

CORRECTED PROOF

## Rapid Communication

**First record of *Koenigia divaricata* (L.) T.M.Schust. & Reveal (Polygonaceae) in Poland**Grzegorz Łazarski<sup>1</sup> and Artur Pliszko<sup>2</sup><sup>1</sup>Institute of Biological Sciences, Cardinal Stefan Wyszyński University, Wóycickiego 1/3, 01-938 Warsaw, Poland<sup>2</sup>Institute of Botany, Faculty of Biology, Jagiellonian University, Gronostajowa 3, 30-387 Kraków, PolandCorresponding author: Grzegorz Łazarski ([grzegorz.lazarski@gmail.com](mailto:grzegorz.lazarski@gmail.com), [g.lazarski@uksw.edu.pl](mailto:g.lazarski@uksw.edu.pl))

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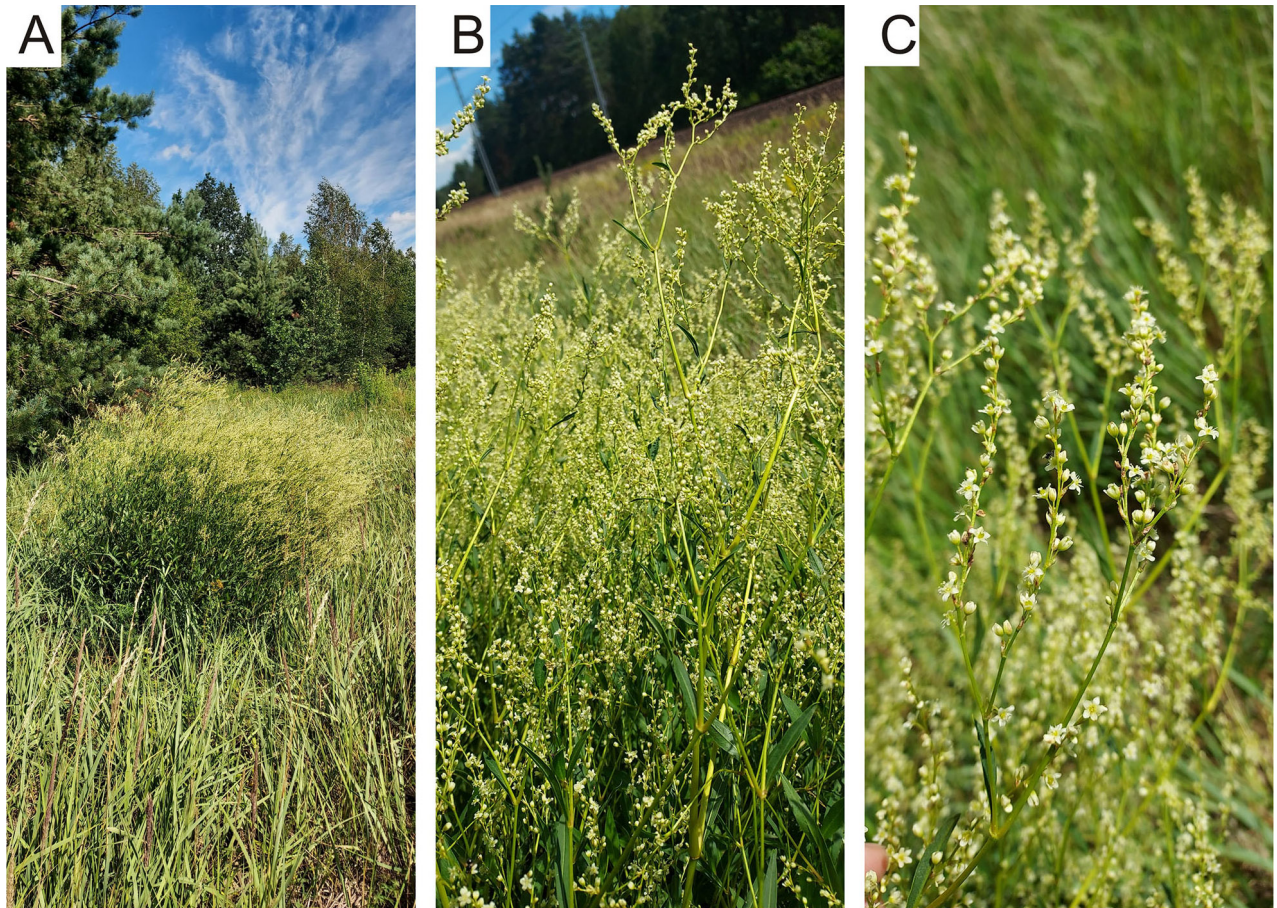
**Abstract**

*Koenigia divaricata* (L.) T.M. Schust. & Reveal [syn. *Polygonum divaricatum* L.; *Aconogonon divaricatum* (L.) Nakai; *Persicaria divaricata* (L.) H. Gross], a perennial herb of Polygonaceae, is native to temperate Eastern Asia and usually occurs in steppes, dry meadows and thickets. In recent decades, the expansion of the species to the west and north of its native range has been observed. Moreover, it was introduced to Western and Southern Siberia and Europe. The naturalisation of *K. divaricata* was confirmed in some countries of Northern Europe and some parts of Russia (the European part of it, as well as Western and Southern Siberia). In Europe, it is a rare species, known mainly for its cultivation as an ornamental or fodder plant. Within its primary and secondary range in Russia, it spreads effectively along transport routes, occupying roadsides, railway embankments and wastelands in their vicinity. In this paper, we report the first spontaneous occurrence of *K. divaricata* in Poland. It was found in September 2021 in Stare Opole near Siedlce, eastern Poland, and confirmed in July 2022. Photographic documentation of the species and phytosociological characteristics of its habitat are presented. Moreover, the locality of the species is mapped using the ATPOL cartogram method. Most likely, *K. divaricata* was introduced by rail transport. Currently, it should be treated as a casual alien species in the Polish flora. However, its naturalisation in Poland is likely due to suitable climatic conditions.

**Key words:** alien species, anthropogenic habitats, biological records, naturalisation, *Aconogonon divaricatum*, *Polygonum divaricatum*

**Introduction**

The genus *Koenigia* L. (Polygonaceae) includes annual and perennial plants distributed in arctic, temperate and alpine regions of the Northern Hemisphere (Schuster et al. 2015). Due to differences in taxonomic treatment, some authors list about 60 species within the genus (Schuster et al. 2015), and others about 40 (POWO 2023). Many of the *Koenigia* species are widely used as ornamental, forage, tanning and medicinal plants (Hanelt and Institute of Plant Genetics and Crop Plant Research 2001; Cullen et al. 2011; Hao et al. 2015). However, some of them, when introduced outside their natural ranges, can spread spontaneously, posing a threat to native biodiversity (Randall 2017; Beringen et al. 2019).



**Figure 1.** *Koenigia divaricata* in Stare Opole near Siedlce, eastern Poland. A. The bushy habit of the species and a fragment of the anthropogenic phytocoenosis in which it grew. B-C. Flowering shoots. Photographs by G. Łazarski; 14 July 2022.

*Koenigia divaricata* (L.) T.M.Schust. & Reveal [syn. *Polygonum divaricatum* L.; *Aconogonon divaricatum* (L.) Nakai; *Persicaria divaricata* (L.) H. Gross] is a perennial herb native to temperate Eastern Asia (Russian Far East and Eastern Siberia, Mongolia, Korea, northern China and Japan) (Steward 1930; Komarov 1936; Li et al. 2003; Smekalova and Ushakova 2004). It usually occurs in steppes, dry meadows and thickets (Li et al. 2003; Ermakov and Krestov 2009; Hilbig and Narantuya 2016; Shagdar and Yadamsuren 2017). It has a bushy habit and grows up to 120 cm in height (Figure 1). The stem is erect, dichotomously branched and glabrous. The leaves are subsessile to petiolate (petiole *ca.* 5 mm), lanceolate or oblong, 5–12 × 0.5–2 cm, glabrous or pilose (on both surfaces), with cuneate or narrowly cuneate base, acute apex, with entire and shortly ciliate margin. The ocrea is tubular, 1–2 cm long, membranous, pilose or glabrous, oblique and dehiscent. The inflorescence is paniculate, with lax, dichotomous branches. The perianth is white, 5-parted and 2.5–3 mm long. The fruits (achenes) are yellow-brown, shiny, broadly ellipsoid, trigonous, 5–6 mm long and distinctly exceed the persistent perianth (Steward 1930; Li et al. 2003). *Koenigia divaricata* can be confused with *K. alpina* (All.) T.M. Schust. & Reveal, but differs from it by having divaricate and glabrous branches. Moreover, the stem of *K. divaricata* is



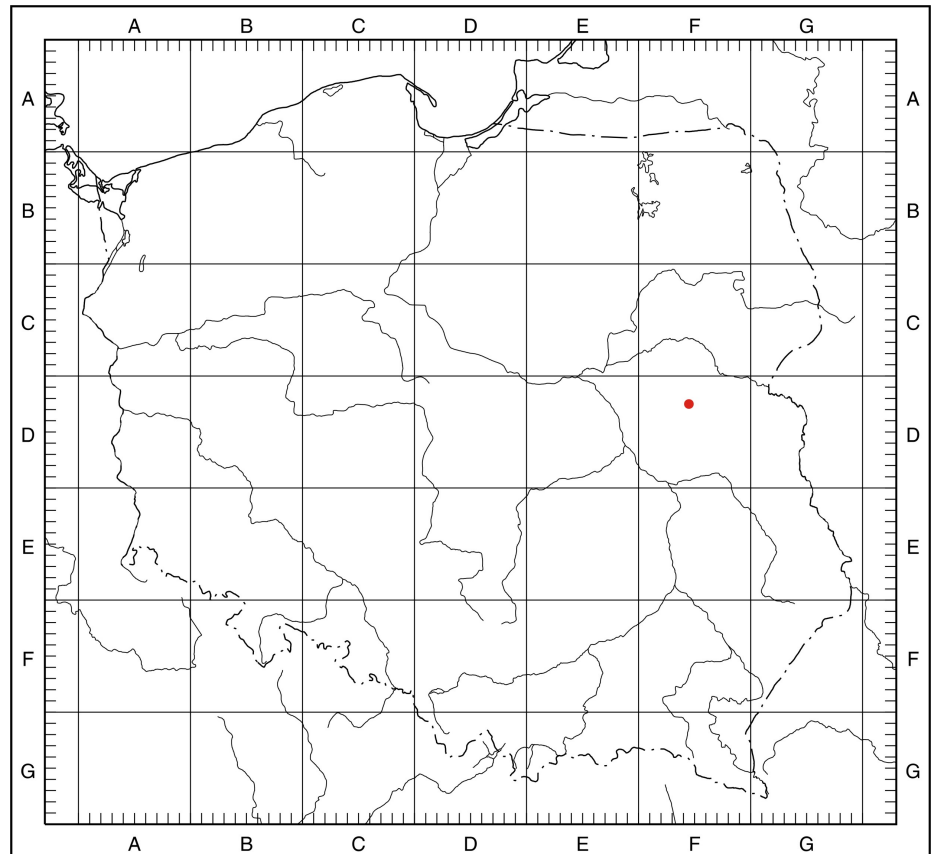
branched from the base, whereas in *K. alpina*, it is branched from above the middle (Li et al. 2003). According to Smekalova and Ushakova (2004), *K. divaricata* is pollinated by wind and its fruits can be dispersed by animals. However, detailed information on what animals are involved in this process is lacking.

*Koenigia divaricata* was introduced to Western and Southern Siberia and Europe (Weidema 2000; Smekalova and Ushakova 2004; Randall 2017; Glazunov et al. 2020; Ebel et al. 2021; Sheremetova et al. 2022). In Europe, it is a rare species, known mainly from its cultivation as an ornamental or fodder plant (Hanelt and Institute of Plant Genetics and Crop Plant Research 2001; Groom 2011; Teleuță et al. 2013; Bondorina et al. 2021; FinBIF 2022). Naturalisation of *K. divaricata* was confirmed in Denmark, Finland, Sweden, Norway and the European part of Russia (Morozova 2014; Weidema 2000; NOBANIS 2022), as well as in Western and Southern Siberia, in Russia (Ebel et al. 2017, 2021; Glazunov et al. 2020; Sheremetova et al. 2022). In Norway, it is treated as an alien species with potentially high impact in constructed sites (Gederaas et al. 2012). Moreover, it was listed among the worst alien species of North-West and Middle Russia, in Tver province, as a naturalised species, known from more than ten sites and abundant in some places (Notov et al. 2011; Vladimirov and Grigoryevskaya 2015). The species successfully spreads along the transport routes in the southern and south-western parts of Siberia: Khakassia, Kuzbas, Tomsk Oblast, south of Krasnoyarsk Krai, inhabiting roadsides, railway embankments, as well as wastelands in their vicinity (Ebel 2004, 2007, 2010; Sheremetova et al. 2011, 2022; Ebel et al. 2017, 2021).

In the spontaneous flora of Poland, only one species of the genus *Koenigia* has been known so far, namely *K. polystachya* (Wall. ex Meisn.) T.M. Schust. & Reveal (Mirek et al. 2020). It is a rare established alien species, treated as regionally invasive (Bartoszek et al. 2006; Tokarska-Guzik et al. 2012, 2021). In this paper, we present the first Polish record of *K. divaricata*.

## Materials and methods

Taxonomic treatment of *Koenigia* followed Schuster et al. (2015). Identification of *K. divaricata* was based on morphological features provided by Li et al. (2003), with the use of some digitized herbarium specimens and photographs of live plants as comparative materials (FinBIF 2022; Seregin 2022). The phytosociological investigation followed Matuszkiewicz (2008) and the Braun-Blanquet method (1964). Names of plant taxa followed POWO (2023) and terminology of alien plants followed Pyšek et al. (2004). A map of the distribution of *K. divaricata* in Poland was prepared using the ATPOL cartogram method (Zajac 1978). Herbarium specimens were deposited in the Herbarium of the Institute of Botany of the Jagiellonian University in Kraków (KRA 616179–616182, 02 Sep 2021, KRA 616177–616178, 14 Jul 2022, *leg.* G. Łazarski, *det.* G. Łazarski & A. Pliszko).



**Figure 2.** Locality of *Koenigia divaricata* in Poland within the ATPOL cartogram grid.

## Results and discussion

*Koenigia divaricata* was found in September 2021 in Stare Opole near Siedlce, southern Podlasie Lowland, eastern Poland (52.173171°N; 22.154204°E; 154 m a.s.l; square FD24 of the ATPOL cartogram grid, Figure 2). The presence of the species at the new locality was confirmed in the next growing season, in July 2022. In 2021, the species formed one, almost spherical cluster, consisting of 12 strongly branching shoots, about 1 m high. A year later, a similar number of shoots was observed in the primary cluster, with an emergence of a new shoot growing about 0.5 m from the primary cluster. The species was recorded in the area adjacent to the railway line (ca. 30 m from the railway track), in a phytocoenosis dominated by the expansive grass *Calamagrostis epigejos* (Relevé 1, Figure 1). In addition, thermophilous fringe species from the *Trifolio-Geranietaea sanguinei* class had a significant share (e.g., *Coronilla varia*, *Geranium sanguineum*, *Galium verum* and *Trifolium medium*). There were also plant species typical of ruderal habitats (e.g., *Saponaria officinalis* and *Solidago gigantea*).

**Relevé 1.** Stare Opole near Siedlce, 52.173171°N; 22.154204°E; 154 m a.s.l; date: July 14, 2022; area of relevé – 25 m<sup>2</sup>; coverage of herb layer (c) – 95%: *Calamagrostis epigejos* 4, *Geranium sanguineum* 2, *Saponaria officinalis* 2, *Arrhenatherum elatius* 1, *Galium album* 1, *Galium verum* 1, *Medicago falcata* 1, *Rumex acetosa* 1, *Veronica chamaedrys* 1, *Agrostis gigantea* +, *Bromus inermis* +,

*Convolvulus arvensis* +, *Coronilla varia* +, *Dactylis glomerata* +, *Euphorbia esula* +, *Hylotelephium maximum* +, *Hypericum perforatum* +, *Jacobaea vulgaris* +, ***Koenigia divaricata*** +, *Lathyrus tuberosus* +, *Lolium pratense* +, *Medicago sativa* +, *Oenothera biennis* +, *Peucedanum oreoselinum* +, *Quercus robur* +, *Silene latifolia* subsp. *alba* +, *Silene vulgaris* +, *Solidago gigantea* +, *Solidago virgaurea* +, *Trifolium medium* +, *Vicia cracca* +, *Viola arvensis* +.

It is difficult to clearly explain how and from where the plant was introduced to the new site. Some authors indicated that *K. divaricata* can spontaneously escape from the place of cultivation or be transported with garden waste, compost or soil containing its diaspores (Groom 2011; FinBIF 2022; NOBANIS 2022). It has been well documented that illegal disposal of garden waste can contribute to the spread of alien plant species in the wild (Rusterholz et al. 2012; Gudžinskas and Taura 2020; Šipek and Šajna 2020). However, the cultivation of *K. divaricata* in private gardens or public green spaces in Siedlce and adjacent areas has not been intensively studied so far. On the other hand, the localisation of the stand near the railroad tracks suggests that the plant may have been introduced by railway transport. This pattern of the *K. divaricata* dispersal was observed in its native range, on railway areas in the Amur section of the Trans-Siberian Railway (Kotenko et al. 2022), as well as in its secondary range in the Tyumen city, Western Siberia (Glazunov et al. 2020) and Kuzbass, Southern Siberia (Ebel 2004; Sheremetova et al. 2022). Following the above-mentioned authors, *K. divaricata* can thrive on railway embankments, rail beds and infiltration trenches. Moreover, many authors have suggested that alien plants can use rail networks as colonization corridors (Rutkowska et al. 2013; Wołkowycki and Banaszuk 2016; Benedetti and Morelli 2017). If *K. divaricata* did not come from Polish cultivation (garden escape or throw-out), it most likely came from Belarus by railway connection between Warsaw, Siedlce and Brest. Some data indicate that the plant is cultivated in Belarus (Hanelt and Institute of Plant Genetics and Crop Plant Research 2001 and references therein). It is also relevant to mention that in Norway, *K. divaricata* inhabits constructed sites (e.g., housing areas, industrial sites sand pits and roads) suggesting that the seeds or vegetative parts of the plant can be dispersed with soil or on construction machinery (Gederaas et al. 2012).

The ecological impacts of *K. divaricata* on species richness and plant communities in Europe are poorly recognised. Nevertheless, considering that the individuals of the species can live for several years and form abundant patches (Notov et al. 2011; Malitskaya et al. 2018a), it might be dangerous for other plant species with low competition capacity. Moreover, experiments conducted in Finnish botanical gardens indicated that *K. divaricata* has a good potential for spread by seeds (Kaukoranta et al. 2019). However, there is a lack of studies that would confirm the persistence of seeds in a soil seed bank, or that would confirm the allelopathic effect of *K. divaricata*. According to Bondorina et al. (2021), *K. divaricata* is a promising ornamental plant

for mass urban landscaping because of its resistance to water deficit as well as resistance to frost. It is particularly recommended to be grown around buildings, on lawns and in flower beds (Malitskaya et al. 2018a). It is also valued for silage, haylage and vitamin-grass dried forage production, especially on soils with a limited moisture content (Teleuță et al. 2013; Malitskaya et al. 2018b). Nevertheless, the cultivation of *K. divaricata* should be controlled to prevent it from escaping into the wild.

Considering the criteria proposed by Pyšek et al. (2004), *K. divaricata* should currently be treated as a casual alien species in Poland; however, its naturalisation is likely due to suitable (temperate) climatic conditions. The plant was found in 2021 and survived the winter. Moreover, it produced fruits that appeared to be well-developed, and from 2021 to 2022, the number of individuals slightly increased. Although *K. divaricata* has not yet been recognised as an invasive alien species of European Union concern (European Commission 2019), its spontaneous spread may pose a threat to native plant species in xerothermic grasslands or urban ruderal habitats due to its adaptation to drought. However, the biology of *K. divaricata* in Europe requires further research, with particular attention to seed production, habitat preferences, seed dispersal patterns, interactions with native species and other factors related to naturalisation and invasion. It is also important to determine the negative impacts of *K. divaricata* on the economy, e.g., whether it is not a source of pathogens that can be transferred to domesticated plants. Finally, due to the insufficient information on alien *Koenigia* species in Central Europe and the possibility of confusion of *K. divaricata* with other closely related species, we present a key to their identification, in accordance with the morphological descriptions provided by Li et al. (2003) and Komarov (1936).

Key to identification of *Koenigia divaricata* and closely related species:

1. Leaves ovate ..... 2
- . Leaves lanceolate or oblong ..... 3
2. Leaves 5–10 × 2–4 cm, ovate or ovate-lanceolate, abase broadly cuneate, margin bristly ciliate, apex acuminate or acute; leaf blade green and nearly glabrous adaxially, greenish and pubescent abaxially; petioles 3–4 mm ..... *K. coriaria*
- . Leaves 12–20 × 10–15 cm, ovate to broad-ovate, acute; leaf blade glabrous adaxially, almost white with dense tomentum abaxially; petioles *ca.* 2 cm ..... *K. weyrichii*
3. Stems branched from above middle, usually sparsely hirsute; branches not divaricate; leaves 3–9 × 1–3 cm, ovate-lanceolate or lanceolate, base broadly cuneate; petiole 5–10 mm ..... *K. alpina*
- . Stems branched from base, glabrous; branches divaricate; leaves 5–12 × 0.5–2 cm, lanceolate or oblong, base cuneate or narrowly cuneate; petiole *ca.* 5 mm ..... *K. divaricata*

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## Authors' contribution

GL: research conceptualization, methodology, investigation and data collection, writing original draft, AP: research conceptualization, methodology, investigation and data collection, writing original draft.

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