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Short Communication

Toxin-free honey despite the alien *Senecio inaequidens* DC. invasion – a pilot study

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Abstract

Senecio inaequidens, a fast-spreading perennial herb native to Southern Africa, is increasingly common in disturbed habitats across Europe, including urban areas. This species contains pyrrolizidine alkaloids (PAs), natural toxins harmful to humans and animals. In this pilot study, we investigated the potential for PA contamination in honey from hives located near large *S. inaequidens* populations in Prague, Czechia. Pollen analysis of honey, hive-stored pollen and honeycomb samples indicated a low and infrequent presence of Asteraceae-type pollen, which could be, but not definitively, attributed to *S. inaequidens*. Chemical analysis using liquid chromatography–mass spectrometry (LC-MS) detected trace amounts of the PA echimidin in three honey samples, likely originating from *Echium vulgare*. No other PAs were detected above quantifiable levels. Our findings suggest that, under current conditions, *S. inaequidens* contributes minimally to PA contamination in honey and does not present a significant health risk. However, potential shifts in flowering phenology warrant continued monitoring to assess future risks.

Key words: Health impact, narrow-leaved ragwort, non-native plant, pollen analysis, pyrrolizidine alkaloids

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Introduction

Invasive species represent a substantial threat to global ecosystems – they degrade natural habitats, cause economic losses or influence human health (Pyšek et al. 2020; Bacher et al. 2024). A notable example in Europe is *Senecio inaequidens* (Asteraceae), an invasive plant that forms dense stands and spreads quickly along disturbed sites, such as roadsides and railways (Ernst 1998; Heger and Böhmer 2009; Vacchiano et al. 2013; Kaplan et al. 2018; Kutlvašr et al. 2024).

Senecio inaequidens DC., also known as Narrow-leaved Ragwort or South African Ragwort, is a perennial herb reaching a height of 30–100 cm. The plant has a shallow taproot; the stems are erect and branched from the base, covered by alternate and narrow leaves, ca. 2–10 cm in length and up to 1 cm in width. It usually flowers from June to November in Central Europe. The flowers are arranged in capitula with a diameter of 15–25 mm, forming a corymbose panicle. Each capitulum contains 10–15 male ray florets, characterised by a 5–8 mm long golden-yellow ligule and 80

bisexual disc florets. The fruit is a cylindrical achene, 3 mm long, with a short, dense covering of hairs (Hilliard 1977; Grulich 2004; Jäger et al. 2013; Kaplan et al. 2019).

It is native to southern Africa (Werner et al. 1991; Grulich 2004; Heger and Böhmer 2009). The first occurrence in Europe is associated with wool-processing facilities in the late 19th and early 20th centuries (Kuhbier 1977; Ernst 1998; EPPO 2006; Heger and Böhmer 2009). In the secondary range, it colonises various ecological habitats, encompassing dry to moist, stony to clay soils and exposed and partially shaded sites (Werner et al. 1991; Adolphi 1997). In its native habitat, it grows on grassy, steep slopes, but also on streambanks from 1400 to 2850 m a.s.l. (Hilliard 1977; Werner et al. 1991). Across Europe, it mainly occupies warm, sandy or gravelly disturbed soils along transportation corridors and in other open habitats, for example, abandoned industrial sites, quarries or logged areas (Werner et al. 1991; Hard 1993; Radkowitsch 1997; Mückschel 2000; Bornkamm 2002; Blanchet et al. 2015; Kaplan et al. 2018). However, it has also been observed to penetrate semi-natural habitats (Brandes 1999; Scherber et al. 2003), where it can compete with some native species (Quaglini et al. 2025). The consequences of climate change, such as mild winters and warm, dry growing seasons, may facilitate the further spread of this species in Europe (Nehring et al. 2013).

In addition to the ecological risk, *S. inaequidens* contains a set of pyrrolizidine alkaloids (PAs), natural plant toxins found in 3% of all flowering plants from a total of 13 families (e.g. Asteraceae, Boraginaceae, Fabaceae, Rhamnaceae) (Smith and Culvenor 1981). A total of nine PAs were found in *S. inaequidens* plants, for example, integerrimine, retrorsine, senecionine, seneciphylline, senecivernine and usaramine (Röder et al. 1981; Bicchi et al. 1985; Eller and Chizzola 2016). The highest concentration of PAs was found in young shoots and inflorescences (Eller and Chizzola 2016).

PAs themselves are not directly toxic to vertebrates. After ingestion, they are metabolised in the liver to reactive pyrrole derivatives that bind to DNA and proteins, causing liver cell death, progressive cirrhosis and eventually liver failure (Mattocks 1986; Johnson et al. 1989). Some PAs are known to be mutagenic and genotoxic (Rubiolo et al. 1992). Furthermore, the significant influence on the metamorphosis of *Hymenoptera* was also proven (Heneberg et al. 2025).

PAs can enter the human food chain most often through contamination of agricultural products by weeds or from food supplements and traditional medicinal products, typically some types of teas (BfR 2013b). Livestock can be intoxicated by direct ingestion of fresh plants and dried forage (Johnson et al. 1989; Stewart and Steenkamp 2001; Stegelmeier 2011; Wiedenfeld 2011). The PAs and their residuals are also transferred further to animal products, as has been reported for eggs (Edgar and Smith 2000) or milk (Panter and James 1990; Mulder et al. 2020; Kalač and Kaltner 2021).

The PAs are commonly reported also in honey (and foods containing honey) from the nectar and pollen of toxic plants (Edgar et al. 2002). Their quantities are sometimes very high, reaching tens to hundreds, sometimes even thousands of µg/kg of honey (Kempf et al. 2008, 2010, 2011; Dübecke et al. 2011; BfR 2013a; Griffin et al. 2013; Kast et al. 2014; EFSA 2016; Neumann and Huckauf 2016). Such honey poses a health risk, especially if honey containing PAs is consumed over a long period, leading to liver damage, fibrosis and increased risk of cancer (Mattocks 1986; Wiedenfeld and Edgar 2011). According to the

German Federal Institute for Risk Assessment, daily doses should not exceed 0.007 µg/kg body weight (BfR 2013a).

In our pilot study, we studied the content of PAs in honey and the presence of *S. inaequidens* pollen from hives situated near large invasion sites. The aim was to determine if PAs could be transferred to honey, thereby posing a health risk to consumers.

Materials and methods

In this study, we examined the occurrence of pollen grains and the presence and concentration of pyrrolizidine alkaloids (PAs) in honey, hive-stored pollen and honeycomb from hives. The hives were situated at two localities in Prague (Czechia; hive 1–50.0504°N, 14.5348°E, hive 2–50.1237°N, 14.3934°E) where *S. inaequidens* is widespread (Fig. 1).

Five honey samples, one sample of pollen and one honeycomb sample from a hive were analysed. Furthermore, a reference sample of *S. inaequidens* flowers was collected to determine the pollen grains. The honey samples were collected at various times to encompass the entire growing season. Samples further referred to a form: hive month/year, for example, hive 1 VII/19. See Table 1 for details.

To confirm the presence of *S. inaequidens* pollen grains, all collected samples were analysed in December 2019. The samples were processed using a standard acetylation method (Moore et al. 1991). Pollen grains were identified using a light micro-

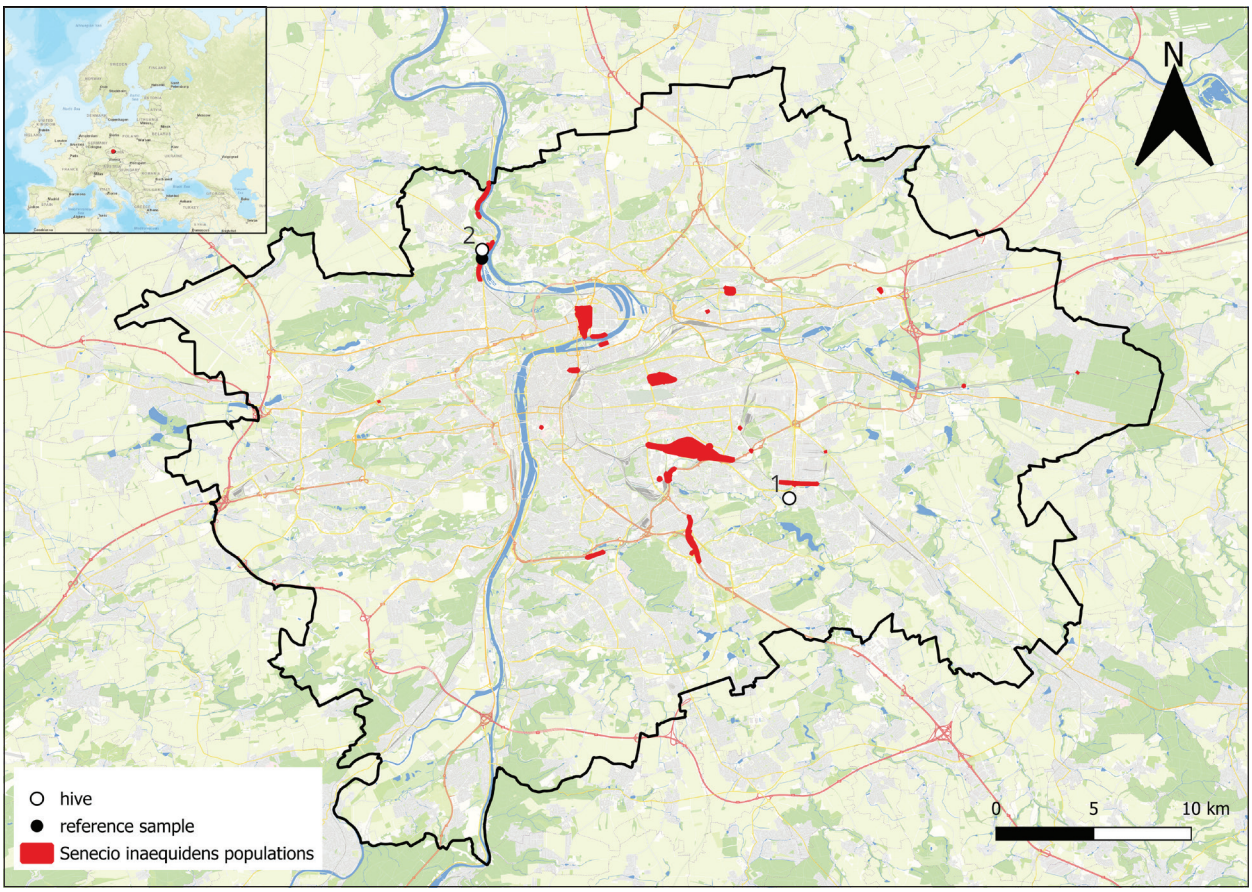


Figure 1. The map of study hives and distribution of *S. inaequidens* in Prague. The red polygons represent the populations of *S. inaequidens* (2019). White points indicate two hives located near large populations. The black point shows the location of the pollen reference sample collection.

Table 1. Overview of the investigated samples. The pollen samples were not undergoing PA analysis due to the low representation of Asteraceae/Senecio type in the pollen analysis found. See Supplementary Material 1 for protocols of PA analyses.

Sample	Date of sampling	Pollen analysis	PA analysis	Type of material	Coordinates
hive 1 VIII/19 pollen	August 2019	yes	no	hive-stored pollen	50.0504°N, 14.5348°E
hive 1 VIII/19 combs	August 2019	yes	no	honeycomb	50.0504°N, 14.5348°E
hive 1 VII/19 honey	July 2019	yes	protocol no. 31/20	honey	50.0504°N, 14.5348°E
hive 2 V/18 honey	May 2018	yes	no	honey	50.1237°N, 14.3934°E
hive 2 V/19 honey	May 2019	yes	protocol no. 28/20	honey	50.1237°N, 14.3934°E
hive 2 VII/19 honey	July 2019	yes	protocol no. 29/20	honey	50.1237°N, 14.3934°E
hive 2 VIII/19 honey	August 2019	yes	protocol no. 30/20	honey	50.1237°N, 14.3934°E
pollen reference sample	August 2019	yes	no	inflorescence	50.1221°N, 14.3938°E

scope and palynological keys (Moore et al. 1991; Beug 2004). We used this method due to the low number of samples and its robustness to possible contamination by non-pollen particles, whereas some other methods (e.g., metabarcoding) could show false positives and noise. As *S. inaequidens* pollen grains are not morphologically distinct from those of other species of the *Senecio* genus or similar Asteraceae (Beug 2004), we classified them under a general "Aster/Senecio" pollen type (Fig. 2).

The presence and quantitative content of PAs were determined using liquid chromatography coupled with mass spectrometry (LC-MS) in January 2020 (Crews et al. 2010; Kempf et al. 2011; Fuente-Ballesteros et al. 2024). A total of 29 different PAs of four honey samples were analysed, including PA-*N*-oxides (see Table 1 and Suppl. material 1 for laboratory protocols; Dzuman et al. (2020)).

Results

Pollen analysis

In total, seven samples were analysed. The honey samples had only a low concentration of pollen grains and crystallised sugar was visible. The Aster/Senecio pollen type was found only in one sample in small quantities (hive-stored pollen from hive 1 VIII/19). For details, see the pollen diagram in Fig. 3.

Honey samples analysis

We investigated 29 PAs or their *N*-oxides that could originate from *S. inaequidens* or other species, but the analysis did not show any such alkaloids, except for echimidin. Echimidin was detected in three samples in low concentrations rang-

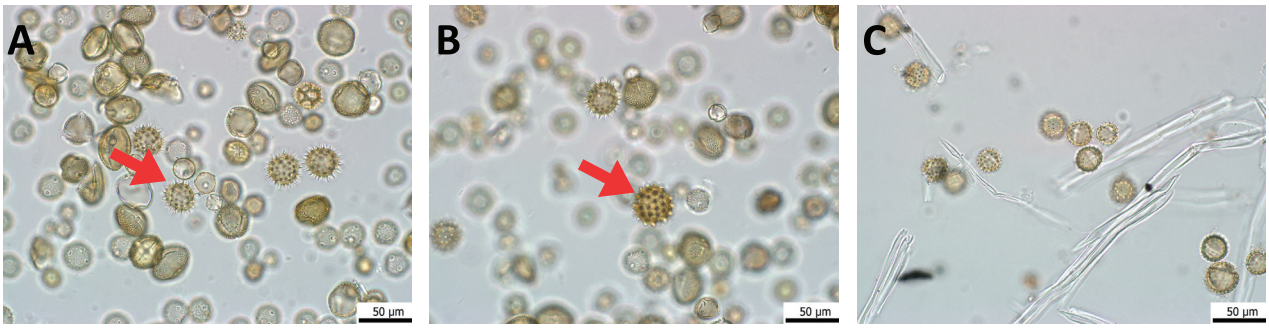


Figure 2. Possible occurrence of *S. inaequidens* pollen grains (marked by the red arrows) obtained from hive 1 VIII/19 pollen (**A, B**) and reference sample acquired from capitula of *S. inaequidens* (**C**).

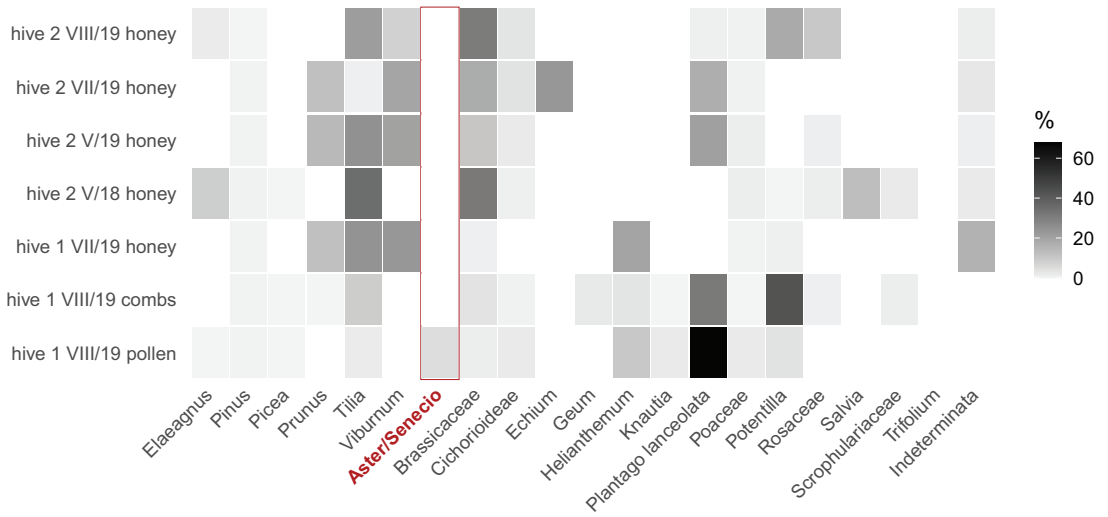


Figure 3. Pollen diagram of the samples, with the Aster/Senecio pollen type shown in red. The average proportion of pollen grains across samples was 331. The number of PA analysis protocols for the investigated sample is shown in Table 1.

ing between 1–7 µg/kg: 1 (p. no. 30/20), 2 (p. no. 31/20) and 7 (p. no. 29/20) (Suppl. material 1).

Discussion

The probable pollen type corresponding to the *S. inaequidens* was detected only in the pollen sample in a very low concentration. The pollen type Aster/Senecio, which could also correspond to the species *S. inaequidens*, was occasionally detected in other samples, but due to the variability of the pollen type of the Asteraceae family, its further occurrence in the samples is unlikely (Fig. 3, Indeterminata group; Beug (2004); Halbritter and Auer (2021)). Based on the pollen spectrum (Fig. 3), we suppose that bees preferred honeydew from flowering woody plants as their main food source. The only comparable study that can be related to *S. inaequidens* is a study on *S. jacobaea* (Kempf et al. 2011), where minimal Senecio-type pollen in honey (0–6.3%) was found, aligning with our results.

All investigated PAs were below the limit of detection except for echimidin. In addition, echimidin was found only in low concentrations. The source of echimidin is most likely *Echium vulgare*, which was found to be abundant in the vicinity of the studied sites. This finding corresponds with pollen analysis (hive 2 VII/19), which also reveals the presence of *Echium* pollen type. *Echium vulgare* is considered to be one of the major reasons for PA contamination in honey (Dübecke et al. 2011; Kempf et al. 2011). We must also add that nectar appears to be a more significant source of PAs in honey than pollen in the case of *E. vulgare* (Lucchetti et al. 2016).

As regards PAs in honey originating from *S. inaequidens*, the risk of contamination will increase significantly if *S. inaequidens* starts flowering earlier than before. In early spring, other sources of honeydew and pollen are scarce and bees may use alternative sources such as *S. inaequidens*. Over the past twenty years, S. inaequidens has begun to bloom in June or July (Grulich 2004; Jäger et al. 2013; Kaplan et al. 2019), whereas in recent years, it has already been blooming in May (Heneberg et al. 2025). In warmer parts of Central Europe, still-flowering overwintering stems have

already been observed in February (Karlík et al. 2020; Suppl. material 2). Autumn flowering, on the other hand, may not pose as a significant risk as many beekeepers leave the honey from the last honey flow with the bees to help them overwinter and, therefore, it does not enter circulation (Sammataro and Avitabile 1998).

Not only the amount, but also the distance of the forage from the hive or the landscape structure can play a significant role. Bees typically use resources from up to about 3 km, but if the forage is dense enough, they usually travel shorter distances (Beekman and Ratnieks 2000; Danner et al. 2016). These studies suggest that the location of hives for studying the content of PAs in honey and pollen should be in the immediate vicinity of the population of the studied species, so that it is offered to the bees as the most easily accessible forage.

In conclusion, we did not find a significant amount of pollen grains in the honey over the season, nor did we find the PAs originating from *S. inaequidens*. Even though the hives were located close to large populations of *S. inaequidens*, the pollen/PAs content in the analysed samples can be described as negligible, not posing a health risk to humans. However, it can be stated that the current flowering phenology of *S. inaequidens* minimises the potential negative impact on human health. As the phenology is slowly changing, the PAs and pollen in honey need to be monitored.

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

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Author contributions

Conceptualization: PK. Data curation: PK, LP. Formal analysis: LP. Methodology: PK. Supervision: JP. Validation: JK. Visualization: PV, KK. Writing – original draft: KK, JK. Writing – review and editing: JP, PV.

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Data availability

All of the data that support the findings of this study are available in the main text or Supplementary Information.

References

Adolphi K (1997) Anmerkungen zu *Senecio inaequidens* DC. nach einem Aufenthalt in Südafrika. Floristische Rundbriefe 31: 162–167.

Bacher S, Galil BS, Nuñez MA, Ansong M, Cassey P, Dehnen-Schmutz K, Fayvush G, Hiremath AJ, Ikegami M, Martinou AF, McDermott SM, Preda C, Vilà M, Weyl OLF, Fernandez RD, Ryan-Colton E (2024) Chapter 4. Impacts of invasive alien species on nature, nature's contributions to people, and good quality of life. In: Roy HE, Pauchard A, Stoett P, Renard Truong T (Eds) Thematic Assessment Report on Invasive Alien Species and their Control of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. IPBES secretariat, Bonn, Germany. https://doi.org/10.5281/zenodo.7430731

Beekman M, Ratnieks FLW (2000) Long-range foraging by the honey-bee, *Apis mellifera* L. Functional Ecology 14: 490–496. https://doi.org/10.1046/j.1365-2435.2000.00443.x

Beug H (2004) Leitfaden der Pollenbestimmung für Mitteleuropa und angrenzende Gebiete. Verlag Friedrich Pfeil (Munich), 1–542.

BfR (2013a) Analytik und Toxizität von Pyrrolizidinalkaloiden sowie eine Einschätzung des gesundheitlichen Risikos durch deren Vorkommen in Honig. Bundesinstitut für Risikobewertung, 1–37.

BfR (2013b) Pyrrolizidinalkaloide in Kräutertees und Tees. Bundesinstitut für Risikobewertung, 1–31.

Bicchi C, D'Amato A, Cappelletti E (1985) Determination of pyrrolizidine alkaloids in *Senecio inaequidens* DC. by capillary gas chromatography. Journal of Chromatography A 349: 23–29. https://doi.org/10.1016/S0021-9673(00)90628-9

Blanchet É, Penone C, Maurel N, Billot C, Rivallan R, Risterucci A-M, Maurice S, Justy F, Machon N, Noël F (2015) Multivariate analysis of polyploid data reveals the role of railways in the spread of the invasive South African Ragwort (*Senecio inaequidens*). Conservation Genetics 16: 523–533. https://doi.org/10.1007/s10592-014-0676-y

Bornkamm R (2002) On the phytosociological affiliations of an invasive species *Senecio inaequidens* in Berlin. Preslia 74: 395–407.

Brandes D (1999) *Senecio inaequidens* am Monte Baldo. Abhandlungen des Naturwissenschaftlichen Vereins zu Bremen 44: 245–256.

Crews C, Berthiller F, Krska R (2010) Update on analytical methods for toxic pyrrolizidine alkaloids. Analytical and Bioanalytical Chemistry 396: 327–338. https://doi.org/10.1007/s00216-009-3092-2

Danner N, Molitor AM, Schiele S, Härtel S, Steffan-Dewenter I (2016) Season and landscape composition affect pollen foraging distances and habitat use of honey bees. Ecological Applications 26: 1920–1929. https://doi.org/10.1890/15-1840.1

Dübecke A, Beckh G, Lüllmann C (2011) Pyrrolizidine alkaloids in honey and bee pollen. Food Additives & Contaminants 28: Part A: 348–358. https://doi.org/10.1080/19440049.2010.541594

Dzuman Z, Jonatova P, Stranska-Zachariasova M, Prusova N, Brabenec O, Novakova A, Fenclova M, Hajslova J (2020) Development of a new LC-MS method for accurate and sensitive determination of 33 pyrrolizidine and 21 tropane alkaloids in plant-based food matrices. Analytical and Bioanalytical Chemistry 412: 7155–7167. https://doi.org/10.1007/s00216-020-02848-6

Edgar JA, Smith LW (2000) Transfer of pyrrolizidine alkaloids into eggs: food safety implications. In: Tu AT, Gaffield W (Eds) Natural and selected synthetic toxins. ACS Publications: 118–128. https://doi.org/10.1021/bk-2000-0745.ch008

Edgar JA, Roeder E, Molyneux RJ (2002) Honey from plants containing pyrrolizidine Alkaloids: A Potential Threat to Health. Journal of Agricultural and Food Chemistry 50: 2719–2730. https://doi.org/10.1021/jf0114482

EFSA [European Food Safety Authority] (2016) Dietary exposure assessment to pyrrolizidine alkaloids in the European population. EFSA Journal 14: e04572. https://doi.org/10.2903/j.efsa.2016.4572

Eller A, Chizzola R (2016) Seasonal variability in pyrrolizidine alkaloids in *Senecio inaequidens* from the Val Venosta (Northern Italy). Plant Biosystems - An International Journal Dealing with all Aspects of Plant Biology 150: 1306–1312. https://doi.org/10.1080/11263504.2015.1054449

EPPO (2006) EPPO data sheet on Invasive Plants. *Senecio inaequidens*. http://www.eppo.org/

Ernst W (1998) Invasion, dispersal and ecology of the South African neophyte *Senecio inaequidens* in The Netherlands: from wool alien to railway and road alien. Acta Botanica Neerlandica 47: 131–151.

Fuente-Ballesteros A, Brabenec O, Tsagkaris AS, Ares AM, Hajslova J, Bernal J (2024) Comprehensive overview of the analytical methods for determining pyrrolizidine alkaloids and their derived oxides in foods. Journal of Food Composition and Analysis 125: 105758. https://doi.org/10.1016/j.jfca.2023.105758

Griffin CT, Danaher M, Elliott CT, Glenn Kennedy D, Furey A (2013) Detection of pyrrolizidine alkaloids in commercial honey using liquid chromatography–ion trap mass spectrometry. Food Chemistry 136: 1577–1583. https://doi.org/10.1016/j.foodchem.2012.02.112

Grulich V (2004) Senecio L. – starček. In: Slavík B, Štěpánková J, Štěpánek J (Eds) Květena České republiky. Academia, Praha, 250–280.

Halbritter H, Auer W (2021) *Senecio inaequidens*. https://www.paldat.org/pub/Senecio_inaequidens/306177;jsessionid=B442E04F4977A8BBE302659D6FB5D40B

Hard G (1993) Neophyten und neophytenreiche Pflanzengesellschaften auf einem Werksgelände (VSG, ehem. Klöckner) in Osnabrück. *Apera interrupta*, *Euphorbia supina*, *Hordeum jubatum*, *Inula graveolens*, *Senecio inaequidens* un Konsorten. Natur und Heimat 53: 1–16.

Heger T, Böhmer HJ (2009) Nobanis – invasive alien species fact sheet *Senecio inaequidens*.

Heneberg P, Bogusch P, Černý J, Žáček P, Karlík P (2025) Invasive plant serves as an important complementary food resource for diverse pollinators in anthropogenic environments at the end of the flowering season. Agriculture, Ecosystems & Environment 387: 109627. https://doi.org/10.1016/j.agee.2025.109627

Hilliard OM (1977) Compositae in Natal. University of Natal Press (Pietermaritzburg): 360–361.

Jäger EJ, Müller F, Ritz C, Welk E, Wesche K [Eds] (2013) Rothmaler-Exkursionsflora von Deutschland, Gefäßpflanzen: Atlasband. 12th edn. Springer-Verlag, Berlin, Heidelberg. https://doi.org/10.1007/978-3-8274-2723-6

Johnson AE, Molyneux RJ, Ralphs MH (1989) *Senecio*: A dangerous plant for man and beast. Society for Range Management.

Kalač P, Kaltner F (2021) Pyrrolizidine alkaloids of European *Senecio*/*Jacobaea* species in forage and their carry-over to milk: A review. Animal Feed Science and Technology 280: 115062. https://doi.org/10.1016/j.anifeedsci.2021.115062

Kaplan Z, Danihelka J, Chrtek J, Prančl J, Ducháček M, Ekrt L, Kirschner J, Brabec J, Zázvorka J, Trávníček B, Dřevojan P, Šumberová K, Kocián P, Wild J, Petřík P (2018) Distributions of

vascular plants in the Czech Republic. Part 7. Preslia 90: 425–531. https://doi.org/10.23855/preslia.2018.425

Kaplan Z, Danihelka J, Chrtek J jun, Kirschner J, Kubát K, Štech M, Štěpánek J, Batoušek P, Bureš P, Businský R, Čáp J, Dančák M, Ducháček M, Duchoslav M, Dvořák V, Ekrt L, Filippov P, Grulich V, Hrčka D, Hroneš M, Hrouda L, Hroudová Z, Jehlík V, Kabátová K, Király G, Kirschnerová L, Kobrlová L, Kočí K, Koutecký P, Krahulec F, Kúr P, Lepší M, Lepší P, Mandák B, Ponert J, Prančl J, Pyšek P, Řepka R, Sádlo J, Suda J, Šída O, Šmarda P, Špryňar P, Štěpánková J, Trávníček B, Trávníček P, Uher J, Vašut RJ, Větvička V, Zázvorka J, Zelený V (2019) Klíč ke květeně České republiky. Academia.

Karlík P, Větvička I, Kugler V (2020) Senecio inaequidens – Mapping, risk assessment and management. – Ms., 78–78. [depon. in: Prague City Hall, Prague]

Kast C, Dübecke A, Kilchenmann V, Bieri K, Böhlen M, Zoller O, Beckh G, Lüllmann C (2014) Analysis of Swiss honeys for pyrrolizidine alkaloids. Journal of Apicultural Research 53: 75–83. https://doi.org/10.3896/IBRA.1.53.1.07

Kempf M, Schreier P, Reinhard A, Beuerle T (2010) Pyrrolizidinalkaloide in Honig und Pollen. Journal für Verbraucherschutz und Lebensmittelsicherheit 5: 393–406. https://doi.org/10.1007/s00003-009-0543-9

Kempf M, Wittig M, Schönfeld K, Cramer L, Schreier P, Beuerle T (2011) Pyrrolizidine alkaloids in food: downstream contamination in the food chain caused by honey and pollen. Food Additives & Contaminants: Part A 28: 325–331. https://doi.org/10.1080/19440049.2010.521771

Kempf M, Beuerle T, Bühringer M, Denner M, Trost D, von der Ohe K, Bhavanam VBR, Schreier P (2008) Pyrrolizidine alkaloids in honey: Risk analysis by gas chromatography-mass spectrometry. Molecular Nutrition & Food Research 52: 1193–1200. https://doi.org/10.1002/mnfr.200800051

Kuhbier H (1977) *Senecio inaequidens* DC. - ein Neubuerger der nordwestdeutschen Flora. Abhandlungen Naturwissenschaftlicher Verein zu Bremen 38: 383–396.

Kutlvašr J, Turková S, Hejda M, Vojík M, Kadlecová M, Berchová Bímová K, Pyšek P, Pergl J (2024) Railways as a source of alien plants. Preslia 96: 247–266. https://doi.org/10.23855/preslia.2024.247

Lucchetti MA, Glauser G, Kilchenmann V, Dübecke A, Beckh G, Praz C, Kast C (2016) Pyrrolizidine alkaloids from *Echium vulgare* in honey originate primarily from floral nectar. Journal of Agricultural and Food Chemistry 64: 5267–5273. https://doi.org/10.1021/acs.jafc.6b02320

Mattocks A (1986) Chemistry and toxicology of pyrrolizidine alkaloids. Academic Press (London): 1–393.

Moore PD, Webb JA, Collison ME (1991) Pollen analysis. Blackwell Scientific Publications: 1–216.

Mückschel C (2000) Floristische Beobachtungen in aufgelassenen Steinbrüchen des Rheinischen Westerwaldes. Decheniana 153: 59–67. https://doi.org/10.21248/decheniana.v153.4539

Mulder PPJ, Klijnstra MD, Goselink RMA, Van Vuuren AM, Cone JW, Stoopen G, Hoogenboom RLAP (2020) Transfer of pyrrolizidine alkaloids from ragwort, common groundsel and viper's bugloss to milk from dairy cows. Food Additives & Contaminants: Part A 37: 1906–1921. https://doi.org/10.1080/19440049.2020.1798028

Nehring S, Kowarik I, Rabitsch W, Essl F (2013) Nature conservation risk assessment of invasive, potentially invasive and wild alien plant species in Germany. Bundesamt für Naturschutz 352: 1–202.

Neumann H, Huckauf A (2016) Jakobs-Kreuzkraut (*Senecio jacobaea*): eine Ursache für Pyrrolizidin-Alkaloide im Sommerhonig? Journal für Verbraucherschutz und Lebensmittelsicherheit 11: 105–115. https://doi.org/10.1007/s00003-015-0986-0

Panter KE, James LF (1990) Natural plant toxicants in milk: a review. Journal of Animal Science 68: 892–904. https://doi.org/10.2527/1990.683892x

Pyšek P, Hulme PE, Simberloff D, Bacher S, Blackburn TM, Carlton JT, Dawson W, Essl F, Foxcroft LC, Genovesi P, Jeschke JM, Kühn I, Liebhold AM, Mandrak NE, Meyerson LA, Pauchard A, Pergl J, Roy HE, Seebens H, Van Kleunen M, Vilà M, Wingfield MJ, Richardson DM (2020) Scientists' warning on invasive alien species. Biological Reviews 95: 1511–1534. https://doi.org/10.1111/brv.12627

Quaglini LA, Yannelli FA, Fasano F, Montagnani C, Caronni S, Citterio S, Gentili R (2025) Abiotic and biotic factors shape the invasion success of the alien plant species *Senecio inaequidens* (Asteraceae) in Northern Italy. Journal of Plant Ecology 18(3): rtaf035. https://doi.org/10.1093/jpe/rtaf035

Radkowitsch A (1997) *Senecio inaequidens* DC. – ein Beitrag zur Verbreitung in Deutschland unter besonderer Berücksichtigung von Bayern. Hoppea 58: 389–404.

Röder E, Wiedenfeld H, Stengl P (1981) Die Pyrrolizidinalkaloide Senecionin und Retrorsin aus *Senecio inaequidens*. Planta Medica 41: 412–413. https://doi.org/10.1055/s-2007-971740

Rubiolo P, Pieters L, Calomme M, Bicchi C, Vlietinck A, Vanden Berghe D (1992) Mutagenicity of pyrrolizidine alkaloids in the *Salmonella typhimurium*/mammalian microsome system. Mutation Research Letters 281: 143–147. https://doi.org/10.1016/0165-7992(92)90050-R

Sammataro D, Avitabile A (1998) The Beekeeper's Handbook. Cornell University Press, 1–210.

Scherber C, Crawley MJ, Porembski S (2003) The effects of herbivory and competition on the invasive alien plant *Senecio inaequidens* (Asteraceae). Diversity and Distributions 9: 415–426. https://doi.org/10.1046/j.1472-4642.2003.00049.x

Smith L, Culvenor C (1981) Plant sources of hepatotoxic pyrrolizidine alkaloids. Journal of Natural Products 44: 129–152. https://doi.org/10.1021/np50014a001

Stegelmeier BL (2011) Pyrrolizidine alkaloid-containing toxic plants (*Senecio*, *Crotalaria*, *Cynoglossum*, *Amsinckia*, *Heliotropium*, and *Echium* spp.). Veterinary Clinics of North America: Food Animal Practice 27: 419–428. https://doi.org/10.1016/j.cvfa.2011.02.013

Stewart MJ, Steenkamp V (2001) Pyrrolizidine poisoning: A neglected area in human toxicology. Therapeutic Drug Monitoring 23: 698–708. https://doi.org/10.1097/00007691-200112000-00018

Vacchiano G, Barni E, Lonati M, Masante D, Curtaz A, Tutino S, Siniscalco C (2013) Monitoring and modeling the invasion of the fast spreading alien *Senecio inaequidens* DC. in an alpine region. Plant Biosystems – An International Journal Dealing with all Aspects of Plant Biology 147: 1139–1147. https://doi.org/10.1080/11263504.2013.861535

Werner DJ, Rockenbach T, Hölscher M-L (1991) Herkunft, Ausbreitung, Vergesellschaftung und Ökologie von *Senecio inaequidens* DC. unter besonderer Berücksichtigung des Köln-Aachener Raumes. Tuexenia: Mitteilungen der Floristisch-Soziologischen Arbeitsgemeinschaft 11: 73–107.

Wiedenfeld H (2011) Plants containing pyrrolizidine alkaloids: toxicity and problems. Food Additives & Contaminants: Part A 28: 282–292. https://doi.org/10.1080/19440049.2010.541288

Wiedenfeld H, Edgar J (2011) Toxicity of pyrrolizidine alkaloids to humans and ruminants. Phytochemistry Reviews 10: 137–151. https://doi.org/10.1007/s11101-010-9174-0

Supplementary material 1

Supplementary information 1

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Data type: pdf

Explanation note: Original laboratory protocols covered 29 PAs or their *N*-oxides in honey samples that could originate from *S. inaequidens*. Výsledek=Result, Jednotky=Units, Zkušební metoda=-Method.

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Link: https://doi.org/10.3897/neobiota.106.175238.suppl1

Supplementary material 2

Supplementary information 2

Authors: Petr Karlík, Josef Kutlvašr, Klára Kušková, Libor Petr, Pavla Vachová, Jan Pergl
Data type: jpg
Explanation note: Overwintering stems of *S. inaequidens* that were observed blooming in February 2020.
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