

Current distribution and spreading of *Euphorbia davidii* (*E. dentata* agg.) in Europe

Research Article

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Abstract: Of the *Euphorbia dentata* aggregate, both *E. dentata* and *E. davidii* have been reported from Europe. A revision of herbarium and published materials, however, indicates that only *E. davidii* can be confirmed in Europe. Although known in Europe since 1968, most records are from the 1990s. There are 46 known populations scattered throughout the continent, in Russia, Ukraine, Moldova, Romania, Bulgaria, Hungary, Italy, Belgium, Switzerland and France. Most populations are small and restricted to railway areas; however, the species can also invade agricultural fields. Due to its wide distribution, the growing number of recently established populations, and its invasive ability, special attention should be paid to changes in distribution and population sizes in Europe.

Keywords: Agricultural fields • Alien plants • Invasion • Neophytes • Ruderal habitats • Weeds

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1. Introduction

As in many areas worldwide, the number of alien plant species in Europe is growing at an alarming pace [1] and they have significant impact on biodiversity and economy [2]. More and more countries and regions have up-to-date checklists of alien plants; however, many countries lack even brief reports, testifying that our knowledge of alien species in Europe varies significantly by region [3].

Despite the growing number of aliens and the associated problems they cause, their impact is sufficiently documented for only a few species (e.g. [4,5]).

Various methods are used to reveal the pattern of spread of important aliens, including reviewing data in the literature and unpublished records [6], studying herbarium vouchers [4,5,7,8] or interviewing landholders [9]. However, there is a lack of records for many species and regions. The more we know concerning the spreading history of alien taxa, the better we can predict their expected impact, and the potential impact and spread of related taxa [8,10].

In the present study we provide a revision of the *Euphorbia dentata* complex in Europe, aim to determine its current distribution, reconstruct its spreading history in Europe, and assess its habitat-preferences

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and modes of spread. This kind of information could be a great help in understanding the spatio-temporal dynamics of *Euphorbia davidii* and might facilitate its control in invaded areas.

2. Experimental Procedures

We investigated European occurrences of *E. dentata* and *E. davidii*. We studied specimens from Herbaria of the Hungarian Natural History Museum (BP), the M.G. Kholodny Institute of Botany, N.A.S. of Ukraine (KW), and the University of Agricultural Sciences and Veterinary Medicine of Iași Romania (IASI), (acronyms of herbaria follow the Index Herbariorum [11]), as well as all relevant recent publications including revisions of European populations of the *Euphorbia dentata* agg.

Revisions in identification were made based on distinguishing characters published in the original description of *E. davidii* [12] amended with later works [13-16].

All relevant available data – the exact locality of the population, the elevation, the time of first observation, the population size, the general habitat description, and the literature references – were used to evaluate methods of spread in time and space across Europe. To check the possibility of a continuous expansion in area, and thus the possible insufficiency of scattered observations of the species against isolated populations (cf. [17]), a linear spread [18] was assumed and its likelihood was tested using correlation between the time of appearance of new stands and their distance from the earliest known population. Also, an average spreading rate was determined for all localities (cf. [6]) using the lowest ratio of distance and time from the already settled populations. Significances have been tested by Student's t-probe. For treating, editing and displaying spatial data QGIS 1.7.3-Wroclaw has been used.

3. Results

3.1 Specific treatment

The *Euphorbia dentata* aggregate includes two species: *E. dentata* Michx. and *E. davidii* Subils. Both *E. dentata* (toothed spurge) and *E. davidii* (David's spurge) belong to subgenus *Poinsettia* (Grah.) House (along with the well-known ornamental poinsettia, *E. pulcherrima* Willd. ex Klotzsch).

Euphorbia dentata, described in 1803, is native to the Central [19] and Eastern United States, Mexico, and perhaps Guatemala [20]. *Euphorbia davidii* was just recently described, in 1984, from Argentina [12] – thus it is widely believed that the species originated from there. However, both *E. dentata* and *E. davidii* are native to North America (cf. [13,14,21,22]) and *E. davidii* is actually an alien in its type locality in South America [23].

Euphorbia dentata and *E. davidii* are widely misidentified [16,22,24], because of the recent recognition and separation of *E. davidii*, and due to similarities in their morphological characters and distribution (see distinguishing characters in Table 1). All reports from Russia [25,26], Ukraine [27-31], Moldova [32], Romania [33-35], Italy (Poldini in [21]), France and Belgium [36] were exclusively published under the name of *E. dentata* Michx. until 2011 (Table 2). The first report on *E. davidii* in Europe is from Bulgaria [14]. Subsequently, a revision of the Italian and French populations indicated that only *E. davidii* occurs in these countries and that *E. dentata* had been reported erroneously [21,24,37]. Similarly, Yena revised the Crimean occurrence and identified the plants there as *E. davidii*; moreover, he suggested that only this latter species is distributed as an alien in Ukraine [15]. Furthermore, Geltman revised the known Russian occurrences and provided new records of *E. davidii* from the European part of Russia [38].

In Hungary, all occurring specimens were originally identified as *Euphorbia dentata*. The first report on it, under this name, was given in 2011 by Szabó (presented

	<i>Euphorbia davidii</i>	<i>Euphorbia dentata</i>
trichomes of the lower leaf surface	strongly tapered with a broad basal cell	weak, lacking broad basal cell
seeds	angular in transection, unevenly and bluntly tuberculate, only a little longer than wide, with a large, yellow, reniform caruncle	rounded in transection, evenly and sharply tuberculate, quite longer than wide, with a small caruncle
lacinia of the cyathium	glandular	non glandular
bracteoles inside cyathium	with non glandular lacinia	with glandular lacinia
ploidy	tetraploid, 2n=56	diploid, 2n=28

Table 1. Morphological and cytological differences between *Euphorbia davidii* and *E. dentata* based on [12] amended with the works [13-16].

	records with name <i>Euphorbia dentata</i>	revisions/published as <i>Euphorbia davidii</i>
Belgium	[36]	
Bulgaria		[14]
France	[16,41]	[24]
Hungary	presentations of Szabó 2011 and Molnár <i>et al.</i> 2012	[42]
Italy	Poldini in [21]	[21]
Moldova	[32]	unpublished revisions
Romania	[33-35]	unpublished revisions
Russia	[25,26,49]	[38]
Switzerland		[16]
Ukraine	[15,27-29,48,50]	unpublished revisions

Table 2. List of sources with reports of *Euphorbia dentata* by countries and the revisions of earlier records for *E. davidii*.

at the 1446th session of the Hungarian Biological Society, Section of Botany, 14.11.2011) and some months later by Molnár *et al.* (presented at the 22nd Forum of Hungarian Plant Protection Society, 27–28.01.2012).

Reviewing the relevant literature and revising the voucher specimens (in cases where the published revisions were missing) we tentatively conclude that only *Euphorbia davidii* occurs in Europe, and reports of *E. dentata* are erroneous (Table 2).

3.2 History of the spread in Europe

Members of the *Euphorbia dentata* aggregate naturally occur in North America, but have extended their presence into South America and have also been introduced into Australia [39], Asia (first reported in the late 1960s [40]) and into Europe.

Euphorbia davidii (as *E. dentata*) was first reported in Europe in 1968 from the territory of Russia [25] (Table 3). At that time the species was distributed along roads, in plough-lands and vineyards within a radius of ca. 40 km of the town of Pyatigorsk, where it was considered an invasive species. Somewhat later it was also found on Mt. Mashuk above the town [26]. The next recorded occurrences were from Moldova [32] in the 1970s and from Belgium in 1986 [36] (Table 3). By the middle of the 1990s, it was reported in many parts of Ukraine: Odessa (1989), Donetsk (1991), Transcarpathia (1992, 1993), Kherson (1995) and Kyiv (1995) [29], later in Zatoka (2006, Odessa Reg., in herb. KW, unpubl.), Kharkiv (2008, in herb. KW, unpubl.) and Sevastopol (2011) [15]. The species appeared in Italy in 1996 [21], in France and in Romania in 1997 [24,33] and in Bulgaria in 2009 [14] (Figure 1).

After its first occurrences in southern and eastern France, it was also found in Burgundy and 6 additional localities, in a scattered distribution from the south-west

to the central-east of the country [16,24,41]. In Italy it is currently known only from 5 localities within the northern regions [21]. There are 4 known populations in Romania, all restricted to the eastern and south-eastern part of the country [35] (Figure 1).

In Hungary, the first collection was made in 2011 a single contaminated maize field at Igar (Maszek-dűlő, coll. Tamás Bali, specimen deposited at BP), where it covered between 0.1 and 30% of different sample plots [42]. According to the farmer, he observed the species in 2008, when he began renting the area. The previous owner indicated that he never bought crop seed from abroad.

In summary, *Euphorbia davidii* is currently known from 46 localities in 10 European countries (Table 3, Figure 1).

3.3 Modes of spread

Members of the *Euphorbia dentata* agg. have no structures (wings, plumes, *etc.* [43]) on their seeds or fruit that facilitate long-distance dispersal; being toxic, they are not consumed by vertebrates [39]. Thus, in the absence of human interference, their propagation and spread is confined to small distances. Testing the possibility of continuous (linear) spread from the earliest known introduction centre (Pyatigorsk) using all known records, the correlation is weak (Figure 2; $R^2=0.1687$ and $t=46$). Assuming more than one point of introduction and continuous spread, very different rates of spread are seen for documented populations (Table 3). The maximum rate of spread varies from 0.42 km/year to 320 km/year (with an average value: 88.23, dispersion: 111.67), with no unidirectional change and large jumps scattered in time.

The number of known localities shows a remarkable recent growth which can be typified as exponential (Figure 3, $y=1E-69e^{0.0807x}$, $R^2=0.9637$).

Country	Locality	Year	Habitats	Km/Year	Reference
Russia	Pyatigorsk	1968	roads, ploughlands, vineyards	-	[25]
Russia	Mashuk	1974	vineyard	0.4	[26]
Moldova	Moldova	1975		230	[32]
Belgium	Flanders	1986		102.8	[36]
Ukraine	Odessa	1989		6.7	[27]
Ukraine	Amvrosiyivka	1991		305	[29]
Ukraine	Donetsk	1991		285	[50]
Ukraine	Chop	1992	railway station	183.3	[28]
Ukraine	Mukachevo	1992	railway station	183.3	[28]
France	Huningue	1993		57.1	[16]
Ukraine	Chynadiyovo	1993	railway station	13	[28]
Italy	Rosolina	1995	railway track	225	[21]
Italy	San Vito di Fagagna	1995	the edge of soybean field	225	[21]
Ukraine	Kyiv	1995	railway road	110	[29]
Ukraine	Bat'ovo	1995	railway station	7.7	[28]
Ukraine	Kherson	1996	oil refinery	21.4	[29]
Ukraine	Vil'ne	1996		37.1	[48]
France	Rodilhan	1997	roadside	320	[41]
Romania	Iasi	1997		13.8	[33]
Italy	Novara	2003	railway station	25	[21]
France	Gers	2004		45.7	[41]
France	Saint-Rome	2005	soybean field	100	[41]
Romania	Buzău	2005	railway station	28.8	[34]
France	Fleurey-sur-Ouche	2006	corn field	16.2	[41]
France	Avignon	2006		3.9	[41]
Ukraine	Zatoka	2006	railway station	3.2	Shevera, Zvyaginseva (2008, in herb., unpubl.)
Hungary	Igar	2008	maize field	22.5	[43]
Bulgaria	Beloslav	2009	along rail tracks (ferry harbour)	57.5	[14]
Bulgaria	Razdelna	2009	railway station	57.5	[14]
Italy	Santhia	2009	railway station	6.7	[21]
Italy	Chivasso	2009	railway track	11.7	[21]
Russia	Sochy	2009		6.3	[49]
Ukraine	Kharkiv	2009	railway station	13.3	2008, in herb. KW, unpubl.
Russia	Nedvygovka	2010		4.7	V. Kolomyichuk pers. comm.
Romania	Tecuci	2011	railway station	10	[35]
Romania	Movileni	2011	railway yard	15	[35]
Russia	Afopostik	2011	railway station	65	[49]
Switzerland	Bussigny-près-Lausanne	2011	industrial area	30	[16]
Ukraine	Sevastopol	2011	railway station	100	[15]
Russia	St. Petersburg	2012	port	61.8	[38]
Russia	Alani	2012		3.4	[38]
Russia	Moscow	2012		216.7	[38]
Russia	Qarachay-Cherkes	2012		1.9	[38]
Russia	Rostov	2012		276.7	[38]
Russia	Stavropol	2012		3.4	[38]
Russia	Udmurtija	2012		456.7	[38]

Table 3. Records of *Euphorbia davidii* in Europe.

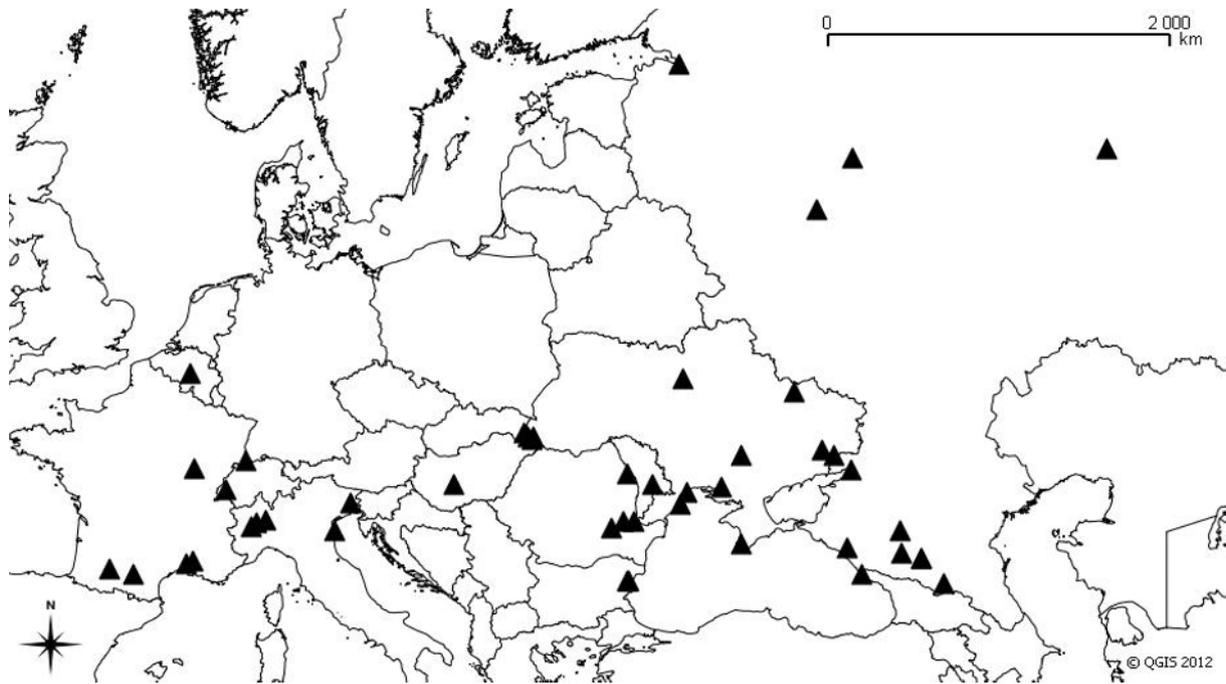


Figure 1. Actual distribution of *Euphorbia davidii* in Europe.

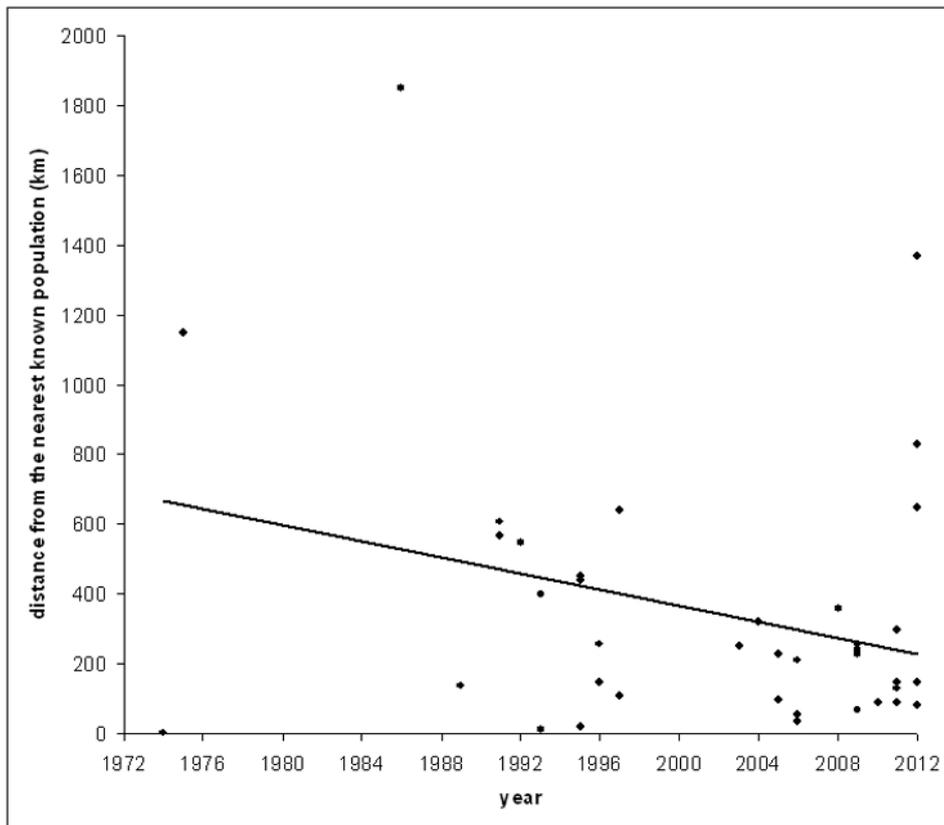


Figure 2. Relations between the distances from the first locality (S Russia) of *Euphorbia davidii* in Europe and the time of appearance (axis x: years of appearances of new populations, axis y: distances of populations from the first Russian introduction centre in kilometres). $y = -11,488x + 23342$, $R^2 = 0,1687$, $P < 0,01$).

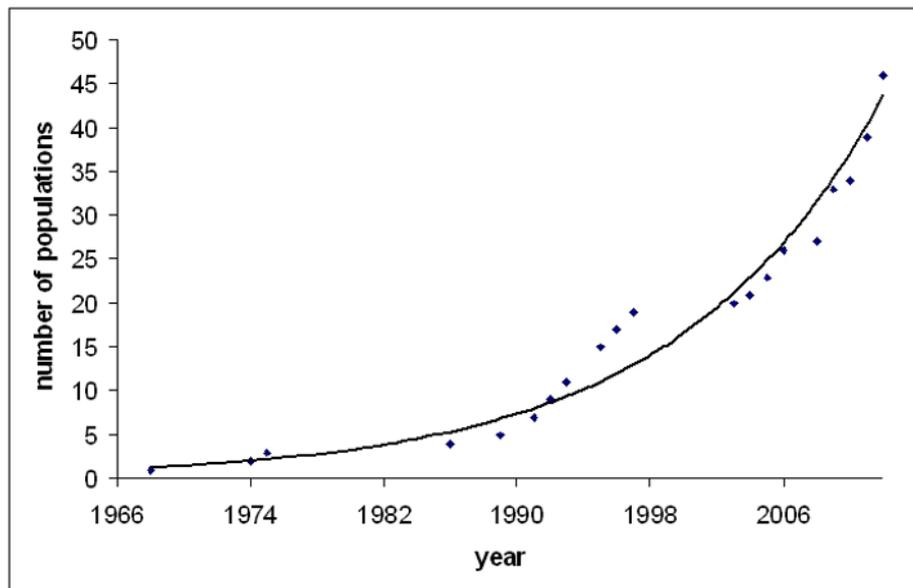


Figure 3. Growth of the number of known populations of *Euphorbia davidii* in Europe. Trend line: $y=1E-69e^{0.0807x}$; $R^2=0.9637$.

The populations in railway environments cover only a few square meters [14,29] while in agricultural environments even 26 hectares large plots can be found [42] and the plant shows a remarkably strong ability to spread [24,25,42].

There is a limited number of records on the survival of populations over time. However, after 44 years at Pyatigorsk, *Euphorbia davidii* is still present on the same location [38] – as is the case in Belgium after 17 years [36]. Likewise, the earliest reported populations in southern France [41], northern Italy [21], western Ukraine (Transcarpathia) and Kyiv (unpublished observations of present authors) are still present. Similarly, in Hungary the first observation of *E. davidii* was made in 2008 and the species has been present on the same plot at least for 3 years [42].

3.4 Habitat types

Reviewing the reported habitat types of *E. davidii* in Europe (Table 3), two main groups can be distinguished. Most of the European records (65.5%) are from railway stations, railway tracks or other places associated with railways [14,15,21,28,29,34,35]. Presumably, its occurrence near a Kherson oil refinery is also connected with railways. The other characteristic habitat of *Euphorbia davidii* in Europe is agricultural field (17.2% of the known occurrences), particularly maize and soybean fields [21,24,42]. In the most highly infested regions it has also been observed in other habitat types, such as in vineyards (6.9%), and along roadsides and other ruderal environments [24,25].

3.5 Range of elevation

Most reported occurrences in Europe occur at elevations between sea level and ca. 400 m. The highest occurrence is at 600 m in southern Russia on the slope of Mt Mashuk, within extended agricultural land [26].

4. Discussion

The situation of the *Euphorbia dentata* group is a unique one in Europe. *Euphorbia davidii* was first introduced to Europe around 1968, but was published as *E. dentata*, the only described taxon of the group at that time. Our study of the European literature and herbarium material indicated the exclusive occurrence of *E. davidii* in Bulgaria, France, Italy, Hungary, Moldavia, Romania, Russia, Switzerland and Ukraine. All herbarium specimens previously identified as *E. dentata* in these countries are actually *E. davidii*.

Interestingly, and similarly to our results, Marchessi *et al.* [23] recognised that the records of *E. dentata* in the Buenos Aires region are actually *E. davidii*; and despite the earlier records of *E. dentata* from Australia; in a recent synthesis of Randall [39] only *E. davidii* is present. It can be concluded that *E. davidii* seems to be the only invasive and widely distributed species of the group [14,23] and the European records do confirm the differences between *E. davidii* and *E. dentata*.

Euphorbia davidii is a relatively new alien in Europe's flora [25]. It is distributed in a band between N 43° and 60°, mainly at low elevations (below 400 m altitude). Although the continuous spread of aliens

has been observed in many cases [18,44], available data does not support the species' continuous spread from one or more centres of introduction in Europe. More likely, the spread of this plant is connected to railway routes, which seems to be the primary path of spreading. However, new populations throughout Europe have been observed at great distances from one another in areas that have no significant trade relations, suggesting the possibility of independent introductions from America (cf. *Ambrosia artemisiifolia* [4,5]; and also confirmed by molecular records in the case of *Bromus tectorum* [45] and *Cytisus scoparius* [46]). Multiple introductions may generate high genetic variability in invasive populations in the introduced range, which could facilitate rapid adaptation to the new environment [47].

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