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Spread of alien invasive *Impatiens balfourii* in Europe and its temperature, light and soil moisture demands

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ABSTRACT

Impatiens balfourii was introduced in the beginning of the 20th century from the Himalayas to Southern Europe where it was able to establish. In recent years an increasing number of more northern situated occurrences were recorded. An overview about the current distribution of *Impatiens balfourii* in Europe is given and new records for Germany are presented. To explore the range of potential habitat conditions, vegetation relevés and autecological experiments were conducted. Gas exchange measurements showed an optimum of net photosynthesis at 24–32 °C and light saturation above 700 μmol m^{-1} s^{-1} PPFD without any signs of photoinhibition. A moisture gradient experiment showed that *Impatiens balfourii* prefers fresh soils of moderate dampness. In contrast to the native *I. noli-tangere* and to the alien species *I. glandulifera* and *I. capensis*, which prefer moister or even wet habitats, *Impatiens balfourii* resembles in its soil moisture demands the alien *Impatiens parviflora* which originates also in Central Asia and which is invasive in Europe. But in contrast to *I. parviflora* and to all other established *Impatiens* species in Europe, *I. balfourii* is able to colonize even open habitats with high light intensities. Against this background, a further expansion of *Impatiens balfourii* in Europe appears to be likely.

Introduction

The increase of international trade, and land use changes, have lead to a worldwide increase in the amount of alien species. In some cases invasive alien species can constitute a major threat for native species and ecosystems and are considered to be one of the driving forces of biodiversity changes and biodiversity loss (McNeely, 2000). Garden escapes constitute more than the half of all alien species (Smith et al., 2006). As it is very difficult to take measures against alien species which are already widespread and abundant, it is very important to observe alien species already in the initial phase of their naturalization process, in order to assess their potential invasiveness. However, <10% of all scientific publications on alien species are regarding the initial phases of naturalization processes (Puht and Post, 2000).

In Europe, besides the native *Impatiens noli-tangere* L., there are four regularly occurring alien *Impatiens* species with different degrees of naturalization: the invasive species *Impatiens glandulifera* Royle from India and *I. parviflora* DC. from Central Asia were introduced in the 19th century (Lohmeyer and Sukopp, 1992) and are nowadays well established, widespread and abundant. *Impatiens capensis* Meerb. from North America is locally established since the 1990s in Central Europe. The Asian *Impatiens balfourii* Hook. fil. is still in the initial phase of its naturalization process in Europe. While this species already has established in parts of Southern and Western Europe, it still occurs only as a casual in Central and Eastern Europe, though possibly tending to naturalize there, too. Recent records of *Impatiens balfourii* in Germany give evidence for this trend and suggested to give an overview about its current distribution in Europe and to examine its ecological demands compared to other species of the same genus.

Methods

Publications and personal communications concerning occurrences of *Impatiens balfourii* in the wild were evaluated. Vegetation relevés were made at two locations of recent German records, following the Braun-Blanquet method (Braun-Blanquet, 1964).

Demands for water supply and waterlogging tolerance were examined by cultivating *Impatiens balfourii* plants under a moisture gradient, following the Hohenheim model (Ellenberg, 1953). Cultivation containers, made from polyvinyl chloride, had a length of 120 cm, a width of 100 cm, a height of 60 cm at the front and a height of 100 cm at the backside. They were filled with soil of pH_{CaCl_2} 7.1 and nutrient contents of phosphate 21.3 ± 3.1 mg/100 g soil, nitrate 14.8 ± 2.9 mg/100 g soil, ammonium 2.9 ± 0.2 mg/100 g soil, calcium ca. 4800 mg/kg soil, potassium ca. 420 mg/kg soil, magnesium ca. 470 mg/kg soil [Analyses with AAS (Analyst 100,

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Perkin-Elmer), following standard procedures]. Inclination of the substrate surface was ca. 45°. Water level was 45 cm from bottom. Soil moisture was measured with TDR-Theta-Probes (Delta-T Device Ltd., Cambridge) in 30 min intervals (using a Squirrel 1000-Data-Logger, Grant Ltd., Cambridge). Three TDR probes were used per container, placed at the upper, middle and basic level of the oblique soil surface, measuring volumetric moisture contents of the uppermost 15 cm of the soil. Height of the plants was measured every 2 weeks. At the end of the experiment the plants were harvested and aboveground dry weight was measured.

Light and temperature demands of *Impatiens balfourii* were examined by measuring net photosynthesis and other leaf gas exchange parameters porometrically (LCA 4–ADC, UK) under field conditions. Plants used for the measurements were cultivated in pots of approx. 600 cm^3 soil volume and regularly watered. Same substrate as in the moisture gradient experiment was used. The key parameters of photosynthesis (maximum photosynthesis rate (A_{max}), radiation intensity at max. photosynthesis (I_S), light compensation point (I_C), respiration rate (R_D) and quantum yield (Φ_{CO_2})) were identified.

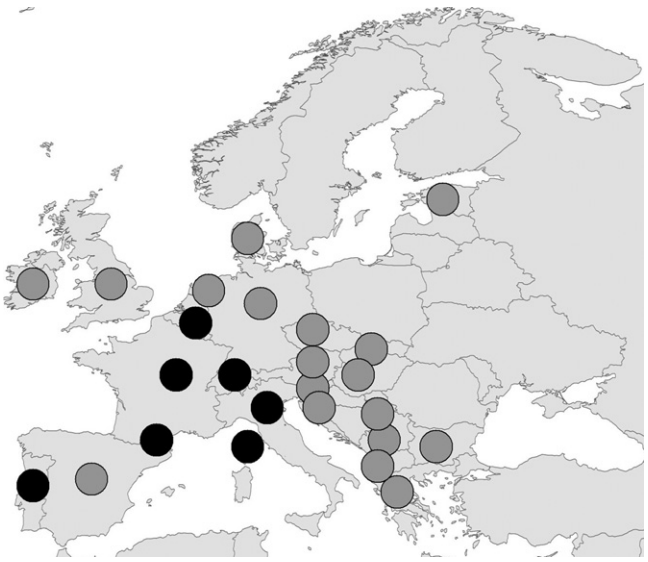

Fig. 1. Wild occurrences of *Impatiens balfourii* in European countries (black = established, grey = casual, tendency to establish or unknown).

Results

History of naturalization and spread in Europe

Impatiens balfourii Hook. f. (= *I. mathildae* Chiovenda, = *I. insubrica* Beauverd, = *I. insignis* Auct. non DC.) originates in the western Himalayas (Hess et al., 1977; Moore, 1968). Information about its habitat preferences there is still lacking. The species was introduced to Southern Europe in 1901 (Fournier, 1952). Early naturalization processes of *Impatiens balfourii*, which already took place in the beginning and the middle of the 20th century, were reported from Italy (Fiori, 1965; Moore, 1968; Pignatti, 1982), France (Moore, 1968), Switzerland (Hegi, 1975; Hess et al., 1977; Jouret, 1977; Moore, 1968; Weber, 1999; Welten and Sutter, 1982) and Hungary (Balogh et al., 2004; Jouret, 1977; Moore, 1968; Priszter, 1965). Since the end of the 20th century, the number of reported occurrences in other parts of Europe has increased. For southeast Europe an increasing number of records of *Impatiens balfourii* is reported from Croatia since the 1990s (Cigić et al., 2003; Ilijanić et al., 1994; Pericin, 1992; Šoštarić and Marković, 1998). Further casual occurrences there were reported from Albania (Barina and Pifkó, 2008), Bulgaria (Adamowski, 2009), Kosovo (Fehér, pers. comm.), Greece (Sfikas, 1995), Serbia (Adamowski, 2009), and Slovakia (Fehér, pers. comm.). There is also an increasing number of records reported for more northern parts of Europe. Clement and Foster (1994), Stace (1997), Sell and Murrell (2009) and the National Biodiversity Network (2009) report *Impatiens balfourii* as a casual garden escape for the British Isles, Lambinon et al. (2004) report *Impatiens balfourii* running wild in the southeast of Belgium. In the Netherlands there are a number of occurrences in the wild since the end of the 20th century (Denters, 2003; Spronk et al., 2005; van der Meijden, 2005; van der Meijden et al., 2003). Further occurrences of *Impatiens balfourii* were published for Austria (Schröck et al., 2004; Walter et al., 2002), Estonia (Adamowski, 2009) and Spain (Juanola and Vilar, 1997) or are listed in the databases DAISIE (www.daisie.ceh.ac.uk), GBIF (www.gbif.org) and NOBANIS (www.nobanis.org) for Andorra, the Czech Republic, Denmark, Slovenia and Portugal. Adamowski (2009) published maps of cultivated and escaped *Impatiens balfourii* in Spain and Italy, Europe and worldwide. An overview over casual and established occurrences in the wild of *I. balfourii* in Europe is given in Fig. 1.

In Germany, records of *Impatiens balfourii* are still very rare. Up to now *Impatiens balfourii* is not included in current German floras (Jäger and Werner, 2005; Oberdorfer, 2001; Schmeil and Fitschen, 2009). The only published records of *Impatiens balfourii* in Germany, known to the authors, are the following presumptive synanthropic and ephemeral occurrences: two specimens of *Impatiens balfourii* were found in 1979 and 1983 at a roadside in the area of Lohmar near Cologne in southern North Rhine-Westphalia (Gerstberger, 1984). A bigger stand was found in 1993 in the Main–Taunus–Vorland near Hattenheim under ornamental shrubs (Gregor, 1994). In Aachen–Burtscheid six specimens of *I. balfourii* were found in 2007 on a shady path in settled area. In 2008 there were still three specimens in the vicinity of this locality (Bomble, pers. comm.). A further occurrence is reported without exact date (1950–1980) in the Floraweb database (www.floraweb.de) from Bad Bergzabern in southern Rhineland–Palatinate.

With the exception of cultivation in botanical gardens, *Impatiens balfourii* is virtually not cultivated in Germany as an ornamental plant. Seeds of *Impatiens balfourii* are usually not available from commercial plant and seed traders in Germany. On European level, there are only few possibilities of receiving the seeds of *Impatiens balfourii* from commercial traders, but few Internet offers of seeds exist and the use of *Impatiens balfourii* for ornamental purposes is repeatedly reported (Lambinon et al., 2004; Stace, 1997). Thus the species seems to be infrequently cultivated in gardens and the occurrence of subspontaneous populations (garden escapes) is reported for Belgium (Lambinon et al., 2004) and the Netherlands (Lehmhus pers. comm., 2008, 2009). Also one case of garden escape in Germany is reported by Kasperek (pers. comm., 2007) who found two subspontaneous specimens in 2003 in Göttingen–Holtenser Berg in paving stone interstices near a garden, where *I. balfourii* was cultivated.

Vegetation of the recent records in Germany

Recently found occurrences of *Impatiens balfourii* near Düsseldorf (Germany) consisted of two stands of ca. 50 and ca. 90 individuals, respectively. The habitat of the first location was a moist meadow, situated at the base of a dike (inland side) along the river Brückerbach, which empties in the River Rhine in the south of Düsseldorf. Though there were gardens in the vicinity of the stand, no *Impatiens balfourii* was seen to be cultivated within these gardens. The vegetation relevé (Table 1) shows that *Impatiens balfourii* was accompanied mainly by plant species of meadows with some moisture indicator species (*Persicaria amphibia*, *Phalaris arun-*