Gorteria – Dutch Botanical Archives 42, 2020: 001–018
ISSN (online) 2542-8578

Artemisia princeps L. (Asteraceae), an overlooked invasive Far Eastern weed in Western Europe

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Key words

Artemisia
Asteraceae
invasive species
Belgium
Netherlands
taxonomy

Abstract – *Artemisia princeps*, originally native to eastern Asia (China, Japan, and Korea), has been present since at least two decades in several localities in Belgium and the Netherlands. It is in many respects intermediate between native *A. vulgaris* and introduced *A. verlotiorum* and, as a result, passed unnoticed for quite a long time. Diagnostic features of these three species as well as of *A.* ×*wurzellii* (a hybrid of *A. vulgaris* × *A. verlotiorum* parentage) are thoroughly discussed and illustrated. *A. princeps* produces – in contrast with *A. verlotiorum* – viable seed in Western Europe. Hence, it is able to reproduce both clonally and sexually and is potentially a bigger threat to native biodiversity than *A. verlotiorum*. Most of the large populations of the latter in the study area turned out to belong to *A. princeps* instead. Genuine *A. verlotiorum* appears to be – at least at present – at the edge of the species' climatic range in Belgium and the Netherlands. Compared with *A. princeps* it is much more widely distributed in an increasing number of localities in both countries, but usually occurs in rather discrete populations.

Samenvatting – *Artemisia princeps*, oorspronkelijk afkomstig uit Oost-Azië (China, Japan en Korea), komt sinds minstens twee decennia op verschillende plaatsen in België en Nederland voor. De soort is in veel opzichten intermediair tussen inheemse *A. vulgaris* en ingevoerde *A. verlotiorum* en bleef allicht daardoor gedurende lange tijd onopgemerkt. Diagnostische kenmerken van deze drie soorten alsook van *A.* ×*wurzellii* (de hybride *A. vulgaris* × *A. verlotiorum*) worden uitvoerig besproken en geïllustreerd. *Artemisia princeps* produceert – in tegenstelling tot *A. verlotiorum* – zaad in West-Europa. Hij is dus in staat om zich zowel klonaal als seksueel te vermeerderen en is daardoor mogelijk een grotere bedreiging voor de natuurlijke biodiversiteit dan *A. verlotiorum*. Nogal wat grote populaties van deze laatste in het studiegebied bleken in feite tot *A. princeps* te behoren. Klimatologisch gezien bevindt *A. verlotiorum* zich bij ons momenteel wellicht aan de noordrand van zijn potentieel secondair areaal. In vergelijking met *A. princeps* komt *A. verlotiorum* zowel in België als Nederland in een veel groter en toenemend aantal plaatsen voor, maar zijn groeiplaatsen zijn doorgaans veel bescheidener.

Published on 28 January 2020

INTRODUCTION

The genus *Artemisia* L. (Anthemideae, Asteraceae) is most widely distributed in the northern hemisphere with only few species in Africa and South America. Two major centres of diversity for the genus are discernible, one located in Eurasia (Ling 1992) and the other – of a slightly lesser importance – in Western North America (Riggins & Seigler 2012). Only five species are native (or at least archaeophytic) in Belgium and the Netherlands: *Artemisia absinthium* L., *A. alba* Turra, *A. campestris* L., *A. maritima* L. and *A. vulgaris* L. (Lambinon & Verloove 2012, van der Meijden 2005); only the latter is a common and widespread species.

The ecological and economic importance among representatives of *Artemisia* is high. Numerous species are cultivated as medicinal plants (anthelmintics), stimulants, culinary herbs, or ornamentals (e.g. Cullen 2011, Mabberley 2008, Wright 2002). However, several species are also reputed environmental or agricultural weeds. More than 20 species are classified as 'world weeds' (Holm et al. 1979). In parts of Europe the Chinese *A. verlotiorum* Lamotte is considered an invasive species (e.g. Boršić et al. 2008, Bouvet 2013, Celesti Grapow et al. 2010, Gassó et al. 2012, Sanz et al. 2004, etc.), whereas *A. vulgaris* is an aggressive invader in the New World (e.g. Barney & DiTommaso 2002).

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Fig. 1. *Artemisia princeps* Pamp., Zeebrugge port area, 29 October 2017. Photo: F. Verloove.

Artemisia is a taxonomically complex genus with uncertain generic boundaries. Molecular studies seem to favour a broad generic concept, i.e. including segregates like *Absinthium* (Mill.) DC., *Dracunculus* Besser, *Seriphidium* Besser, etc. (e.g. Torrell et al. 1999, contrary to Ling et al. 2011). However, even then, *Artemisia* is paraphyletic only by the exclusion of several small Asian genera and the North American genus *Sphaeromeria* Nutt. (Riggins & Seigler 2012). Additional research obviously is required in order to correctly assess the genuine boundaries of *Artemisia*. Species delimitation is controversial within *Artemisia* as well and species numbers range between 522 (Oberprieler et al. 2007) and c. 400 (Mabberley 2008), or even less. This particularly holds true for section *Artemisia* to which *A. vulgaris* and its allies belong. Several species from this section are poorly understood and often overlooked. *Artemisia verlotiorum*, for instance, a Far Eastern relative of *A. vulgaris*, was neglected for quite a long time in Belgium and the Netherlands (Andeweg 2007, Verloove 2003). Section *Artemisia* counts about 100 species that are mainly distributed in Asia (> 70 species, 28 endemic to China) and North America (27 species) (Ling 1992, Ling et al. 2011, Shultz 2006). All species are perennial herbs (rarely subshrubs), with bisexual disk florets and glabrous receptacles. Phyllaries are scarious only at margin, leaf segments are more than 2 mm wide and glandular hairs are lacking (sessile glands may be present). Most species have markedly bicoloured leaves with densely white or grey tomentose lower leaf surfaces and glabrous to sparsely hairy upper leaf surfaces. Section *Artemisia* is exceedingly complex in terms of taxonomy and nomenclature. The range of polymorphism of many species is insufficiently known and type specimens are often lacking or not yet designated. Also, the taxonomic value of certain characteristics is in need of critical re-assessment. It is possible that too many species have been described in this section in the past while – conversely – others sometimes have been synonymized unjustified.

Since the 1980s an increasing number of Asian (predominantly Far Eastern) species of section *Artemisia* has been recorded as aliens in Eastern Europe. For instance, Mosyakin (1990) reported about Ukrainian occurrences of *A. argyi* Léveillé & Vaniot, *A. rubripes* Nakai, *A. selengensis* Turcz. ex Besser, *A. umbrosa* (Turcz. ex Besser) Turcz. ex Verlot and *A. verlotiorum* (see also Bagatska 2008, Boiko 2009, 2013, Bortnyak & Voityuk 1991, Dubovik & Mosyakin 1991, Mosyakin 2006, Mosyakin et al. 2018, 2019, Mosyakin & Yavorska 2002). Almost simultaneously *A. codonocephala* Diels (referable, in fact, to the species named *A. umbrosa* in Ukraine) and *A. selengensis* were reported for the first time from Lithuania (Gudžinskas 1990, 1997). *Artemisia lancea* Vaniot, *A. argyi* and *A. lavandulaefolia* DC. (the latter also corresponding with Ukrainian *A. umbrosa*) are known since 2008 and 2009 from the Socola railway yard in Northeastern Romania (Sîrbu & Oprea 2011a, b).

Fig. 2. *Artemisia princeps* Pamp., Lochristi, E17 motorway, 27 September 2015. Photo: F. Verloove.

In Western Europe – geographically even more isolated from the Far East – only a single Asian species of the section was known to be naturalized, i.e. *Artemisia verlotiorum* (Andeweg 2007, Verloove 2003), whereas some additional species have been recorded in the past as ephemeral or very locally naturalized aliens (*A. argyi*, *A. mongolica* (Fischer ex Besser) Nakai, and *A. selengensis* also in recent times; Verloove et al., in preparation). However, in August 2011 our attention was drawn to a peculiar species of *Artemisia* occuring in the Antwerp port area (Ekerse Dijk, East of the Churchilldock) in Belgium. These plants were much reminiscent of *A. verlotiorum,* but immediately caught the eye because they were about to flower already, two months earlier than usually assumed for that species in Western Europe. Nearby, at a distance of less than 750 m, a population was known of what then was thought to be *A. verlotiorum* (Verloove 2003). Therefore, this population was initially thought to belong to *A.* ×*wurzellii* C.M. James & Stace, a spontaneous hybrid of *A. verlotiorum* and *A. vulgaris* that was described shortly before from London in the British Isles (James et al. 2000). Closer examination, however, proved this species to belong to *A. princeps* Pamp., a weedy species from the Far East that had apparently not previously been reliably reported outside of its native distribution range. Alerted by this, this species was recorded in several additional localities in the following years, in Belgium as well as in the Netherlands. Moreover, most of the large populations of alleged *A. verlotiorum* in the study area turned out to belong to *A. princeps* instead.

In this paper the main diagnostic features of *Artemisia princeps* are discussed, illustrated and compared with similar-looking taxa. Further chorological, ecological and taxonomic comments are also provided.

MATERIALS AND METHODS

The data presented in this paper are mainly the result of fieldwork in Belgium and the Netherlands, mostly between 2011 and 2019. Individuals of *Artemisia princeps* from several populations were collected and further grown ex situ in order to better understand the species' morphological characteristics. For its identification numerous relevant Floras (mainly covering the former USSR, Japan and China), as well as other literature references, were consulted. Also, several experts of the genus *Artemisia* were queried in order to assure species identification.

The identity of this and similar species was not only assessed based on macro- and micro-morphological features. In order to ascertain our identifications we used molecular phylogenetic analyses of sequences from nuclear ribosomal ITS and one chloroplast region (*trnL-F*). In addition, genome size of *Artemisia princeps* and related species were determined using flow cytometry with propidium iodide. Also, chemical pollen staining techniques were performed and seed viability was tested under controlled laboratory circumstances. The results of this specific

Fig. 3. *Artemisia princeps* Pamp., Antwerp port area, Scheldelaan, 7 August 2016. The mass vegetation of dark green, non-flowering plants refers to *A. princeps*. The post-flowering plants (front-right) are native *A. vulgaris* L. Photo: F. Verloove.

part of our study will be dealt with elsewhere (Verloove et al., in prep.).

Acronyms of herbaria follow Index Herbariorum (Thiers 2019+).

RESULTS

Taxonomic part

***Artemisia princeps* Pamp.**, Nuovo Giorn. Bot. Ital., n.s. 36(4): 444–446 (1930) — Fig. 1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 16.

= *A. indica* Willd. var. *maximowiczii* (Nakai) H. Hara, J. Jap. Bot. 59: 236 (1984).

= *A. montana* (Nakai) Pamp. f. *occidentalis* Pamp., Nuovo Giorn. Bot. Ital., n.s. 36(4): 462 (1930).

= *A. parvula* Pamp., Nuovo Giorn. Bot. Ital., n.s. 36(4): 460 (1930).

= *A. vulgaris* L. var. *maximowiczii* Nakai, Bot. Mag. (Tokyo) 26(304): 104 (1912).

= *A. vulgaris* L. f. *nipponica* Nakai, Bot. Mag. (Tokyo) 26(304): 104 (1912).

[for extended synonymy, see Ling 1992]

Originally described from Japan (Pampanini 1930). A lectotype was designated by Hara (1984): Shiga, Shizugatake (*T. Makino*, November 1894; TI). Syntypes are available from Nippon media (*Tschonoski*, 1866; LE) and China, Beijing, Yangchia-ping (*A. K. Schindler 121*, 27 July 1905; B, probably destroyed).

Long-rhizomatous perennial herb, 60–150 cm tall. Stems erect, sparsely arachnoid puberulent in upper half, glabrescent towards base. Leaves densely arachnoid tomentose beneath, glabrous above. Lowermost leaves long petiolate; leaf blade ovate or elliptic-ovate, 1- or 2-pinnatipartite; segments 2 pairs, oblong or oblong-elliptic. Middle cauline leaves: petiole 1–2(–3) cm; leaf blade ovate or ovate-elliptic, 6–12 × 4–8 cm, pinnatipartite; segments 2–3 pairs, elliptic-lanceolate or elliptic; distal lobe and lobules of lateral lobes larger, obtuse to acute apically. Uppermost leaves pinnatipartite; leaflike bracts 3-lobed or entire. Inflorescence a broad panicle with divaricate, erecto-patent branches. Capitula oblong or oblong-ovoid, 1.5–2 mm wide × 2.5–3.5 mm long, sessile or shortly pedicellate. Phyllaries imbricate, in four series, the outer oblong to broadly ovate, the inner rounded, sparsely arachnoid puberulent to glabrescent. Marginal florets female, threadlike, 1.2 mm long, 5–7 in number. Disk florets bisexual, tubular, purplish, 2 mm long, usually 4–9 in number (sometimes less). Achenes oblong, truncate at both ends, 1.5 × 0.5 mm, glabrous, seed coat loose.

Fig. 4. *Artemisia princeps* Pamp., Antwerp port area, Ekerse Dijk, 30 september 2018. This species is flowering markedly earlier than *A. verlotiorum* Lamotte. The inflorescence is usually widely divaricately branched. Photo: F. Verloove.

Phenology — In Western Europe flowering starts towards the end of August or early in September and lasts until the first frost. In Japan *Artemisia princeps* has a similar phenology (Iwatsuki et al. 1995), whereas in China it flowers markedly earlier, from July onwards (Ling et al. 2011).

Chromosome number — 2n = 34 (Iwatsuki et al. 1995, Ling et al. 2011, Nishikawa 1986). 2n = 36 was reported by Taniguchi et al. (1975), if correct.

Habitat and elevation — In the Far East *Artemisia princeps* is found in roadsides, slopes, shrublands, forest margins, valleys, riverbanks, (degraded) coastal dunes and dry grassy fields, between 0 and 1,400 m altitude. In Western Europe it grows in roadsides, embankments, railway sidings, and rough ground, often in port areas, between 0 and 20 m altitude.

Distribution — Originally confined to China (Anhui, S Gansu, Guangdong, Guangxi, Guizhou, S Hebei, Henan, Hubei, Hunan,

Fig. 5. *Artemisia princeps* Pamp., Zeebrugge port area, 12 October 2014. Photo: F. Verloove.

Jiangsu, Jiangxi, S Liaoning, SE Nei Mongol, S Shaanxi, Shandong, S Shanxi, Sichuan, Taiwan, Yunnan), Japan (Honshu, Shikoku, Kyushu), and Korea (Iwatsuki et al. 1995, Ling et al. 2011). Adventive in Europe: Belgium and the Netherlands (this paper). *Artemisia princeps* was formerly also claimed from Brazil (Hashimto 1976), but this record requires confirmation. In contemporary Brazilian Floras and databases (e.g. Quaresma 2019) only *A. verlotiorum* (as 'verlotorum') and *A. vulgaris* are accepted.

Identification and morphology

Artemisia princeps shares characters with both *A. verlotiorum* and *A. vulgaris* and is not easily distinguished from these two species, especially the identification of herbarium material is challenging. *Artemisia princeps* differs from *A. vulgaris* in always having long rhizomes (Fig. 9) and hence ultimately forming large stands. From *A. verlotiorum* it differs in usually being much less aromatic (but see below). White glands are always absent from the upper leaf surface of *A. princeps*, whereas the presence of such glands is characteristic for *A. verlotiorum* (Ling et al. 2011). A complicating factor is, however, that these glands are usually absent from or very sparse and / or early deciduous in *A. verlotiorum* populations that are naturalized in Europe. *Artemisia princeps* shares with *A. verlotiorum* the long rhizomes, but in *A. princeps* the rhizomes tend to be slightly shorter having the buds more closely spaced (Fig. 9 & 10). As a result, the root system of *A. princeps* is more compact and massive and the plant grows in even denser stands, leaving no space for the pre-existing vegetation. *Artemisia princeps* differs from both species in flowering period. This period starts end of August/early September and lasts until the end of October or early November. It falls later than the flowering period of *A. vulgaris* and markedly earlier than that of *A. verlotiorum*. The inflorescence of *A. princeps* has usually widely divaricate branches (Fig. 4) and heads of c. 1.5–2 mm across and is usually somewhat larger than the inflorescence of *A. vulgaris* and definitely larger than that of *A. verlotiorum*. The seed coat is remarkably loose in *A. princeps* as compared with the tight seed coat of the other two species. Finally, the number of tubular florets usually is lower.

Artemisia princeps itself also is a variable species and its taxonomy is not uncontested. Some authors – mainly in Japan – prefer to treat it as a synonym of the very variable *A. indica*, or consider it as a mere variety of the latter, var. *maximowiczii* (e.g. Iwatsuki et al. 1995, Shimono et al. 2013). Despite being accommodated in the same series by Ling (1992) and being morphologically similar, *A. princeps* is not very closely related to *A. vulgaris* (Tkach et al. 2008, Vallès et al. 2011). Most of the varieties and forms described by Pampanini (1930) are now subsumed under related species such as *A. igniaria* Maxim., *A. indica* (s. str.) and *A. verbenacea* (Kom.) Kitag. (Ling et al. 2011).

Fig. 6. *Artemisia princeps* Pamp., clonal growth in the central reservation of A15 motorway South of Pernis, Rotterdam, 23 April 2013. Each patch seems to originate from the roadside barrier. Photo: R. Andeweg.

The populations recently discovered in Belgium and the Netherlands also show some degree of variation, especially with respect to leaf shape (Fig. 7, 11 & 12), inflorescence shape (compare Fig. 1, 2, 3, 4, and 5), as well as to odour. In *Artemisia princeps* mid stem leaves are pinnatipartite with usually a short apical segment, but in some populations the apical segment is much longer, somehow approaching that of *A. verlotiorum*. As a rule, inflorescences ultimately have widely divaricate, straight branches in *A. princeps*. Sometimes, however, early inflorescences can have slightly but distinctly arcuate branches (Fig. 2), a feature also seen in *A. verlotiorum*. Based on panicle characteristics, Pampanini (1930) divided all species in two major informal groups, 'Rectae' and 'Flexuosae' for species with, respectively, straight and arcuate inflorescence branches. He obviously overestimated the weight of this feature. Odour also often is accepted as a useful feature, especially to distinguish between *A. verlotiorum* and *A. vulgaris* (e.g. Bini Maleci & Bagni Marchi 1983, James et al. 2000). The former is usually strikingly aromatic, its smell resembling that of citrus or florist's daisy. The other taxa here concerned, on the other hand, are almost odourless – in reality, these species have a slightly spicy smell of varying intensity. Hall & Clements (1923) described the smell of *A. vulgaris* as "… a peculiar pungent odor". However, exceptions to this rule occur. One population of *A. princeps* (from A12 motorway in Antwerp, Belgium) is obviously more aromatic. Inversely, one population of *A. verlotiorum* (from Weststation Brussels, Belgium) was observed to be almost odourless. The variability of *A. princeps* in Western Europe seems to point at separate introductions and/or a much broader genetic diversity than observed in the morphologically more homomorphous *A. verlotiorum*. Also, especially in mixed populations, it is possible that hybrids occur with intermediate features. The ease with which simultaneously flowering species hybridize is remarkable (see also below).

Artemisia ×*wurzellii* was described as a hybrid of *A. verlotiorum* and *A. vulgaris* and is – like *A. princeps* – more or less intermediate morphologically, although not in every diagnostic character (James et al. 2000). Both *A. princeps* and the hybrid are diploids with a chromosome number of 2n=34 (or rarely 2n=36 in *A. princeps*; see before). They also have a similar genome size and form a cluster in a phylogenetic tree based on sequences from nuclear ribosomal ITS and chloroplast *trnL-F* region (Verloove et al., in prep.). Yet, they are considered to be two distinct entities that are morphologically quite dissimilar, although most of the characters are difficult to quantify precisely. First of all, *A.* ×*wurzellii* is a sterile hybrid in which stamens are absent in most flowers. In a few, stamens may be detected but these will contain a very high proportion of abortive pollen. In *A. princeps*, on the other hand, all flowers have stamens (usually five in number) that contain perfect pollen and viable seed is produced, also in Western Europe. Our germination tests demonstrated almost 100% seed germination within one week.

Fig. 7. *Artemisia princeps* Pamp., Antwerp port area, Ekerse Dijk, 30 september 2018. Mid-cauline leaves. Photo: F. Verloove.

In addition, *A.* ×*wurzellii* has a leafier inflorescence with narrow, not divaricately branched and contracted panicles (Fig. 13 & 14). According to Wurzell, who first discovered the hybrid, the most reliable feature for an accurate identification of the British specimens of *A.* ×*wurzellii* are the group of pectinate appendages at the junction of leaf blade and petiole ('petiolar pectinations'): these are broader, shorter, more abruptly acute and more numerous than in either of the parent species (Fig. 11). This character separates the hybrid from its parents (pers. comm. B. Wurzell, 23 February 2013; see also James et al. 2000) as well as from *A. princeps.* While this feature characterizes *A.* ×*wurzellii* well, the petiolar pectinations in *A. princeps* are more or less intermediate between those of *A. vulgaris* and *A. verlotiorum*.

Distinguishing features of *Artemisia princeps* and similar taxa are summarized in Table 1 (see also Fig. 1–16).

Table 1. Characters differentiating *Artemisia princeps* Pamp. and similar taxa in Western Europe (data in part after James et al. 2000).

	A. princeps	***A. vulgaris***	***A. verlotiorum***	***A. ×wurzellii***
Growth habit	rhizomatous	usually tufted, very rarely rhizomatous	rhizomatous	rhizomatous
Beginning of flowering	end of August – September	July	October or later	September – October
Chromosome number	2n = 34 (36)	2n = 16,18	2n = 48,50,52	2n = 34
Seed-set in Western Europe	yes	yes	exceptionally	no
Number of stamens	5	5	5	0 in most flowers
Middle cauline leaves	pinnatipartite, with apical segment short or long but not parallel-sided	pinnatipartite, with short apical segment	pinnatisect, with long apical segment; segments and rachis more or less parallel-sided.	pinnatipartite, with short apical segment
Petiolar pectinations	2–3 on each side, varying in form and shape, lanceolate, slightly curved, rarely toothed	2–5(–8) on each side, varying, lanceolate to linear-lanceolate, mostly curved, often toothed	(1–)2–3 on each side, linear-lanceolate to lanceolate, straight, the small basal ones sometimes curved, rarely toothed	numerous, up to 8 on each side, elliptic, mucronulate
Capitulum (L/W, in mm)	2.5–3.5 × 1.5–2	3.1–3.7 × 2.1–2.5	3.5–4.2 × 2.4–3	1.8–2.4 × 1.6–1.8
Inflorescence	usually a widely divaricate panicle	variable, usually a wide panicle	narrow panicle	narrow panicle
Tubular florets (number)	4–9, usually c. 5	8–20	usually at least 10	(3–)4–6
Seed coat adherence	loose	tight	tight	no seeds produced
Leaf colour in winter / early spring	greyish green	greyish green	pure green	greyish green

From the Asian species currently known to occur elsewhere in Europe, *Artemisia princeps* is probably most reminiscent of *A. rubripes* (both from series *Artemisia*; Ling 1992). The latter is known from Ukraine (Mosyakin 1990) and has glabrescent stems, a much narrower inflorescence with suberect, non-divaricate branches and smaller, glabrescent heads up to 2 mm long.

Artemisia princeps and similar taxa known to occur in Western Europe are distinguished in the following identification key. As a rule, *A. vulgaris* is readily separated from the other species, especially in the field: it is more or less caespitose and grows in clumps with long rhizomes usually absent (although shoots are sometimes prolonged). In addition, first flowering always starts about two months earlier than in the other taxa here concerned. In case of late flowering of plants that resemble *A. vulgaris*, it is advisable to check whether the plant was cut or otherwise damaged earlier in the season or whether there are older inflorescences indicating a second flowering. The key is best used in conjunction with the illustrations and Table 1.

Key to the identification of *Artemisia princeps* and similar taxa in Western Europe

1. Plants usually tufted and growing in clumps, rarely with short or longer rhizomes, growing solitary or in small groups. Flowering from July onwards (but often with second flowering in autumn) . . . . . *Artemisia vulgaris*
   Plants always with long rhizomes ending with a bud, eventually always growing in large colonies. Never flowering before the end of August 2
2. Stamens absent in most flowers. Petiolar pectinations numerous, up to 8 on each side, elliptic, mucronulate (Fig. 11 & 12) . . . . . *Artemisia ×wurzellii*
   Each 'bisexual' (tubular) flower with five stamens. Petiolar pectinations 2–3 on each side, lanceolate to linear-lanceolate (Fig. 11 & 12) 3
3. Leaves glandular punctate or not (glands, if present, only visible on leaf upper side and often early deciduous), nearly always distinctly aromatic. Middle cauline leaves pinnatisect, with apical undivided segment much longer than wide. Inflorescence normally a narrow panicle with branches not widely diverging, often arcuate; heads c. 2.4–3 mm wide; tubular florets usually at least 10. Flowering from October onwards (sometimes not at all) and thus seeds very rarely produced. Seeds with tight coat (Fig. 16) . . . . . *Artemisia verlotiorum*
   Leaves always without glands, very rarely strikingly aromatic. Middle cauline leaves pinnatipartite, with shorter apical segment (Fig. 7 & 11). Inflorescence ultimately a wide panicle with branches diverging at 50° or more (Fig. 4); heads ca. 1.5–2 mm wide; tubular florets always less than 10, usually c. 5. Flowering from the end of August onwards and thus seeds always produced. Seeds with loose coat (Fig. 16) . . . . . ***Artemisia princeps***

Distribution in Western Europe

At present, *Artemisia princeps* is known from several different localities in Belgium and the Netherlands.

In Belgium, our attention was first drawn to this species in August 2011 in the Antwerp port area (Ekerse Dijk, East of the Churchilldock; Province of Antwerp). The species was found on rough ground adjacent to a railway track in a nearly monospecific stand of ca. 10,000 m². It was probably introduced there a long time ago already. Since its discovery it has only slightly further extended. The locality has been used in the past as a storage area for road works debris, which can explain how the species arrived there. Nearby, alongside the Noorderlaan between the Churchill- and Delwaidedock, scattered populations

Fig. 8. Basal leaves of *Artemisia princeps* Pamp., Zeebrugge port area, 24 August 2014. Photo: F. Verloove.

of alleged *Artemisia verlotiorum* had been known since at least 2001 over a distance of about six kilometres (Verloove 2003). These roadside populations are regularly mowed and hence their identity was difficult to assess based exclusively on morphological characters. DNA sequences and genome size measurements unequivocally demonstrated that these plants in fact also belong to *A. princeps*, not to *A. verlotiorum*. In identical circumstances alleged *A. verlotiorum* was known to occur in another part of the Antwerp port area where it was first discovered in 2010. Enormous populations alongside the Scheldelaan between Lillo and Berendrecht are found in an almost uninterrupted stretch of about four kilometres. Here, the species grows in a vast area between the road and railway infrastructure, along fences, etc. These plants are also mowed several times per year which – again – initially prevented an accurate identification. Molecular data and genome size measurements showed that these plants also doubtlessly belong to *A. princeps*, at least most of them. However, the morphological variation in this population (that also consists of *A. vulgaris* and *A. mongolica*) is great and additional genome size measurements indicate that probably even more species are involved. In 2013 two small populations were discovered alongside the E17 motorway, one in Lokeren (Everslaar), the other in Beervelde (both in the Province of East Flanders), c. 3–4 kilometres apart. In 2014, *A. princeps* was found in the Zeebrugge port area (Province of West Flanders). The species grows in a very dense colony on top of and on the flanks of an embankment, as well as alongside the adjacent road and must have been introduced there on the occasion of the construction of the embankment in 2009. In 2015, another large population was observed in similar circumstances alongside the A12 motorway in Wilrijk (Antwerp, Province of Antwerp). In 2016, scattered plants were seen in the central reservation of the R4 motorway in Oostakker (Gent, Province of East Flanders) and in 2019 a single individual was seen in a roadside in Zandvliet in the Antwerp port area, an extension further north of the well-known massive population between Lillo and Berendrecht. Finally, another large population was discovered on and near the construction site of a cycling tunnel in Aalst (Province of East Flanders), also in 2019. In all these places *A. princeps* is very well established.

In the Netherlands, *Artemisia princeps* was first discovered in 2008 in several locations over a distance of about eight kilometres in the central reservation of the A15 motorway, south of the Rotterdam port area (Province of Zuid-Holland). It was initially identified as *A. verlotiorum* mostly because all spots were inaccessible for visiting or collecting and could only be seen from afar or from a driving car. In April 2013, the second author got the opportunity to visit the largest population near Pernis and to collect living plants. At that moment his attention was drawn to the greyish colour of the plants, which was quite different from the bright green colour of leaves of *A. verlotiorum* at that time of year. This population clearly arose by clonal spread from scattered starting points as can be seen in Fig. 6. Probably the dispersion and rooting of shredded particles after mowing acted as the main vector of introduction here. The species may have been further dispersed as a result of traffic or road works, also to the opposite side of the road. However, reconstruction works probably also have destroyed one of the populations. In 2018, another large population of *A. princeps* was discovered two kilometres further east in the central reservation of the A15 motorway (Vaanplein), between Rotterdam and Barendrecht. In 2019, a small group of plants was found just south of the A15 motorway, which forms the first accessible population in the Netherlands.

Selection of specimens examined (including hybrids; see below)

Unless otherwise stated, all collections cited below refer to *Artemisia princeps*.

Belgium

Harbour of Antwerp, Ekerse Dijk (W-side), wasteland, very dense population, 06.08.2011, *F. Verloove* 8930 (BR);

Harbour of Antwerp, N101 (Scheldelaan), S of Berendrechtsluis, rough ground, roadside, locally frequent, 05.08.2012, *F. Verloove* 9608 (BR);

Zeebrugge, port area (Koffieweg), on top of artificial talus slope, dense population, 21.07.2014, *F. Verloove* 10910 (BR);

Wilrijk, A12 motorway (W side), talus slope, dense population, 16.08.2015, *F. Verloove* 11674 (BR);

Lokeren, Everslaar, E17 motorway, roadside, 20.09.2015, *F. Verloove* 12065 (BR);

Beervelde, E17 motorway at km 63.2, roadside, 27.09 and 08.11.2015, *F. Verloove* 12063 and 11977 (BR);

Oostakker (Gent), R4 motorway at km 17, central reservation, 07.08.2016, *F. Verloove* 12530 (BR);

Harbour of Antwerp, Kruisweg S of Delwaidedok, roadside, 26.09.2016, *F. Verloove* 12604 (BR);

Aalst, Siesegemlaan (R41), construction site of new cycling tunnel, near the hospital, two massive populations on both sides of the main road, 30.09.2019, *F. Verloove* 13676 (BR);

Zandvliet, Oudedijkweg N of Berendrechtsluis, roadside, a single individual, 06.10.2019, *F. Verloove* 13706 (BR).

Netherlands

Rotterdam, near Pernis, median strip of A15 motorway, 06.10.2013 [grown in a garden in Dordrecht, from a rhizome collected on 23.04.2013], *R.W.G. Andeweg*, Natural History Museum Rotterdam 9999.10918 (dupl. BR);

Dordrecht, garden, 04.10.2015, seedling, *R.W.G. Andeweg*, Natural History Museum Rotterdam 9999.12129 (*A. mongolica* × *princeps*);

Rotterdam, IJsselmonde, Kreekhuizenlaan, roadside, 20.09.2016, *R.W.G. Andeweg,* Natural History Museum Rotterdam 9999.12136 (*A. vulgaris* × *princeps)*.

Fig. 9. *Artemisia princeps* Pamp. Rhizomes of a plant cultivated in pot. Photo: R. Andeweg.

DISCUSSION: BENEFITS VERSUS ADVERSE IMPACT

In Asia, *Artemisia princeps* is a highly appreciated species that is frequently used medicinally, as a culinary herb, as an essential oil and even for re-vegetation (e.g. Hanelt 2001, Shimono et al. 2013). Plants named as such are offered for sale for these purposes, also in Western Europe (e.g. Plants for a Future Database, accessed in January, 2019; Plant Finder, accessed in January, 2019). It is unknown how and when *A. princeps* exactly arrived in Western Europe, but it is possible that it was initially introduced on purpose. The occurrence of the species in other localities in Western Europe, therefore, is not unlikely, especially in areas with high concentrations of Asian immigrants. On the other hand, the species' presence in or near some of the larger commercial port areas of Western Europe, especially Rotterdam and Antwerp, might also point at an involuntary introduction with imported foreign goods. The presence of at least one further Far Eastern species, *A. mongolica*, which is a weed without any known particular benefits, in the largest Belgian population, rather seems to suggest the latter as the most likely introduction vector.

Artemisia princeps is a very vigorous species that rapidly spreads by means of strong rhizomes. As a result, it is a fast colonizer and it is often considered an undesirable weed. Several recent authors emphasize on this, e.g. Shimono et al. (2013) and Shah (2014). It is classified as a very harmful weed in many regions in Southeastern Asia (Reed 1977). Even in areas where *A. princeps* is native, it is often dominant and expansive, for instance in coastal sand dunes in South Korea (Kim 2005). Also in Japan it is classified as a major weed (e.g. Holm et al. 1979). In several of the localities where it is currently known to occur in Belgium and the Netherlands, this species forms massive, nearly monospecific stands. In the sense of Richardson et al. (2000) it can be considered an invasive species, i.e. spreading more than 6 m/3 years for taxa spreading by roots, rhizomes, stolons, or creeping stems, and thus having the potential to spread over a considerable area. In Western Europe, *A. princeps* in fact appears to be more invasive than *A. verlotiorum*, the latter obviously being a more thermophilous species that thrives better in more southern areas. *Artemisia verlotiorum* was first recorded from Belgium in 1937 (Verloove 2003) and now occurs in several dozens of stable populations and the same applies to the Netherlands. However, even in those populations which are known since more than half a century the species merely persists, only very exceptionally produces viable seed, and at most slightly extends as a result of clonal growth. Nevertheless, in recent years we observed earlier flowering in populations of *A. verlotiorum*, in Belgium as well as in the Netherlands, which may indicate that this situation may change in the near future as a result of a changing climate (see also Verlinden & Nys 2010). Large, monospecific

Fig. 10. *Artemisia verlotiorum* Lamotte. Rhizomes of a plant cultivated in pot. Photo: R. Andeweg.

populations as known in parts of Southwestern Europe are very exceptional in Western Europe, at least at present. A fortiori, all vigorous stands of alleged *A. verlotiorum* in the area under study turned out to belong to *A. princeps* instead.

During our studies it was shown that *Artemisia princeps* is able to produce viable seed in Belgium and the Netherlands. This enables the species to spread not only clonally but also reproduce sexually, which considerably enhances the species' dispersal possibilities. Moreover, hybridization with other species of section *Artemisia* has been observed on several occasions during our study. A seedling that spontaneously arose in our living collection that is composed of several species of *Artemisia* section *Artemisia* turned out to be morphologically intermediate between *A. princeps* and *A. mongolica* and – based on genome size measurements – was assumed to be their hybrid (Verloove et al., in prep.). The next year similar hybrid plants could be grown out of seeds obtained from the *A. mongolica* mother plant. Both species flower about the same period, i.e. in the beginning of September. One specimen of this hybrid is still part of our living collection and shows an, even for this group of plants, extremely vigorous rhizomatous growth.

Also, in a single locality in Rotterdam, the Netherlands, a plant with intermediate features was shown to be of putative *Artemisia vulgaris* × *A. princeps* parentage. A common feature this putative hybrid shares with the hybrid discussed above, and that originates from *A. princeps*, is the very wide divaricately branched panicle (Fig. 15).

The highly weedy and widespread *Artemisia princeps* is known to hybridize with rare, threatened congeners, for instance with *A. gilvescens* Miq. in Japan (Yamashiro et al. 2018).

Although, at least at present and to our current knowledge, *Artemisia princeps* is only known from degraded and man-made habitats in Western Europe, it is advisable to closely monitor the species in its known populations. Like *A. verlotiorum* in Southern Europe (e.g. Sanz et al. 2004, Boršić et al. 2008, Bouvet 2013, Celesti Grapow et al. 2010, Gassó et al. 2012), it may soon become a pest species in natural or natural-like habitats. Its most impressive populations (in the Antwerp port area in Belgium) are located next to several nature reserves. The dense local network of road and railway infrastructure in the port could easily serve as ideal dispersal vectors. Populations of any rhizomatous *Artemisia vulgaris*-like plant are therefore best checked against *A. princeps,* since it is expected that this species has been overlooked so far. Analogously, early flowering populations of alleged *A. verlotiorum* are suspect and may point to other species, including *A. princeps*. An accurate identification is a critical first step in the management of new invasions. Correctly identified pest species allow for immediate control and management efforts without wasting valuable time, placing the discipline of taxonomy at the forefront of invasive species research (Gotzek et al. 2012).

Acknowledgements – The authors are much indebted to Dr. Koji Yonekura (Tohoku University, Japan) for assessing the correct identity of our plants. Ben Zonneveld (Naturalis, Netherlands) and Steven Janssens (Botanic Garden Meise, Belgium) are sincerely thanked for their assistance with genome size measurements and molecular analyses respectively. Indra Jacobs, Nico Wijsmantel, Dirk De Beer and Alain Pieters drew our attention to new localities of *Artemisia princeps* in Beervelde, Lokeren, Antwerp (Wilrijk), Zandvliet and Aalst. Prof. Clive Stace (University of Leicester, UK) and Brian Wurzell, London, are thanked for providing useful data about *A.* ×*wurzellii*. Quentin Groom (Botanic Garden Meise, Belgium) accompanied the first author to the type locality of *A.* ×*wurzellii* in London.

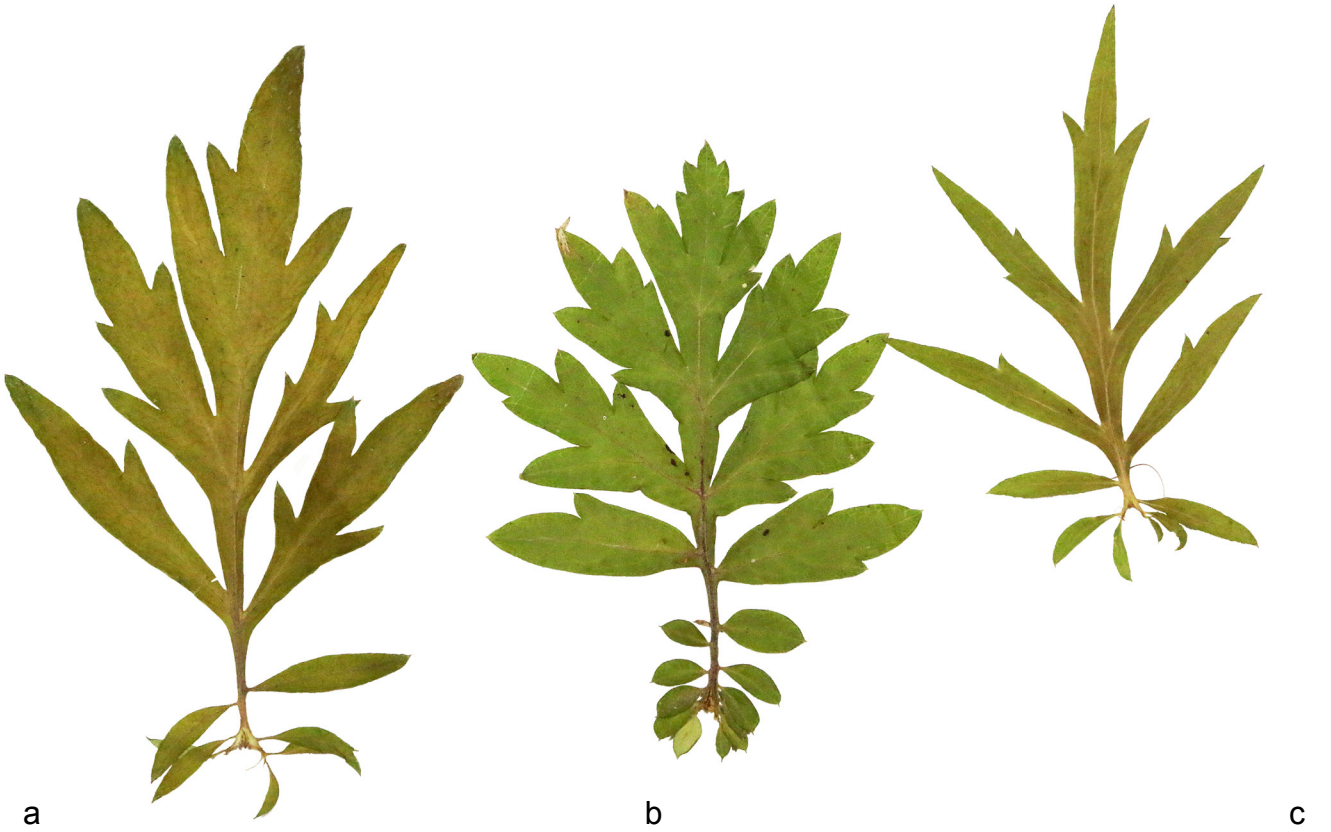

Fig. 11. Comparison of mid-stem leaves of *Artemisia princeps* Pamp. and *A.* × *wurzellii* C.M. James & Stace: a. *A. princeps* from the population along the A15 motorway, Rotterdam; b. *A.* × *wurzellii* from the type locality in Tottenham, London; c. *A. princeps* from a population at the Ekerse Dijk, Antwerp. Photo: R. Andeweg.

REFERENCES

Andeweg R. 2007. Herfstalsem (Artemisia verlotiorum Lamotte) aangetroffen in Rotterdam. Gorteria 32: 53 – 55.

Bagatska TS. 2008. Finds of new localities of alien plants Artemisia argyi Leveillie [sic] et Vaniot and Heracleum sosnovskyi Manden. near Kyiv water bodies (in Ukrainian). Ukrayins'k. Bot. Zhurn. 65: 535–543.

Barney JN, DiTommaso A. 2002. The biology of Canadian weeds. 118. Artemisia vulgaris L. Canad. J. Pl. Sci. 83: 205–215.

Bini Maleci A, Bagni Marchi A. 1983. Artemisia vulgaris L. ed A. verlotiorum Lamotte: studio di alcuni caratteri morfo-anatomici distintivi delle due specie. Webbia 37: 185–196.

Boiko GV. 2009. New data on alien species of the genus Artemisia L. (Asteraceae) in the Ukrainian flora (in Ukrainian). Ukrayins'k. Bot. Zhurn. 66: 833–835.

Boiko GV. 2013. Identification key for the species of the genus Artemisia L. (Asteraceae) of the flora of Ukraine (in Ukrainian). Ukrayins'k. Bot. Zhurn. 70: 479–482. (doi 10.15407/ukrbotj70.04.479).

Boršić I, Milović M, Dujmović I, Bogdanović S, Cigić P, Rešetnik I, Nikolić T, Mitić B. 2008. Preliminary Check-list of Invasive Alien Plant Species (IAS) in Croatia. Nat. Croatica 17: 55–71.

Bortnyak MM, Voityuk Y.A. 1991. An adventive species, Artemisia selengensis Turcz. ex Bess., new for the Ukrainian flora (in Ukrainian). Ukrayins'k. Bot. Zhurn. 48: 91.

Bouvet D. (ed.) 2013. Piante esotiche invasive in Piemonte. Riconoscimento, distribuzione, impati. Museo Regionale di Scienze Naturali, Torino.

Celesti-Grapow L, Pretto F, Carli E, Blasi C. 2010. Flora vascolare alloctona e invasive delle regioni d'Italia. Casa Editrice Università La Sapienza, Roma.

Cullen J. 2011. Artemisia. In: Cullen J, Knees SG, Cubey HS (eds.). The European Garden Flora 5, ed. 2: 503–507. Cambridge University Press, Cambridge.

Dubovik ON, Mosyakin SL. 1991. Artemisia verlotiorum (Asteraceae), a new adventive species of the north Caucasus flora (in Russian). Bot. Zhurn. (Moscow & Leningrad) 76: 1408–1411.

Gassó N, Thuiller W, Pino J, Vilà M. 2012. Potential distribution range of invasive plant species in Spain. NeoBiota 12: 25–40.

Gotzek D, Brady SG, Kallal RJ, LaPolla JS. 2012. The Importance of Using Multiple Approaches for Identifying Emerging Invasive Species: The Case of the Rasberry Crazy Ant in the United States. PloS ONE 7(9). (doi: 10.1371/journal.pone.0045314).

Gudžinskas ('Gudzhinskas') Z. 1990. New data on genus Artemisia (Asteraceae) in Lithuanian flora (in Russian). Bot. Zhurn. (Moscow & Leningrad) 75: 1171–1174.

Gudžinskas Z. 1997. Conspectus of alien plant species of Lithuania. 4. Asteraceae. Bot. Lithuan. 3 : 335–366.

Hall HM, Clements FE. 1923. The phylogenetic method in taxonomy: the North American species of Artemisia, Chrysothamnus, and Atriplex. Publ. Carnegie Inst. Wash. 326: 1–355.

Hanelt P. 2001. Mansfeld's Encyclopedia of Agricultural and Horticultural Crops. Springer Verlag, Berlin / New York.

Hara H. 1984. Comments on the East Asiatic plants: 15. J. Jap. Bot. 59: 225–237.

Hashimto G. 1976. Weeds of Upland Field in Brazil (6). J. Weed Sci. Technol. 21: 189–194.

Holm L, Pancho JV, Herberger JP, Plucknett DL. 1979. A geographical atlas of world weeds. J. Wiley & Sons, New York.

Iwatsuki K, Yamazaki T, Boufford DE, Ohba H (eds.). 1995. Flora of Japan. 3b. Angiospermae-Dicotyledoneae: Sympetalae. Kodansha,Tokyo.

James CM, Wurzell BS, Stace CA. 2000. A new hybrid between a European and a Chinese species of Artemisia (Asteraceae). Watsonia 23: 139–147.

Kim KD. 2005. Invasive plants on disturbed Korean sand dunes. Estuarine Coastal Shelf Sci. 62: 353–364.

Lambinon J, Verloove F. 2012. Nouvelle Flore de la Belgique, du Grand-Duché de Luxembourg, du Nord de la France et des Régions voisines (Ptéridophytes et Spermatophytes), ed. 6. Jardin botanique national de Belgique, Meise.

Ling Y-R. 1992. The Old World Artemisia (Compositae). Bull. Bot. Res., Harbin 12: 1–108.

Ling Y-R, Humphries CJ, Gilbert MG. 2011. Artemisia. In: Wu ZY, Raven PH, Hong DY (eds.), Flora of China. Vol. 20 (Asteraceae): 676–737. Science Press, Beijing, and Missouri Botanical Garden Press, St. Louis.

Mabberley DJ. 2008. Mabberley's plant-book, ed. 3. Cambridge University Press, Cambridge.

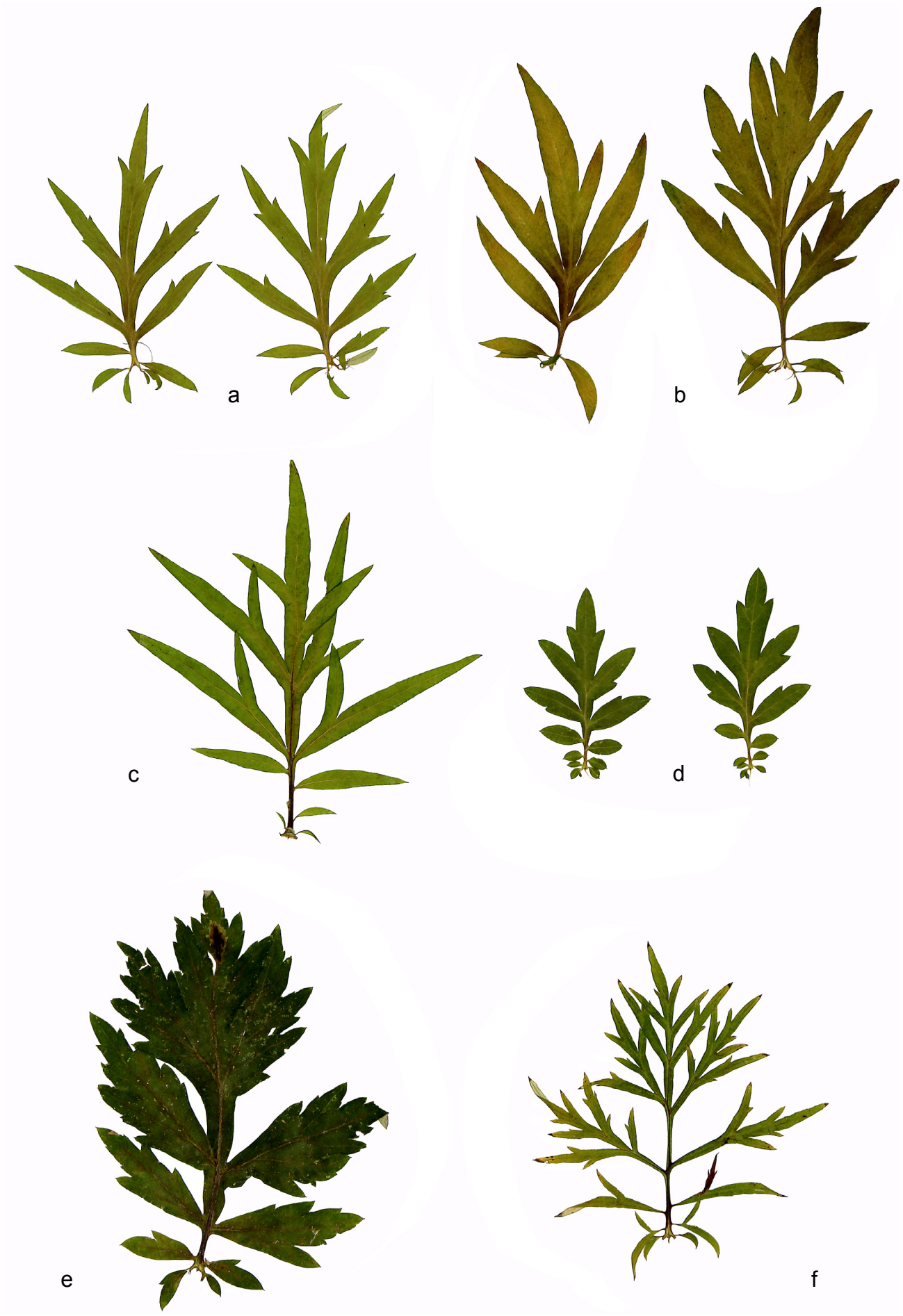

Fig. 12. Comparison of mid-stem leaves of the various species of *Artemisia* that are relevant to our study: (a, b). *Artemisia princeps* Pamp.: (a) Antwerp, Belgium, 2016, and (b) A15 motorway, Rotterdam, Netherlands; (c) *Artemisia verlotiorum* Lamotte, De Punt, Rotterdam, Netherlands; (d) *Artemisia* x*wurzellii* C.M. James & Stace, type locality Tottenham, London, UK; (e, f) *A. vulgaris* L.: (e) Noorderhagen, Rotterdam, and (f) Museumpark Rotterdam, Netherlands. Photos: R. Andeweg.

Fig. 13. *Artemisia* x*wurzellii* C.M. James & Stace from two different localities (Left: West End, UK; Right: Type locality Tottenham, London, UK). Collection R. Andeweg, Dordrecht, Netherlands, 30 September 2018. Photo: R. Andeweg.

Mosyakin SL. 1990. New and noteworthy alien species of Artemisia L. (Asteraceae) in the Ukrainian SSR. Ukrayins'k. Bot. Zhurn. 47: 10–13.
Mosyakin SL. 2006. On distribution of Artemisia verlotiorum Lamotte (Asteraceae) and related alien species in Ukraine (in Ukrainian). Chornomors'k. Bot. Zhurn. 2(1): 93–97.
Mosyakin SL, Boiko GV, Glukhova SA. 2019. Artemisia verlotiorum (Asteraceae) in the continental part of Ukraine: now in Kyiv. Ukrayins'k. Bot. Zhurn. 76: 3–8. (doi: 10.15407/ukrbotj76.01.003).
Mosyakin SL, Verloove F, Boiko GV. 2018. The correct authorship and nomenclature of Artemisia umbrosa (Asteraceae), with comments on some misapplied names and distribution of the species in Eastern Europe. Ukrayins'k. Bot. Zhurn. 75: 213–229. (doi: 10.15407/ukrbotj75.03.213).
Mosyakin SL, Yavorska OG. 2002. The Nonnative Flora of the Kyiv (Kiev) Urban Area, Ukraine: A Checklist and Brief Analysis. Urb. Hab. 1: 45–65.
Nishikawa T. 1986. Chromosome counts of flowering plants of Hokkaido (10). J. Hokkaido Univ. Educ., 2B 37: 5–17.
Oberprieler C, Himmelreich S, Vogt R. 2007. A new subtribal classification of the tribe Anthemideae (Compositae). Willdenowia 37: 89–114.
Pampanini R. 1930 ['1929']. Quinto contributo alla conoscenza dell' "Artemisia Verlotorum" Lamotte. Nuovo Giorn. Bot. Ital. n. s. 36: 395–547.
Quaresma AS. 2019. Artemisia. In: Flora do Brasil 2020 under construction. Jardim Botânico do Rio de Janeiro.Available at: http://floradobrasil.jbrj.gov.br/reflora/floradobrasil/FB15960. Accessed on 19 Februari, 2019.
Reed CF. 1977. Economically important foreign weeds. Potential problems in the United States. Agriculture Handbook n° 498, Washington.
Richardson DM, Pyšek P, Rejmánek M, Barbour MG, Panetta FD, West CJ. 2000. Naturalization and invasion of alien plants: concepts and definitions. Diversity & Distrib. 6: 93–107.

Fig. 14. *Artemisia* x*wurzellii*, C.M. James & Stace, in collection R. Andeweg (origin: type locality Tottenham, London, UK), 13 October 2016. Photo: R. Andeweg.

Riggins CW, Seigler DS. 2012. The genus Artemisia (Asteraceae: Anthemideae) at a continental crossroads: Molecular insights into migrations, disjunctions, and reticulations among Old and New World species from a Beringian perspective. Molec. Phylogen. Evol. 64: 471–490.

Sanz M, Dana ED, Sobrino E. 2004. Atlas de las plantas alóctonas invasoras de España. Ministerio de Medio Ambiente. Dirección General para la Biodiversidad, Madrid.

Shah NC. 2014. The Economic and Medicinal Artemisia species in India. The SciTech Journal 1: 29–38.

Shimono Y, Hayakawa H, Kurokawa S, Nishida T, Ikeda H, Futagami N. 2013. Phylogeography of Mugwort (Artemisia indica), a Native Pioneer Herb in Japan. J. Heredity 104: 830–841.

Shultz LM. 2006. Artemisia. In: Flora of North America Editorial Committee (eds.), Flora of North America North of Mexico 19: 503–534. Oxford Univ. Press, New York and Oxford.

Sîrbu C, Oprea A. 2011a. New records in the alien flora of Romania (Artemisia argyi, A. lavandulaefolia) and Europe (A. lancea). Turk. J. Bot. 35: 717–728.

Sîrbu C, Oprea A. 2011b. Plante adventive în flora României. Ion Ionescu de la Brad, Iaşi.

Taniguchi K, Tanaka R, Yonezawa Y, Komatsu H. 1975. Types of banding patterns of plant chromosomes by modified BSG method. Kromosomo, II 100: 3123–3135.

Fig. 15. Hybrids of *Artemisia princeps* Pamp. with *A. mongolica* (Fischer ex Besser) Nakai and the native species *A. vulgaris* L. Left: *A. princeps* x *mongolica* arosen in cultivation in between plants of the parent species. Right: *A. princeps* x *vulgaris* collected in the wild in Rotterdam. Both hybrids share the widely divaricate inflorescence of *A. princeps*. Photo: R. Andeweg.

Thiers B. 2019+ (continuously updated). Index Herbariorum: A global directory of public herbaria and associated staff. New York Botanical Garden's Virtual Herbarium, New York.

Tkach NV, Hoffmann MH, Röser M, Korobkov AA, von Hagen KB. 2008. Parallel evolutionary patterns in multiple lineages of arctic Artemisia L. (Asteraceae). Evolution 62: 184–198.

Torrell M, Garcia-Jacas N, Susanna A, Vallès J. 1999. Phylogeny in Artemisia (Asteraceae, Anthemideae) Inferred from Nuclear Ribosomal DNA (ITS) Sequences. Taxon 48: 721–736.

Vallès J, Garcia S, Hidalgo O, Martín J, Pellicer J, Sanz M, Garnatje T. 2011. Biology, Genome Evolution, Biotechnological Issues and Research Including Applied Perspectives in Artemisia (Asteraceae). Advances Bot. Res. 60: 349–419.

van der Meijden R. 2005. Heukels' Flora van Nederland, ed. 23. Wolters-Noordhoff, Groningen and Houten.

Fig. 16. Seed with seed coat of *Artemisia princeps* Pamp. (left), *A. vulgaris* L. (middle) and *A. verlotiorum* Lamotte (right). The seed coat of *A. princeps* is loose, compared with the tight seed coat of the other two species. Photo: R. Andeweg.

Verlinden M, Nys I. 2010. Alien plant species favoured over congeneric natives under experimental climate warming in temperate Belgian climate. Biol. Invas. 12: 2777–2787.
Verloove F. 2003. Artemisia verlotiorum in Flanders (Belgium): recently increasing or overlooked in the past? (in Dutch). Dumortiera 81: 76–81.
Verloove F, Andeweg R, Janssens S, Zonneveld B. (in prep.). Morphological, genome-size and molecular evidence for the presence of another invasive East Asian Artemisia (Asteraceae) in Western Europe.
Wright CW (ed.) 2002. Artemisia. Taylor & Francis, London.
Yamashiro T, Ogawa M, Yamashiro A, Maki M. 2018. Natural Hybridization between the Endangered Herb Artemisia gilvescens (Asteraceae) and the Common Congener, Artemisia indica var. maximowiczii in Japan. Acta Phytotax. Geobot. 69: 109–117.