

First records of 56 invasive alien vascular plants in Luxembourg

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Abstract. The present study provides, for 56 invasive alien vascular plant species in Luxembourg, the first records in the country, the first records in the wild and their invasion status as a contribution to the national portal on invasive alien species (neobiota.lu) and to the Global Alien Species First Record Database (GASFiReD). Most species are of horticultural origin. More than half of the species were deliberately introduced in the 19th century, or even earlier, and escaped to the wild after a certain lag phase. Global and increased trade, as well as ongoing climate change are accelerating the propagation of non-native species in the last decades.

Keywords. Neophytes, invasive alien species, IAS, Luxembourg, first record, invasion status.

1. Introduction

The Internet portal neobiota.lu (Ries & Pfeiffenschneider 2021) presents invasive or potentially invasive neophytes (vascular plants), neomyceta (fungi) and neozoa (invertebrates and vertebrates) that are established in Luxembourg or are expected to appear in the country in the near future.

For a better understanding of the invasion behaviour and the distribution of an alien species, detailed information is required regarding the history of introduction, first record in a given country or region, first record in the wild in the given area, spread, etc. Comprehensive knowledge and understanding of these processes are crucial for policy-making bodies, e.g. the IAS Group Luxembourg (Groupe de coordination sur les espèces exotiques envahissantes au Luxembourg), which was set up in 2016 by the Ministry for the Environment to support the development of national strategies for the prevention and management of invasive alien species (Mémorial 2016).

A first record denotes the year of the first observation of an alien species in a region

or the year of introduction for deliberately introduced – often horticultural – species. First records are sampled unevenly in space and time and across taxonomic groups, and thus first records are affected by sampling biases, which is why analyses on national levels should be interpreted carefully. For national analyses, it is recommended to consult the original data sources to check sampling methods, quality, etc. individually (Seebens et al. 2017). First records are particularly important to enable large scale analysis which contribute to a better understanding of invasion processes on a supra-regional, supranational, continental or global scale. Analyses on a continental or global scale have been experienced as rather robust (Seebens et al. 2017).

A worldwide consortium of invasion biologists has compiled first records of alien species across taxonomic groups and regions into The Global Alien Species First Record Database (GASFiReD) (Seebens et al. 2017). Based on these data, they were able to analyse temporal dynamics of alien species accumulations across regions and taxa, global temporal trends in first record rates

for all species and taxonomic groups, and temporal trends in continental first record rates for various taxonomic groups and continents. They showed for the first time at a global scale that the increase in numbers of alien species does not show any sign of saturation. For most taxa, even the rate of first records increased over time, with the highest rates of first records being observed in recent times (Seebens et al. op. cit.).

The present study provides the first records in Luxembourg for 56 alien vascular plant taxa, as a contribution to both the national portal on invasive alien species neobiota.lu and the worldwide GASFiReD database.

2. Methods

The 56 reviewed taxa originate from the list of neophytes relevant for Luxembourg on the neobiota.lu portal (Ries & Pfeiffenschneider 2021). Six taxa from this source – all of EU concern (OJ 2016, 2017) – were not considered as they are absent from the territory (*Hydrocotyle ranunculoides*, *Lagarosiphon major*, *Ludwigia grandiflora*, *Ludwigia peploides*, *Lysichiton americanus* and *Myriophyllum heterophyllum*).

The temporal data type used in GASFiReD is a time series beginning in 1500 and ending in 2015 with a temporal resolution of one year (Seebens et al. 2017). Within this study we extend the time series to the year 2020.

We gathered data on first year of record or deliberate introduction of alien vascular plants from various sources including the Herbarium “LUX” of the Luxembourg National Museum of Natural History, the national online database Recorder-Lux on the natural heritage of the Grand Duchy, published by the Luxembourg National Museum of Natural History (MNHNL 2000-), the iNaturalist (2021) and GBIF (2021) data portals, as well as historic and recent Floras of Luxembourg (e.g. Tinant 1836, Löhr 1844, Koltz 1873, Krombach 1875, Klein 1897, Lambinon & Verloove 2015) and neighbouring areas (e.g. Lejeune 1824, Holandre 1829, Holandre 1842, Wirtgen 1842, Godron 1857). Furthermore, scientific articles compiling floristic find-

ings in Luxembourg were helpful (Bronn & Courtois 1827, Fischer 1872, Koltz 1874a, b, 1875, 1877a, b, c, Fischer 1882, 1886, Robert 1910), especially the series of articles “Herborisations faites dans le Grand-Duché de Luxembourg” launched by Beck et al. (1950) in the “Bulletin de la Société des naturalistes luxembourgeois”. The series was continued by Reichling (1953a), later under the new title “Notes floristiques” (Reichling 1955), and continued to the present by Yves Krippelel, Guy Colling and Thierry Helminger, the latest issue having been published in 2020 (Krippelel et al. 2020). Finally, we screened commemorative publications such as the “Livre du Centenaire” by Massard & Geimer (1990), the historic overview on Botany in Luxembourg by François Léon Lefort (1950), the common online portal of libraries in Luxembourg a-z.lu, reports and personal communications.

The year of first record was provided in more than half of cases as a single year [55 % of all records], e.g. “1822” for *Conyza canadensis* (Krombach 1875: 344). When a species is first mentioned without an exact date in a Flora, the year of first record is indicated as the year of publication of the Flora preceded by the lesser than symbol “<” [36 % of all records], e.g. “<1825” for *Acer negundo* (Koltz 1875: 27). When the time specification is approximative, the year of first record is preceded by the approximate symbol “~” [9 % of all records], e.g. “~1720” for *Helianthus tuberosus* (Pirotte 1976).

The status of invasion was assessed as “casual” for 13 taxa and “established” for 43 taxa, according to the definitions outlined by Pyšek et al. (2004): casual (ephemeral) alien plants may flourish and even reproduce occasionally outside cultivation in an area, but eventually die out because they do not form self-replacing populations, and rely on repeated introductions for their persistence; established or naturalised plants sustain self-replacing populations for at least 10 years without direct intervention by people (or in spite of human intervention) by recruitment from seed or ramets (tillers, tubers, bulbs, fragments, etc.) capable of independent growth.

We follow the nomenclature of Luxembourg's current official flora, the "Nouvelle Flore" by Lambinon & Verloove (2015).

3. Results

For 56 alien vascular plants the year of first record/introduction in Luxembourg and the first occurrence in the wild is given (Table 1); 43 taxa are considered as established, 13 are considered as casual.

4. Discussion

4.1. General considerations

Trade has been a major driver of alien species introductions, especially in the 19th century, when many wealthy property owners hired internationally renowned botanists and/or gardeners to design their parks, e.g. Philipp Franz von Siebold (1796-1866) in 1849 in the Royal park of Walferdange (Koltz 1875: 38) and Édouard André (1840-1911) who, after the dismantling of the fortress of the city of Luxembourg, laid out several parks in Luxembourg City between 1871 and 1878, including walking areas in the Pétrusse valley and to Trois-Glands. Later he also signed the concepts for the parks of the spa area and the Grand-Chef hotel in Mondorf, and the parks of Mertert, Kockelscheuer, Bofferdange and Walferdange (Schoellen 2009: 37).

In parallel, since the second half of the 18th century, the sector of nurseries and market gardens developed in Luxembourg, very early around Preisch Castle – in what is now Lorraine and in that time the Duchy of Luxembourg –, where the well-known Luxembourg gardener and botanist Nicolas Bové (1802-1842) worked before becoming "chef de carré" at the "Jardin des plantes" in Paris (Marson 2006). In addition to a detailed description of these parks, market gardens and nurseries, Koltz (1875) lists no less than 1,424 taxa in his work "Dendrologie luxembourgeoise - catalogue des arbres, arbrisseaux et arbustes spontanés, subspontanés ou introduits dans les cultures du Grand-Duché de Luxembourg",

among which are numerous species newly introduced to Luxembourg. Koltz (1875: 6) also outlines the rapid development of the nurseries here: from 2 nurseries in 1823 to 15 nurseries in 1870 [1830 (4), 1837 (6), 1850 (8)]. In 1872, Eugène Fischer counted no less than 318 plants introduced or propagated in crops, i.e. more than a fifth of the plant species observed in the country (Koltz 1875: 2, Fischer 1872).

The date of first record often differs from the date of first introduction, the latter remaining unknown for a majority of species. In some rare cases, the year of first introduction was published by meticulous botanists, sometimes quite soon after the introduction: e.g. Koltz (1875: 127) reports that *Fallopia japonica* was introduced in Luxembourg in 1849: "*Polygonum cuspidatum* [...] Introduit en 1849 sous le nom de *P. Sieboldi* (Hort.) par de Siebold; parc de Walferdange"; while Fischer (1872: 89) reports that *Fallopia japonica* was introduced in Luxembourg around 1852. Sometimes the year of introduction was published after a longer period: e.g. the introduction of *Robinia pseudoacacia* from Italy around 1769, which was only reported more than a century later by Fischer (1872: 37-38). Sometimes the year of first introduction had to be deduced from a paraphrased time period, e.g. in the case of *Acer negundo*, for which Koltz (1875: 27) stated "at the beginning of the century", which we translated as <1825.

We must also be aware that the data situation in Luxembourg has to be regarded as rather sparse and incomplete. Due to its small territory, the country was not at the forefront of science. Scientific research developed later than in our larger neighbouring countries with universities and other research facilities. In Luxembourg, similar institutions did not exist until the second half of the 20th century. So, it came about that botany, known as "scientia amabilis", was initially practised as a leisure activity by a few biology professors, doctors, pharmacists and employees of the forest administration.

In 2019 and 2020, the digitisation of more than 90 % of the vascular plants of the herbarium of the Luxembourg National Museum of Natural History (Helminger et

Table 1. First records and status of 56 alien vascular plants in Luxembourg. Invasion status: casual species are marked *, the remaining species are established. Abbreviations: (1) terms: ea. et al, il. in litt., unkn. unknown, LU Luxembourg, LUX Herbarium LUX; (2) references: An Anonymous, Bk Beck, Br Bricher, Co Colling, Fe Feltgen, Fi Fischer, Fo Fontaine, Gi Gillen, Ka Kariger, Ko Koltz, Kl Klein, Kp Krippel, Kr Krombach, Mo Moes (G.), MU MNHNL 2000-, Pa Parent, Pi Pirotte, Pr Proess, Re Reckinger (Ch.), Rg Reichling, Sa Saintenoy-Simon, Si Signoret, Ti Tinant, We Weicherding.

Taxon	In LU	Source	In the wild	Source
<i>Acer negundo</i>	<1825	Ko 1875: 27; Kr 1875: 66	<1875	Ko 1875: 27
<i>Ailanthus altissima</i>	<1875	Ko 1875: 31; Kr 1875: 108	<2013	MU
<i>Ambrosia artemisiifolia</i>	1949	Bk ea. 1950: 162, 204	1950	Bk ea. 1951: 171; LUX 18797
<i>Amelanchier lamarckii</i>	1961	MU	<2000	MU
<i>Asclepias syriaca</i> *	<1836	Ti 1836: 135	id.	ibid.
<i>Aster lanceolatus</i>	1934	LUX 52294; MU	1949	LUX 22445
<i>Aster novi-belgii</i>	<1872	Fi 1872: 83	id.	Ibid.
<i>Atriplex micrantha</i>	2007	We 2007; LUX 22483	id.	ibid.
<i>Azolla filiculoides</i>	~2002	Re il.	2009	Kp & Co 2010: 12
<i>Bidens frondosa</i>	1959	Rg 1962: 44-46	id.	ibid.
<i>Buddleja davidii</i>	1961	MU	id.	ibid.
<i>Bunias orientalis</i>	1874	Ko 1877a: 8; Fi 1886: 58	id.	ibid.
<i>Claytonia perfoliata</i> *	<1988	Rg 1990: 58-59	id.	ibid.
<i>Cochlearia danica</i> *	2011	Kp ea. 2018: 61-62; MU	id.	ibid.
<i>Conyza canadensis</i>	1822	Kr 1875: 344	id.	ibid.
<i>Cornus sericea</i>	1823	Ko 1975: 94	1950	LUX 51729
<i>Cotoneaster horizontalis</i>	1949	LUX 21984; MU	id.	ibid.
<i>Crassula helmsii</i> *	2020	MU	id.	ibid.
<i>Duchesnea indica</i>	<2007	Mo il. 2021	2008	Kp ea. 2010: 17
<i>Egeria densa</i> *	2016	MU	id.	ibid.
<i>Elodea canadensis</i>	~1875	Fi 1882: 122	id.	ibid.
<i>Elodea nuttallii</i>	1975	Pa 1983: 17	id.	ibid.
<i>Epilobium ciliatum</i>	1950	Rg 1961: 68ff.; LUX 17920	id.	ibid.
<i>Erigeron annuus</i>	<1836	Ti 1836: 428	id.	ibid.
<i>Fallopia ×bohemica</i>	2005	Sa 2008: 32	id.	ibid.
<i>Fallopia japonica</i>	1849	Ko 1875: 127	<1872	Fi 1872: 89
<i>Fallopia sachalinensis</i>	1959	MU	id.	ibid.
<i>Helianthus tuberosus</i>	~1720	Pi 1976: 36-40	1875	Kr 1875: 331
<i>Heracleum mantegazzianum</i>	~1934	Rg il. 2008	1980	Rg 1990: 62
<i>Impatiens balfourii</i> *	<1995	Mo il. 2021	2016	Kp & Pr 2017
<i>Impatiens glandulifera</i>	<1897	Kl 1897: 249	1958	Ka 1961: 101
<i>Impatiens parviflora</i>	1956	Rg 1958: 64, 104-105	id.	ibid.
<i>Lemna minuta</i> *	2002	Kp & Co 2016: 39	id.	ibid.

Table 1. (Continued)

Taxon	In LU	Source	In the wild	Source
<i>Lupinus polyphyllus</i>	<1901	Br 1901: 179	1991	Kp 1992
<i>Mahonia aquifolium</i>	1842	Ko 1875: 18	<1875	ibid.
<i>Mimulus guttatus</i>	1998	Co & Kp 2001: 42	id.	ibid.
<i>Myriophyllum aquaticum</i>	~1990	Co & Kp 2003: 16	id.	ibid.
<i>Parthenocissus</i> spp.	<1872	Fi 1872: 22	<1957	Ka 1959: 74
<i>Pennisetum setaceum</i> *	2019	Si 2020: 20	unkn.	
<i>Phytolacca americana</i> *	<1946	An 1946: 54	1980	Rg 1985: 136
<i>Pinus nigra</i>	1823	Ko 1875: 173	unkn.	
<i>Populus ×canadensis</i>	1823	Ko 1875: 138	1987	MU
<i>Prunus laurocerasus</i>	<1875	Ko 1875: 55	1989	Ka 1990: 86, 94
<i>Prunus serotina</i>	<1910	Gi 1951: 87	1960	MU
<i>Quercus rubra</i>	<1873	Ko 1873: 150	unkn.	
<i>Rhus typhina</i>	<1875	Ko 1875: 38	1986	MU
<i>Robinia pseudoacacia</i>	1787	Fo 1862: 89; Kl 1897: 432	<1836	Ti 1836: 371
<i>Rosa rugosa</i>	<1923	An 1923: 2	2002	MU
<i>Rudbeckia laciniata</i> *	1887	Fe 1901: 254	id.	ibid.
<i>Senecio inaequidens</i>	1988	Rg 1990: 67	id.	ibid.
<i>Solidago canadensis</i>	<1872	Fi 1872: 82	id.	ibid.
<i>Solidago gigantea</i>	1882	LUX 15568	1882	LUX 15568
<i>Spiraea alba</i> *	1823	Ko 1875: 67	1949	Bk ea. 1952: 77; LUX 19696
<i>Spiraea ×billardii</i> *	<1875	Ko 1875: 66	1949	LUX 21985
<i>Spiraea douglasii</i> *	1847	Ko 1875: 67	1954	LUX 50664
<i>Syringa vulgaris</i>	<1836	Ti 1836: 17	id.	ibid.

al. 2020) made accessible several specimens that had not previously been referenced in any database. In addition, larger data sets became accessible only after a somewhat long latency period. For example, the herbarium Jos. Witry (1901-1971) with its 1,461 specimens (Massard et al. 2020). As a result, several first records could be dated back from several years to decades. For example, before the present study, we thought the first record of *Solidago gigantea* L. to be the observation in 1960 by Léopold Reichling in several locations of the Grund district in Luxembourg City (MNHNL 2000-). Due to the above-mentioned digitisation effort, we were able to find several older herbarium

specimens, of which the oldest one was collected in 1882 by Jean Feltgen (1833-1904) in a hedge near Angelsberg (herb. LUX n° 15568, MNHNL 2000-).

Having a look at the number of first records per time unit in our time series (1500-2020), the rate of first records is very low with only 2 first records in the first 3 centuries from 1500 to 1800 (Fig. 1). Between 1801 and 1850, the first botanists started to investigate the territory of the Grand Duchy (12 first records).

With the foundation of the “Société des sciences naturelles du grand-duché de Luxembourg” in 1850, aimed at promoting the progress and propagation of natural sciences in

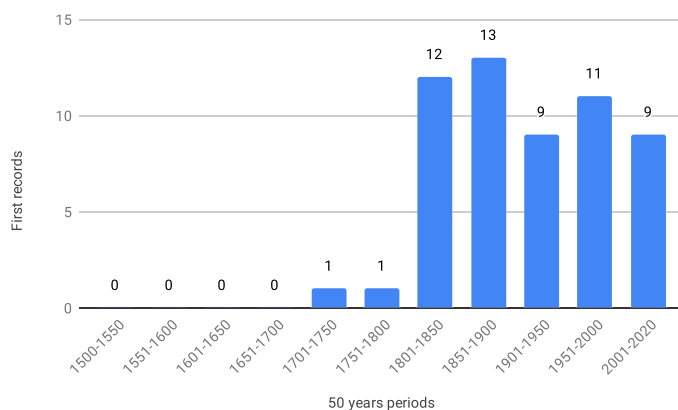


Fig. 1. Number of first records of 56 alien vascular plants in Luxembourg per half century in our time series (1500-2020).

Luxembourg, and which created in the “Athénée de Luxembourg” the “cabinet d’histoire naturelle” in 1854, the cornerstone of the actual National Museum of Natural History (Massard 1990: 16), and with the foundation of the “Société de botanique du grand-duché de Luxembourg” in 1872 (Lefort 1950), floristic investigation flourished during the next half century, from 1851 to 1900, which resulted in another 13 first records. The first half of the 20th century, from 1901 to 1950, shows 9 first records, in line with the slight decrease of botanical and floristic activities, causing the “Société de botanique” to merge in 1907 with the “Société des naturalistes luxembourgeois” (founded in 1890). In the second half of the 20th century, the rate increases to 11 first records, in line with botany experiencing a revival in Luxembourg from 1949, boosted by François Léon Lefort (1917-1975) and leading to the creation of the “Service de la carte des groupements végétaux” within the Department of Natural Sciences of the State Museums, to which the young botanist Léopold Reichling (1921-2009) was immediately assigned (Reichling 1953b, Ries 2003: 22). During the following 18 years, Reichling systematically carried out plant surveys throughout the country.

Finally, in the first 20 years of the 21st century, 9 first records reflect the intensification of botanical surveys within the scope of several biotope mapping exercises covering the whole territory and involving lots of biologists within the framework of the reporting scheduled by the implementation of the European Habitat Directive (OJ 1992).

With as few as 56 taxa, the data of the present study do not show trends in first record rates, while huge data sets show a continuous rise in first record rates during the last 200 years (Seebens et al. 2017).

4.2. Lag phase

Temporal trends in biological invasions are often characterised by a lag phase of little or no increase in species occurrence followed by an increase phase in which species occurrence rises rapidly. While several biological and environmental mechanisms may underlie lag phases, they may also represent statistical artefacts or temporal changes in sampling effort (Aikio et al. 2010).

We have a more or less precise year of introduction for 11 species in our data set: *Helianthus tuberosus* (~1720), *Robinia pseudoacacia* (1787), *Cornus sericea*, *Pinus nigra*, *Populus × canadensis* and *Spiraea alba* (1823), *Mahonia aquifolium* (1842), *Spiraea douglasii* (1847), *Fallopia japonica* (1849), *Prunus serotina* (<1910) and *Heracleum mantegazzianum* (~1934). For the majority of the remaining species we only have a first record, which in most cases may not match the time of introduction into present-day Luxembourg. In the following interpretation we consider the lag phase as the difference between the first record of a species, be it the year of introduction or first report, and its first observation in the wild.

Three species (5 %) have not been observed in the wild yet, so that a lag phase cannot be calculated. For 27 species (48 %) in our data

an eventual time lag is not known as they were first observed in the wild. For 13 species the lag phase ranged from 1 to 50 years between the first record in the country and the first observation in the wild. For 5 species, the lag phase ranged from 61 to 90 years. For 8 species, the lag phase was above a century, ranging from 107 to 164 years (Table 2).

If we have a closer look at the 26 species with a lag phase (Table 3), we notice that 16 out of 20 species with a lag phase of more than 30

Table 2. Lag phase between the first records of our data set and their first observations in the wild.

Lag phase (years)	# Species	%
Cannot be calculated	3	5
Lag phase unknown	27	48
1-50	13	23
51-100	5	9
>100	8	14
Total	56	100

Table 3. Alien vascular plants in Luxembourg (LU) with a lag phase between their first record and their first observation in the wild. * marks species with a documented introduction.

Taxon	1 st record in LU	1 st record in the wild	Lag phase (years)	Life cycle
<i>Ambrosia artemisiifolia</i>	1949	1950	1	annual
<i>Duchesnea indica</i>	< 2007	2008	1	perennial
<i>Azolla filiculoides</i>	~ 2002	2009	7	perennial
<i>Aster lanceolatus</i>	1934	1949	15	perennial
<i>Impatiens balfourii</i>	<1995	2016	21	annual
<i>Fallopia japonica</i> *	1849	<1872	23	perennial
<i>Mahonia aquifolium</i> *	1842	<1875	33	shrub
<i>Phytolacca americana</i>	<1946	1980	34	shrub
<i>Amelanchier lamarckii</i>	1961	<2000	39	shrub
<i>Heracleum mantegazzianum</i> *	~1934	1980	46	biennial
<i>Robinia pseudoacacia</i> *	1787	<1836	49	tree
<i>Acer negundo</i>	<1825	<1875	50	tree
<i>Prunus serotina</i> *	<1910	1960	50	shrub
<i>Impatiens glandulifera</i>	<1897	1958	61	annual
<i>Spiraea xbillardii</i>	<1875	1949	74	shrub
<i>Rosa rugosa</i>	<1923	2002	79	shrub
<i>Parthenocissus</i> spp.	<1872	<1957	85	vine
<i>Lupinus polyphyllus</i>	<1901	1991	90	perennial
<i>Spiraea douglasii</i> *	1847	1954	107	shrub
<i>Rhus typhina</i>	<1875	1986	111	shrub
<i>Prunus laurocerasus</i>	<1875	1989	114	shrub
<i>Spiraea alba</i> *	1823	1949	126	shrub
<i>Cornus sericea</i> *	1823	1950	127	shrub
<i>Ailanthus altissima</i>	<1875	<2013	138	tree
<i>Helianthus tuberosus</i> *	~1720	<1875	155	perennial
<i>Populus xcanadensis</i> *	1823	1987	164	tree

years are woody plants (4 trees, 11 shrubs and 1 vine). In the two following examples climate change appears to play a decisive role.

The shrub *Prunus laurocerasus* was introduced to Luxembourg before 1875 and was reported by Koltz (1875: 55) and Krombach (1875: 145) as a cultivated evergreen shrub. In Luxembourg, cherry laurel has become a common garden plant, mostly planted to build hedges. After a lag phase of 142 years, the plant was discovered in 2017 in the wild in forest areas near Steinsel (Krippel et al. 2018: 70). Since then, a considerable number of locations have been reported, showing an expansion of the species into the wild, especially in forests near to villages (Ries et al. 2021). A similar behaviour can be observed in neighbouring Belgium (Henneresse 2014). Considering its numerous invasion histories in Southern and Central Europe, the species may have recently changed its behaviour due to climate change, as outlined by Branquart et al. (2010).

The tree *Ailanthus altissima* was already reported as cultivated by Koltz (1875: 31) and Krombach (1875: 108) – thus introduced before 1875. After a lag phase of 118 years, adult individuals of the plant were reported in 2013 in the wild, from a forest edge near Elvange, by Jerry Grün (MNHNL 2000-). Since the 2010s the species started to reproduce with seedlings and shoots in several urban areas, e.g. parks in Luxembourg City and Diekirch, and spread in the wild, e.g. on sandstone cliffs in the Grund district of Luxembourg City, or in urban areas, i.e. Echternach (Krippel et al. 2020) or Mersch (MNHNL 2000-). In Europe, *Ailanthus* shows a closed distribution area in the Mediterranean. Along a gradient from the meridional to the temperate zone, its occurrences are increasingly confined to cities at northern outposts of its range. This had been mostly attributed to the effects of urban climate, assumed to provide a longer vegetation period, compensating for missing heat sums, and to curb frost intensity and duration towards the northern limits of its range (Kowarik & Säumel 2007). Meanwhile, due to recent global warming, Luxembourg's smaller urban spaces now seem increasingly suitable for an expansion of the population of the tree of heaven.

4.3. Restrictions and ambiguities

A major problem when reviewing taxa over a few decades or even centuries are the endless changes in taxonomy and nomenclature. In this context, for example, all specimens of the genus *Spiraea* in the LUX herbarium had to be revised, as most specimens collected in Luxembourg were labelled *Spiraea salicifolia* L., a species that was frequently – but erroneously – mentioned in the past for Luxembourg and surrounding areas, but probably confused with *Spiraea alba* du Roi or *S. ×billardii* Hérincq, the latter by far the most common taxa in the region (Lambinon & Verloove 2015).

To sort out all uncertainties resulting from reams of synonyms for some taxa, the consultation of different floras, taxon lists and synonym databases (e.g. Wisskirchen & Haeupler 1998, WFO 2021) was compulsory. One problem we did, however, not manage to sort out was *Parthenocissus*. *Parthenocissus inserta* (A. Kerner) Fritsch has long been confused with *Parthenocissus quinquefolia* (L.) Planch. originating from North America (Lambinon & Verloove 2015: 457, David 2010, Pringle 2010). *Parthenocissus quinquefolia* – even if often mentioned in Luxembourgish floras – is supposed to be a rather rare ornamental species and is known as an escape from cultivation in Belgium only since 2001 (Verloove 2006). The numerous – often ambiguous – synonyms in the old floras and papers (i.e. Fischer 1872, Krombach 1875, Klein 1897) don't help to elucidate the problem. The diverging morphological descriptions in the floras, together with the fact that missing organs on the few specimens in the LUX herbarium did not allow a revision, led us to assess *Parthenocissus* on the genus level only.

An important issue are the changing limits of Luxembourg in the early 19th century. In fact, the present-day state of Luxembourg first emerged after the Congress of Vienna in 1815. The Grand Duchy became an independent state under the personal possession of William I of the Netherlands. In 1839 however, following the turmoil of the Belgian Revolution, more than half of the territory was ceded to Belgium. Floras published before 1839 thus cover a different – larger

– territory for Luxembourg, and only data with exact location information was considered in the present study, i.e. *Asclepias syriaca*, *Erigeron annuus* and *Syringa vulgaris* listed by Tinant (1836).

In some cases, historical references can be quite tricky. Was *Robinia pseudoacacia* introduced to Luxembourg in the 17th or 18th century? In 1836 François Auguste Tinant mentions “*Robinia Pseudo-Acacia*” as a naturalised exotic tree (Tinant 1836: 371). In 1860, Eugène Fischer reports that Jean-Mathias de Blochausen brought back several tree species from a journey to Italy in 1669, including false acacia and Italian poplar, the latter for roadside planting (Fischer 1860: 178-181). Around 1872, according to the same Eugène Fischer (1872: 37-38), “it is frequently and advantageously cultivated on our slopes, poor iridescent marls, in groves, promontories, and it is sometimes even used to make fence hedges. So, the first *Robinia* trees planted in the Grand Duchy were apparently imported from Italy around 1669 by de Blochausen. For more than a century this tree was still considered as rare in the country, since Mr. de la Fontaine, former governor of the Grand Duchy, mentioned, as one of the first specimens of this tree in our country, an acacia tree planted in 1787 by Mr. Baron de Maréchal in the garden dependent on Stadtbredimus castle” (de la Fontaine 1862: 89). The year “1669” mentioned by Fischer (1860) appears to be an error, as the Family de Blochausen only arrived in Luxembourg around 1764, when Marie-Gisberte de Blochausen bought the Domaine de Brückenberg in Colmar-Berg and Jean-Mathias de Blochausen bought the Rollingen forge (Ottelé n.d.). We therefore presume that it should read 1769 instead of 1669, which would also be in line with two reports of first planting in 1787 in Stadtbredimus (Fontaine 1862: 89) and in the same year at Kaaschtel near Altwies, today in Lorraine, France (Wikipedia contributors 2021). Consequently, we consider 1787 as the year of first record in Luxembourg until historic research brings new evidence.

Sometimes we also faced uncertainties in documents: e.g. an herbarium specimen of *Solidago gigantea* collected by Feltgen (herb.

LUX n° 15568), on which the year is not easily readable, entered in the database as 1889. After comparing with several other herbarium specimens by Feltgen we rectified this to 1882.

For many cultivated species in our data set, the year of introduction is unknown and we therefore must assume they must have been occurring much earlier than indicated by their first records, e.g. *Duchesnea indica*, *Buddleja davidii* and *Rosa rugosa* which were certainly present in the country before their first record in Luxembourg. *Buddleja davidii*, for example, was introduced as a horticultural plant to Europe in the late 1890s and naturalised on a significant scale in the 1940s in parts of Europe after the destruction of cities during World War II. Bombed sites and building rubble were suitable colonisation habitats and therefore dense *B. davidii* thickets established on these sites. In the 1950s and 1960s, *B. davidii* became a popular garden shrub, which further contributed to its spread when it escaped from cultivation and naturalised in the wild (CABI 2019).

5. Conclusions

For the first time, detailed information about the introduction and invasion history of 56 alien vascular plants in Luxembourg is compiled, and even if some uncertainties persist, an insight into the invasion pathways and processes, such as entrance into the country, spread in the territory, and lag phases can be given.

The present study shows that invasive alien plant species are not a recent phenomenon and that most of the species were introduced to Luxembourg a long time ago. They are often of horticultural origin, and especially woody species were deliberately planted in parks and gardens, their escape occurring after a somewhat long – species dependent – lag phase. Over the decades – with global and increased trade – an increased number of alien species has become available for planting in private gardens; hence an increased probability that they escape into the wild. Unfortunately, ongoing cli-

mate change is accelerating the propagation of non-native species, and horticultural taxa (e.g. *Ailanthus altissima*, *Buddleja davidii* and *Prunus laurocerasus*) can become invasive – after a long period of latency – in only a few years.

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