

Prilozi poznavanju flore Hrvatske / Contributions to the knowledge of the Croatian flora

The new circumscription of the genus *Alyssum* L. (Brassicaceae) in the flora of Croatia

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Abstract

Until now, the genus *Alyssum* L. has been represented by a total of 19 taxa in the Flora Croatica Database (FCD). In this paper a detailed review of this genus in Croatian flora was carried out based on most recent phylogenetic, taxonomic, and nomenclatural studies. Based on the presented results five of the current taxa are not subjected to any nomenclatural change, five require nomenclatural change, nine should be excluded from the Croatian flora while one new taxon should be included. Three taxa should be excluded from the genus *Alyssum* and included in the resurrected genus *Odontarrhena* C.A.Mey. ex Ledeb., namely *O. muralis*, *O. tortuosa* and *O. metajnae*. The most substantial change in

the genus *Alyssum* is the exclusion of *A. montanum* and some related segregates (variety *molliusculum* and subspecies *pagense*) from Croatian flora and classification of the attributed populations as *A. austrodalmaticum*, *A. gmelinii*, *A. pluscanescens* and *A. repens*. The other excluded taxa, without reliable data indicating their presence in Croatia, are: *A. hirsutum*, *A. ovirens*, *A. repens* subsp. *transsilvanicum*, *A. repens* subsp. *trichostachyum* and *A. wierzbickii*. Following this review, taking into account the latest taxonomic and nomenclatural revisions, the genus *Alyssum* is represented by eight species and the genus *Odontarrhena* by three species in Croatian flora.

Keywords: *Alyssum*, flora of Croatia, *Odontarrhena*, revision

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Sažetak

U bazi podataka Flora Hrvatske (FCD) rod *Alyssum* L. dosad je bio zastupljen sa ukupno 19 svojti. Na temelju najnovijih filogenetskih, taksonomskih i nomenklaturnih istraživanja napravljena je detaljna revizija roda u flori Hrvatske. Nakon provedene revizije utvrđeno je da pet dosadašnjih svojti ostaje nepromijenjeno, za pet svojti je potrebna nomenklatura promjena, devet svojti je potrebno isključiti iz flore Hrvatske dok je jednu svojtu potrebno uključiti. Tri svojte je potrebno izdvojiti iz roda *Alyssum* i uključiti u ponovno uspostavljeni rod *Odontarrhena* C.A.Mey. ex Ledeb.; *O. metajnae*, *O. muralis* i *O. tortuosa*. Unutar roda *Alyssum* najznačajnija

promjena je isključenje vrste *A. montanum* kao i pojedinih povezanih svojti (varijetet *molliusculum* i podvrsta *pagense*) iz hrvatske flore te podjela svih pripadajućih populacija vrstama *A. austrodalmaticum*, *A. gmelinii*, *A. pluscanescens* i *A. repens*. Ostale isključene svojte, bez pouzdanih podataka koji potvrđuju njihovu prisutnost na području Hrvatske, su: *A. hirsutum*, *A. ovirens*, *A. repens* subsp. *transsilvanicum*, *A. repens* subsp. *trichostachyum* i *A. wierzbickii*. Na temelju ove revizije i uzimajući u obzir sadašnje taksonomske i nomenklaturne prijedloge, rod *Alyssum* je u flori Hrvatske zastupljen s osam vrsta dok je rod *Odontarrhena* zastupljen s tri vrste.

Ključne riječi: *Alyssum*, hrvatska flora, *Odontarrhena*, revizija

Introduction

A recent series of molecular and morphological studies contributed considerably to our understanding of the phylogenetic relationships in the genus *Alyssum* L. and required changes in circumscription of the genus and nomenclature of taxa (Španiel et al. 2011a,b, 2012a,b, 2015, 2017a,b, Rešetnik et al. 2013, Zozomova-Lihová et al. 2014). Although the recognition and delimitation of some Balkan species and the speciation processes behind their formation still remain to be addressed, the available data allows us to make taxonomic re-arrangements in the flora of Croatia in order to comply with newly adopted treatments (i.e. in the Euro+Med PlantBase, Euro+Med 2006-2018).

The genus *Alyssum* has traditionally been regarded as the largest genus in the tribe Alyseae comprising about 195 species worldwide and 70 species in Europe (Ball & Dudley 1993, Warwick et al. 2006). The infrageneric classification acknowledged five sections, namely nominal section *Alyssum*, and sections *Gamosepalum* (Hauskn.) T.R.Dudley, *Meniocus* (Desv.) Hook.f., *Odontarrhena* (C.A.Mey. ex Ledeb.) W.D.J.Koch, and *Psilonema* (C.A.Mey.) Hook.f. The recent molecular studies revealed that the traditional morphology-based taxonomic concept of the genus was artificial and that *Alyssum* was polyphyletic (Bailey et al. 2006, Warwick et al. 2008, German et al. 2009, Warwick et al. 2010, Rešetnik et al. 2013). The polyphyletic *Alyssum* comprised of three clades: (1) “*Alyssum* s.str. clade” consisting of *A. sect. Alyssum*, *A. sect. Gamosepalum*, and *A. sect. Psilonema* (except “*A. homalocarpum*-*A. antiatlanticum* clade”), (2) “*A. homalocarpum*-*A. antiatlanticum* clade”, and (3) “*Clypeola* clade”, comprising *A. sect. Odontarrhena*, *A. sect. Meniocus*, and the genus *Clypeola*. These novel findings provided an updated generic concept, the list of accepted species and infraspecific names and new combinations (Španiel et al. 2015). The new delimitation thus recognises monophyletic *Alyssum* which is circumscribed more narrowly and includes most of the taxa of the previous *A. sect. Alyssum*, *A. sect. Gamosepalum*, and *A. sect. Psilonema*. The second “*A. homalocarpum*-*A. antiatlanticum* clade” is described as a new genus *Cuprella* Salmerón-Sánchez, Mota & Fuertes comprising two species, *C. antiatlantica* (Emb. & Maire) Salmerón-Sánchez, Mota & Fuertes and *C. homalocarpa* (Fisch. & C.A.Mey.) Salmerón-Sánchez, Mota & Fuertes which are distributed in northern Africa and southwestern Asia (Salmerón-Sánchez et al., unpublished data). The relationships within the third, “*Clypeola* clade”, are not yet sufficiently resolved because they are hampered with incongruences among the results obtained from different molecular

markers (Rešetnik et al. 2013). The inconsistencies refer mainly to the relationships among the genus *Clypeola* and *A. sect. Meniocus* taxa, while *A. sect. Odontarrhena* appears to be monophyletic. Thus until their phylogenetic relationships are fully resolved by additional molecular markers and taxonomic sampling they are tentatively treated as three separated genera (*Clypeola* L., *Meniocus* Desv. and *Odontarrhena* C.A.Mey. ex Ledeb.) in agreement with their morphology (Španiel et al. 2015).

In Croatian flora there are currently 19 *Alyssum* taxa recognized on species and subspecies level according to Flora Croatica Database (Nikolić 2018). According to the traditional infrageneric classification they are members of sect. *Alyssum*: *A. austrodalmaticum* Trinajstić, *A. desertorum* Stapf, *A. hirsutum* M.Bieb., *A. montanum* L. (including nominal subspecies *montanum*, subsp. *gmelinii* (Jord. & Fourr.) Em.Schmid, subsp. *pagense* (Jos. Baumgartner) Hayek, subsp. *pluscanescens* (Raim. ex Jos.Baumgartner) Trpin, and *A. montanum* [rankless] *molliusculum* (Rchb.) Jáv. – erroneously reported as “subsp. *molliusculum*”, see below), *A. ovirens* A.Kern., *A. repens* Baumg. (including nominal subspecies *repens*, subsp. *transsilvanicum* (Schur) Nyman, and subsp. *trichostachyum* (Rupr.) Hayek), *A. simplex* Rudolphi, *A. strigosum* Banks & Sol. and *A. wierzbickii* Heuff.; sect. *Psilonema*: *A. alyssoides* (L.) L.; and sect. *Odontarrhena*: *A. murale* Waldst. & Kit., *A. serpyllifolium* Desf. and *A. tortuosum* Waldst. & Kit. ex Willd. The latest review of the Croatian *Alyssum* taxa was carried out by Plazibat (2006, 2009) and was based on the revision of herbarium material in ZA and ZAHO herbaria. He provided the description of species, an identification key and highlighted the ambiguous data and distribution occurrences.

The aim of this study is to present a review of taxa traditionally attributed to the genus *Alyssum* in Croatian flora, based on the most recent taxonomic and nomenclatural revisions. A new identification key to all taxa growing in Croatia, now classified in genera *Alyssum* and *Odontarrhena*, is provided.

Materials and methods

The current list of *Alyssum* taxa and their distributional data in the Flora Croatica Database (Nikolić 2018) served as the starting point for the review. All relevant Croatian literature with the data of taxa occurrence and problematics as well as most recent molecular systematic studies (Španiel et al. 2011a,b, 2012a,b, 2015, 2017a,b, Rešetnik et al. 2013, Magauer et al. 2014, Zozomova-Lihová et al. 2014) were analysed. The nomenclature was updated according to

AlyBase (<http://www.alyssae.sav.sk>; Španiel et al. 2015). The presented identification key was created based on species descriptions, previously published identification keys (Pignatti 1982, Ball & Dudley 1993, Domac 1994, Hartvig 2002), and the most recent morphometric study of Balkan *Alyssum* taxa (Španiel et al. 2017b).

Results

Out of the 19 currently recognized taxa in Flora Croatica Database (Nikolić 2018), five of them are not subjected to any nomenclatural change, five require nomenclatural change, nine should be excluded from the Croatian flora while one new taxon should be included (Table 1). *Alyssum murale*, *A. serpyllifolium* and *A. tortuosum* should be excluded from the genus *Alyssum* and

included in resurrected genus *Odontarrhena*, as *O. muralis*, *O. metajnae* and *O. tortuosa*, respectively (Fig. 1). In the genus *Alyssum* the most substantial change is the exclusion of *A. montanum* and some related segregates (variety *molliusculum* and subspecies *pagense*) from Croatian flora and classification of the attributed populations as *A. austrodalmaticum*, *A. gmelinii*, *A. pluscanescens* and *A. repens* (Fig. 2). These species represent the *Alyssum* perennial group, while the members of the annual group are *A. alyssoides*, *A. simplex*, *A. strigosum* and *A. turkestanicum* (Fig. 3). The other excluded taxa, without the reliable data indicating their presence in Croatia, are: *A. hirsutum*, *A. ovirens*, *A. repens* subsp. *transsilvanicum*, *A. repens* subsp. *trichostachyum* and *A. wierzbickii*.

Table 1. The comparison of traditional taxonomic and nomenclatural treatment in Flora Croatica Database and the newly proposed treatment.

Flora Croatica Database	new treatment for Croatian flora
<i>Alyssum alyssoides</i> (L.) L.	<i>Alyssum alyssoides</i> (L.) L.
<i>Alyssum austrodalmaticum</i> Trinajstić	<i>Alyssum austrodalmaticum</i> Trinajstić
<i>Alyssum desertorum</i> Stapf	<i>Alyssum turkestanicum</i> Regel & Schmalh.
<i>Alyssum hirsutum</i> M. Bieb.	excluded
<i>Alyssum montanum</i> L.	excluded, populations attributed to <i>Alyssum austrodalmaticum</i> Trinajstić
<i>Alyssum montanum</i> L. ssp. <i>gmelinii</i> (Jord.) Em. Schmid	<i>Alyssum gmelinii</i> Jord. & Fourr.
<i>Alyssum montanum</i> L. ssp. <i>molliusculum</i> (Rchb.) Jáv.	excluded, populations attributed to <i>Alyssum austrodalmaticum</i> Trinajstić
<i>Alyssum montanum</i> L. ssp. <i>pagense</i> (Baumgartner) Hayek	excluded, populations attributed to <i>Alyssum austrodalmaticum</i> Trinajstić
<i>Alyssum montanum</i> L. ssp. <i>pluscanescens</i> (Raim. ex Baumgartner) Trpin	<i>Alyssum pluscanescens</i> (Raim. ex Jos. Baumgartner) Španiel, Lihová & Marhold
<i>Alyssum murale</i> Waldst. et Kit.	<i>Odontarrhena muralis</i> (Waldst. & Kit.) Endl.
<i>Alyssum ovirens</i> A. Kern.	excluded
<i>Alyssum repens</i> Baumg.	<i>Alyssum repens</i> Baumg.
<i>Alyssum repens</i> Baumg. ssp. <i>transsilvanicum</i> (Schur) Nyman	excluded
<i>Alyssum repens</i> Baumg. ssp. <i>trichostachyum</i> (Rupr.) Hayek	excluded
<i>Alyssum serpyllifolium</i> Desf.	excluded, populations attributed to <i>Odontarrhena metajnae</i> (Plazibat) Španiel, Al-Shehbaz, D.A. German & Marhold
<i>Alyssum simplex</i> Rudolphi	<i>Alyssum simplex</i> Rudolphi
<i>Alyssum strigosum</i> Banks et Solander	<i>Alyssum strigosum</i> Banks & Sol.
<i>Alyssum tortuosum</i> Willd.	<i>Odontarrhena tortuosa</i> (Waldst. & Kit. ex Willd.) C.A. Mey.
<i>Alyssum wierzbickii</i> Heuff.	excluded

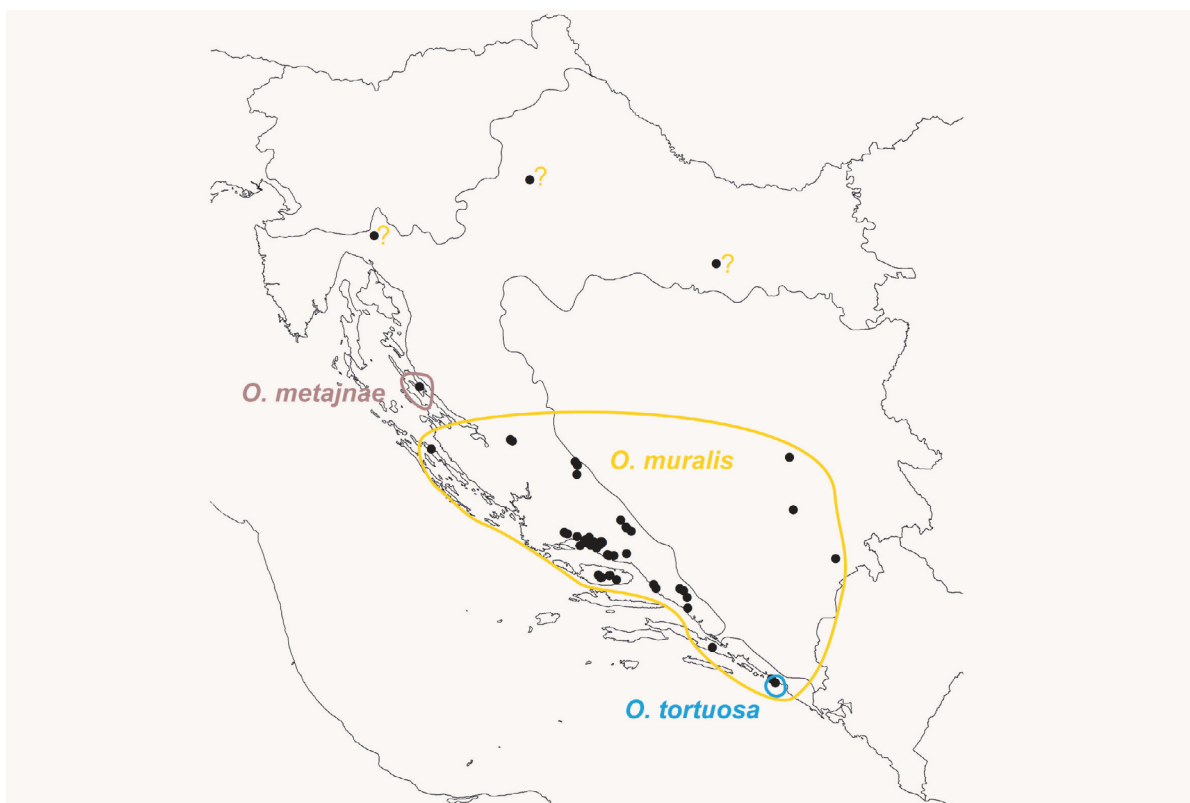


Figure 1. Distribution of *Odontarrhena* taxa in Croatia according to Flora Croatica Database.

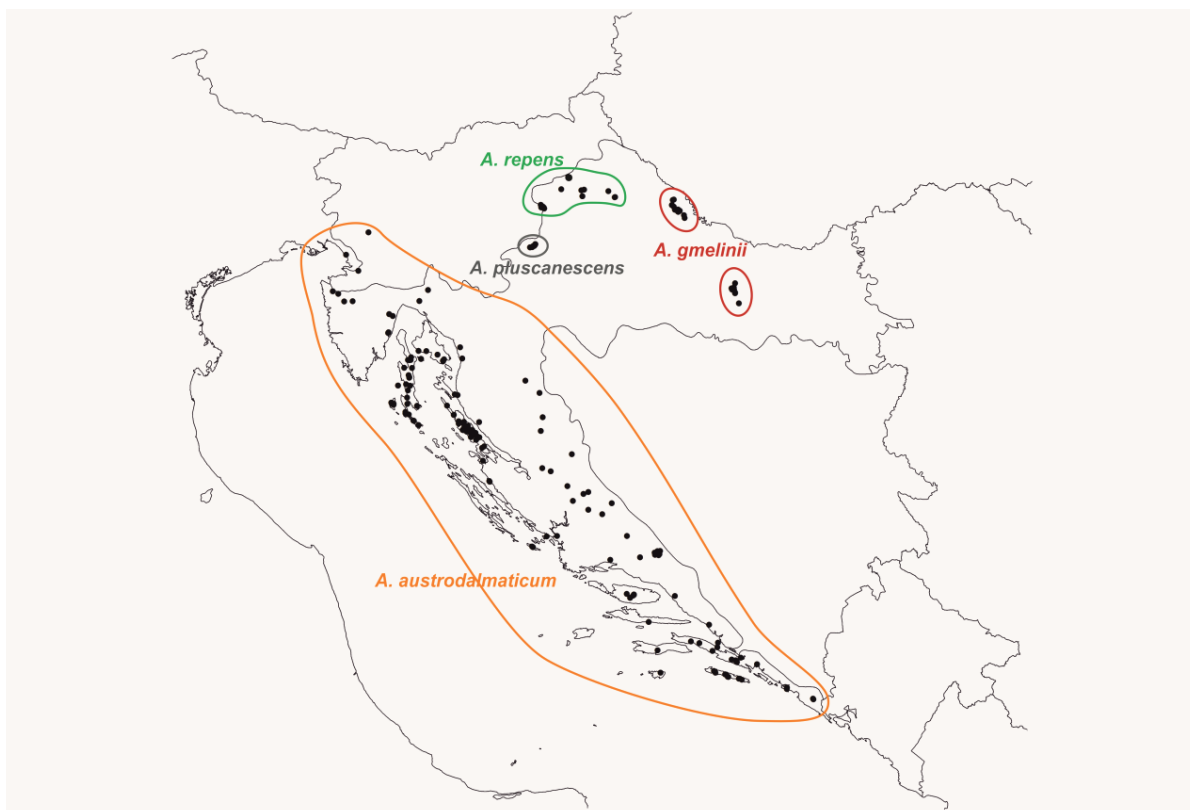


Figure 2. Distribution of perennial *Alyssum* taxa in Croatia according to Flora Croatica Database.

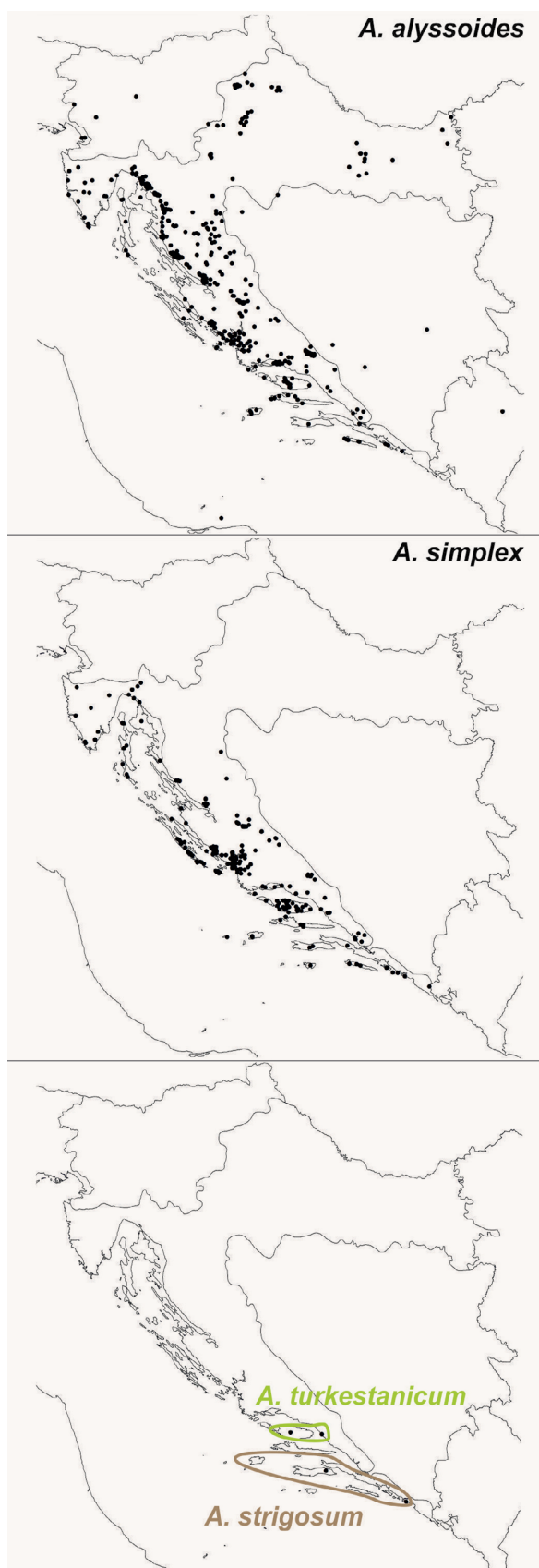


Figure 3. Distribution of annual *Alyssum* taxa in Croatia according to Flora Croatica Database.

Discussion

The generic and species concepts of the genus *Alyssum* implemented in the present paper reflect the most recent phylogenetic, taxonomic, and nomenclatural studies at the genus and tribe level (Španiel et al. 2011a, b, 2012a, b, 2015, 2017a, b, Rešetnik et al. 2013, Zozomova-Lihová et al. 2014).

The most evident change is the resurrection of the genus *Odontarrhena* (Španiel et al. 2015) with the three representatives in the Croatian flora. The genus *Odontarrhena* was established in 1830 (Ledebour 1830), and although its species were frequently described and acknowledged in older literature, they are treated as members of the genus *Alyssum* (comprising the section *Odontarrhena*) in majority of the recent floras (Ball & Dudley 1993, Ančev 2007, Király et al. 2011, Meyer 2011, Sârbu et al. 2013, Španiel et al. 2014, Strid 2016, Uhlemann 2017, Vangjeli 2017). The species of the genus are perennials with uniovulate locules, usually toothed, appendaged filaments, yellow, rarely creamy white petals, with style usually 1 - 3 mm long and often subumbellate compound inflorescence (rarely a simple raceme). Eighty seven species are predominantly distributed in mountainous areas of Palaeoarctics (one native species in north-west North America) with the centre of diversity in Mediterranean region, Balkan Peninsula, and southwestern Asia (Španiel et al. 2015).

The most common species of the genus in Croatia is *O. muralis* (Waldst. & Kit.) Endl. (syn. *Alyssum murale*). It is distributed in the southern parts (Lika and Dalmatia), while the three observations (Risnjak, Zagreb and Požega) need confirmation (Fig. 1). The second species that has been mentioned in Croatian flora is *O. tortuosa* (Waldst. & Kit. ex Willd.) C.A.Mey. (syn. *Alyssum tortuosum*) which is regarded highly doubtful for Croatia by Plazibat (2009). In ZA there is only one herbarium specimen from the 19th century and the only literature reference in Flora Croatica Database is by Hećimović (1982) from Island Lokrum near Dubrovnik. As the molecular and morphological analysis of the genus is currently in progress by the authors, we are tentatively including this species in the identification key, pending new results. The new species that should be included in the flora of Croatia is newly recognized *O. metajnae* (Plazibat) Španiel, Al-Shehbaz, D. A. German & Marhold. It has been described as a variety of *O. serpyllifolia* (Desf.) Jord. & Fourr. (syn. *Alyssum serpyllifolium*) by Plazibat (2006, 2009) and thus species *A. serpyllifolium* was included in the Flora Croatica Database (due to the fact that the database does not include taxa on the variety level). However, *O. serpyllifolia* is a species distributed in western Mediterranean (France, Spain, Portugal)

and northern Africa (Morocco) and therefore *O. metajnae* is considered to be a separate species (Španiel et al. 2015) that should be included in the flora of Croatia while *A. serpyllifolium* should consequently be excluded. The relationship of this Croatian endemic taxon, currently known only from the island Pag, to other Balkan *Odontarrhena* species and lineages will be addressed in a future study (Španiel et al. unpubl.)

After the exclusion of *Alyssum* sect. *Odontarrhena*, the remaining species in the Croatian flora belong to the *Alyssum* s.str. clade i.e. genus *Alyssum*. The species of now more narrowly circumscribed *Alyssum* are annuals or perennials, with two ovules developing in each loculus, with yellow petals, inflorescence a simple raceme, rarely with few branches from the base, infructescence distinctly elongated, and variously shaped fruit slightly unilaterally inflated. One hundred and fourteen species are distributed throughout North Africa, Asia, and Europe, while several species are naturalized in North and South America, South Africa, and Australia. Molecular data indicate that *Alyssum* consists of two clades: (1) most of the annual and perennial taxa of *A.* sect. *Alyssum*, (2) *A.* sect. *Gamosepalum*, few perennials of *A.* sect. *Alyssum*, and annual *A. dasycarpum* (Rešetnik et al. 2013, Salmerón-Sánchez et al., unpublished data). Even though future phylogenetic studies are needed to identify morphological synapomorphies and to resolve the sectional classification of *Alyssum*, currently the Croatian taxa can most easily be divided into annual group and perennial group.

The most widespread annual species in Croatia is *A. alyssoides* with somewhat denser distribution in coastal and mountainous areas, but also commonly present in lowland, continental Croatia (Fig. 3). This annual or very rarely biennial species is found on dry patches, rocky grounds and on sandy soil, by the field roads, on railway embankments, in ruderal and weed vegetation, and mostly on the rich limestone base. The species is readily distinguishable from other Croatian annuals with sepals persistent by the fruits until fruits are fully ripe.

The second most common annual species is *A. simplex* that is found in coastal and mountainous areas, however not present in continental Croatia (Fig. 3). It is also commonly found on dry patches by the roads and as a part of ruderal vegetation, but unlike *A. alyssoides* its sepals are soon deciduous after fruit formation.

Similar taxon with deciduous sepals is *A. strigosum*, which differs from *A. simplex* by usually having bifurcate, strigose hairs in addition to stellate hairs on siliculae (vs. siliculae usually with monomorphic indumentum of \pm symmetrical stellate

hairs) and glabrous style (vs. hairy style). This species is in Croatia known only from few locations along the coast: herbarium specimens from the Island of Vis (ZA) and literature data from Dubrovnik and Korčula (Visiani 1852, Jeričević et al. 2014). The annual species that should be excluded from the flora of Croatia is *A. hirsutum*. The previously reported occurrence of this taxon in Croatia was based on three dubious herbarium sheets in the Schlosser's collection from the surroundings of Zagreb and Mt Kalnik (Plazibat 2009) which most likely belong to perennial *A. repens*. There are no recent literature records, while all photographs in FCD are from localities in Bosnia and Herzegovina and probably should be attributed to *A. bosniacum* Beck.

The older records and literature data regarding the above mentioned four taxa are sometimes misleading as there is a substantial nomenclatural confusion of these names with the names *A. minus* Rothm. and *A. campestre* (L.) L. Both of these names are indeed the synonyms of *A. alyssoides* (AlyBase, Španiel et al. 2015), but they were commonly erroneously used for what is currently called *A. simplex*, *A. strigosum* or even *A. hirsutum*. This confusion is well documented by the number of infraspecific combinations which belong to the synonymy of the latter three taxa. For example *A. campestre* var. *edentulum* Andr. and *A. campestre* var. *hirtum* W.D.J.Koch are synonyms of *A. simplex*; *A. campestre* var. *micranthum* (C.A.Mey.) Boiss., *A. campestre* var. *pilosum* Post, *A. minus* var. *micranthum* (C.A.Mey.) T.R.Dudley and *A. minus* subsp. *micranthum* (C.A.Mey.) Breistr. are synonyms of *A. strigosum*; and *A. minus* subsp. *hirsutum* (M.Bieb.) Stoj. & Stef. and *A. campestre* subsp. *hirsutum* (M.Bieb.) Schmalh. are synonyms of *A. hirsutum* (for other synonyms and data see AlyBase, Španiel et al. 2015).

The species subjected to nomenclatural change is *A. turkestanicum* Regel & Schmalh. which is the accepted name of *A. desertorum* currently used in FCD. *A. turkestanicum* is the only annual species in Croatian flora that has glabrous ovary and siliculae valves. The occurrence of this species in Croatia is presently doubtful as the evidence is scarce. There are only three herbarium specimens from the 19th century in ZA (Plazibat 2009), one old literature reference originally cited as *A. minimum* (Host 1802) and one recent field observation from the island of Brač (FCD, Ruščić 2009), while photographs in FCD are from localities in Bosnia and Herzegovina (Fig. 3). The species is tentatively included in the identification key, but its presence should be confirmed with additional data.

The perennial group consists of species belonging to the wide spread *Alyssum montanum* – *A. repens* polyploid complex. The group has been extensively studied with genetic (plastid DNA

sequences, low-copy nuclear genes and amplified fragment length polymorphism markers), flow-cytometric and morphological data during the last seven years (Španiel et al. 2011a, b, 2012a, b, 2017a, b, Magauer et al. 2014, Zozomová-Lihová et al. 2014, Arrigo et al. 2016, Melichárková et al. 2017), which resulted in changes in circumscriptions and nomenclature of taxa (Španiel et al. 2012a, 2015, 2017b). The complex is notorious due to the very complex morphological variation patterns and therefore the taxonomic treatment of the group is also based on genetic distinction and allopatric distributions of lineages.

The most notable difference with the previous taxonomic treatments, which considerably affects traditional delimitation in Croatia and on the Balkan Peninsula, is the genetic and morphological differentiation of central and western European lineages from the Balkan lineages (Španiel et al. 2011a, 2012a, 2017a, Zozomová-Lihová et al. 2014). The name *Alyssum montanum*, which is the lectotype of the genus *Alyssum*, was recently proposed to be conserved with a conserved type with the type location in Switzerland (Marhold et al. 2011). *Alyssum montanum* comprises populations from France, Germany and Switzerland, while central and eastern European populations belong to *A. gmelinii* Jord. & Fourr. (syn. *A. montanum* subsp. *gmelinii*) (Španiel et al. 2012a, Zozomová-Lihová et al. 2014).

The westernmost Balkan populations, distributed in regions along the Adriatic coast (Croatia, Bosnia and Herzegovina, Italy, Slovenia), are assigned to *A. austrodalmaticum* (for the detailed overview of other Balkan taxa previously treated as *A. montanum* see Španiel et al. (2017a, b)). Recognition of this species is strongly supported by molecular analyses and allopatric distribution, while the populations are morphologically similar to the polymorphic species *A. gmelinii* and *A. spruneri* Jord. & Fourr. (Španiel et al. 2017a, b). All the populations of *A. montanum* and its various subspecies in the FCD and other relevant resources, distributed along the Adriatic coast, can unambiguously be referred to *A. austrodalmaticum* (Fig. 2). The species exhibits substantial morphological variation, possibly due to phenotypic plasticity. For example, some populations growing in extremely dry places on the islands of Rab and Pag or in the vicinity of Karlobag conspicuously differ from other populations by the presence of succulent leaves, while the southern populations are morphologically somewhat different as well (Španiel et al. 2017b). The morphological variation, however, does not correspond to taxonomical division into *A. montanum* subsp. *pagense* and *A. montanum* var. *molliusculum*. The phylogeographic analyses revealed three genetic and geographic subgroups also not corresponding

to the abovementioned taxa (Španiel et al. 2017a), which should be excluded from the FCD and treated as the synonyms of *A. austrodalmaticum*. Actually, the name "*A. montanum* subsp. *molliusculum*", which was used in FCD database as well as in the work of Plazibat (2009), is the incorrect interpretation of *A. montanum* [rankless] *molliusculum* (Rchb.) Jáv. According to Holub (1984) the paragraph taxa in Jávorka (1924–1925) cannot be treated as subspecies (with some notable exceptions) as he did not assign them particular infraspecific rank. Nevertheless, the combinations based on this taxon at the level of form, subvariety and variety exist (Španiel et al. 2017b).

The continental Croatian populations traditionally assigned to *A. montanum* can be attributed to three other perennial *Alyssum* instead. The *A. montanum* subsp. *gmelinii*, which was previously reported also from Croatia and now treated as separate species *A. gmelinii* (see above) most probably includes populations from Đurđevački, Kloštarski, Molvanski and Imovinski pijesci, and Papuk in FCD (Fig. 2). However, the fresh plant material from these localities was not investigated in the present or previous study (Španiel et al. 2017a, b) and it requires further detailed examination by molecular as well as morphometric methods. In conclusion, *A. gmelinii* is a widespread species occurring in central and eastern Europe, with confirmed southern distributional border in northern Serbia, extending probably to the abovementioned localities in Slavonia (Španiel et al. 2017b).

The taxon *A. montanum* subsp. *pluscanescens* is now recognised as a separate species *A. pluscanescens* (Raim. ex Jos. Baumgartner) Španiel, Lihová & Marhold. This hexaploid species is known from only two locations, one in Smerovišće, Samoborska gora (Fig. 2) and other one in Žiče, Slovenia. The distinction of Smerovišće population was first noticed by Horvat in his herbarium material (ZAHO) and corroborated by Kušan (Kušan 1970) under the name *Alyssum samoborensense* Horvat ex Kušan (designation not validly published, AlyBase). The molecular data showed genetic differences between Croatian and Slovenian populations and different molecular analyses indicated ambiguous phylogenetic relationships with other taxa within the complex (Španiel et al. 2017a). Therefore the origin of this polyploid taxon should be investigated in more detail. The morphological data in the identification key is based only on individuals from Žiče population, as Smerovišće population was too scarce for collection of appropriate material for morphometric measurements. Based on these measurements, the species clearly differs from the geographically closest species *A. repens* (see Identification key; Španiel et al. 2017b).

The fourth Croatian perennial *Alyssum* is *A.*

repens to which populations from north-western Croatia should be attributed to (Fig. 2; see also comments on *A. hirsutum* and *A. wierzbickii* about Schlosser's herbarium collections). The overall distribution of the species is disjunct, comprising populations in Austria and Croatia and populations in Romania. The current data reveal the presence of two cytotypes and three genetic clusters: diploids from Austria and Croatia, diploids from the Apuseni Mts in Romania and tetraploids from the Eastern and Southern Carpathians (Španiel et al. 2017a). All populations are tentatively delimited under the name *A. repens*, although further studies are in progress in order to clarify relationships of diploid and tetraploid populations and their taxonomic classification. The two subspecies listed in the FCD, *transsilvanicum* and *trichostachyum*, should be excluded as there is no reliable evidence supporting the use of these names for any of the Croatian populations. *A. transsilvanicum* Schur was described from the mountains of Romania (Schur 1866), while *A. trichostachyum* Rupr. was originally described from Caucasus (Ruprecht 1869) and the most recent studies do not support their application for any of the Balkan populations (Španiel et al. 2017b).

The two other taxa that should be excluded from the Croatian flora are *A. ovirens* and *A. wierzbickii*. The occurrence of *A. ovirens* in Croatia was already rejected by Trinajstić (1983) and Plazibat (2009) and according to new molecular and morphologically based studies *A. ovirens* should be treated as a subspecies of Alpine species *A. wulfenianum* which is not present on the Balkan Peninsula (Magauer et al. 2014, Zozomová-Lihová et al. 2014). The second species without any reliable data indicating its presence in Croatia is *A. wierzbickii* (Plazibat 2009). In the recent study the occurrence of this species was only confirmed from the type locality in SE Romania (Španiel et al. 2017a, b), therefore the presence of this species in Croatia and other parts of Balkan Peninsula is rejected. The dubious Schlosser's herbarium specimen from Ljubeščica (south of Varaždin) (ZA; FCD) is assigned to *A. repens*.

Due to the character range overlaps, morphological identification may not be straightforward in every case, and therefore several specimens per population should be examined. For the *A. montanum* – *A. repens* complex a detailed explanation of the measurement methodology of the morphological characters used in the identification key is provided in Španiel et al. (2017b). Flower parts should be measured on the largest flowers found on plants and recorded during an early flowering period. Asterisks (*) indicate that the value of a character for an examined individual

should be scored as a mean value of three random counts/measurements per leaf surface and a value range given in the key represents the variation of the mean value in the dataset (not the range of a character within an individual).

Identification key in English

- 1a. Inflorescence compound, often subumbellate, rarely a simple raceme. Ovules 2 per ovary (1 ovule developing in each loculus). Perennials***Odontarrhena***
- 1b. Inflorescence a simple raceme, rarely with few branches from the base. Ovules 4 per ovary (2 ovules developing in each loculus). Annuals or perennials***Alyssum***

***Odontarrhena* C.A.Mey. ex Ledeb.**

- 1a. Stem erect, 25-80 cm high. Leaves bicolorous, green or grey-green on the upper surface, grey or white beneath. Silicula is not densely pubescent, surface of valves is visible. Seeds c. 3 mm long, with wing***O. muralis***
- 1b. Stem procumbent to erect, or ascending, 6-35(-60) cm high. Leaves concolorous, grey or white, but the cauline sometimes differing from the basal in colour. Silicula densely pubescent, surface of valves is not visible. Seeds c. 1.5 mm long, not or only narrowly winged**2**
- 2a. Leaves of non-flowering shoots more or less flat***O. tortuosa***
- 2b. Leaves of non-flowering shoots plicate***O. metajnae***

***Alyssum* L.**

- 1a. Annuals, without non-flowering shoots**2**
- 1b. Perennials, generally with non-flowering shoots**5**
- 2a. Ovary and siliculae valves glabrous***A. turkestanicum***
- 2b. Ovary and siliculae valves hairy**3**
- 3a. Sepals persistent until fruits are fully ripe. Nectaries 0.5-0.7 mm long, thread-like***A. alyssoides***
- 3b. Sepals soon deciduous. Nectaries less than 0.2 mm long, not elongated**4**

- 4a. Style hairy. Petals retuse or emarginate with a very narrow sinus and the lobes shorter than broad. Siliculae usually with monomorphic indumentum of \pm symmetrical stellate hairs **A. simplex**
- 4b. Style glabrous. Petals deeply emarginate to bifid with diverging lobes usually as long as broad. Siliculae usually with bifurcate, strigose hairs in addition to stellate hairs **A. strigosum**
- 5a. Flowering stem 23 - 48 cm long (not including inflorescence). 15th cauline leaf 14.6 - 33.9 mm long and 2.5 - 6.2 mm wide; 8th cauline leaf 16.7 - 32.3 mm long and 2.4 - 5.5 mm wide. Siliculae sparsely pubescent; stellate trichomes on siliculae with c. 10 - 12 terminal rays **A. repens**
- 5b. Flowering stem 6.0 - 30 cm long (not including inflorescence). 15th cauline leaf 5.5 - 18.7 mm long and 1.4 - 4.0 mm wide; 8th cauline leaf 5.4 - 17.2 mm long and 1.0 - 3.1 mm wide. Siliculae densely pubescent; stellate trichomes on siliculae with c. 14 - 18 terminal rays **6**
- 6a. Petals 2.5 - 2.9 mm wide. Lower surface of middle cauline leaf densely hairy (indumentum overlaying more than 2/3 of the leaf epidermis) with 11 - 18 trichomes per 0.5 mm² area **A. pluscanescens**
- 6b. Petals 1.0 - 2.9 mm wide. Lower surface of middle cauline leaf sparsely to moderately hairy (indumentum usually overlaying less than 2/3 of the leaf epidermis) with 3 - 16 trichomes per 0.5 mm² area **7**
- 7a. Lower surface of middle cauline leaf usually sparsely hairy (indumentum overlaying less than 1/3 of the leaf epidermis); stellate trichomes on lower surface of middle cauline leaf with 7 - 16* terminal rays **A. austrodalmaticum**

Lower surface of middle cauline leaf usually moderately hairy (indumentum overlaying more than 1/3 of the leaf epidermis); stellate trichomes on lower surface of middle cauline leaf with 12 - 29* terminal rays **A. gmelinii**

Identification key in Croatian

- 1a. Cvat složen, često štitasta metlica, rijetko jednostavni grozd. Dva sjemena zametka u plodnici (1 sjemeni zametak u svakom pretincu). Trajnice **Odontarrhena**
- 1b. Cvat jednostavni grozd, rijetko s par ogranaka od baze. Četiri sjemena zametka u plodnici (2 sjemena zametka u svakom pretincu). Jednogodišnje biljke ili trajnice **Alyssum**

Odontarrhena C.A.Mey. ex Ledeb.

- 1a. Stabljika uspravna, 25 - 80 cm duga. Listovi dvobojni, zeleni ili sivo-zeleni na gornjoj strani, sivi ili bjelkasti na donjoj strani. Komuščica nije gusto dlakava, površina zaklopaca je vidljiva. Sjemenke duge oko 3 mm, s krilcima **O. muralis**
- 1b. Stabljika polegnuta do uspravna ili pridignuta, 6 - 35 (-60) cm duga. Listovi jednobojni, sivi ili bjelkasti, stabljični listovi se ponekad razlikuju u boji od bazalnih. Komuščica vrlo gusto dlakava, površina zaklopaca nije vidljiva. Sjemenke duge oko 1.5 mm, bez ili samo s uskim krilcima **2**
- 2a. Listovi sterilnih izdanaka su plosnati **O. tortuosa**
- 2b. Listovi sterilnih izdanaka su žljebovito smotani **O. metajnae**

Alyssum L.

- 1a. Jednogodišnje biljke, bez sterilnih izdanaka **2**
- 1b. Trajnice, uglavnom sa sterilnim izdancima **5**
- 2a. Plodnica i zaklopci komuščice goli **A. turkestanicum**
- 2b. Plodnica i zaklopci komuščice dlakavi **3**
- 3a. Lapovi poslije cvatnje ne otpadaju, već su prisutni do potpune zrelosti ploda. Nektariji 0.5 - 0.7 mm, končasti **A. alyssoides**
- 3b. Lapovi poslije cvatnje ubrzo otpadnu. Nektariji manji od 0.2 mm, nisu izduženi **4**
- 4a. Vrat tučka dlakav. Latice uzubljenе ili izrubljene sa vrlo malim, uskim udubljenjem i režnjevima kraćim nego što su široki. Komuščice obično s jednolikim dlačnim pokrovom od \pm simetričnih zvjezdastih dlaka **A. simplex**
- 4b. Vrat tučka gol. Latice duboko izrubljene do dvocijepne s režnjevima koji su obično jednako dugi i široki. Komuščice obično s rašljastim, stršećim, krutim dlakama koje dolaze uz zvjezdaste dlake **A. strigosum**
- 5a. Cvjetni ogranak 23 - 48 cm dug (ne uključujući cvat). Petnaesti stabljični list 14.6 - 33.9 mm dug i 2.5 - 6.2 mm širok; osmi stabljični list 16.7 - 32.3 mm dug i 2.4 - 5.5 mm širok. Komuščice rijetko dlakave; zvjezdaste dlake na komuščici sa oko 10 - 12 krakova **A. repens**

- 5b. Cvjetni ogranak 6.0 - 30 cm dug (ne uključujući cvat). Petnaesti stablični list 5.5 - 18.7 mm dug i 1.4 - 4.0 mm širok; osmi stablični list 5.4 - 17.2 mm dug i 1.0 - 3.1 mm širok. Komušćice gusto dlakave; zvjezdaste dlake na komušćici sa oko 14 - 18 krakova **6**
- 6a. Latice 2.5 - 2.9 mm široke. Donja površina srednjeg stabličnog lista gusto dlakava (dlačni pokrov pokriva više od 2/3 lisne epiderme) sa 11-18 dlaka na površini od 0.5 mm² **A. pluscanescens**
- 6b. Latice 1.0 - 2.9 mm široke. Donja površina srednjeg stabličnog lista rijetko do umjereno dlakava (dlačni pokrov obično pokriva manje od 2/3 lisne epiderme) sa 3-16 dlaka na površini od 0.5 mm² **7**
- 7a. Donja površina srednjeg stabličnog lista obično rijetko dlakava (dlačni pokrov obično pokriva manje od 1/3 lisne epiderme); zvjezdaste dlake na donjoj površini srednjeg stabličnog lista sa 7 - 16* krakova **A. austrodalmaticum**
- 7b. Donja površina srednjeg stabličnog lista obično umjereno dlakava (dlačni pokrov pokriva više od 1/3 lisne epiderme); zvjezdaste dlake na donjoj površini srednjeg stabličnog lista sa 12 - 29* krakova **A. gmelinii**

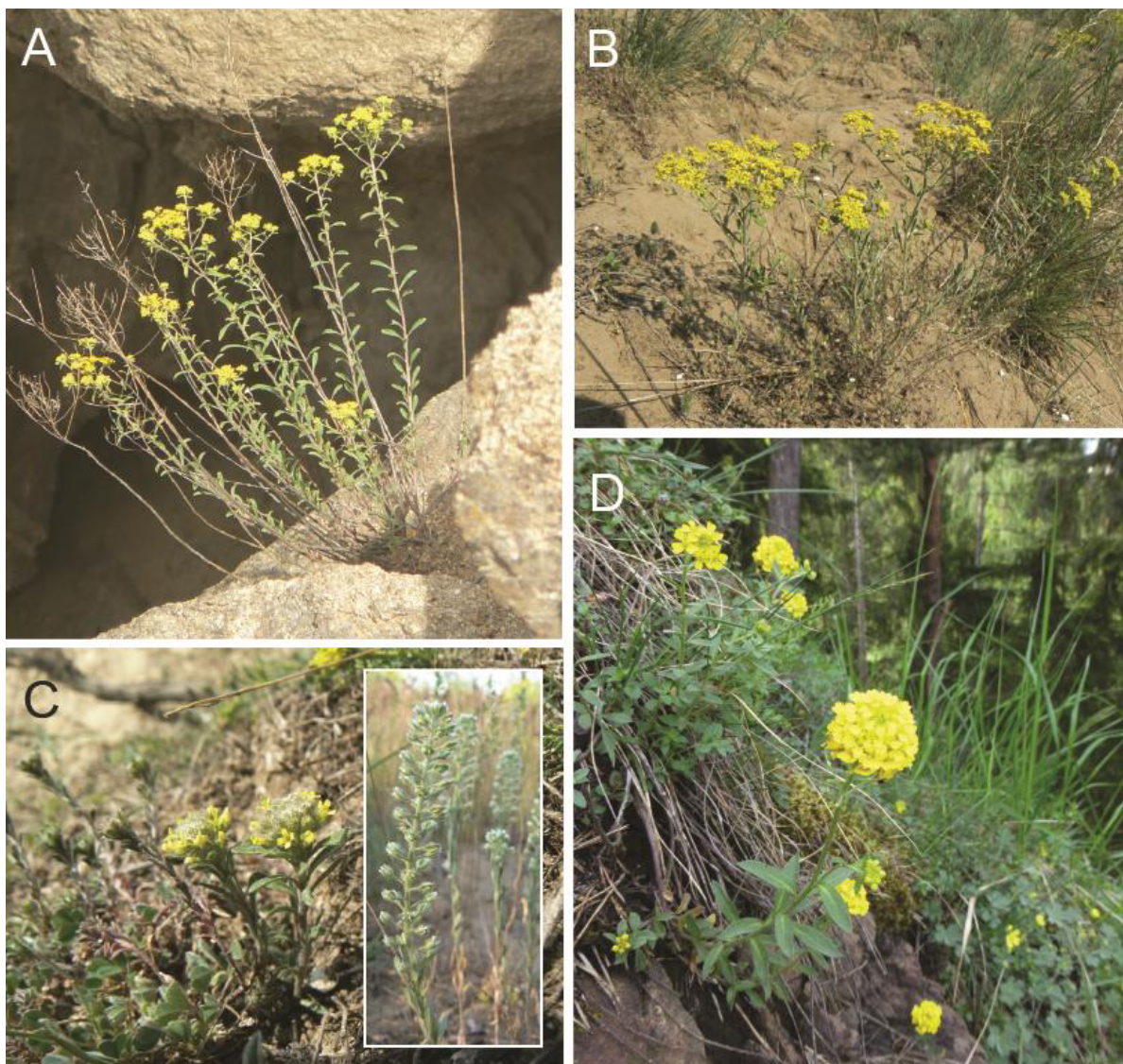


Figure 4a. Photographs of the selected *Alyssum* and *Odontarrhena* species: A) *O. muralis* (Măcin, Romania); B) *O. tortuosa* (Grebenac, Serbia); C) *A. alyssoides* (Tokod, Hungary); D) *A. repens* (Kirchdorf, Austria);

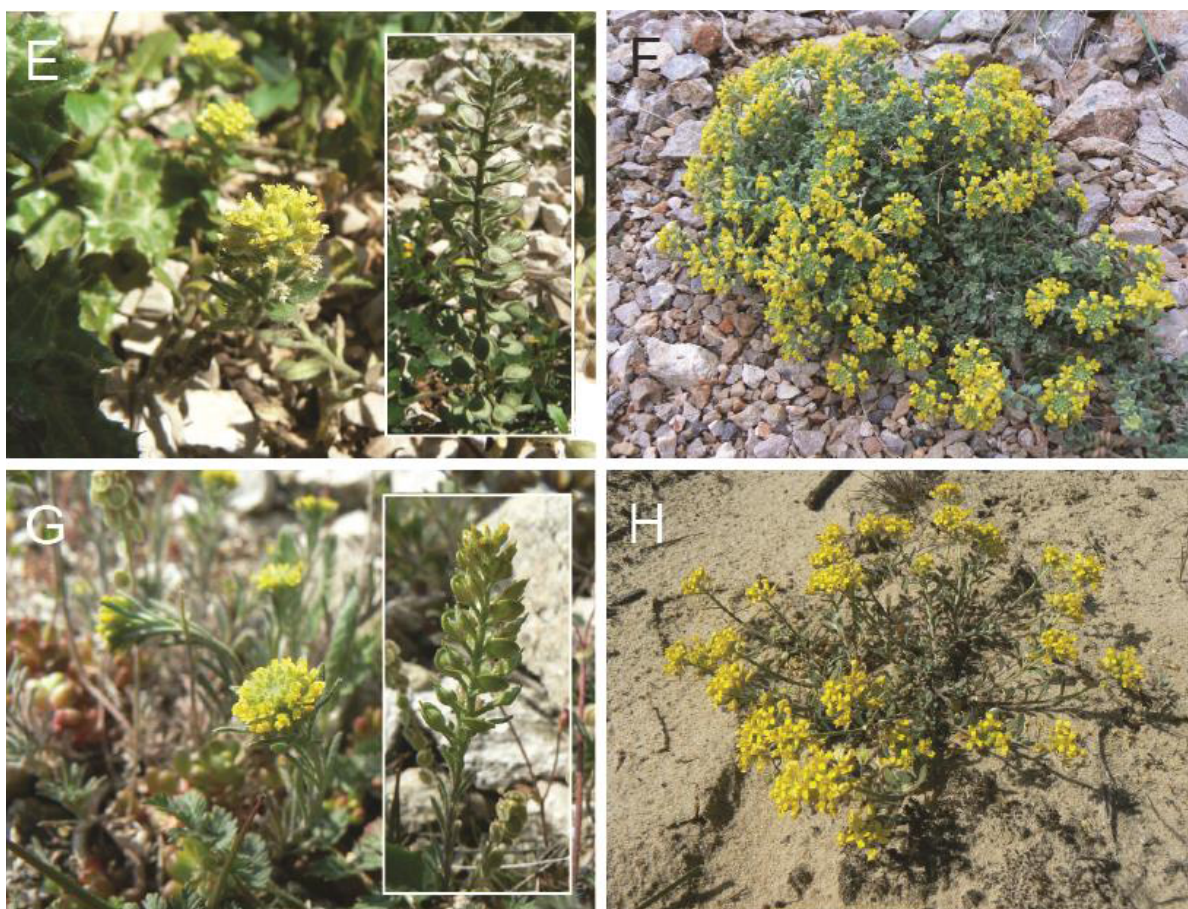


Figure 4b. Photographs of the selected *Alyssum* and *Odontarrhena* species: E) *A. simplex* (Primošten, Croatia); F) *A. austrodalmaticum* (Karlobag, Croatia), G) *A. turkestanicum* (Ognyanovo, Bulgaria), H) *A. gmelinii* (Ciechocinek, Poland) (Photos: S. Španiel).

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