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ORIGINAL ARTICLE

Aubrieta deltoidea (L.) DC. (Brassicaceae) in Ukraine and Eastern Europe

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The genus Aubrieta Adans. includes 12-24 species naturally distributed in South-West Asia (mainly in Anatolia) and in South and Southeast Europe. Most of these species grow in mountain, subalpine and alpine altitudinal belts. The most common is *A. deltoidea* (L.) DC. It has long been known as a garden ornamental plant in Western Europe and in other countries. During the last 10-15 years, plants of this species began to be cultivated in Ukraine and in Eastern Europe. For the genus and for *A. deltoidea*, the nomenclature, basic synonymy, complete morphological description, ecological affinity, range, and also features of distribution in Ukraine and in Eastern Europe are given at the first time. Based on the analysis and generalization of ecological and biological specificity, features of plant distribution and cultivation, it was suggested that in the climatic conditions of Ukraine *A. deltoidea* plants may run wild and form spontaneous populations.

Keywords: *Aubrieta deltoidea*; ornamental plants; potential ergasiophyte; flora of Ukraine

Introduction

According to modern data, the Brassicaceae Burnett family includes about 4,000 species, which belong to more than 300 genera and 52 tribes (Al-Shehbaz, 2012; Hohmann et al., 2015; BrassiBase, 2017). Species of Brassicaceae are common in all continents, except Antarctica. Many of them have strong scientific and economic significance. There are food, honey, fodder, technical, medicinal and decorative plants among the crucifers. Some of them began to grow in prehistoric times (Sinskaya, 1969). The earliest cultivated plants are *Brassica oleracea* L., *B. rapa* L., *Raphanus sativus* L., *Eruca sativa* Mill., *Camelina sativa* Boiss. etc. A lot of ornamental plants, which are widely cultivated in many countries under different environmental conditions, belong to Brassicaceae. In Ukraine and in Eastern Europe the most popular species of them are: *Arabis caucasica* Willd., *Aurinia saxatilis* Desv., *Hesperis matronalis* L., species of genus Iberis L. (*I. amara* L., *I. umbellata* L., *I. saxatilis* L.), *Lobularia maritima* (L.) Desv., *Lunaria annua* L., species of genus Matthiola W.T.Aiton (especially *M. incana* (L.) W.T.Aiton and *M. longipetala* (Vent.) DC.) etc.

During the last 10-15 years the assortment of decorative crucifers in Ukraine has been widened with one more species- *Aubrieta deltoidea* (L.) DC., which was evidently promoted by the development and constant expansion of the e-commerce network. The plants of this species have been grown in botanical gardens of Ukraine since the second half of the last century (Katalog ..., 1988; Katalog ..., 1997). In particular, one of the hybrids of *A. deltoidea* (Aubrieta x cultorum) was used for creation a collection and exposition area “Stony Garden” in the arboretum “Oleksandriya” of the National Academy of Sciences of Ukraine (Rubis, 2008), they are part of the collection of herbal plants of the National Dendrological Park “Sofiyivka”of the National Academy of Sciences of Ukraine (Shvets, 2014), they are proposed for the greening of Kharkiv city (Mazur & Bengus, 2016), included in the assortment of ornamental plants for the roof gardening (Demessiye & Zavarzina, 2013), and one of the species cultivars (Aubrieta x cultorum) is in the list of herbal plants of Syretskyi Dendrological Park in Kyiv (Hlukhova et al., 2016; Aubrieta, 2017). In 2015, *A. deltoidea* plants and their hybrids were grown in 12 botanical gardens and arboretums of Ukraine (Katalog..., 2015). More than 10 years they have grown in the Botanical Garden of the University of Latvia (Naburga-Ermakova, 2016) and the Tallinn Botanical Garden (GBIF, 2019). According to Plantarium (2019), they have recently been cultivated in Kyiv, Zaporizhzhia, Sevastopol, as well as in private plots in Kyiv Oblast and in other regions of Eastern Europe, etc.

A. deltoidea plants applied for decorative design of “Gravel Garden” in M.M. Gryshko National Botanical Garden of NAS of Ukraine (NBS) were used for description of morphological features of this species. As it turned out, there is no data on this

genus and species in the floristic and systematic publications of Ukraine and Eastern Europe. So we have done it for the first time.
The aim of this work is to provide systematic, morphological, ecological and chorological information on *A. deltoidea*, as well as to evaluate the future prospects of spreading this species in the natural and climatic conditions of Ukraine.

Materials and methods
The paper was based on the field observations of the authors as well as on literary and electronic data about the genus Aubrieta Adans. and its species *A. deltoidea*.

Results and discussion
A brief history of genus Aubrieta investigation
In the second edition of "Species Plantarum" Linné (1763) was described a new species – *Alyssum deltoideum*, which was characterized as a plant with semi-woody stems, lanceolate deltoid leaves and pubescent silicles. The scientist included polynomial «*Alyssum creticum* foliis angulatis flore violaceo. Tourn! cor. i5» in synonyms. At the same time, Adanson (1763), also in 1763, based on the same polynomial, described the new genus Aubrieta. For a long time this genus was monotypic or oligotypic. Thus, de Candolle (1821) included in this genus only two species (*A. deltoidea*, *A. purpurea* DC.), and he located it in the tribe Alyssineae noting that this genus is very clear according to its species habitus and features and can be distinguished from other genera of the tribe.
The systematic position of Aubrieta was not permanent. So, Prantl (1891) associated Aubrieta with genera of subtribe Capsellinae of tribe Hesperideae. In this work, the genus has already included 12 species. Developing a system of crucifers on a phylogenetic basis and applying a set of features for the differentiation of genera, Hayek (1911) brought Aubrieta (Aubrietia) closer to Arabis L., in particular with Euarabis section, and both genera were included in Arabideae DC. tribe. The author noted that according to almost features of genus Aubrieta is similar with species of section Euarabis of genus Arabis and it could be differentiated from them only in less length of fruits and in the absence of median nectaries. He thought that the relationship between Aubrieta and Draba L. and Alyssum L., which was supposed by A.P. de Candolle and K. Prantl, hardly exist. The relation of Aubrieta to the genus Arabis was also accepted by Janchen (1942), while Cullen (1965) and Hedge (1968) included it in tribe Matthioleae O.E. Schulz.
The results of molecular and biological studies confirmed that Aubrieta belongs to the tribe Arabideae and has close relation to the genus Arabis, especially with species *A. verna* (Al-Shehbaz, 2012; Liu et al., 2012; Karl et al., 2012; Karl & Koch, 2013; Koch et al., 2012; Koch et al., 2016). The genus Arabis is a sister group of genus Aubrieta, which causes several variants of taxonomic realization of the obtained molecular and phylogenetic data. It would be possible to combine genera Arabis and Aubrieta. Then the priority name of the new genus will be Aubrieta, which will result in numerous nomenclatural combinations. It is generally accepted to isolate *A. verna* in a separate genus. Especially, because of some morphological features, it differs from the species Aubrieta (Koch et al., 2016). Actually, the authors did not mention by which diagnostic features of the new genus would be differ from Arabis. Due to significant morphological similarity of the Aubrieta species and the allopatry of their ranges, only two species can be considered: *Arabis* (Aubrieta) *verna* and *Aubrieta deltoidea* sensu lato or each local population should be accepted as a separate species (Muhammed 2016). J.J. Muhammed brought the following nomenclature combination for Arabis verna: Aubrieta verna (L.) J. Muhammed, comb. nov. (=*Hesperis verna* L. (1753, Sp. Pl. 2: 664)=*Arabis verna* (L.) W.T. Aiton (1812, Hort. Kew., ed. 2, 4: 105) in his PhD thesis on taxonomy and genomics of the genus Aubrieta.
Systematic characterization of the genus
Genus Aubrieta Adans. 1763, Fam. Pl. 2: 420-Aubretia.
Etymology: It was named after the French artist and botanist Claude Aubriet (1665–1742), who worked in the genre of botanical illustration.
Dwarf perennial herbs, Hairs furcate, stellate or simple (rarely). Stems erect to decumbent, branched basally, slender. Leaves basal and cauline; petiolate sessile or subsessile; basal rosulate, petiolate, blade margins entire or dentate; cauline petiolate, subsessile or sessile, base not auriculate, margins entire or dentate. Racemes few-flowered, elongated in fruit. Fruiting pedicels erect to divaricate, slender. Flowers large and usually showy. Calyx dimorphic, glabrous or pubescent. Sepals erect, oblong, lateral pair saccate basally. Petals usually purple to violet, rarely white or pink; obovate or spatulate; apex obtuse. Stamens tetradynamous; filaments free, somewhat narrowly winged, lateral pair with toothed appendage; anthers oblong. Nectar glands lateral, semi-annular, extrastaminal. Fruits siliques or, rarely, silicles, sessile, linear, oblong, or elliptic, ellipsoid or terete; valves flattened or inflated not torulose; each with distinct or not midvein; pubescent or glabrous (rarely); replum rounded; septum usually complete, sometimes perforate; style long; stigma capitate. Seeds biseriate, flattened, not winged, ovoid; seed coat mucilaginous or not when wetted; cotyledons accumbent. The main number of chromosomes in this genus is x = 8 (Warwick & Al-Shehbaz, 2006).
Holotype: *A. deltoidea* (L.) DC. *(Alyssum deltoideum* L., 1763, Sp. Pl. 2, 2: 908).
The genus includes 12–24 species, which are naturally common in Southwest Asia (mostly in Anatolia) and in Southern and Southeastern Europe (the Balkan and Apennine peninsulas, Southwest Romania) (Cullen et al., 1965; Hedge, 1968; Ančev & Goranova, 2009; Al-Shehbaz, 2012; Koch et al., 2016). Most species grow in mountain, subalpine and alpine altitudinal belts at an altitude of 200 to 2900 m a.s.l.; they usually grow on open slopes, rocks, rockslides and open woodlands and prefer sunshine or penumbra habitats; sometimes they occur on limestones or granites. Some species, especially *A. deltoidea*, are

represented by numerous varieties and hybrids, which have long been grown as garden ornamental plants. It is this species *A. deltoidea* has been recently cultivated in Ukraine.

A. deltoidea (L.) DC. 1821, Syst. Nat. 2: 294. – Purple rock cress.

– *Alyssum deltoideum* Linnaeus, 1763, Sp. Pl. ed. 2, 2: 908.

Plants forming mats or cushions; densely pubescent, trichomes stellate, mixed with fewer, setiform and forked ones. Stems several from base (caudex), ascending to procumbent, 0.7-3(5) dm, pubescent. Basal leaves: petiole 0.1-1 cm; blade obovate, oblanceolate, or rhombic, (0.5)1-3(4.5) cm × (2)4–13(20) mm, base cuneate to attenuate, margins entire or 1-3 teeth on each side, surfaces densely pubescent. Cauline leaves: petiolate or sessile; blade similar to basal. Racemes 1-13-flowered, lax. Fruiting pedicels erect to ascending, 5-12(16) mm. Flowers: sepals 6-10 × 1-1.5 mm; petals (10)15-28 × 4-7(8) mm, (attenuate to claw, 5-12 mm); filaments 5-10 mm; anthers 1.2-1.6 mm. Fruits terete or slightly flattened, 0.7-2(2.8) cm × 2-4(4.8) mm; valves: trichomes long-setiform and forked, mixed with smaller, stellate ones; style 4-12 mm. Seeds 1.2-16 × 0.7-1 mm. 2n=16.

The species was described from the East: «Habitat in Oriente». Lectotype: Linn. 828.25, LINN (Al-Shehbaz & Turland, 2002, in Cafferty et Jarvis (ed.), Taxon, 51: 530).

The natural habitats are open slopes, crushed stone meadows in the foothills and in the mountains, on eroded humus-carbonate soils; from xerothermic oak-hornbeam forests to the coniferous forest belt.

Distribution in Ukraine: it is sporadically cultivated; and it is known from Kyiv, Zaporizhzhia and Cherkasy Oblasts and Crimea.

General distribution: Western (alien), South West (alien), Central (alien), North West (alien), North (alien), South (Balkans) and Southeast (native or alien) Europe; Southwest Asia (west of Anatolia); North America (alien: Canada, The United States of America).

Aubrieta deltoidea: **ecological and biological specificity, peculiarities of distribution and cultivation**

Aubrieta deltoidea grows in well-lighted areas in botanical gardens, in public recreation areas (parks, squares, alpine hills, rebates, mixborders, flower-beds) and on private plots. This species is popular and has decorative attractiveness due to the complex of its biological and environmental features.

A. deltoidea plants are evergreen due to the formation of several generations of leaves. Their shoots, usually wooden at the basis, intensely and repeatedly branch along their entire length, and they can be rooted by additional roots, and as a result, can form loose low clumps or "mats" shape. Most shoots form inflorescences at the top, they consist of rather large bright crimson, violet, purple, lavender, pink and white (occasionally) flowers. The flowering period is longer-term, it begins at the end of May and lasts until the beginning of July. The flowers are protogynous, that provides cross-pollination (entomophily). Insects are attracted by bright petals and a light, pleasant odour because of honey glands (nectaries) at the basis of stamen filaments. There are two ways of propagation for this species: seed and vegetative. Usually, in each locule of silicle there are 10-15 seeds, which release mucilage after moisturizing (Karaismailoglu, 2017). It should be noted that myxospermia is typical for many other species of Brassicaceae, including those in the flora of Ukraine (Ilinska & Nytsenko, 2010a,b). Releasing of mucilage around the seeds after their moisturizing is a plant adaptation to arid factors of environment, which was formed in the process of evolution of species. Consequently, propagules of dissemination can be dry or moist seeds, which determine an anemochory, zoochory or anthropochory. Plants can be propagated by rooting vegetative shoots, but, usually, this process does not occur in nature. Seeds of *A. deltoidea*, such as other species of crucifers, have the physiological dormancy period, which lasts for several months.

Mountain, Anatolian-Balkan-Apennine origin explains the stability of *A. deltoidea* to intensive insolation, dry conditions of habitats, as facilitated by well-developed pubescence of all plant organs, as well as unpretentiousness to soil fertility and tolerance to low temperatures (up to -23°C).

A. deltoidea is also a promising medicinal plant, since high antioxidant activity and significant content of phenolic compounds were recently revealed in it (Kaska et al., 2017).

This species belongs to the very ancient and still popular ornamental plants, especially in Western Europe. In the United Kingdom, for example, people began to cultivate it in the early 18th century, at least since 1710. However, only in 1928 the plants, which were run wild and began to reproduce by the self-sown, were registered (BRC, 2019). Naturalized plants were also found in Belgium, initially in 1966, on the roadside in Dadizele, and after that in 2008 on the old walls of Colfontaine and Thuin (Groom, 2012). The authors have no doubt that the same plants grow in other regions of this country. The spontaneous local populations is also noted in France (Gibbons, 2008), Italy (Galasso et al., 2017), the United States of America (California, 1955) (Rollins, 1982, 1993) and etc. (CABI, 2019). As noted above, in Eastern Europe, the distribution of *A. deltoidea* is mostly concentrated in botanical gardens and private plots. We have not found documented information about the plants of this species that run wild the culture. However, the ability of plants to propagate by seeds, the unpretentiousness to soil fertility and tolerance to environmental conditions (due to xeromorphy, drought and frost resistance) could bring about preconditions for a wider, then now, spontaneous distribution of species in the natural and climatic conditions of Ukraine and other regions of Eastern Europe.

Discussion and conclusion

In this paper the nomenclature, basic synonymy, complete morphological description, ecological affinity, range, as well as features of distribution in Ukraine and in Eastern Europe were provided for whole genus and for *A. deltoidea* species. According to the results of the analysis and generalization of ecological and biological specificity, peculiarities of plant propagation and cultivation, we made an assumption that in the climatic conditions of Ukraine, *A. deltoidea* plants are able to

run wild from the culture and form spontaneous populations.

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