

THE DISTRIBUTION OF *ELATINE HEXANDRA* (LAPIERRE) DC. (ELATINACEAE)

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ABSTRACT

General distribution map of *Elatine hexandra* (Lapierre) DC. was made based on literature and web-based data confronted and possible reasons of the formation of taxon's distribution range and history are discussed.

KEY WORDS: vascular plants, *Elatinella*, map, chorology, Isoëto-Nanojuncetea, Europe.

INTRODUCTION

Elatine hexandra (Lapierre) DC. belongs to a small cosmopolitan family of herbaceous aquatic and semi-aquatic plants and terrestrial shrubs – Elatinaceae, containing only just two genera, i.e. *Elatine* L. (about 15-25 taxa occurring in areas of moderate temperatures in both hemispheres), and *Bergia* L. (about 25 species occurring mostly in tropical areas of the Old World, first of all in Africa and Australia) (Tucker 1986; Leach 1989). Both genera are poorly known in respect of their phytogeography and taxonomy. No monograph of the genus *Bergia* has been published yet, whereas the only worldwide monograph of *Elatine* was published in the second half of the 19th century (Dumortier 1872). Of about 35-40 species of the family, a few have their general distribution mapped (see Hultén 1971; Meusel et al. 1978; Hultén and Fries 1986; Lampe 1996; Popiela and Łysko 2010).

Subdivision of the genus *Elatine* into lower units was proposed by Niedenzu (1925, after Seubert 1845) who allocated – based on leaves arrangement on stem – the subgenus *Potamopithys* (Adanson) Seub. and the subgenus *Elatine* (*Hydropiper* Moesz.) Seub. The latter includes two sections: *Elatinella* Seub. (number of stamens is double in

relation to petals), and *Triandra* Seub. (=Crypta (Nutt. Seub.), in which the number of stamens is equal to that of petals (Tucker 1986). *Elatine hexandra* is one of eight species of the section *Elatinella*, of which six are found in Europe (three of them also in North Africa) – *E. hexandra*, *E. macropoda* Guss., *E. gussonei* (Sommier) Brullo, *E. bronchonii* Clavaud, *E. hungarica* Moesz., *E. orthosperma* Dueben, one in Eurasia (*E. hydropiper* L.), and one in North America (*E. californica* Gray).

Against other taxa of the section, *Elatine hexandra* clearly distinguishes itself in respect of morphology by triple flowers placed on short pedicels that have six stamens and almost straight, rather robust, 0.5 mm long, yellow-brown, shiny seeds – hence, identification of this species does not create larger difficulties. It is found in the western and the central part of Europe. Although its general distribution maps have been already published three times (Meusel et al. 1978; Hultén and Fries 1986; Lampe 1996), there are however new data having been constantly gathered and mapping methods with the use of satellite base maps allow more accurate presentation of its distribution range.

This paper aims at making a general distribution map of *Elatine hexandra* and discussing possible reasons of formation of the taxon's distribution range and history.

METHODS

The maps presented in this paper were made basing on floristic and phytosociological literature, search queries at the Kew Herbarium and the Herbarium of Natural History Museum in London, as well as web-based sources (Table 1). During research work, two types of data about species distribution were used: analogue data in the form of publications with information about location or paper map and electronic ones made available in web-based collections.

Electronic data were exported to *.shp format when they had geographical coordinates and then, due to their variation, they were given coordinates in common cartographic system WGS84. When geographical data (longitude and latitude) were missing, they were converted into text format and then, in case of detailed information about location, the record was digitalised manually on a satellite base map prepared earlier. When accurate description was missing and location was given only in cartogram grid, a cartogram was made according to principles for a given atlas and then spatial queries connecting grid area with map were used.

Paper data, in the form of location description, were mapped manually using satellite base map. In case of paper maps, calibration and rectification to UTM grid was made earlier and digitalisation was performed. The vector layers prepared this way were converted to WGS84 reference system.

All analyses and maps were made using PostGIS spatial database extension software and QGIS (Quantum GIS) application software operating in the LINUX environment.

RESULTS AND DISCUSSION

Elatine hexandra belongs to the Holarctic element, the Sub-Atlantic and Central European sub-element (according to the approach of Pawłowska 1972). The species is found in habitats being temporarily flooded with water in communities of the alliance *Elatini-Eleocharition ovatae*, most abundantly in the association *Eleocharo-Caricetum bohemicae* Klika 1935 (syn. *Eleocharetum ovatae*) with the north-western type of distribution in Europe. Most phyto-

TABLE 1. Literature and web sources from which data were used to present the distribution of *Elatine hexandra*.

Area	Data
Scandinavia	Vestergaard and Hansen 1989; Hultén 1971; Edqvist and Karlsson 2007; Uotila 2009 (www.flora-nordica.org). GBIF – Biodiversity occurrence data provided by: Herbarium of Oskarshamn (OHN), Oslo (O), Natural History Museum, University of Oslo, Vascular Plants, Field notes, Oslo (O), Natural History Museum, University of Oslo, University Museums of Norway (MUSIT), GBIF-Sweden, Vascular plant herbarium, Agder naturmuseum og botaniske hage, Vascular Plant Herbarium, Trondheim (TRH), (Accessed through GBIF Data Portal, www.gbif.net , 2009-12-08).
The middle, southern and south-eastern Europe (Poland, Czech, Slovakia, Austria, Slovenia, Romania, the Balkan Peninsula, Italy)	Fiori and Paleotti 1896-1898; Pospichal 1897; Hayek 1927; Săvulescu 1955; Slavik 1990; Żukowski 1975; Heyny and Slavik 1990; Seitter 1977; Pignatti 1982; Maurer 1996; Popiela 1998, 2001; Popiela et al. 2010 [in print]; Polatschek 1999; Stefanowicz 1999; Jogan 2001; Nejc 2001. GBIF – Biodiversity occurrence data provided by: Herbarium Berolinense, Botanic Garden and Botanical Museum Berlin-Dahlem, Bundesamt fuer Naturschutz / Netzwerk Phytodiversitaet Deutschland, Bundesamt für Naturschutz / Netzwerk Phytodiversität Deutschland, NLBIF Herbarium GJO Steiermärkisches Landesmuseum Joanneum, Karl Franzens University of Graz, Insitute for Botany – Herbarium GZU (Accessed through GBIF Data Portal, www.gbif.net , 2009-12-08).
The western and southwestern Europe (the British Islands, France, Belgium, the Netherlands, Germany, Switzerland Spain, Portugal)	Boreau 1849; Lefèvre 1866; Saint-Lager 1873; Legué 1891; Tourlet 1908; Coste 1937; Coutinho 1939; Abbayes et al. 1971; Sjörgren 1973; Eriksson et al. 1974; Mennema et al. 1980; Corillion 1981; Guinochet and Vilmorin 1982; Haeupler and Schönfelder 1989; Cirujano and Velayos 1993; Berten 1993; Netien 1993; Provost 1993; Wohlgemuth 1993; Benkert et al. 1996; Bugnon et al. 1998; Bolomier and Cattin 1999; Preston et al. 2002; Catalogue Raisonné des Plantes Vasculaires de la Gironde 2005; Diard 2005; Duhamel and Hendoux 2005; Antonetti et al. 2006; Muller 2006; Boudin et al. 2007; Jeanmonod and Gamisans 2007; Brinkkemper et al. 2008. Système d'Informations sur la Biodiversité en Wallonie (Accessed through http://biodiversite.wallonie.be , 2009-12-15) Anthos (2009). Information System of the plants of Spain. Real Jardín Botánico, CSIC – Fundación Biodiversidad (Accessed through Anthos Portal, www.anthos.es 2009-12-02). GBIF – Biodiversity occurrence data provided by: EUNIS European Environment Agency Real Jardín Botánico (Madrid), Vascular Plant Herbarium (MA) GBIF-Spain, Aranzadi Zientzi Elkartea GBIF-Spain, Universidad de Extremadura, UNEX, GBIF-Spain, Botanical Society of the British Isles – Vascular Plants Database UK National Biodiversity Network, Take a Pride in Fife Environmental Information Centre – Records for Fife from TAPIF EIC, UK National Biodiversity Network, Environment and Heritage Service – EHS Species Datasets, UK National Biodiversity Network, Observations du Conservatoire botanique national du Bassin parisien. Conservatoire botanique national du Bassin parisien Limnodata, Countryside Council for Wales – Freshwater site visits (species and habitats), UK National Biodiversity Network Botanical Society of the British Isles – Vascular plant data for Scottish Vice-counties (VCs 80, 84, 103 and 104), UK National Biodiversity Network, National Vegetation Data bank, NLBIF Inventaire national du Patrimoine naturel (INPN), Service du Patrimoine naturel, Muséum national d'Histoire naturelle, Paris Wetland Inventory (NV), Fundación Biodiversidad, Real Jardín Botánico (CSIC): Anthos. Sistema de Información de las plantas de España GBIF-Spain (Accessed through GBIF Data Portal, www.gbif.net , 2009-12-08)

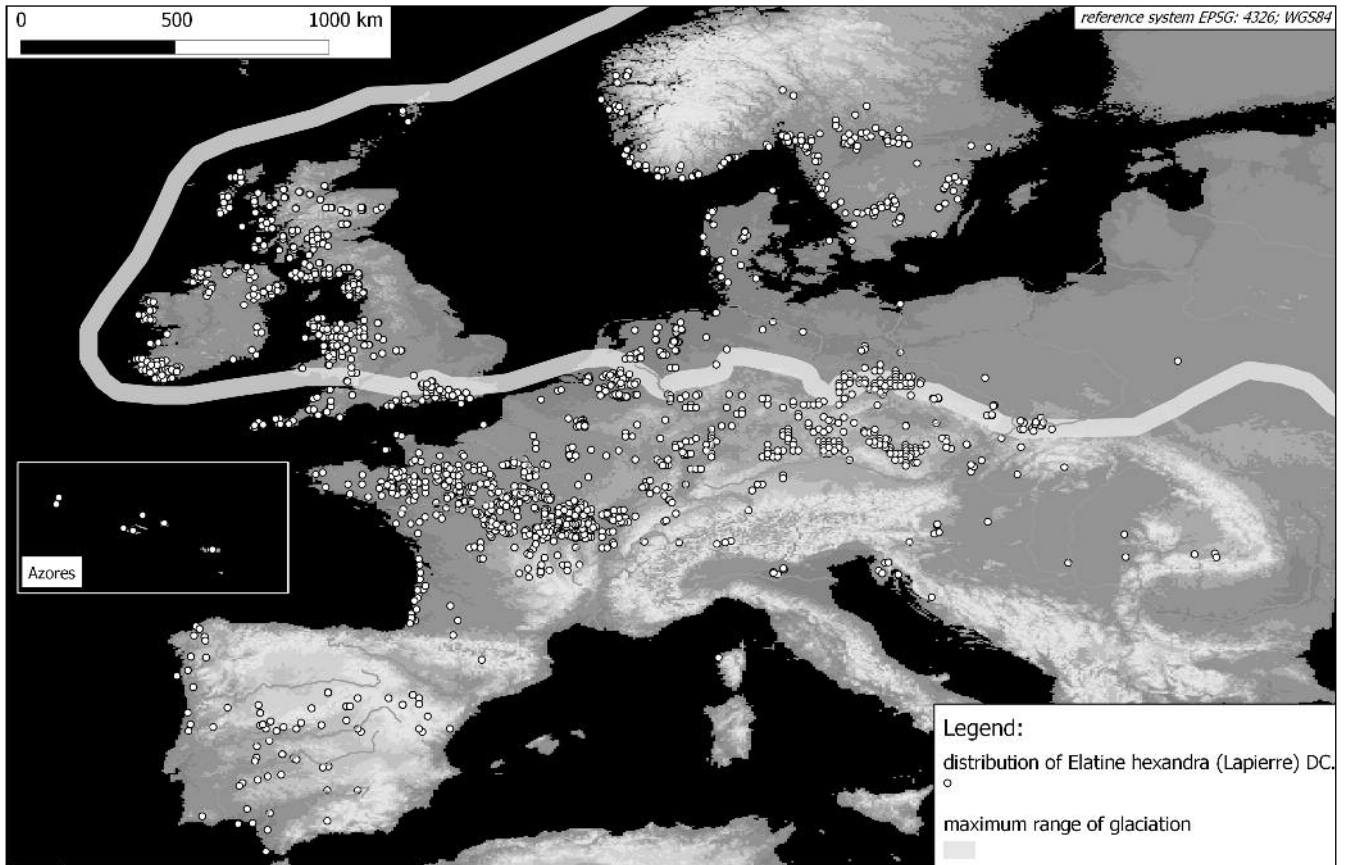


Fig. 1. Distribution of *Elatine hexandra* (Lapierre) DC. in Europe.

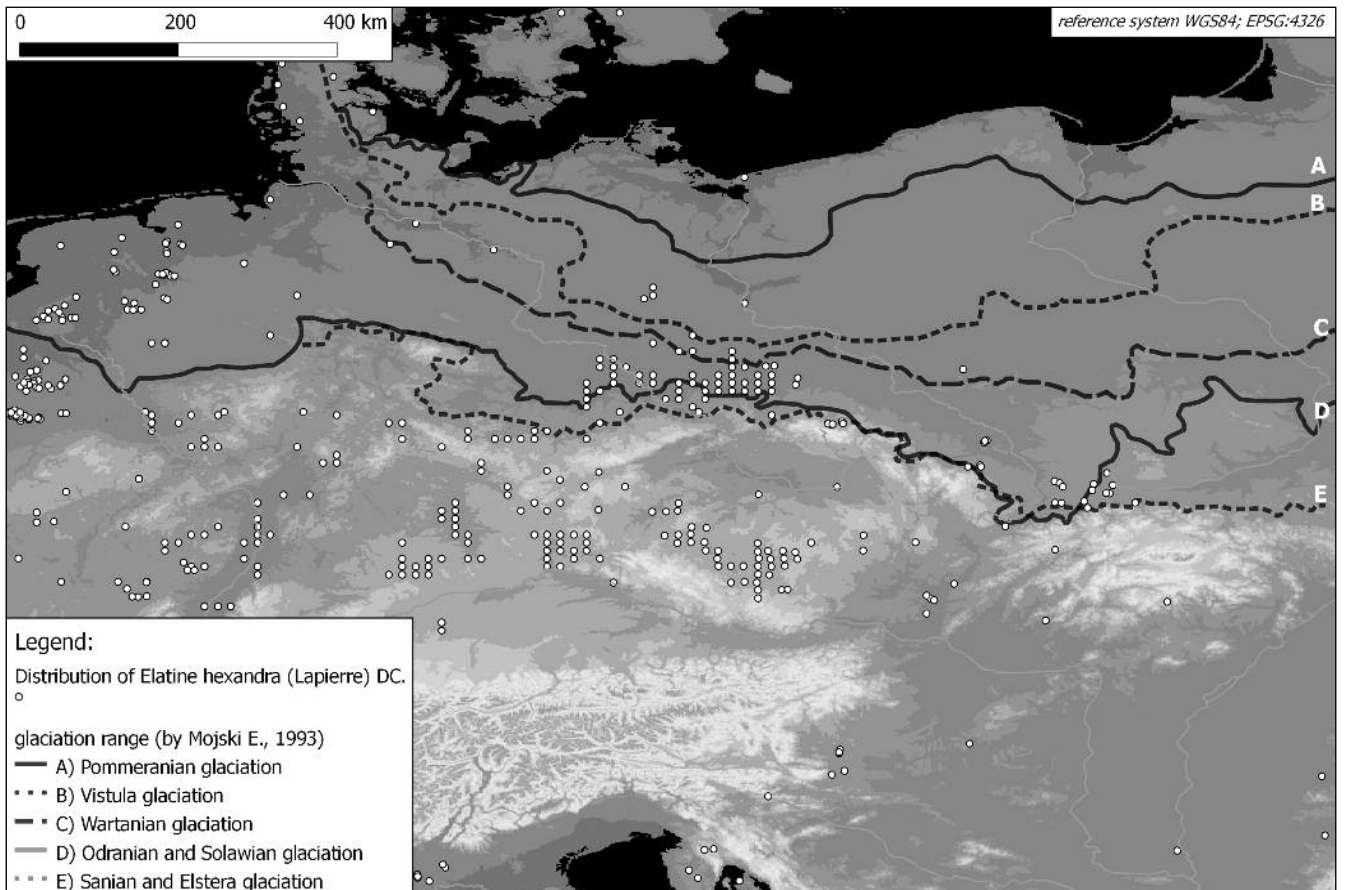


Fig. 2. Distribution of *Elatine hexandra* (Lapierre) DC. in Central Europe on the background of glacial coverage.

sociological data come from Germany (Brullo and Minisalle 1998), while in Poland this association reaches the absolute north-eastern limits of its range (Popiela 2005; Popiela et al. 2010).

Locations of *Elatine hexandra* are being found in the Azores, British Isles (western and eastern Ireland, western and south-western Great Britain, Shetland Islands, and the Hebrides), and France (western Aquitaine, Brittany, Normandy, the western part of the Northern Plain, the Loire River Basin, and Burgundy); scattered locations in the Iberian Peninsula (mainly in the central part), the Netherlands (mainly in the Rhine, Meuse and Ems River Basins), in the southern part of the North German Plain and Plateau, in Lusatia, Moravia, Bohemia and Poland (Oświęcim Basin). Single floristic data are reported from the northern part of the Balkan Peninsula, Romania, Alpine valleys, the Po River Basin and Corsica. In Northern Europe, *E. hexandra* has isolated locations in the Jutland Peninsula, on western shores of the Scandinavian Peninsula and in Southern Sweden (Figs 1 and 2, Table 1). *E. hexandra* is not found outside Europe; its distribution range to the south of the continent borders on the home range of *E. bronchonii* and *E. macropoda*, while to the east and north on that of *E. triandra*, *E. hydropiper* and *E. orthosperma*.

From among eight species included in the section *Elatinella* Seub., *Elatine hexandra* is most probably the most closely related to *E. bronchonii* – a taxon being known from single scattered locations in the Atlantic part of south-western France (Clavaud 1883; Fiton 1916; Schotsman and Bosserdet 1966; Vanden Berghen 1966; Olivier et al. 1995), in the central part of the Iberian Peninsula (Cirujano and Velayos 1993), in Morocco (Hamada et al. 2004; Fennane and Ibn Tattou 2005), in the Mediterranean part of Algeria (Quézel and Santa 1962-1963) and in Corsica (Lorenzoni and Paradis 1997). Both species are characterised by triple flowers and the presence of eight stamens but differ in the length of pedicel, seed size and structure as well as the position of flowers on stalk.

Distribution of *Elatine hexandra* as well as that of other species of the section and the genus suggests a long history of the range formation. Molecular phylogenetic studies, consisting in the comparison of sequences rbcL, ndhF and PHYC, have maintained allocation of Elatinaceae (together with Clusiaceae) to the order Malpighiales (see Cronquist 1981), with the closest taxonomic relations being seen between Elatinaeae and Malpigiaceae (Davis and Chase 2004; Heywood et al. 2007). A common ancestor of both families could have occurred in the Cretaceous period at the beginning of Albion, i.e. 111-100 million years ago, while both families separated presumably at the end of this period, i.e. about 98-89 million years ago (Davis and Chase 2004; Davis et al. 2005). Based on fossil data and molecular findings, Davis et al. (2001) have raised a hypothesis that the family Malpighiaceae, and presumably also other families of the order Malpighiales, originates in the northern part of South America and then their representatives migrated to North America and later, via northern Atlantic, to the Old World.

Thus, the genus *Elatine* has undoubtedly a very long history going down to the Mediterranean Tertiary and the Madrean Tertiary floras in the northern hemisphere, while the hypothesis mentioned above referring to the migration route across Atlantic could explain disjunctive distribution

patterns both within the order and the section *Elatinella* (seven species in Europe and one species in California).

Paleobotanical records of *Elatine* species elsewhere in Northwestern and Central Europe are very scarce, but they confirmed the presence of macro samples, seeds and pollen from, among others, the Pliocene, Middle Pleistocene – and the Holocene (e.g. Latałowa 1992; Kvaček and Teodoridis 2007; Brinkkemper et al. 2008). A question about the Pleistocene refuge area of *Elatine hexandra* seems to be interesting. Two answers appear to be possible. When analysing its distribution map, attention is called by a concentration of the locations of this species to the north of the Alps – this may point to the existence of a hypothetic refuge in this region, in ice-free areas within the maximum range of glaciation (see Fig. 1). The second possibility is a refuge area in the Iberian Peninsula – a trace of it would be a single relic location existing there at present.

Many authors bring up a possibility of the formation of distribution range of ephemeral wetland flora, and the same of species of the genus *Elatine*, through general dispersal of diaspores by water and marsh birds (exozoochoria); this phenomenon is however very poorly examined, while no documentation is available for the genus *Elatine* at all (see Deil 2005 and references cited there as well as Brinkkemper et al. 2008). Therefore, while not excluding a possibility of the transport of diaspores by birds, it can be assumed that this does not occur frequently and the present pattern of distribution may have been invariable for very long time (seed bank in soil). A characteristic habitat for species of the genus *Elatine* are locations that are fluctuantly flooded. The original location of *E. hexandra* was presumably lake- and riversides, whereas at present many reported locations are from sites of the anthropogenic origin – most frequently from fish ponds with a controlled level of water table. Thus, its present distribution range has presumably an anthropogenic extension as far as the quantity of locations within it is concerned.

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