Two alien species of *Bidens* (*Compositae*), new to the flora of Serbia

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Abstract. Two new alien species, *Bidens subalternans* and *B. connatus*, have been recorded in the flora of Serbia. While *B. subalternans* is recorded in ruderal areas, *B. connatus* can be found among the nitrophilous vegetation of the wet habitats in the urban and suburban parts of the town of Niš, in East Serbia. *Bidens subalternans* is native to South America and *B. connatus* to North America, but on the territory of Serbia, as in the other parts of Europe, they show a potentially invasive character. Spreading of the above-mentioned species is discussed and supplemented by new distribution data, with a specific review of the European territory. The types of habitats are presented where the newly recorded species can be found in Serbia. A new key is provided for identification of all species of the genus *Bidens* registered on the territory of Serbia, together with the invasive representatives which are realistically expected to appear in Serbia in the near future. Furthermore, the differences between *B. subalternans* and *B. bipinnatus*, as well as between *B. connatus* and *B. frondosus* are reviewed on the basis of the fact that the latter are invasive taxa with which the newly recorded species show the greatest morphological similarity.

Key words: *Bidens connatus*, *Bidens subalternans*, *Compositae*, invasive plants, habitats, Serbia

Introduction

The genus *Bidens* consists of 230 to 280 species (Sherff 1937; Mitich 1994; Sell & Murell 2005), generally widely spread as native or naturalised. The greatest number of species is recorded on the territory of America, which represents the taxonomic centre of diversity for the mentioned genus (Sell & Murell 2005). Most species of *Bidens* spread easily, naturally or anthropogenically, and many of them have shown a strong invasive character in the process of enlarging their areas (Pyšek & al. 1998; Šilić & Edita-Šolić 1999; Pandža & al. 2001; Walter & al. 2005; Sirbu & Oprea 2008; Anastasiu & Negrean 2009; Zelnik 2012).

On the territory of Serbia, seven species of genus *Bidens*, including *B. subalternans* DC. and *B. connatus* Willd. as two new species for its flora, have been recorded so far. Sherff (1937) classified all species of genus *Bidens* into 14 sections, where *B. subalternans* was classified in the section *Psilocarpaea* DC. This section, as its name implies, includes representatives with linear, glabrous achenes and contains almost half of all described species of the genus. Besides *B. subalternans*, the mentioned section also includes the species *B. pilosus* L., recently discovered in the western parts of Serbia (Niketić 2010).

Bidens connatus and all other species of genus *Bidens* (*B. frondosus* L., *B. vulgatus* Greene, *B. tripartitus* L. and *B. cernuus* L.) in the flora of Serbia (Gajić 1975; Sarić & Diklić 1986) belong to the section *Platycarpaea* DC., characterized by representatives with ovate to obovate-cuneate achenes, which are flattened or indistinctly 4-angled at apex. A typical representative of this section is *B. tripartitus* (Sherff 1937), since

it is one of the most frequent and the most widespread species of genus *Bidens* in Serbia. The invasive species *B. vulgatus*, confirmed as present in many localities in the northwestern parts of Serbia (Tatić & Žukowski 1973), was also referred to the mentioned section after publication of the treatment of genus *Bidens* in the Serbian flora (Gajić 1975).

Material and methods

Herbarium specimens of the species *B. subalternans* and *B. connatus*, as well as specimens of the species *B. frondosus* (HMN 9260, 9261) used for comparison, were deposited in the Herbarium of the Faculty of Sciences and Mathematics, Department of Biology and Ecology, University of Niš (HMN). The nomenclature and classification of taxa was matched with the Euro+Med Plant Base (http://ww2.bgbm.org/EuroPlusMed/). Morphological descriptions of the species in the paper are based on literature sources (Sherff 1937; Duvigneaud 1975; Sell & Murell 2005) and supplemented with observations of the collected plants. Differential characters for eight presented species are determined on the basis of relevant literature (Tutin 1976; Sell & Murell 2005; Bojňanský & Fargašová 2007; Petrova & Vladimirov 2009) and analyses of the herbarium material. Distribution of the studied taxa within the territory of Serbia was mapped in a UTM grid system (10×10 km, UTM Zone 34T). In order to determine the status of invasion, terminology of Lambdon & al. (2008) and Mitić & al. (2008) was used. Data on the abundance of species, condition of the populations and characteristics of the habitats inhabited by *B. subalternans* and *B. connatus* in Serbia are based on field researches.

Results and discussion

Considering the fact that after publication of the treatment on genus *Bidens* in *The Flora of Serbia* (Gajić 1975) four new species of genus *Bidens* were recorded in Serbia, we believe that it is necessary to present a new key for identification of the species of this genus in the Serbian flora. Taking into consideration its invasive character and the fact that it is present in the flora of many neighbouring countries (Pulević 2005; Kovačević & al. 2008; Sirbu & Oprea 2008; Petrova & Vladimirov 2009), the key also processes the species *B. bipinnatus* L., whose appearance can realistically be expected in Serbia in the near future.

Key to the species of *Bidens* in the Serbian flora is provided below:

1a. Lower and middle cauline leaves lobed, lobes petiolulate **2**

2a. Leaves 1-pinnate, achenes flattened, cuneiform, with 2 bristled awns **3**

3a. Upper leaves usually with 3, seldom 5 lobes, outer involucral bracts 5–8(10), achenes blackish, bristled . . . . . ***B. frondosus***

3b. Upper leaves usually with 5 lobes, outer involucral bracts 10–16(21), achenes olive-green to brownish, glabrous . . . . . ***B. vulgatus***

2b. Leaves 1–3-pinnate, achenes tetragonal, linear, with 3–4 bristled awns **4**

4a. Leaves usually 1-pinnate, leaf-lobes ovate to lanceolate, achenes fusiform . . . . . ***B. pilosus***

4b. Leaves 2–3-pinnate, leaf-lobes rhomboid or lanceolate, achenes linear **5**

5a. Leaves 2(3)-pinnate, lobes rhomboid to widely lanceolate, achenes usually with 3 bristled awns, 2–4 mm long, erecto-patent at maturity . . . . . ***B. bipinnatus***

5b. Leaves 2-pinnate, lobes usually linear-lanceolate, achenes usually with 4 bristled awns, 1–2.5 mm, erect, almost parallel when ripe . . . . . ***B. subalternans***

1b. Lower and middle cauline leaves simple or lobed but lobes not petiolulate **6**

6a. Leaves sessile, simple . . . . . ***B. cernuus***

6b. Leaves petiolate, simple or lobed **7**

7a. Leaves usually simple, achenes verrucose, usually with 4 bristled awns, 2 longer and 2 shorter, central achenes strongly 4-angled . . . . . ***B. connatus***

7b. Leaves with 1–2 pairs of lobes, achenes not verrucose, usually with 3 bristled awns, middle awn usually shorter than outer awns, central achenes flat . . . . . ***B. tripartitus***

Bidens subalternans DC., Prodr. 5: 600. (1836) (Fig. 1)

Annual, herbaceous plant with an erect and branched stem. Stem 40–100(300) cm, 4-angled, glabrous or sparsely hairy. Leaves petiolate, 6–21 cm long, 2-pin-

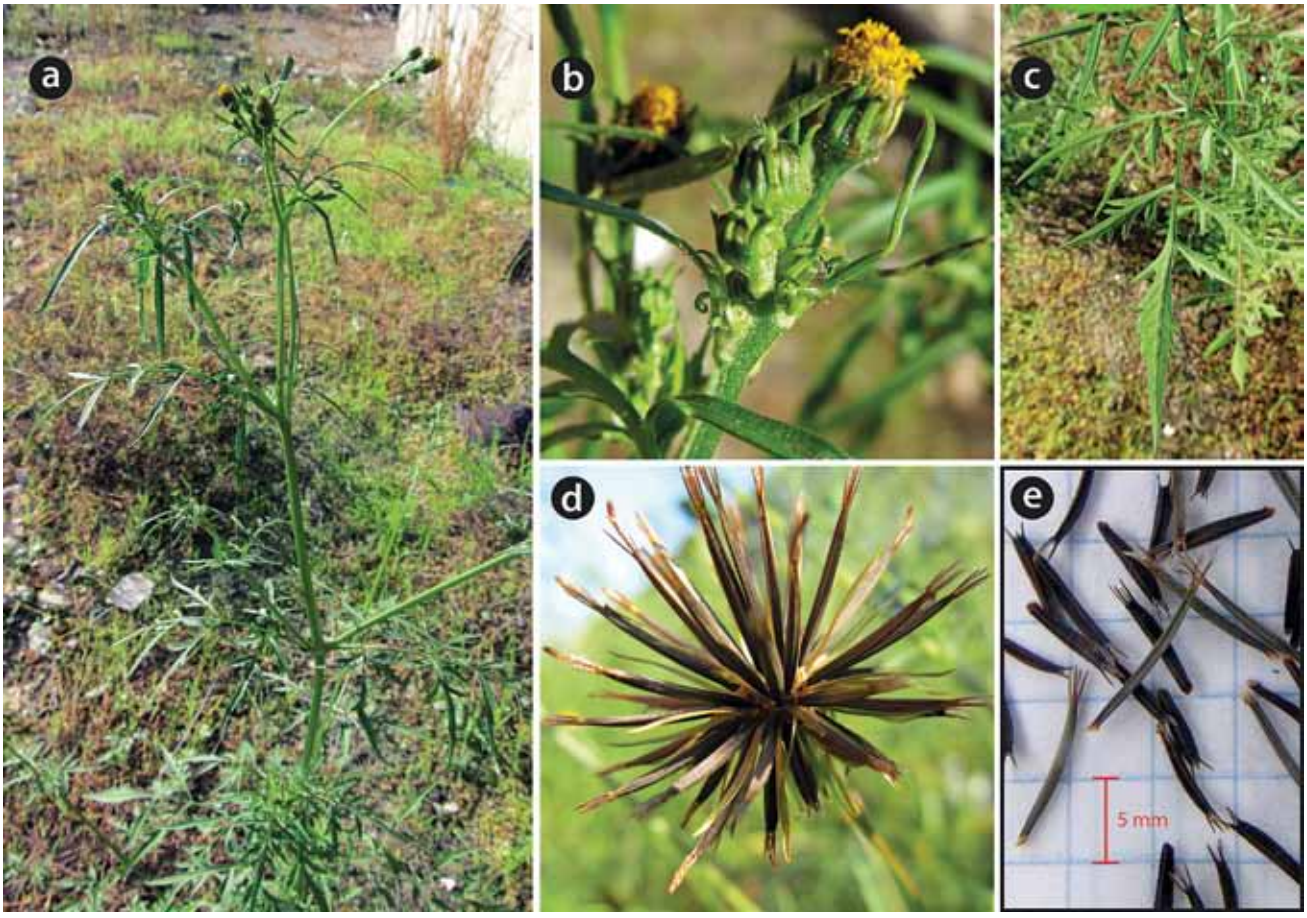

Fig. 1. *Bidens subalternans*: **a** – plant habit; **b** – flowering capitula; **c** – cauline leaf; **d, e** – ripe fruits (photos **a, b, c** & **d** – B. Zlatković, **e** – S. Bogosavljević).

natisect or simply incised; lobes with short, dense or sparse hairs, more or less dentate, or coarsely serrate, oblong-lanceolate or oblong-linear, acuminate. Capitula terminal, solitary, at the time of flowering 8–10 × 5–6 mm, at the time of fructification up to 17 × 16 mm; peduncles 1–4 cm long. Involucral bracts in 2 rows; the outer usually 8, narrowly-linear, ciliate, more or less hairy, acuminate or obtuse, 4–6 mm long, the inner linear-lanceolate. Ligulate florets white, pale-yellow or yellow, often vestigial or missing. Achenes numerous, 30–50, linear, 4-angled, furrowed, blackish, glabrous or sparsely hairy at apex; the outer 6–8 mm, thicker and verrucose, the inner 8–14 mm, thinner, glabrous, with longitudinal furrows. Pappus of 4 (seldom 2 or 3) erect to almost erect awns, 1–2.5 mm, with retrorsely directed barbs. Flowering in August to October, fruiting in September and October. $2n = 48$ (Grombone-Guaratini & al. 2006). The plant produces a large number of achenes. The ways of dispersion is anthropochory and epizoochory.

Distribution in Serbia (Fig. 2):

1. Serbia (*East*): The town of Niš, Central Railway Station, waste places and ruderal habitats around the abandoned tracks and platforms, *Artemisietea vulgaris*, 190 m, 43.31667°N, 21.86667°E, EN79, 11.10.2014, coll. *S. Bogosavljević* & *M. Ranđelović* and 19.10.2014, coll. *S. Bogosavljević* & *B. Zlatković* (HMN 9258, 9259).

As compared to the other species of genus *Bidens* growing in Europe, *B. subalternans* has the greatest similarity to *B. bipinnatus.* However, the difference between the two species is that *B. subalternans* is a considerably larger plant and on the average has a greater number of capitula. The most significant character, however, is that the awns of the achenes in *B. subalternans* are almost perfectly erect and mutually parallel, while in *B. bipinnatus* they are placed at an acute angle in relation to the body of the achene. This difference is visible even in unripe fruits. Furthermore, the leaves of *B. subalternans* are generally triangular, while the leaves of *B. bipinnatus* are rhomboid. The lobes of

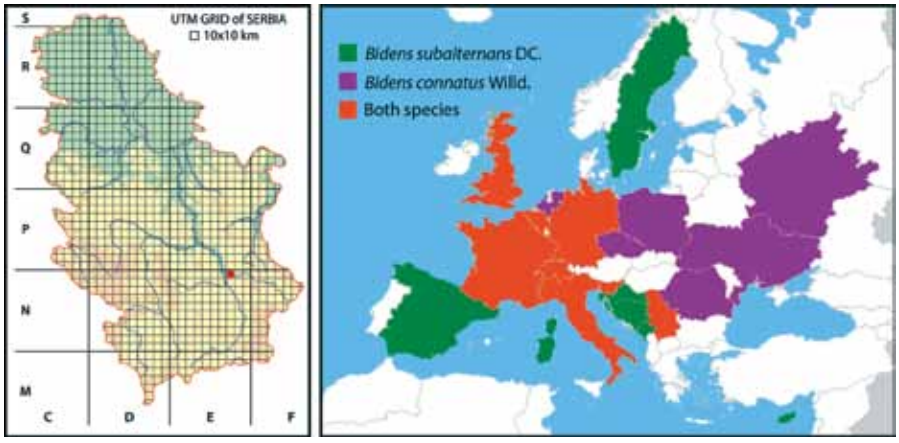

Fig. 2. Distribution of *B. subalternans* and *B. connatus* in Serbia (left) and in the European countries (compiled according to Greuter 2006) (right).

B. subalternans are linear-lanceolate, while the lobes of the species *B. bipinnatus* are again rhomboid.

The population of *B. subalternans* has been recorded in ruderal habitats, in marginal parts of the Central Railway Station – Niš infrastructure complex, close to the old industrial zone of the town. The population covers an area of several hundred square metres, around the abandoned railway tracks and unused coaches for a longer period of time. The species is a constituent of the ruderal vegetation of *Artemisietea vulgaris* class, where it is an almost dominant plant species. In a relatively dense population, *B. subalternans* reaches the number of several hundred individuals. Therefore, individuals at all stages of development were recorded, beginning with the early vegetative stage, then flowering stage, and on to the late stage of fructification. Besides *B. subalternans*, the following taxa were recorded in the habitat: *Amaranthus albus*, *A. retroflexus*, *Anchusa officinalis*, *Ballota nigra* subsp. *foetida*, *Bassia scoparia* subsp. *densiflora*, *Euphorbia maculata*, *Chenopodium album*, *Clematis vitalba*, *Convolvulus arvensis*, *Cuscuta* sp., *Digitaria sanguinalis*, *Erigeron annuus*, *E. canadensis*, *Galium album*, *Geranium purpureum*, *G. pyrenaicum*, *Medicago sativa*, *Portulaca oleracea*, *Rubus* sp., *Setaria* sp., and *Sonchus arvensis*.

Considering the territory occupied by the species and the number of individuals in its population, it could be inferred that *B. subalternans* was introduced to Serbia only a several years ago. Mention deserves the fact that physical removal of weeds and use of herbicides have been almost regularly applied for several years on the territory occupied by this species, as a means of organizing and maintaining the functionality of the infrastructure.

Bidens subalternans is native to Brazil (Sherff 1937), central, northern and eastern Argentina (Giorgis & al. 2005), Colombia (Jansen & al. 1984), Bolivia (Hind 2011), Paraguay (Morales & al. 2007), and Cuba (Sherff 1937). Furthermore, the species also occurs in other South American countries, such as Uruguay and Chile, where it has been recorded as a constituent of weedy vegetation (Cardenas & Coulston 1967; Fuentes & al. 2012).

As an introduced species, it has also been recorded in Australia, mainly in arable lands (Randall 2007). As far as Asia is concerned, the species was first recorded in 2011, only in South Korea, where it is considered naturalized (Kim & al. 2012).

In Europe, the species was first recorded in Belgium in 1903 (Duvigneaud 1975). Presently, it occurs in 14 European countries, including Serbia (Fig. 2). Presumably, the species was introduced to Central Europe through transport of wool and fruits (Simon 1974). As an invasive species, it has been recorded in a great number of localities in Croatia (Boršić & al. 2008), Spain (Sanz-Elorza & al. 2004; Campos & Herrera 2009), Italy (Celesti-Grapow & al. 2010), Slovenia (Glasnović & al. 2013), France (Muller 2006), Montenegro (Stešević & Petrović 2010), and Bosnia and Herzegovina (Maslo 2014). The species has been also recorded in Cyprus, where it has the status of a casual alien species (Hand 2009).

Considering its origin and its thermophilic character, a further spread and invasiveness of the species is expected, primarily in the countries with milder climate. That explains its expansion in the countries of South Europe, mainly in the Mediterranean-sub-Mediterranean region (Pandža & al. 2009). In the countries of Central, North and Northwestern Europe like Belgium (Verloove 2006), Germany (Buttler & Harms

1998), United Kingdom (Grenfell 1984), Switzerland (Wittenberg 2005), and Sweden (Karlsson 2002), the appearance of *B. subalternans* is either ephemeral, or there is no information about its invasiveness. It is assumed that *B. subalternans* should have the status of a casual alien species in those countries, as countries positioned mainly further north.

In many countries, *B. subalternans* acts as an important agricultural weed (Randall 2012). In the countries on the Balkan Peninsula (Bosnia and Herzegovina, Croatia, and Montenegro), *B. subalternans* is characterised solely as an invasive species.

In Europe, the species occurs in different habitats: wet places near streams and rivers, agricultural, ruderal habitats, along the coastline, at roadsides, in vineyards, olive groves, gardens, city parks, meadows, orchards, trash dumps, or on railway embankments.

As far as Serbia is concerned, *B. subalternans* could currently have the status of a casual alien species, considering the fact that it has been found only in one locality, and that it does not have a negative influence on the natural habitats and agro-ecosystems at present. However, bearing in mind that *B. subalternans* is an invasive alien species in some European countries, primarily in the countries of South Europe, its monitoring and control is suggested in the following years. That would prevent its potential spreading to larger areas of the urban territories and, furthermore, of becoming a threat to the natural ecosystems of Serbia. Therefore, it is necessary to pay special attention to the areas of eastern, southern and southeastern Serbia, which are under warmer climatic influence from the Mediterranean region. Along with this, these areas have a good infrastructural connection with the countries of South Europe and thus are convenient areas for the spread of a large number of invasive species originating from the warmer regions of the world (Zlatković & Bogosavljević 2014).

Bidens connatus Willd., Sp. Pl. 3: 1718. (1803) (syn. ***B. decipiens*** Warnst.) (Fig. 3)

Bidens connatus is a species that also belongs to therophytes. It is characterized by rapid growth, formation of a strong taproot and many lateral roots. Stem glabrous, 40–150 cm high, pale-yellowish-green, in later stages occasionally brownish-purple, erect, strongly branched, leafy. Leaves opposite, 5–15 × 2–8 cm, green on upper surface, paler beneath, lanceolate to elliptical,

Fig. 3. *Bidens connatus*: **a** – plant habit; **b** – flowering capitula, **c** – cauline leaf, **d, e** – ripe fruits (photos S. Bogosavljević).

acute at apex, mostly simple or with 2–4 divergent lobes reaching no more than halfway to midrib; infrequently, lower cauline leaves can be lobed; blades dentate, narrowed at base into a short, winged petiole 0.5–3 cm long, or sessile, glabrous or slightly pubescent. Capitula 10–15 mm in diameter, more or less erect, glabrous, one to few, with terminal position at stems or branches, peduncles 1–6 cm long. Involucral bracts in 2 rows; the outer 4–5(–7) in number, 10–20(40) mm long, occasionally leaf-like, narrow and linear, spreading or loosely ascending in the terminal part; the inner 6–10 mm, green with black lines and scarious margins, elliptical, ovate or ovate-lanceolate and obtuse at apex, glabrous. Flowers all tubular, bisexual, orange or reddish-yellow; the outer ligulate and sterile, yellow, with small 3-lobed ligules, and the inner tubular, 5-lobed at apex and bisexual. Receptacle flat or slightly convex. Outer achenes (3)4–7 mm, inner (4)5–8 mm long, brownish, obovoid-oblong, compressed, verrucose; achenes (primarily inner) strongly 4-angled in general, the marginal with 3, the central usually with 4 awns, two longer and two shorter, usually on the margins covered with retrorsely directed barbs. Flowering in July to September and fruiting in August to November. $2n = 48$ (Angelo & Boufford 2012). The plant produces a large number of achenes. The ways of dispersion are anthropochory and epizoochory.

As compared to the other species of genus *Bidens* in the flora of Serbia, *B. connatus* has the greatest similarity to *B. frondosus*. The two species often share similar habitats in nature. For this reason, it is necessary to discuss the differential characters which make their identification easier. On the basis of vegetative characters, the two species can most easily be distinguished by their leaves. The leaves of *B. frondosus* are lobed, with 3–5 lobes, while the leaves of *B. connatus* are mostly simple (Fig. 4a, 4b, 4d). Furthermore, at the flowering stage the most noticable difference is in the shape of outer involucral bracts. The outer involucral bracts of *B. frondosus* are narrower, smaller and more hairy, while these of *B. connatus* are glabrous and considerably larger (Fig. 4c, 4e). At the fruiting stage, *B. frondosus* produces black achenes, bristled, each with mainly 2 awns. On the other hand, *B. connatus* has somewhat paler, brownish achenes, verrucose, with mainly 4 (two longer and two shorter) awns. Besides, the achenes of *B. connatus* are prominently 4-angled (especially those in the middle), while the achenes of *B. frondosus* are compressed (Fig. 4f, 4g, 4h).

Distribution in Serbia (Fig. 2):

1. Serbia (*East*): The town of Niš, along river Gabrovačka, in the nitrophilous vegetation of muddy riverbanks, ass. *Polygono-Bidentetum*, 209 m, 43.30992°N, 21.92333°E, EN79, 09.11.2014, coll. *S. Bogosavljević* & *M. Ranđelović* (HMN 9256).
2. Serbia (*East*): The town of Niš, along river Nišava, in cracks in the rampart for the river course regulation, 195 m, 43.32512°N, 21.91667°E, EN79, 11.11.2014, coll. *S. Bogosavljević* (HMN 9257).

On the territory where it has been recorded, *B. connatus* spreads in a lengthwise area of about 1800-2000 m. It occupies several, more or less wet habitat types along the streams and riverbanks. The presence of this species is primarily characteristic for shallow, slowly flowing waters of the canals, streams, river branches, all places where the water is held longer. The species is also in abundance in rocky habitats of anthropogenic origin, for example, cracks in the ramparts used for the regulation of river course on the city territory, in marshy places. In nitrophilous habitats, where there is a layer of shallow, slowly flowing water, and where *B. connatus* is very numerous and represents one of the most common species, the following plant species have also been recorded: *Cyperus fuscus*, *Echinochloa crus-galli*, *Lycopus europaeus*, *Persicaria hidropiper*, *Ranunculus repens*, *Rorripa* sp., *Rumex crispus*, *Salix alba*, *Saponaria officinalis*, *Typha* sp., *Veronica beccabunga*. On ramparts, where *B. connatus* is less numerous, the following taxa are common: *Anchusa officinalis*, *Arctium lappa*, *Ballota nigra* subsp. *foetida*, *Bidens frondosus*, *Calystegia sepium*, *Chondrilla juncea*, *Cichorium intybus*, *Clematis vitalba*, *Echinochloa crus-gali*, *Equisetum arvense*, *E. ramosissimum*, *Erigeron canadensis*, *E. annuus*, *Humulus lupulus, Lycopus europaeus*, *Lythrum salicaria*, *Mentha longifolia*, *Persicaria mitis*, *Plantago lanceolata*, *Salix alba*, *Saponaria officinalis*, *Trifolium pratense*, *Urtica dioica*, *Xanthium italicum*.

In the researched territory, *B. connatus* has established a stable population, which occupies a relatively large area. Considering the relatively great number of individuals, approximately several thousands of them, it can be assumed that the population of this species is stable in Serbia and that it was introduced many years ago. However, as the use of herbicides is not justified in this habitat, and depending on the degree of invasiveness, the only effective way to repress and control this species could be the physical removal of the plant

Fig. 4. Differences between *B. frondosus* (**a, c, d, f, g**) and *B. connatus* (**b, e, h**) (photos S. Bogosavljević).

during its vegetative stage, when it can be differentiated from other plants very easily.

Bidens connatus is native to the eastern parts of North America and to several southern provinces of Canada. However, it is anthropogenically spread to almost all parts of North America (Strother & Weedon 2006). As a naturalised species, it was recorded in New Zeland too, where it inhabits stream banks and marshes (Given 1984).

In Europe, it was recorded first in 1965, on the territory of the Central European countries (Lohmeyer & Sukopp 2005). Presently, it occurs altogether in 14 European countries, including Serbia (Fig. 2). Its presence has been recorded in many localities in the Netherlands (Sparrius & al. 2014), United Kingdom (Sell & Murell 2005), Ukraine (Kovalchuk & Tokhtar 2013), Switzerland (Wittenberg 2005), Germany (Buttler & Harms 1998), Italy (Celesti-Grapow & al. 2010), Russia (Seregin 2013), Poland (Tokarska-Guzik & al. 2012), France (Muller 2006), Romania (Anastasiu & al. 2007), Czech Republic (Pyšek & al. 2012), Slovenia (Lešnik 2009), and Belgium (Verloove 2006). In most

parts of its European range, *B. connatus* is considered invasive, naturalised species.

According to the data presented by Randall (2012), *B. connatus* is also an important weedy species. In the countries of the Balkan region, it has been recorded only in Romania (Danube Delta) as a naturalised species (Anastasiu & al. 2007).

Judging by the number of individuals and the territory occupied by *B. connatus*, we can assume that this species is naturalised in Serbia, as it is in most European countries where it has been recorded so far. Considering the fact that it grows together with other invasive species, above all *B. frondosus*, in the same localities, their presence and abundance repress the native representatives of the flora and change the composition of natural vegetation in the habitats. Therefore, similar habitats in the adjacent areas should be investigated next, in order to determine more precisely the distribution of this species and the degree of its influence on the natural ecosystems in Serbia. Thus some measures could be implemented, in order to prevent its further spreading.

Conclusions

On the territory of Serbia, the presence of two new alien plant species of genus *Bidens* has been recorded: *B. subalternans* and *B. connatus*. The population of *B. subalternans*, represented by several hundreds of individuals, has been recorded in waste places around the Central Railway Station in Niš. Presumably, the species has been introduced by railway transportation from the countries situated in warmer parts of the Balkan Peninsula. According to the degree of invasiveness that it shows in Serbia, this species has the status of a casual alien species. However, it has a clearly invasive character on the territory of Europe. Therefore, there is a risk that it will spread further to other parts of Serbia and, above all, its southern, southeastern and eastern parts.

Besides it, a population of the North American species *B. connatus*, represented by several thousands of individuals, has been recorded in the suburbs of the town of Niš, in wet habitats along the riverbanks, canals and streams. This species is relatively well incorporated in the natural vegetation and occurs in several different habitat types. It can be considered naturalised. However, it is necessary to investigate the similar habitats in other regions in order to determine its realistic distribution in the country and, if necessary, to implement certain measures for control of its further spreading.

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