²	-	15/20	-
	Bjelovar-Bilogora County	2009	5	2	1000 m ²	1 ha	15/20	3/5
	Karlovac County	2009	12	5	3000 m ²	several dozen ha	15/20	3/7
	Sisak-Moslavina County	2010	18	83	3000 m ²	100 ha	20/30	3/10
	Brod-Posavina County	2011	11	75	1000 m ²	100 ha	15/30	3/10
	Požega-Slavonija County	2011	16	20	1000 m ²	1000 m ²	20/50	3/6
	Virovitica-Podravina County	2012	11	4	3000 m ²	100 m ²	15/40	3/10
	Osijek-Baranja County	2013	12	20	1000 m ²	100 ha	15/50	4/10
	Vukovar-Srijem County	2014	20	55	5000 m ²	10 ha	20/50	4/7
	Lika-Senj County	2009	1	-	100 m ²	-	10/5	-
	Primorje-Gorski kotar County	2010	1	-	100 m ²	-	10/5	-
Coastal part	Lika-Senj County	2009	48	-	5000 m ²	-	15/60	-
	Primorje-Gorski kotar County	2010	59	-	several ha	-	20/60	-
	Istria County	2010	65	-	several ha	-	20/40	-
	Zadar County	2011	72	-	several ha	-	20/60	-
	Šibenik-Knin County	2012	90	-	several ha	-	25/60	-
	Split-Dalmatia County	2013	92	8	several ha	200 m ²	25/60	3/5
	Dubrovnik-Neretva County	2014	62	3	several ha	50 m ²	25/60	1,8/2

Japanese Knotweed (*Reynoutria japonica* Houtt)

Japanese knotweed is the most common *Fallopia* species in Croatia, which is in line with Forman and Kesseli (2003) and Bailey et al. (1995) who states that Japanese knotweed is the most common *Fallopia* species in general. The results of Japanese knotweed distribution by Croatian counties are presented in Table 2.

On many locations in the continental region of Croatia, it suppresses native vegetation and forms dense monocultures. Its habitats are very diverse but usually related to human activity. It is usually found near water courses, traffic roads, in towns, near building sites, industrial yards and other urban areas. Large populations usually exist on humid habitats. Recorded findings are in the line with Beerling, 1991. The largest infested area is the city of Karlovac and the surrounding area with many infested locations and hectares of monocultures of Japanese knotweed. From the Table 2 it is evident that the highest infested area is in Karlovac County. Four rivers which flow through the city of Karlovac make favourable conditions for the invasion of this species. Aguilera et al. (2010) state that Japanese knotweed often forms monocultures being in line with our results.

In the coastal part of Croatia, it is present only sporadically on few locations, mostly as ornamental species and is not considered a threat to biodiversity. Although it was proven to be well tolerant to the salty soil (Richards et al. 2008), the prediction is that it will not become invasive because of dry conditions in Mediterranean part of Croatia.

Giant Goldenrod (*Solidago gigantea* Ait)

According to our observations, *Solidago gigantea* is the most common *Solidago* species in Croatia. The obtained results are in accordance with those reported by Weber (1998) who states that *Solidago gigantea* had the highest colonization rate. The results of giant goldenrod distribution by Croatian counties are presented in Table 2.

In the continental part of Croatia, it has been found on many different ruderal areas usually related to human activity. Infested areas are extremely large and they include thousands of hectares. It is rarely present as an agricultural weed in crops and was recorded only on field margins in maize, being in line with Dajdok and Wuczyński (2008) and Novak and Kravaršćan (2011). The highest level of aggressiveness was recorded in abandoned agricultural areas where it often forms dense monocultures and suppresses native species.

Table 2. Distribution of *Reynoutria japonica* Houtt and *Solidago gigantea* Ait by Croatian counties

Tablica 2. Rasprostranjenost vrsta *Reynoutria japonica* Houtt i *Solidago gigantea* Ait po hrvatskim županijama

	County Županija	Year of monitoring Godina monitoringa	No. of findings <i>Br. nalaza</i>		Max. infected area per finding (m ² or ha) <i>Maks. zaraženo područje po nalazu (m² or ha)</i>		Max. height (m) and density of plants m ⁻² <i>Maks. visina (m) i gustoća biljaka (m⁻²)</i>	
			<i>Reynoutria</i>	<i>Solidago</i>	<i>Reynoutria</i>	<i>Solidago</i>	<i>Reynoutria</i>	<i>Solidago</i>
Continental part	City of Zagreb and Zagreb County	2007	83	70	1500 m ²	10 ha	4/60	2/200
	Varaždin County	2007	16	40	400 m ²	10 ha	4/50	2/200
	Koprivnica-Križevci County	2008	52	160	3000 m ²	10 ha	4/50	2/200
	Krapina-Zagorje County	2008	16	67	400 m ²	10 ha	4/50	2/200
	Međimurje County	2008	15	85	600 m ²	10 ha	4/50	2/200
	Bjelovar-Bilogora County	2009	25	150	5000 m ²	10 ha	4/60	2/200
	Karlovac County	2009	62	77	2 ha	10 ha	4/60	2/200
	Sisak-Moslavina County	2010	42	50	5000 m ²	5000 m ²	4/50	2/150
	Brod-Posavina County	2011	65	51	3000 m ²	1000 m ²	4/50	2/100
	Požega-Slavonija County	2011	82	65	2000 m ²	5000 m ²	4/60	2/100
	Virovitica-Podravina County	2012	17	80	3000 m ²	10 ha	4/50	2/100
	Osijek-Baranja County	2013	32	40	2000 m ²	1 ha	4/50	2/100
	Vukovar-Srijem County	2014	17	32	500 m ²	1 ha	4/50	2/100
	Lika-Senj County	2009	21	25	1000 m ²	100 ha	4/50	2/200
Primorje-Gorski kotar County	2010	11	25	500 m ²	5000 m ²	4/50	2/150	
Coastal part	Lika-Senj County	2009	-	3	-	100 m ²	-	1,5/40
	Primorje-Gorski kotar County	2010	1	4	2 m ²	100 m ²	3/30	1/50
	Istria County	2010	1	9	5 m ²	100 m ²	3/35	2/50
	Zadar County	2011	-	-	-	-	-	-
	Šibenik-Knin County	2012	1	3	2 m ²	individual plants	3/30	0,5/1
	Split-Dalmatia County	2013	8	-	200 m ²	-	3/5	-
	Dubrovnik-Neretva County	2014	3	-	50 m ²	-	1,8/2	-

In the coastal part of Croatia, it is only sporadically present, with individual plants or small populations that include several square meters on few locations, but mostly as ornamental species in gardens. Only few individual plants were recorded in Mediterranean part of Croatia e.g. Šibenik-Knin County (as shown in Table 2), so no significant influence on biodiversity in this part of the country is expected. It is evident that this species is not very competitive in Mediterranean pedo-climate conditions.

The obtained results showed that all species included in this study may reduce native species diversity being in line with many authors (Pyšek and Pyšek, 1995; Higgins et al., 1999). Although only a small number of alien species appear to negatively affect native communities (Cronk and Fuller, 2001), it is evident that these species have that feature in some parts of Croatia.

CONCLUSION

Invasive alien plants colonize many areas of Croatia. Different species behave differently in the continental and coastal part of Croatia. The presence and prevalence of invasive alien plant species are in accordance with pedo-climatic conditions in different parts of Croatia. Indigo bush, Japanese knotweed and giant goldenrod are widespread and very aggressive in the continental and rarely present in Mediterranean region of Croatia. Tree of heaven is present in each Croatian county but it shows greater aggressiveness in the coastal region, including islands and even some protected areas. Human impact is a very important factor in the invasive alien plants spreading. Invasive alien plants can hardly be found in stable ecosystems and untouched environment. Japanese knotweed and Giant Goldenrod are planted and cultivated as ornamental plants. Most of the public is unaware of the danger and potential damages that invasive species can cause. In Croatia, there is no legislation on control and prevention of invasive alien plant species spreading, except ragweed which, despite to the legislation, continues to spread.

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RAZLIKE U INVAZIVNOSTI NEKIH STRANIH BILJNIH VRSTA IZMEĐU KONTINENTALNOG I OBALNOG DIJELA HRVATSKE

SAŽETAK

*Hrvatska je mala, ali heterogena zemlja, s različitim pedološko-klimatskim uvjetima u svojim dijelovima. U kontinentalnoj regiji, isključujući planinsku regiju, klima je umjerena kontinentalna, mediteranska i submediteranska. Cilj ovog istraživanja bio je istražiti prisutnost i razinu agresivnosti nekih invazivnih stranih biljaka između kontinentalnoga i obalnoga dijela Hrvatske. Amorfa (*Amorpha fruticosa* L.), Japanski dvornik (*Reynoutria japonica* Houtt.) i velika zlatnica (*Solidago gigantea* Ait) široko su rasprostranjene i vrlo agresivne u kontinentalnoj, ali slabo prisutne u obalnome dijelu Hrvatske. Pajasen (*Ailanthus altissima* (Mill.) Swingle) je prisutan u svim županijama, međutim veću agresivnost pokazuje u obalnome području, uključujući otoke i neka zaštićena područja.*

Ključne riječi: *Hrvatska, invazivne biljne vrste, invazivnost, otoci, zaštićena područja*

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