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The buckler mustard (*Biscutella laevigata* L.) – species description

Adam Rostański[1*], Grażyna Szarek-Łukaszewska[2], Monika Jędrzejczyk-Korycińska[3]

[1,3] *Institute of Biology, Biotechnology and Environmental Protection, Faculty of Natural Sciences, University of Silesia, 28 Jagiellońska St., 40-032 Katowice*
[1] *e-mail: adam.rostanski@us.edu.pl, ORCID: 0000-0001-7312-7799*
[2] *W. Szafer Institute of Botany Polish Academy of Sciences, 46 Lubicz St., 31-512 Cracow, e-mail: g.szarek@botany.pl, ORCID: 0000-0003-3170-8522*
[3] *e-mail: monika.jedrzejczyk-korycinska@us.edu.pl, ORCID: 0000-0001-8189-6707*

Most species of *Biscutella* L. genus are perennials, rarely annuals. They belong to the family Brassicaceae. Leaves on a stem are scarce. Basal leaves clustered in distinct rosettes. Flowers are regular, with four yellow petals. The Latin name of the genus refers to the characteristic shape of the fruit – a flat, winged, two-chambered silicula (in Latin *bis* means two, *scutellum* means scute).

The *Biscutella* L. genus comprises over 50 species found mainly in rocky and stony areas of southern Europe. Some species occur in northern Africa and southwestern Asia, reaching as far as Iran (Anonymous 2018a). Most *Biscutella* species have very small geographical ranges, some of them are endemic. In Poland, only one species is present, *Biscutella laevigata* (Figs 1–3), first described by Linnaeus (Linne 1771). Its common name in English is the buckler mustard, and the Polish name is *pleszczotka górska*, or *pleszczotka gładkołuszczynkowa* (Mirek et al. 2002). However, in the first decades of 20th century, in the Polish literature, the species was referred to as *tarczyk*, or *tarczyk podwójny* (Rostafiński 1900, Wóycicki 1913).

The detailed morphological description of *B. laevigata* was provided by Malinowski in 1910 in his comprehensive monograph of the genus *Biscutella* L. Subsequent taxonomi descriptions of the genus were based on that publication (Kulczyński 1927, Mądalski 1963, Guinea and Heywood 1964, Pawlus 1985, Szafer et al. 1986, Piękoś-Mirkowa and Mirek 2007). *B. laevigata* has an erect stem, branched in the upper part, which is 10–40 cm tall (Fig. 4). The lower part of the flower stem is covered by downward facing trichomes. Leaves on the stem are scarce, and they become smaller and narrower the higher up the stem. Basal

* Corresponding author

CAR. A LINNÉ
EQU. AUR.
MANTISSA
PLANTARUM
ALTERA
GENERUM editionis VI.
&
SPECIERUM editionis II.
Cum Privilegio S:æ R:æ M:tis Sveciæ & Electoris Saxon.
HOLMIÆ,
IMPENSIS DIRECT. LAURENTII SALVII,
1771.

levigata. BISCUTELLA siliculis glabris, foliis lanceolatis serratis.
Leucojum alyssoides umbellatum montanum. *Col. ecphr.* 1. p. 283. t. 284.
Habitat in Italia. ☉.
Folia *radicalia, lanceolata, petiolata, acuminata, remote serrata serraturis parvis acutis erectis, undas. subscabra, margine scabra.*
Caulis *pedalis, fere totus aphyllus, levis, superne corymboso-ramosus.*
Siliculæ *leves, magnitudine B. auriculatæ.*
Obs. Columnæ *planta differt caule foliisque magis pilosis et Caule folioso.*

Fig. 1. Linnean protologue of *Biscutella laevigata* L. (Linne 1771)
Ryc. 1. Protolog gatunku *Biscutella laevigata* L. (Linne 1771)

leaves of generative stems form rosettes. The basal leaves are usually spatulate, wavy-toothed or entire (simple with smooth margins), 3–12 cm long, and petiolate. Entire basal leaves are rarer. The leaves are hispid, covered on both sides by unbranched, unicellular trichomes of varying density. Flowers are bright yellow and composed of 4 petals (corolla) and 4 sepals (calyx) (see also Kwiatkowska and Kłosowska – Chapter 4 of this volume). Petals are usually 4–7 mm long, but can be up to 8 mm, gradually narrowing toward the base. Sepals are usually 2.5–3 mm long, smooth, and slightly broader at the base. The pedicel is smooth and 6–12 mm long. The carpel is fixed on a short stalk. The two-chambered silicula is smooth, flattened, 5–7 mm long and 8–14 mm wide. Seeds are broadly ovate, and 2–4 mm in size. Each chamber of the silicula contains one seed. At the end of the vegetative season, mature silicules, as well as the stem, often change colour from green to purple violet.

Biscutella laevigata L. shows high morphological variability. Of the dozen or so subspecies characterized, three have been found in Poland (Pawlus 1985, Anonymous 2018a). In addition to the typical subspecies, *B. laevigata* L. subsp. *laevigata*, the subspecies of *B. laevigata* L. subsp. *gracilis* Mach.-Laur and *B. laevigata* L. subsp. *kerneri* Mach.-Laur also occur. The variability in measurable traits in these subspecies partly overlap, which makes their distinction difficult.

Like many species of the temperate zone, *B. laevigata* is a hemicryptophyte; its overwintering buds, which enable the plant to regenerate after winter, are at ground level (on or near the soil surface). The plant has a fairly long, robust taproot, partly lignified, with sprawling lateral branches. The root can easily penetrate cracks (crevices) in hard stony substratum. There are sites where the root can be up to 2.1 m long (Kutschera et al. 1992). In the roots of the buckler mustard, arbuscular mycorrhiza (endomycorrhiza) has been found even though the plant belongs to the Brassicaceae family, a species which is not usually associated with fungi (Orłowska et al. 2002). Arbuscules

Fig. 2. Herbarium specimen of *Biscutella laevigata* L., collected in the Tatra Mountains by K. Łapczyński in the summer of 1881. Specimen kept in the University of Warsaw Scientific Herbarium (WA0000071421) (photo M. Graniszewska)

Ryc. 2. Okaz zielnikowy *Biscutella laevigata* L. zebrany w Tatrach przez K. Łapczyńskiego latem 1881 roku. Okaz przechowywany w Zielniku Naukowym Uniwersytetu Warszawskiego (WA0000071421) (fot. M. Graniszewska)

Fig. 3. Herbarium specimen of *Biscutella laevigata* L. collected in Olkusz by R. Kobendza in 1922. Specimen kept in the University of Warsaw Scientific Herbarium (WA0000071422) (photo M. Graniszewska). A holotype of *B. laevigata* subsp. *woycickii* M. Wierzb., Pielich. & Wasowicz (Wierzbicka et al. 2020)

Ryc. 3. Okaz zielnikowy *Biscutella laevigata* L. zebrany przez R. Kobendzę w Olkuszu, w 1922 roku. Okaz przechowywany w Zielniku Naukowym Uniwersytetu Warszawskiego (WA0000071422) (fot. M. Graniszewska). Holotyp *B. laevigata* subsp. *woycickii* M. Wierzb., Pielich. & Wasowicz (Wierzbicka i in. 2020)

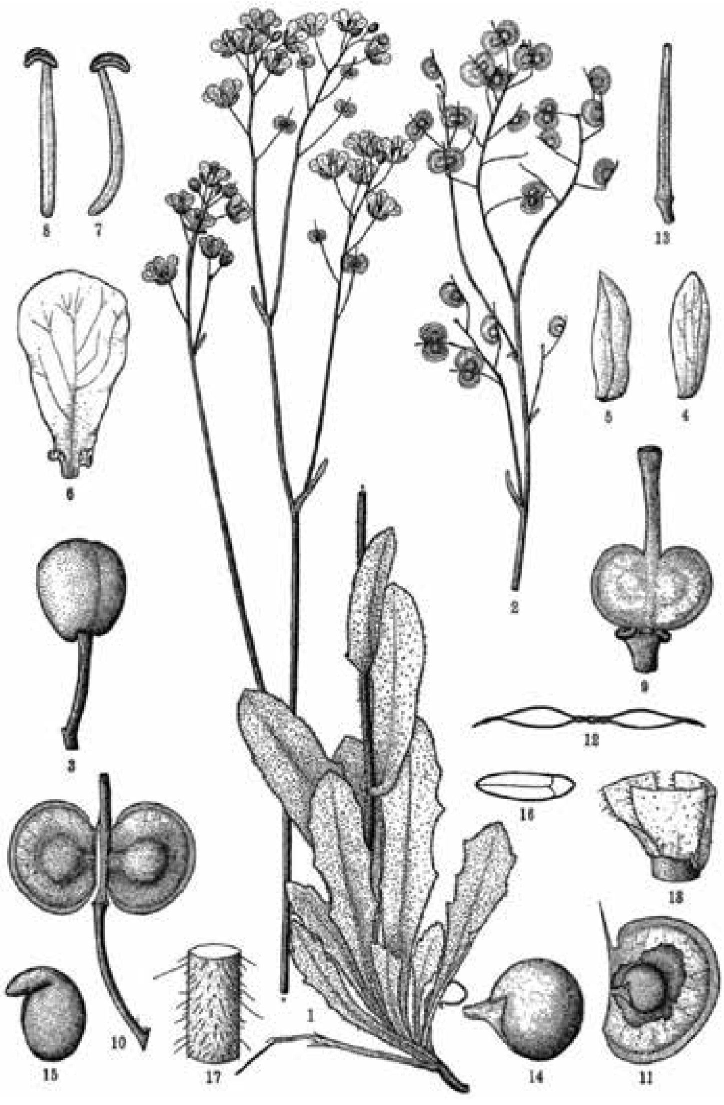

Fig. 4. Morphology of *Biscutella laevigata*: 1 – shape of blooming plant, 2 – shape of branchlet with fruits, 3 – flower buds, 4 – outer sepal, 5 – inner sepal, 6 – petal, 7 – outer stamen, 8 – inner stamen, 9 – young pistil after removal of calyx, corolla and stamens, 10 – silicula, 11 – half of silicula, 12 – transverse section of silicula, 13 – silicula septum, 14 – seed, 15 – embrio after removal of seed coat, 16 – cross section of the seed, 17 – section of the hairy stem, 18 – section of the lower part of stem with basal parts of two leaves (from Mądalski 1963)
Note: the drawing is based on the specimen collected by R. Kobendza in Olkusz in 1992 (Fig. 3)

Rys. 4. Morfologia *Biscutella laevigata*: 1 – pokrój rośliny kwitnącej, 2 – pokrój owocującej gałązki, 3 – pączek kwiatowy, 4 – zewnętrzna działka kielicha, 5 – wewnętrzna działka kielicha, 6 – płatek korony, 7 – pręcik zewnętrzny, 8 – pręcik wewnętrzny, 9 – młody słupek po usunięciu działek kielicha, płatków korony i pręcików, 10 – łuszczynka, 11 – połowa łuszczynki, 12 – poprzeczny przekrój łuszczynki, 13 – przegroda łuszczynki, 14 – nasienie, 15 – zarodek po usunięciu łupiny nasiennej, 16 – poprzeczny przekrój nasienia, 17 – wycinek owłosionej łodygi, 18 – wycinek dolnej części łodygi z nasadami dwóch liści (za Mądalski 1963)
Uwaga: rysunek według okazu zebranego przez R. Kobendzę w Olkuszu, w 1922 roku (Ryc. 3)

of mycorrhizal fungi are observed in the roots of *B. laevigata* in the blooming season.

Biscutella laevigata reproduces generatively (sexually, with seeds). It flowers abundantly in spring and less abundantly in summer (Gasser 1986). It is exclusively cross-pollinated, pollinated mostly by dipterans and butterflies (Gasser 1986, Parisod and Bonvin 2008). Fruits (silicules) fall in abundance close to the maternal plants; however, sudden gusts of wind or flowing water may transport them over long distances (Gasser 1986, Parisod and Bonvin 2008). Seeds of *B. laevigata* may be viable for several years (Gasser 1986). Most seeds do not have a dormant phase (Dannemann 2000). In laboratory conditions they germinate quickly, and its germination ability is almost 100%. The seeds also germinate easily in natural conditions (Godzik 1981, Gasser 1986). The fresh seeds usually germinate quickly. However, the seeds produced in late summer only germinate in the next vegetation season (Urbańska and Schütz 1986). Further stages of the *B. laevigata* life cycle are poorly understood. Gasser (1986) and Urbańska and Schütz (1986) investigated alpine species, including *B. laevigata*, and showed that the development and survival of seedlings were strongly dependent on microhabitat conditions influencing seed germination. They found that the microtopography of soil surface, humidity, light conditions, and temperature were important for all species, combining to create safe sites for the development of seedlings, specific for different taxa and ecosystems (Urbańska 1997). In calcareous grasslands, both the germination of *B. laevigata* seeds and survival of its seedlings may be reduced by a moss layer (Jeschke and Kiehl 2008). Mosses separate seeds from soil and create unfavorable light conditions. In the adverse conditions of metal-contaminated habitats, *B. laevigata* may reproduce

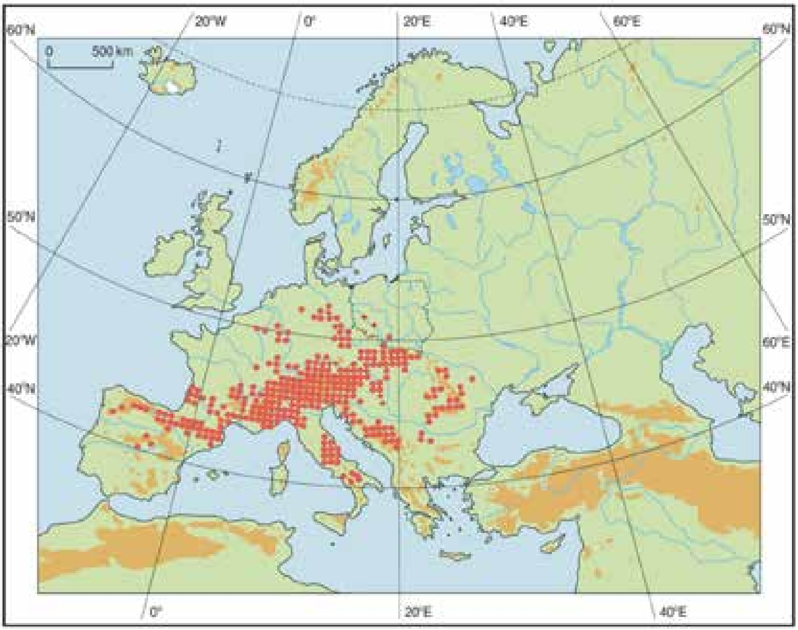

Fig. 5. Distribution of *Biscutella laevigata* in Europe (base on Anonymous 2018b, modified)

Rys. 5. Rozmieszczenie *Biscutella laevigata* na terenie Europy (za Anoymous 2018b, zmienione)

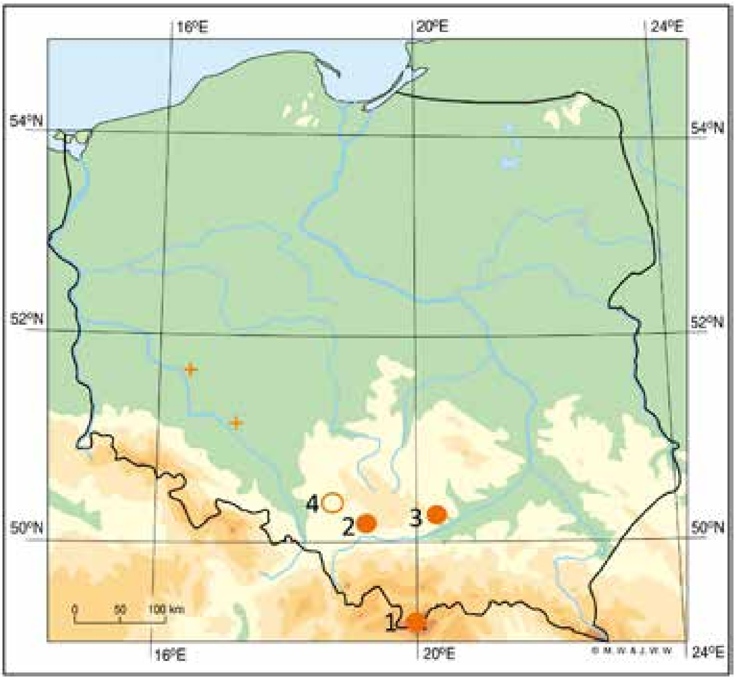

Fig. 6. Distribution of *Biscutella laevigata* in Poland: 1 – the Tatra Mountains, 2 – the Olkusz region, 3 – the Nida Basin, 4 – the place of the introduction in Piekary Śląskie ('Dołki'), **+** – extinct populations

Rys. 6. Rozmieszczenie populacji *Biscutella laevigata* w Polsce: 1 – Tatry, 2 – region olkuski, 3 – Niecka Nidziańska, 4 – miejsce introdukcji Piekary Śląskie („Dołki"), **+** – populacje zanikłe

vegetatively, as described in Chapters 6 and 9 of this volume.

The geographical range of *B. laevigata* covers the mountain areas of Europe, from Portugal and Spain to the Carpathians and Balcans (Fig. 5) (Pawlus 1985, Anonymous 2018b). The species was even found at altitudes over 3,000 m a.s.l. (Dobrzańska 1955). In high mountains the species occurs on limestone rock and screes, and occasionally in meadow communities (Kulczyński 1927, Pawlus 1985). In the mountain foothills and in the lowland the buckler mustard occupies dry, warm, and sunlit habitats. In xerothermic grasslands its occurrence is often restricted to more humid northern slopes (Dobrzańska 1955, Wąsowicz et al. 2014). *B. laevigata* grows and reproduces better on the loose deposits of rock debris than on the established substrata. It is a pioneer species, and it is less competitive with other plants (Peniastekova 1981, Gasser 1986, Babst-Kostecka et al. 2014).

Sites where *B. laevigata* occurs in Poland are shown in Figure 6. They are not typical sites of this species, as they are situated in both mountains and lowland. Regions of Oława and Wrocław in Lower Silesia have been mentioned as sites of occurrence in historical records (Fieck 1881, Schube 1903), including those regarding the post-war flora of Poland (Pawlus 1985). The buckler mustard is no longer found in these regions. The remaining four sites where it occurs are situated in the southern part of the country and they are geographically isolated, separated by a distance of about 100 km. One site is in the West Tatra Mountains, where populations of *B. laevigata* occur from the lower mountain forest belt to the alpine meadow belt (i.e. from 880 to 2,123 m a.s.l.). The plant grows on gravel, scree, and limestone rock outcrops in grassland communities (Malinowski 1910, Wierzbicka et al. 2015) (Fig. 7). The second site is beyond the mountains, in the Silesian-Cracow Upland, in the area where zinc and lead ores were once exploited (the region of Olkusz), on heaps of mining waste. The first mention of this site can be found in the publication by Uechtritz from 1877. It was the first record of *B. laevigata* in the flora of lowland Poland. Wóycicki (1913), in his work entitled 'Pictures of the vegetation of the Polish Kingdom and neighbouring countries', describes these lowland sites of *B. laevigata* in detail: 'On the undulating plateau, covered fairly densely by *Juniper* (Juniperus communis L.) and sparsely by *Pine* (Pinus silvestris L.) or *Common barberry* (Berberis vulgaris L.), which separates the Bolesław basin from the Olkusz basin [and] which was once a mining area […]. In hollows […] which remained after the filled-in mineshafts, once numerous in the area, *Tarczyk podwójny* (Biscutella laevigata L.) occurs abundantly. Though its occurrence extends beyond these sites, *B. laevigata* prefers the quiet recesses with hidden fern *Green spleenwort* (Asplenium viride Huds.) and *Limestone fern* (Phegopteris robertiana A. Br.) to open, wind-lashed expanses of land.' At present, Nowak et al. (2011) indicate that *B. laevigata* still occurs in this abandoned mining area (Fig. 8). As it was one hundred years ago, it is found in grasslands growing on heaps of mine waste and in pinewoods planted on these heaps as part of the reclamation program (Wierzbicka and Rostański 2002, Nowak et al. 2011, Kapusta et al. 2015). The best specimens of *B. laevigata* grow on the unvegetated rock debris of waste heaps (Fig. 9). Interestingly, *B. laevigata* from this site differs in morphological and biological traits from the nearest high mountain populations in the Carpathians (Kwiatkowska and Kłosowska – Chapter 4 of this volume, Bemowska-Kałabun et. al. – Chapter 6 of this volume). Wierzbicka and co-authors (2015, 2017, 2020) have proposed that this population should be distinguished as a separate taxon as a subspecies – *B. laevigata* L. subsp. *woycickii* M. Wierzb., Pielich. & Wasowicz (Bemowska-Kałabun et al. – Chapter 5 and 6 of this volume).

Fig. 7. *Biscutella laevigata* in the Tatra Mountains (photo P. Kauzal)

Ryc. 7. *Biscutella laevigata* na stanowisku w Tatrach (fot. P. Kauzal)

Recently, the third site of *B. laevigata* has been described from the lowland area, Zagorzyce near Pińczów (the Nida Basin).

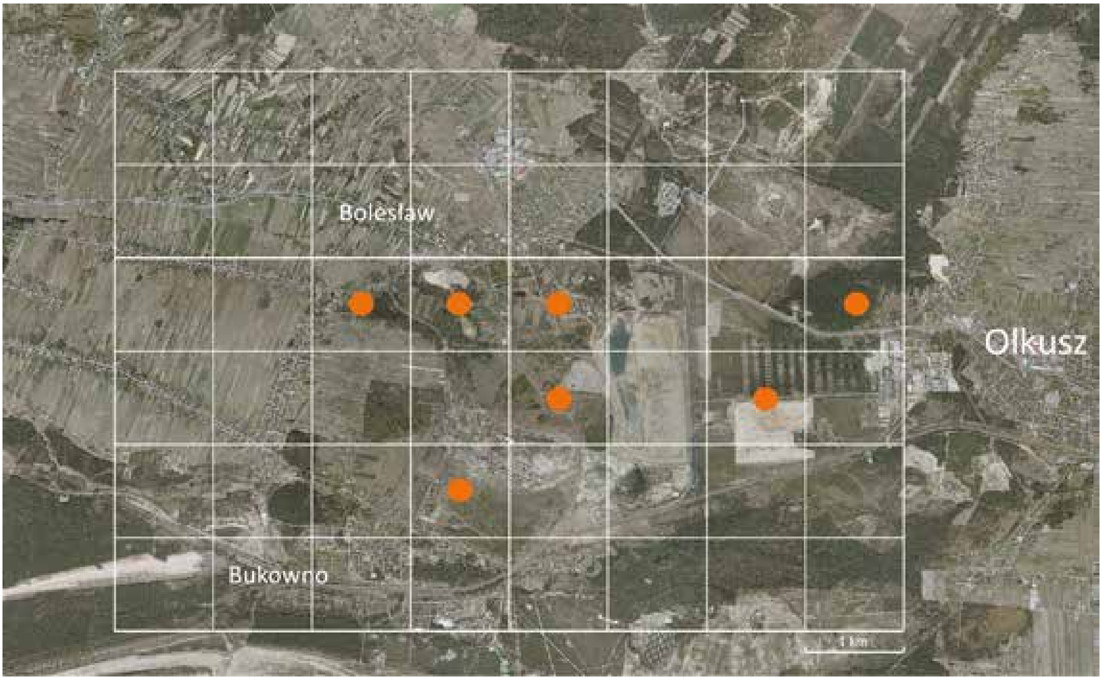

Fig. 8. *Biscutella laevigata* in the Olkusz region (base on Nowak et al. 2011, updated in 2019). A locality was defined as an occurrence of a species within a 1 × 1 km cell, the adopted grid system follows the 'Atlas of distribution of vascular plants in Poland (ATPOL)' (Zając 1978, Nowak et al. 2011) [Orthophotomap originate from the National Geodetic and Cartographic Resources (PZGiK)]

Ryc. 8. Występowanie *Biscutella laevigata* na stanowisku w rejonie olkuskim (za Nowak i in. 2011, uaktualnione w 2019 r.), za stanowisko przyjęto występowanie gatunku w kwadracie 1 × 1 km, siatka kwadratów została wyznaczona zgodnie z założeniami metodycznymi „Atlasu rozmieszczenia roślin naczyniowych w Polsce (ATPOL)" (Zając 1978, Nowak i in. 2011) [Ortofotomapa pochodzi z Państwowego Zasobu Geodezyjnego i Kartograficznego (PZGiK)]

B. laevigata grows numerously in the patchy xerothermic grassland on limestone rock debris (Fig. 10) (Przemyski and Piwowarczyk 2012). The fourth site, 'Dołki', in the region of Piekary Śląskie, is a result of the deliberate introduction of the species on the heaps of flotation tailings (after zinc and lead ore enrichment) (Fig. 11) (Rostański 2014). A few years after germination of the first plants in 2010, the population of *B. laevigata* appears to be stable and comprises nearly 1,000 individuals in different developmental stages (Rostański et al. 2016). The history and present condition (in 2019) of this population are described by Rostański et al. in Chapter 9 of this volume.

Biscutella laevigata is a pseudometallophyte (facultative metallophyte) because it grows and propagates on soils with both high and low metal concentrations (Szarek-Łukaszewska et al. 2015, Babst-Kostecka et al. 2014, Babst-Kostecka et al. 2016, Bemowska-Kałabun et al. – Chapter 5 and 6 of this volume). In Table 1, the concentrations of zinc, cadmium, lead and thallium in soil samples are listed. These samples were collected from *B. laevigata* sites in Poland and in other European countries, in both natural and anthropogenic, post-mining areas. Given that the properties of soil in these sites are greatly varied (Baker et al. 2010), the concentrations of metals in soil from rooting

Table 1. Metal concentrations [mg/kg] in the soils of *Biscutella laevigata* sites in Poland and other European countries. Data after Babst-Kostecka et al. 2016[1], Wenzel and Jockwer 1999[2], Fellet et al. 2012[3], Pavoni et al. 2017[4]. Range – minimum and maximum average concentration in soil from rooting zone of plants

Tabela 1. Stężenia metali [mg/kg] w glebie na stanowiskach *Biscutella laevigata* w Polsce i innych krajach Europy. Dane za Babst-Kostecka i in. 2016[1], Wenzel i Jockwer 1999[2], Fellet i in. 2012[3], Pavoni i in. 2017[4]. Zakres – minimalne i maksymalne średnie stężenia metali w glebie wokół korzeni roślin

Site Stanowisko	Soils Gleby	Zn mg/kg Range Zakres	Cd mg/kg Range Zakres	Pb mg/kg Range Zakres	Tl mg/kg Range Zakres
Zagorzyce, Poland[1] Zagorzyce, Polska	Native Naturalne	93 – –	5 – –	65 – –	– – –
Tatra Mountains, Poland and Slovakia[1] Tatry, Polska i Słowacja	Native Naturalne	52 – 356	4 – 6	82 – 250	2 – –
Olkusz region, Poland[1] Rejon olkuski, Polska	Mining Górnicze	16581 – 59654	110 – 360	1590 – 7259	– – –
Austrian Alps[2] Alpy, Austria	Native Naturalne	28 – 63	3 – –	12 – 33	– – –
	Mining Górnicze	13400 – 15000	25 – 43	2500 – 4010	– – –
Julian Alps, Italy[3] Alpy Julijskie, Włochy	Native Naturalne	48 – –	1 – –	33 – –	161 – –
	Mining Górnicze	8836 – 18336	21 – 32	4431 – 7502	288 – 424
Italian Alps[4] Alpy, Włochy	Mining Górnicze	128 – 18297	– – –	13 – 3144	<LOD – 2

LOD – the limit of detection
LOD – granica wykrywalności

zone of *B. laevigata* are shown. In the natural sites, the total concentrations of metals in the soil were: 28–356 mg/kg for zinc, 1–6 mg/kg for cadmium, 12–250 mg/kg for lead, and 2–161 mg/kg for thallium. In the soils of the zinc and lead mining areas, the concentrations of metals were much higher due to the presence of waste that remained after ore processing. These concentrations reached up to 59,654 mg/kg of zinc, 360 mg/kg of cadmium, 7,502 mg/kg of lead, and 424 mg/kg of thallium (Table 1). In the site of 'Dołki' where *B. laevigata* was successfully introduced, the concentrations of metals were even higher, amounting to 89,900 mg/kg of zinc, 447 mg/kg of cadmium, and 18,300 mg/kg of lead (Kucharski et al. 2011). *B. laevigata* was also found in areas where nickel, ores were once mined, specifically on serpentine soils characterized by elevated concentrations of nickel, magnesium and chrome (Gasser 1986, Lombini et al. 1998). All the soils where *B. laevigata* grows are usually shallow, stony, mineral, and alkaline, with low levels of nutrients (Gasser 1986, Lombini et al. 1998, Wenzel and Jockwer 1999, Fellet et al. 2012, Babst-Kostecka et al. 2016, Pavoni et al. 2017).

Biscutella laevigata, growing on soils contaminated by metals, has developed resistance to toxic amounts of metals in its tissues (Jędrzejczyk-Korycińska and Rostański 2015, Wierzbicka et al. 2015, Bemowska-Kałabun

Fig. 9. *Biscutella laevigata* in the abandoned mine land of the Olkusz region (photo G. Szarek-Łukaszewska)

Ryc. 9. *Biscutella laevigata* na nieużytku górniczym w regionie olkuskim (fot. G. Szarek-Łukaszewska)

et al. – Chapter 5 and 6 of this volume). The concentrations of metals in plants growing on metalliferous soils can be many times higher than the metal concentrations found in plants growing in 'clean' sites, and than the concentrations commonly accepted as necessary for the normal functioning of the organism (Szarek-Łukaszewska and Niklińska 2002, Pavoni et al. 2017, Bemowska-Kałabun et al. – Chapter 6 of this volume). *B. laevigata* usually accumulates metals taken from the soil (zinc, cadmium, lead) in its roots, protecting the above-ground parts against the excessive amounts of metals. However, some authors report that lead and thallium can also accumulate in the above-ground parts of the plants (Leblanc et al. 1999, Wenzel and Jockwer 1999, Reevers 2003, Wierzbicka et al. 2004, Krämer 2010, Wierzbicka et al. 2016). Although these elements are toxic and not essential, *B. laevigata* accumulates them in large amounts in the stems, over 1,000 mg/kg and 500 mg/kg respectively. Such high concentrations of these elements in plant tissues is known as hyperaccumulation (e.g. Krämer 2010, Van der Ent et al. 2013, Szarek-Łukaszewska 2014). Thus, *B. laevigata* may be considered as one of few plant species in the world, known so far, that hyperaccumulate metals. This interesting property is discussed in detail by Bemowska-Kałabun et al. in Chapter 6 of this volume.

Fig. 10. *Biscutella laevigata* in Zagorzyce (photo G. Szarek-Łukaszewska)

Ryc. 10. *Biscutella laevigata* na stanowisku w Zagorzycach (fot. G. Szarek-Łukaszewska)

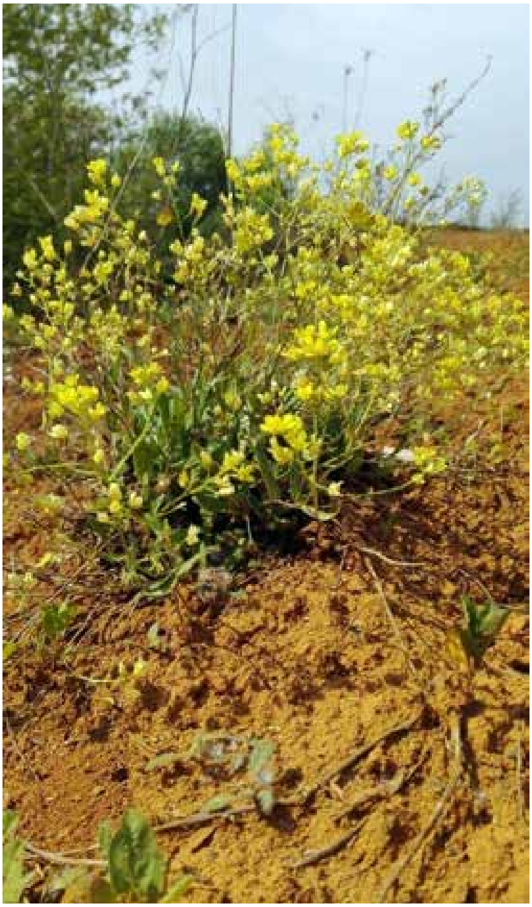

Fig. 11. *Biscutella laevigata* in Piekary Śląskie – site of 'Dołki' (photo A. Rostański)

Ryc. 11. *Biscutella laevigata* na stanowisku „Dołki" w Piekarach Śląskich (fot. A. Rostański)

To summarize, *B. laevigata* is a small perennial which blooms in spring and summer. Its flowers are tiny and yellow, with four petals. Its fruits are flat, two-chambered silicules, most of which fall near maternal plants, and its seeds germinate easily. The plant occurs in the mountainous areas of Europe, and occasionally in lowlands (only in Poland). It is found in natural and man-made habitats where non-ferrous metal ores, mainly zinc and lead ores, were once exploited. *B. laevigata* is a pioneer species, growing well on bare and stony soil. It shows preference for warm and dry habitats. In Poland, it has four isolated sites: one in the Tatra Mountains, one in the the Nida Basin and two in the Silesian-Cracow Upland, in the post-mining areas. The plant thrives and successfully reproduces on soils containing high amounts of heavy metals. It is a pseudometallophyte. Owing to the strongly contaminated soils on which it grows, *B. laevigata* has developed many adaptations to these unconventional habitats. It shows a high tolerance to the high concentrations of metals, accumulating large amounts of these elements in its roots, with the exception of lead and thallium which are also found in large amounts in the aboveground parts.

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