The Hogweed Story: Invasion of Europe by Large *Heracleum* Species

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Large hogweed species as invaders in Europe

One of the most spectacular invasions of Europe by alien plants is that of species of the hogweed genus (*Heracleum*) from the family Apiaceae (Pyšek et al. 2007). Several of the large members of the genus were introduced as garden ornamentals or as fodder crops outside their native range. The most distinctive characteristic of these closely related species is their size; they can attain heights of up to 4-5 m, which ranks them among the tallest and largest herbs in Europe, thus they are called "large, tall or giant" hogweeds. Three "tall" hogweeds have become invasive in Europe: *Heracleum mantegazzianum* (native to Western Greater Caucasus), *H. sosnowskyi* (native to Central and Eastern Greater Caucasus and Transcaucasia) and *H. persicum* (native to Turkey, Iran and Iraq). For several reasons, historical data on the occurrence of these species in Europe are fairly detailed, especially in countries with a strong floristic tradition, and allow a good retrospective analysis of their spread. Large hogweed species are attractive enough to be recorded by botanists, because of their alien origin, tendency to spread and conspicuous appearance; this holds true especially for the most widely distributed species, giant hogweed, *Heracleum mantegazzianum* (Figure **1**) (Jahodová et al. 2007a). In addition, the production of phototoxic sap, dangerous to human health (Figure **2**) increases public awareness of this invasion (Nielsen et al. 2005).

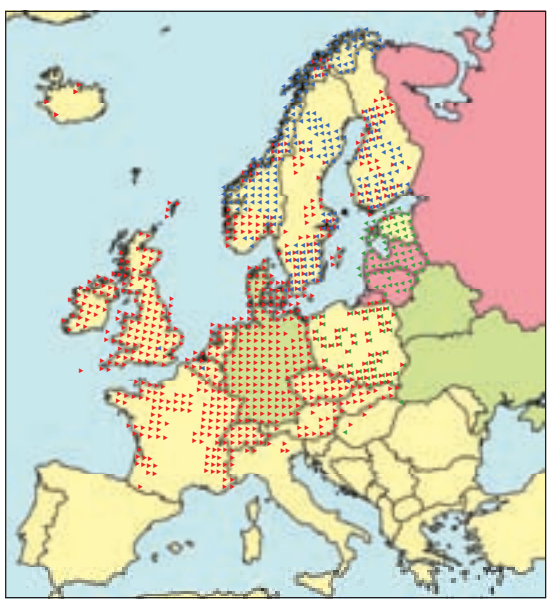

Figure 3. Distribution of three "tall hogweed" species invading in Europe in 50 × 50 km grid cell. Red – *Heracleum mantegazzianum*, blue – *H. persicum*, green – *H. sosnowskyi*. Regions displayed in respective colours are those from which the species are reported but exact distribution in grid cells is unknown. Note that *H. sosnowskyi* also occurs in Russia (Adapted from Jahodová et al. 2007a).

History of introduction

Heracleum sosnowskyi was introduced into Europe as an agricultural crop for silage, to provide fodder for livestock in north and north-west Russia since its introduction in 1947. From the 1940s onwards, it was introduced as a crop to the Baltic countries (Latvia, Lithuania and Estonia), Belarus, Ukraine and the former German Democratic Republic. Although this practice was later abandoned, because the anise-scented plants affected the flavour of meat and milk of the animals fed this fodder and phototoxic saps imposed health risk to humans and cattle, it is still cultivated in northern Russia (Jahodová et al. 2007a).

Figure 1. Plants of giant hogweed (*Heracleum mantegazzianum*) are up to 4-5 m tall and a solitary plant can give rise to a population by means of self-fertilization. Photo: Jan Pergl.

The other two hogweed species were introduced as garden ornamentals from their native ranges in the 19th century. The main mechanism of their introduction into Europe and further spread was ornamental curiosity. Seeds were planted in botanic gardens and the grounds of important estates; this continued for most of the 19th century and only declined and eventually ceased after warnings about the dangers of the plant appeared in western European literature towards the end of the 20th century (Nielsen et al. 2005). The first known record of *Heracleum mantegazzianum* is for England, when it appeared on the Kew Botanic Gardens, London seed list in the 1817. Eleven years later, in 1828, the first naturalized population was recorded in the wild in Cambridgeshire, England, and soon afterwards, the plant began to spread rapidly across Europe. Data from the Czech Republic confirm that the species was able to escape from cultivation after a very short period of time; in this country it needed 15 years to appear in the wild. Ranked according to the date of introduction, the UK was followed by the Netherlands, Switzerland, Germany, Ireland, Denmark, the Czech Republic; other countries followed later on and currently giant hogweed is reported to occur in 19 European countries (Pyšek et al. 2008). The earliest record of *Heracleum persicum* comes from the seed list of the Kew Botanic Gardens in London, from 1819. Seeds from London populations of were taken by English horticulturalists and planted in northern Norway as early as 1836.

Figure 2. Plants contain phototoxic juices which create blisters on human skin if it is exposed to the sun. Photo: Marion Seier.

Current distribution of large hogweed species in Europe

In all three species, the introduction history determines their current distribution in the invaded European range. This is the main reason why *H. sosnowskyi* and *H. persicum* occur in the north-eastern part of Europe and Fennoscandia, respectively (Figure **3**). In *Heracleum mantegazzianum*, the most widespread of the three species, the distribution is clearly biased towards the central and northern part of the continent (Figure **3**; Jahodová et al. 2007a). That the species is virtually absent from southern Europe reflects its origin in the Caucasus mountains where the climate is cooler; plants are not adapted to the warm climate in the south of Europe which constrains their invasion (Moravcová et al. 2006). A likely reason for the widespread current distribution of *Heracleum mantegazzianum* in Europe is multiple introductions as suggested by genetic analysis of invading and native populations of this species (Jahodová et al. 2007b).

What makes giant hogweed so invasive?

Unlike many other alien species, majority of which do not form large populations, *Heracleum mantegazzianum* usually occurs as a dominant species of invaded communities (Figure **4**). It has been estimated that in the Slavkovský les region in the western part of the Czech Republic, where the species was first introduced, its invaded population cover about 7 % of non-forested landscape. This is made possible by a unique combination of traits (Table **1**) and suitable environmental conditions. Although the species does not seem to possess any special characteristic/mechanism, extremely high fecundity, rapid growth, capability of self-pollination, extended germination period by means of short-term persistent seed bank, high germination and negligible impact of natural enemies are all characteristics associated with invasiveness in plants (Figure **5**). Therefore, it is a combination of superior traits acting at different stages of the life cycle with remarkable invasion potential which resulted in the strategy

Figure 4. Giant hogweed form large stands that dominate the landscape and are conspicuous at both flowering (a–b) and fruiting stage (c). Photo: Petr Pyšek (a, c), Jan Pergl (b).

Table 1. Life history traits of *Heracleum mantegazzianum* supporting its invasiveness. Based on data collected in invaded populations in the western part of the Czech Republic (see Pyšek et al. 2007 for summary).

Germination	germinates in early spring	advantage of developing populations well ahead of resident vegetation
	high germination rate, 91 % seed germinate in laboratory	rapid and effective space pre-emption
Seedling competition	seedling density 500-700/m^2, with maxima up to 3700/m^2	rapid and effective space pre-emption
	a high relative growth rate of seedlings	competitive advantage over resident vegetation
	low mortality of established seedlings	competitive advantage, space pre-emption
Vegetative plants	rapid growth of rosettes	formation of dense cover, suppression of other species
Flowering strategy	no constraints to flowering (completed in ca 30-40 days), fruit released after 2 months	assurance of population reproduction
	ability to postpone flowering under unfavourable conditions	population persistence over long period
Reproductive system	ability to self-pollinate	reproductive assurance, potential to found invasive population from a single individual
	high fecundity, single plant produces ca 20,000 seeds	population maintenance and spread
Dispersal	effective dispersal by various means (human activities, water, wind)	good capacity for spread of seed to distant areas
Seed bank	extensive and short-term persistent seed bank, > 2000 viable seeds/m^2 present in soil in the spring	adjustment to between-year variation in environmental conditions
	seed longevity minumum 5 years	long-term population persistence in the form of dormant seed
Regeneration ability	if cut at ground level, regeneration in the same year produces 3-4 % of seed of control plants	resistance to control measures

Figure 5. High density of seedlings early in the spring (a) and massive production of fruits (b) are among traits supporting the invasion of giant hogweed. Photo: Jan Pergl (a), Petr Pyšek (b).

of *Heracleum mantegazzianum* being called a 'master-of-all-traits' of plant invasions (Pyšek et al. 2007).

Spread of giant hogweed at local, regional and continental scales

The data collated during the 5FP project GIANT HOGWEED (www.giant-alien.dk) and analysed within the ALARM project make it possible to assess the spread of *Heracleum mantegazzianum* at the local scale of the Slavkovský les region (Figure **6**, Müllerová et al. 2005), regional scale of the Czech Republic (Figure **7**) and the European scale (Figure **8**). Comparison of the rate of spread at the three scales indicates that there are two different mechanisms of spread acting together in this system, namely human influences and natural spread, and the relative influence of these mechanisms appears to change in an inverse proportion from the largest to the smallest scale: the invasion was slowest at the continental scale and did not differ significantly between regional and local scales. At the local scale, under suitable habitat conditions, the process is driven by biological traits of the species related to dispersal. At the continental and regional scales, humans played a crucial role in the invasion of *H. mantegazzianum* by planting it as a garden ornamental, and human-mediated dispersal seems to have been the major driver of spread, responsible for creating dispersal foci in the initial phases of invasion. Species traits played an important role in local spread, resulting in the colonization of new sites (Pyšek et al. 2008).

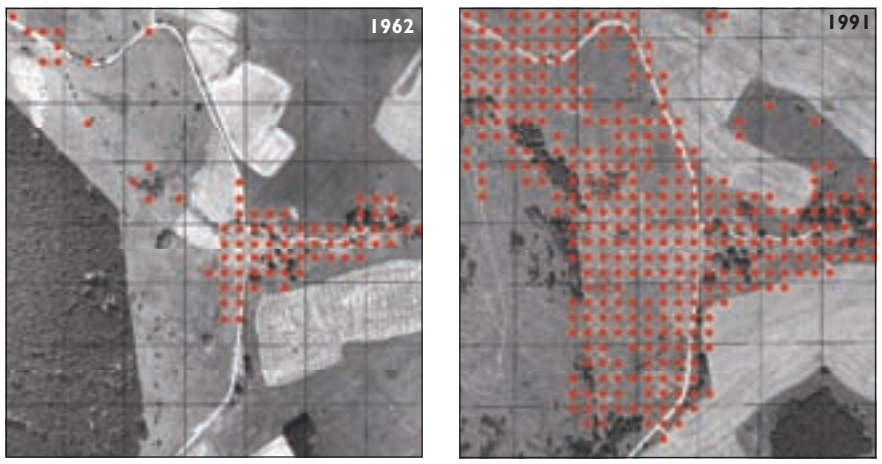

Figure 6. Invasion of giant hogweed at a local scale in the Slavkovský les Protected landscape area, Czech Republic. Individual plants are recognizable by large white flowering umbels, the grid indicates extent of hogweed population in 1962 and 1991 (Adapted from Müllerová et al. 2005).

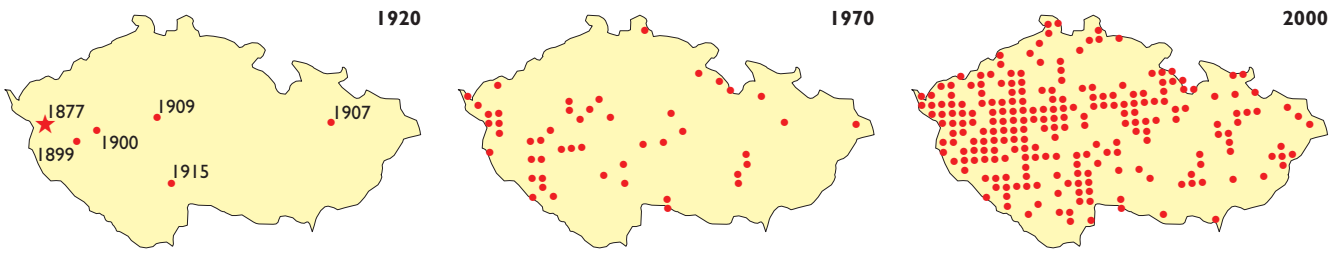

Figure 7. Invasion of giant hogweed at a regional scale of the Czech Republic. Distribution in grids of 11 × 12 km is shown for 1920, with years of first records indicated), 1970, before the start of the massive spread) and 2000 (Adapted from Pyšek et al. 2008).

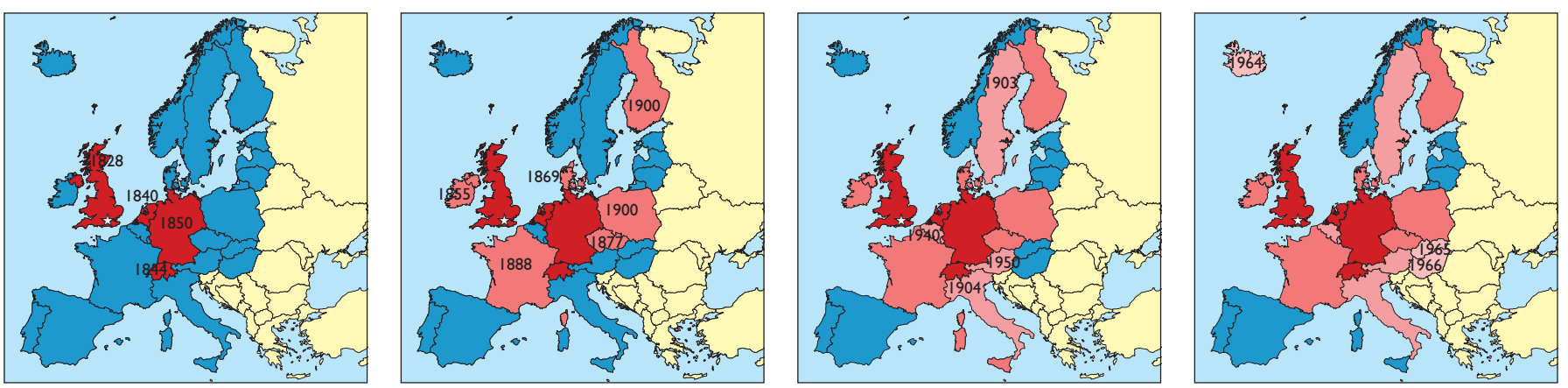

Figure 8. Invasion of giant hogweed at the continental scale of Europe. Countries from which the species was reported are shown in 50-yr intervals, with the year of the first record in the country indicated. Countries with earlier introduction are indicated using a darker shade of red. Countries in blue are those that were studied but giant hogweed was not recorded there or the date of introduction is unknown (Adapted from Pyšek et al. 2008).

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