EUROPEAN AND MEDITERRANEAN PLANT PROTECTION ORGANIZATION
ORGANISATION EUROPEENNE ET MEDITERRANEENNE POUR LA PROTECTION DES PLANTES

17-23150 (V.2)

Pest Risk Analysis for *Cardiospermum grandiflorum*

2017

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This pest risk analysis scheme has been specifically amended from the EPPO Decision-Support Scheme for an Express Pest Risk Analysis document PM 5/5(1) to incorporate the minimum requirements for risk assessment when considering invasive alien plant species under the EU Regulation 1143/2014. Amendments and use are specific to the LIFE Project (LIFE15 PRE FR 001) 'Mitigating the threat of invasive alien plants to the EU through pest risk analysis to support the Regulation 1143/2014'.

Cite this document as:
EPPO (2017) *Pest risk analysis for Cardiospermum grandiflorum*. EPPO, Paris.
Available at:

Photo: *Cardiospermum grandiflorum* (Photo by Johannes J Le Roux)

EUROPEAN AND MEDITERRANEAN PLANT PROTECTION ORGANIZATION

Pest risk analysis for *Cardiospermum grandiflorum* Swartz

This PRA follows EPPO Standard PM5/5 Decision support scheme for an Express Pest Risk Analysis

PRA area: EPPO region **First draft prepared by:** Johannes J Le Roux

Location and date: Paris (FR), 2016-10-17/21

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The pest risk analysis for *Cardiospermum grandiflorum* has been performed under the LIFE funded project:

LIFE15 PRE FR 001

Mitigating the threat of invasive alien plants to the EU through pest risk analysis to support the Regulation 1143/2014

In partnership with

EUROPEAN AND MEDITERRANEAN PLANT PROTECTION ORGANIZATION

And

NERC CENTRE FOR ECOLOGY AND HYDROLOGY

Review Process

- This PRA on *Cardiospermum grandiflorum* was first drafted by Johannes J Le Roux

- The PRA was evaluated in an Expert Working Group (EWG) at the EPPO Headquarters between 2016-10-17/21

- Following the finalisation of the document by the EWG the PRA was peer reviewed by the following:

  (1) The EPPO Panel on Invasive Alien Plants (November and December 2016)
  (2) The EPPO PRA Core members (December and January2016/17)
  (3) The Scientific Forum on invasive alien species (2017)[1]

[1] Additional information has been included in the original document following review from the Scientific Forum on invasive alien species

Contents

Summary[2] of the Express Pest Risk Analysis for *Cardiospermum grandiflorum* Swartz

PRA area: EPPO region

Describe the endangered area:

Based on the species distribution modeling, suitable areas for establishment of *C. grandiflorum* have been identified in the Mediterranean biogeographical region, including Portugal, Spain, and Italy and outside of the EU in the Macaronesia biogeographical region. Areas in Portugal, Spain, Malta and Italy are suitable for the establishment of the species and areas in North Africa (Morocco and Algeria) are marginally suitable. In addition, areas of Israel and countries bordering the Adriatic and Ionian Sea (specifically Greece) provide marginally suitable areas for the establishment of *C. grandiflorum*.

The most limiting environmental factors for the establishment of *C. grandiflorum* are temperature and rainfall. In specific situations, such as urban environments, old fields, Insubria (Great Lakes in Northern Italy and Southern Switzerland), meso-climatic conditions may help overcome these limitations.

Specific habitats, within the endangered area most suitable for establishment, include woodlands, forests, wastelands, riparian systems, old fields, fallow gardens, successional habitats, roadsides, and urban habitats.

Cardiospermum grandiflorum has already been introduced and showed invasive tendencies in Malta. In France and Italy the species is considered transient and may become established.

Main conclusions

Cardiospermum grandiflorum presents a moderate phytosanitary risk for the endangered area within the EPPO region with moderate uncertainty. The risk of further spread within and among countries is moderate. The overall likelihood of *C. grandiflorum* continuing to enter the EPPO region is moderate because the species is traded by a small number of suppliers.

Given the species' known occurrences within the EPPO region and its desirable characteristics as an ornamental, it remains likely that it could be moved non-commercially (e.g., through seed exchange by collectors), resulting in further human-assisted spread.

Natural dispersal from existing populations within the region is the most likely mode of further spread. The seed-carrying balloons of *C. grandiflorum* can float for extensive periods in watercourses (e.g., along rivers and across the sea) and are carried by wind and thus can cover substantial distances over short time scales.

Under climate change the range of suitable habitat for establishment is expected to expand and shift northwards.

Entry and establishment

The pathways identified are: Plants or seed for planting (moderate likelihood of entry).

Within the EPPO region, *Cardiospermum grandiflorum* already has been introduced and shows

[2] The summary should be elaborated once the analysis is completed

invasive tendencies in Malta. In France the species is considered casual and in Italy the species is considered transient and may become established.

The overall likelihood of *C. grandiflorum* entering the EPPO region (via the pathway plants for planting) is moderate with low uncertainty. There is some evidence that the plant is available from a small number of horticultural suppliers within the EPPO region. The overall likelihood of *C. grandiflorum* establishing in the EPPO region is moderate (natural habitat) and high (managed habitat) with low uncertainty. The species already is present within the EPPO region, in particular in Malta where there is evidence of invasive tendencies (smothering behaviour).

Cardiospermum grandiflorum may establish throughout climatically suitable regions within the EPPO region. Climate change could increase the likelihood of establishment, spread, and impact in other areas of the EPPO region.

Spread

The rating for spread of *C. grandiflorum* within the EPPO region is moderate with moderate uncertainty. *C. grandiflorum* fruits (balloons) and seeds are well adapted for extreme (i.e. inter-continental) long-distance dispersal (Gildenhuys *et al.* 2015a). That is, seed-carrying balloons can float for extensive periods in watercourses and so cover substantial distances over short time scales, e.g. along rivers and even across the sea. The known presence of the species within the EPPO region makes natural dispersal the most likely mode of spread within the region. The fruits may also be spread further by wind. For human assisted spread, online vendors still sell seeds of the genus, but mostly for *C. halicacabum*. Within the EPPO region several traders do list the species. Many of these traders misidentify the species, i.e. selling *C. halicacabum* under the name *C. grandiflorum*. It is possible that the species may still be in the horticultural trade within the PRA area since it is already present in several EPPO countries and may therefore be traded as whole plants.

Potential impacts in the PRA area

The overall potential impact of the species is moderate with high uncertainty. The high uncertainty reflects the difficulty in assessing impacts due to conflicting information on the species. For example, in Australia and South Africa, the species does not exhibit the invasive tendencies in the Mediterranean areas that are seen in the more tropical and sub-tropical regions of these countries (Personal Communication Jaco Le Roux, 2016). However, in Malta, where the species has formed extensive invasive populations, there may be impacts on biodiversity.

Although empirical data are lacking, *C. grandiflorum* is considered an ecological "transformer" species in its invasive ranges in South Africa and Australia (Henderson 2001, Carroll *et al.,* 2005a). Infestations of *C. grandiflorum* can cause problems commonly associated with invasive climbing vines (e.g., cover tree canopies). Along forest margins and watercourses, and in urban open spaces, especially in subtropical regions, the species smothers indigenous vegetation, thereby blocking sunlight and photosynthesis and outcompeting native plants.

Potential impacts in the PRA area will be greatest where the climate is conducive for establishment and the phenology of the species (see endangered area). Temperature seems to impact phenology of *C. grandiflorum*, with warmer climates supporting longer flowering periods (JJ Le Roux, personal observation). Therefore, the Mediterranean biogeographical region will experience the greatest impacts compared to other EU biogeographical regions. The text within this section relates equally to EU Member States and non-EU Member States in the EPPO region.

Climate change
By the 2070s, under climate change scenario RCP8.5 (RCP8.5 is the most extreme of the RCP scenarios, and may therefore represent the worst case scenario for a reasonably anticipated climate change), projected suitability for *C. grandiflorum* increases, most notably in Italy and northwards into the Atlantic Biogeographic Region as far north as The Netherlands and southern Britain (Fig. 6). Presumably this is driven by increases in summer and winter temperatures. There is little increase in suitability around the Mediterranean coastlines, which may be because of reduced predicted precipitation for these areas. The extent of suitable areas will increase in the Atlantic biogeographical region (France, Germany, Belgium, Netherlands and England), even including a very small area of the Continental biogeographical region.

The PRA results suggest that *C. grandiflorum* poses a moderate risk to the endangered area (Mediterranean biogeographical region) with moderate uncertainty.

Given the significant impact of the species in other parts of the world and the risk to the PRA area, the EWG recommends the following measures for the endangered area:

International measures:

For the pathway plant for planting the EWG recommends that:

> Plants labeled or otherwise identified as *Cardiospermum grandiflorum* should be prohibited for import into and movement within countries in the endangered area,
> *Cardiospermum grandiflorum* is banned from sale within the endangered area,
> *Cardiospermum grandiflorum* should be recommended as a quarantine pest within the endangered area.

National measures:

Cardiospermum grandiflorum should be monitored and eradicated where it occurs in the endangered area. In addition, public awareness campaigns to prevent spread from existing populations or from gardens in countries at high risk are necessary. If these measures are not implemented by all countries, they will not be effective since the species could spread from one country to another. National measures should be combined with international measures, and international coordination of management of the species among countries is recommended.

The EWG recommends the prohibition of selling and, movement of the plant. These measures, in combination with management plans for early warning, obligation to report findings, eradication, and containment plans, and public awareness campaigns should be implemented.

Containment and control of the species in the PRA area
Eradication measures should be promoted where feasible with a planned strategy to include surveillance, containment, treatment, and follow-up measures to assess the success of such actions. As highlighted by EPPO (2012), regional cooperation is essential to promote phytosanitary measures and information exchange in identification and management methods. Eradication only may be feasible in the initial stages of infestation, and should be a priority. The EWG considers this possible at the current level of species occurrence in the EPPO region.

General considerations should be taken into account for all potential pathways where, as detailed in EPPO (2014), these measures should involve awareness raising, monitoring, containment, and eradication measures. NPPOs should facilitate collaboration with all sectors to enable early identification, including education measures to promote citizen science and linking with universities, land managers, and government departments. **Import for plant trade:** Prohibition of the import, selling, planting, and movement of the plant in the endangered area. **Unintended release into the environment:** The species should be placed in NPPO alert lists and a ban from sale is recommended in countries most prone to invasion. Export of the plant should be prohibited within the EPPO region. Integrated management measures are recommended to include control of existing populations with manual and mechanical techniques, targeted herbicides, and biological control techniques. Monitoring and surveillance for early detection in countries most prone to risk. NPPOs should report new findings in the EPPO region. **Intentional release into the environment:** Prohibition on planting the species or allowing the plant to grow in the environment. **Natural spread** (method of spread within the EPPO region): Increase surveillance in areas where there is a high risk the species may invade. NPPOs should provide land managers and stakeholders with identification guides and facilitate regional cooperation, including information on site specific studies of the plant, control techniques, and management. See Standard PM3/67 'Guidelines for the management of invasive alien plants or potentially invasive alien plants which are intended for import or have been intentionally imported' (EPPO, 2006)

Phytosanitary risk for the *endangered area* (current/future climate) **Pathway for entry** Plants for planting: Moderate/Moderate Likelihood of establishment in natural areas: Moderate/High Likelihood of establishment in managed areas: High/High Spread: Moderate/High **Impacts in the current area of distribution** Biodiversity and environment: Moderate/high Ecosystem services: Moderate/High Socio-economic: Moderate/High **Impacts (EPPO region)** Biodiversity and environment: Moderate/high Ecosystem services: Moderate/High Socio-economic: Moderate/High	High ☐	Moderate X	Low ☐
Level of uncertainty of assessment (current/climate change) **Pathway for entry** Plants for planting: Low/Low Likelihood of establishment in natural areas: Low/High Likelihood of establishment in managed areas: Low/High	High ☐	Moderate X	Low ☐

Spread: Low/High **Impacts in the current area of distribution** Biodiversity and environment: Moderate/high Ecosystem services: Moderate/High Socio-economic: Moderate/High **Impacts (EPPO region)** Biodiversity and environment: High/high Ecosystem services: High/High Socio-economic: High/High			
Other recommendations: • ***Inform EPPO or IPPC or EU*** • The EWG recommends a PRA is conducted on the closely related species *Cardiospermum halicacabum*. • ***Inform industry, other stakeholders*** • Ask industry to confirm if there is mislabelling *of Cardiospermum halicacabum* and *Cardiospermum grandiflorum* • ***Specify if surveys are recommended to confirm the pest status*** • Assess the current impact of *Cardiospermum grandiflorum* in Malta and other regions where the species *is established.* • Specific studies on the species biology are necessary.			

Express Pest Risk Analysis:

Cardiospermum grandiflorum

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Date: 2016-10-17

Stage 1. Initiation

Reason for performing the PRA:

In 2016, *Cardiospermum grandiflorum* was prioritized (along with 36 additional species from the EPPO List of Invasive Alien Plants and a recent horizon scanning study[3]) for PRA within the LIFE funded project "Mitigating the threat of invasive alien plants to the EU through pest risk analysis to support the Regulation 1143/2014' (see www.iap-risk.eu). *Cardiospermum grandiflorum* was one of 16 species identified as having a high priority for PRA (Tanner *et al*., 2017).

Cardiospermum grandiflorum currently has a relatively limited distribution in the EPPO area, with known records from France (Landes and Alpes-Maritimes departments), Italy (Catania, Canalicchio; Sicily and Liguria), Malta, Portugal (Madeira Island), and Spain (Canary Islands: Gran Canaria, Tenerife Island, La Gomera, La Palma), as reported, e.g., by Ameen (2013), Celesti-Grapow et al. (2010), DAFF (2011), EPPO (2012), Gómez-Bellver et al., (2016), Alberti (2014). Malta is the only region invasive populations of the species are reported as widespread in natural areas where they smother and outcompete native plant communities (Ameen 2013). It is anticipated that the species' potential use as an ornamental plant and its capacity for extreme long-distance natural dispersal, especially via water courses (including open ocean) poses a risk for future establishment into the EPPO region. Whilst the trade of *C. grandiflorum* appears to be relatively low based on online trading inventories, other closely related species such as *C. halicacabum* are readily available. Many instances of mislabeling of these two species have been noted by the EWG in online catalogs. The fruits and seeds of *Cardiospermum* species are well adapted for natural long-distance water dispersal. For example, inflated fruit capsules floated in seawater for more than 6 months can harbor viable seeds (Gildenhuys *et al.* 2013).

While the species commonly flourishes under tropical to subtropical moist conditions in both native and introduced areas, accounts of establishment have been noted in Mediterranean-type regions. For example, the species has been recorded as established from South Africa's Cape Floristic Region (JJ Le Roux, personal observation) and in Western Australia (Carroll *et al.*, 2005a, FloraBase 2012), and has been reported as having formed invasive populations in Malta (Ameen 2013). In Malta, a congeneric species, *C. halicacabum*, is recorded. Bioclimate suitability modeling suggests that Mediterranean areas are suitable for the species'

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3 http://ec.europa.eu/environment/nature/invasivealien/docs/Prioritising%20prevention%20efforts%20through%20horizon%20scanning.pdf

establishment, albeit with relatively low probability compared to tropical and subtropical regions (Gildenhuys *et al*. 2013, USDA 2013).

Cardiospermum grandiflorum is perceived to have major biodiversity impacts in invaded areas, such as in Australia (New South Wales and Queensland) and eastern parts of South Africa (Carroll *et al.* 2005a, Gildenhuys *et al.* 2013), where dense infestations can smother large swathes of underlying vegetation, including trees of up to 16 to 20 m in height (Carroll *et al.*, 2005a). *Cardiospermum grandiflorum* thus putatively outcompetes native plants by depriving them of sunlight and restricting photosynthesis. A congeneric species, *C. halicacabum*, has substantial economic impacts on agricultural productivity (Brighenti *et al.* 2003, Dempsey *et al.* 2011). Similar impacts may manifest from *C. grandiflorum* invasions in agricultural settings. The species has been on the EPPO 'List of Alien Invasive Plants' since 2013 and is included in the Global Invasive Species Database. It has been listed as a noxious weed (prohibited plants that must be controlled as they serve no economic purpose and possess characteristics that are harmful to humans, animals or the environment) in South Africa and in the Australian states of New South Wales and Queensland, Australia. For example, in Australia, southeastern Queensland, the species is ranked 13th in terms of potential environmental impacts out of 66 'priority' environmental weeds (Batianoff and Butler 2003). The presence of the species in the EPPO region (with highly invasive populations in at least one locality, Malta), high dispersal capabilities, as well as the potential continued use of this plant as an ornamental species within EPPO countries, indicate that a PRA is needed.

PRA area:
The EPPO region (see https://www.eppo.int/ABOUT_EPPO/images/clickable_map.htm.).

Stage 2. Pest risk assessment

1. Taxonomy: *Cardiospermum grandiflorum* Sw. (Kingdom Plantae; Phylum Magnoliophyta; Class Magnoliopsida; Superorder Rosanae; Order Sapindales; Family Sapindaceae; Genus Cardiospermum). (Integrated Taxonomic Information System, accessed 15 August 2016)

EPPO Code: CRIGR

Main synonyms: *Cardiospermum barbicaule* Baker, *Cardiospermum coluteoides* Kunth, *Cardiospermum duarteanum* Cambess., *Cardiospermum elegans* Kunth, *Cardiospermum grandiflorum f. elegans* (Kunth) Radlk., *Cardiospermum grandiflorum f. hirsutum* (Willd.) Radlk., *Cardiospermum grandiflorum var. hirsutum* Hiern, *Cardiospermum hirsutum* Willd., *Cardiospermum hispidum* Kunth, *Cardiospermum inflatum* Vell. *Cardiospermum macrophyllum* Kunth,*Cardiospermum pilosum* Vell. *Cardiospermum velutinum* Hook. & Arn., *Cardiospermum vesicarum* Humb.

Common names: Balloon vine, blaasklimop (Afrikaans), grand balloon vine, heart pea, heart seed, heart seed vine, intandela (Zulu), kopupu takaviri (Cook Islands), showy balloon vine.

Plant type: Annual or perennial vine-like climber

Related species in the EPPO region:

Horticulture: *Cardiospermum halicacabum* L.

2. Pest overview

Introduction

The genus *Cardiospermum* L. encompasses 17 shrub, subshrub, and climber species, commonly referred to as balloon vines (Gildenhuys *et al.* 2013). Most balloon vine species are restricted to the Neotropics from southeastern Brazil to northcentral Mexico (Ferrucci and Umdiriri 2011), with most species (12) found in Brazil. The biogeography (native vs. non-native ranges) of some balloon vine species remains inconclusive (Gildenhuys *et al.* 2013, 2015a). For example, it was only recently discovered that *Cardiospermum corindum* from southern Africa several million years ago diverged from its New World conspecific populations, and therefore should be regarded as native to these areas and not non-native as previously was assumed (Gildenhuys *et al.* 2015a, 2015b).

Cardiospermum grandiflorum is a large (up to 8 m in height), semi-woody annual or perennial often draping over other vegetation. The stems usually are covered with reddish green bristly hairs. Bright green leaves are strongly serrated and sometimes hairy. White or yellow, fragrant flowers (7-11 mm in size) on compact heads appear from late spring to early summer (GISD 2015). The species has elongated inflated balloon-like fruit 4.5–6.5 cm in length. Fruits consist of three dorsally keeled membranous capsules, each consisting of three internal blades (Weckerle and Rutishauser 2005). The fruit are septifragal with the capsules breaking away from each other when fruit are ripe, changing colour from green to brown (Weckerle and Rutishauser 2005). Three seeds normally are produced per fruit, each having a characteristic round or kidney-shaped hilum (Weckerle and Rutishauser 2005). The species is also capable of vegetative reproduction through coppicing or suckering (Personal Communication, Le Roux, 2017).

Cardiospermum grandiflorum has a near-cosmopolitan distribution (though mainly distributed in the warmer parts of the southern hemisphere), in part owing to its widespread introduction globally for ornamental purposes (Ferrucci and Umdiriri 2011, Urdampilleta *et al.* 2013; see also section 6). However, unresolved biogeographic statuses (alien or native), in particular in the species' distribution in tropical parts of Africa, remain problematic (Gildenhuys *et al.* 2015a). For example, the species has been variously regarded as native (Perreira *et al.* 2012) and alien (Mosango *et al.*, 2001) in Uganda. Fruit morphology differs substantially between Ugandan specimens and those from the Neotropics (S.P. Carroll, personal communication) and divergence between Ugandan and South American taxa may pre-date possible human-mediated dispersal (Gildenhuys *et al.* 2015a). Irrespective of these issues, the species is conclusively non-native in at least 14 countries (see section 6). In the EPPO area the species has non-native records from France (Landes and Alpes-Maritimes departments, considered a casual species and may be in the process of becoming naturalised), Italy (Canalicchio close to Catania in , Sicily and in Liguria), Malta, Portugal (Madeira Island), and Spain (Canary Islands: Gran Canaria, Tenerife, La Gomera, La Palma). The fruits of balloon vines are extremely well adapted for natural long-distance dispersal. For example, *C. grandiflorum* seeds retained viability after fruit floated for more than six months in seawater (Gildenhuys *et al.* 2013). At the same time, *Cardiospermum* seeds may be dispersed by wind after the dry fruit capsules open, with each of the three seeds attached at the center of a disk-shaped sail.

Reproduction

The breeding system of *C. grandiflorum* is not well understood though the species is monoecious (male and female flowers on the same plant). The species' flowers are functionally unisexual (Acevedo-Rodríguez 2005). In addition, experimental data from closely related species support potential self-compatibility. *Cardiospermum halicacabum* is self-compatible, producing a high percentage of viable seeds when self-fertilized (Acevedo-Rodríguez, 2005). Another congener, *C. canescens*, exhibits geitonogamy, that is, successful pollination between flowers of the same plant (Solomon Raju *et al.* 2011). Temperature seems to impact phenology of *C. grandiflorum*, with warmer climates supporting longer flowering periods (JJ Le Roux, personal observation). The species is thought to form large seed banks, as individual plants can produce hundreds of seeds (JJ Le Roux, personal observation) especially in dense invasive populations (FloraBase 2012). Seeds can remain viable for up to two years (Vivian-Smith *et al.* 2002). The fruits of *C. grandiflorum* are well-adapted for wind and water dispersal (Gildenhuys *et al.* 2013). Seed germination success and optimal growth requirements are not well studied in *C. grandiflorum*, but again, research on the closely related *Cardiospermum halicacabum* may provide insights into key requirements on the reproductive biology of the species. For *C. halicacabum* optimum germination takes place at 35 °C, with well-drained soil conditions increasing germination success (Johnston *et al.* 1979, Jolley *et al.* 1983, Dempsey 2011). *Cardiospermum grandiflorum* is also capable of vegetative reproduction through resprouting.

Natural enemies

Cardiospermum grandiflorum produces numerous secondary compounds (e.g., flavone aglycones and cyanogenic compounds) that likely protect it against herbivores such as soapberry bugs (Subramanyam *et al.* 2007). Soapberry bugs from the genera *Leptocoris*, *Jadera* and *Boisea* (family Rhopalidae) feed exclusively on seeds of Sapindaceae and are natural seed predators of *Cardiospermum* globally, including in their non-native ranges (Carroll *et al.* 2005b). Soapberry bugs co-occur with the widespread distribution of *Cardiospermum* (excluding Europe) and thus may impact reproduction globally. For example, American soapberry bugs can destroy ca. 95% of invasive balloon vine seeds (Carroll *et al.* 2003).

Habitat and environmental requirements

Cardiospermum grandiflorum thrives in well-drained soil types. Research on invasive populations of *C. grandiflorum* from Australia found soil types to vary substantially among regions of high-density populations indicating a wide edaphic tolerance by the species. It also has been noted that optimal growth takes place in well-lit (sunny) locations, although it is capable of germinating under dark conditions (Gildenhuys et al., 2013). Seeds and young plants are able to survive flooded, saturated, and dry conditions, while performing best in intermediate conditions (Dempsey 2011). In both native and introduced ranges, *C. grandiflorum* performs best in subtropical climates, in habitats such as forest margins, along watercourses, and in disturbed urban open areas (Carroll 2005a, Gildenhuys *et al.* 2013). The species also responds rapidly to environmental disturbances (Carroll *et al.* 2005a) and is commonly observed in highly disturbed habitats such as abandoned agricultural fields, urban environments, and areas outside domestic gardens (JJ Le Roux, personal observation).

Identification

Cardiospermum grandiflorum is a large, semi-woody annual or perennial often draping over other vegetation (see Figure 1; Appendix 3). While the fruit of *C. grandiflorum* can be variable (size and shape), their distinct shape and coverage by hairs make the species easily recognizable and distinguishable from closely related taxa such as *C. halicacabum* and *C. corindum*. *Cardiospermum grandiflorum* has hairy ribbed stems that are reddish-green in colour covered in bristly hairs. Leaves are compound and up to 16 cm long and are dark green and heavily serrated. The species' flowers have four petals that are white with a yellow lip (see Figure 2, Appendix 3). Flowers are fragrant and grow in clusters with a pair of tendrils at the flower base. Fruits are balloon-shaped, up to 65 mm long, inflated, representing a 3-angled and pointed tipped capsule, covered in fine bristly hair. Young fruit capsules are green, turning brown as the fruit matures. Each fruit is septifragal and contains three black seeds each with a characteristic white heart-shape hilum (Weckerle and Rutishauser 2005).

Symptoms
Although empirical data are lacking, *C. grandiflorum* is considered an ecological 'transformer' species in its invasive ranges in South Africa and Australia (Henderson 2001, Carroll *et al.* 2005a). Infestations of *C. grandiflorum* can cause problems commonly associated with invasive climbing vines. The species can grow into the upper canopy of native tree communities (Figure 3, Appendix 3). Along forest margins and watercourses (Figure 4, Appendix 3), and in urban open spaces, especially in subtropical regions, the species smothers indigenous vegetation, thereby blocking sunlight and reducing photosynthesis, and thus outcompeting native plants. In East Africa, where the species is presumably native, dense populations of *C. grandiflorum* are reported to hinder the free movement of wildlife and livestock (BioNET International 2016). In Australia native soapberry bugs (genera *Leptocoris*, *Jadera* and *Boisea*) prefer *C. grandiflorum* as their primary host to native *Sapindaceae* plants (Carroll & Loye 2012).

Existing PRAs
USA: United States Department of Agriculture (USDA) conducted a weed risk assessment using the Plant Protection and Quarantine Weeds Risk Assessment (PPQ WRA) model (Koop *et al.* 2012). This model assumes geographic and climatic 'neutrality' and therefore aims to determine the baseline weed/invasive potential of a particular species for the entire US. Based on these analyses, *C. grandiflorum* scored 17 for establishment and spread potential in the US, and 2.5 for potential impacts, which falls within the category 'High Risk'. The species also has been evaluated using the Australian/New Zealand Weed Risk Assessment adapted for Hawaiʻi (HWRA) by the Pacific Island Ecosystems at Risk and scored a total of 18, again falling in the category 'High Risk' (PIER 2013).

Europe (overall): The current PRA is being conducted under the LIFE project (LIFE15 PRE FR 001) within the context of European Union regulation 1143/2014, which requires a list of invasive alien species (IAS) to be drawn up to support future early warning systems, control and eradication of IAS.

Socio-economic benefits
Cardiospermum grandiflorum is available in the ornamental trade within the EPPO region and is listed as present in various botanical gardens throughout the region (including the EU). However, Schoenenberger (2017) considers the socio-economic benefits to the ornamental plant industry are low as only small volumes of the species are traded.

Schoenenberger (2017) conducted an online search (3.11.2017) with the terms "buy / for sale

Cardiospermum grandiflorum” on Google, first 20 hits analysed, restricted to websites from Europe, in Spanish (comprar / en venta Cardiospermum grandiflorum), Italian (acquistare / in vendita Cardiospermum grandiflorum), French (acheter / en vente Cardiospermum grandiflorum), German (Cardiospermum grandiflorum kaufen / zum Verkauf) and English, resulted in the following hits:

- English: one nursery offering *Cardiospermum* spp. (several offering *C. halicacabum*).
- Spanish: one botanical garden (Real Jardín Botánico Juan Carlos I Universidad de Alcalá, Catálogo de especies 2011, Spain) offering C. grandiflorum seeds.
- Italian: one living C. grandiflorum plant for sale on ebay.
- French: no record. German: one botanical garden (University Duisburg Essen, Germanx, Index Seminum 2016) offering *C. grandiflorum* seeds from natural habitats non-commercially and two websites selling C. grandiflorum seeds commercially (http://www.sunshineseeds.de/Cardiospermum-grandiflorum-45722p.html / https://www.exot-nutzzier.de/Samenliste/Samen_Ranker_Kletterpflanzen_C/Cardiospermum_grandiflorum/Product Details8848.aspx?Category=1&SubCategory=67&ProductDetailsTemplate=).

Numerous extracts from the species have been reported for their medicinal uses. For example, root derivatives of the plant have been shown to offer laxative, emetic, and diuretic effects. The leaves of the plant have been used to alleviate swelling, oedema and pulmonary complications (GISD 2015) and may have anti-bacterial activity (Nnamani *et al.* 2012), however, these socio-economic benefits are relevant to developing countries rather than the EU. Up to date, no commercial enterprises make use of this species in the production of medicinal products.

3. Is the pest a vector?	**No**
4. Is a vector needed for pest entry or spread?	**No**

No vector required for entry of *C. grandiflorum* into PRA area.

5. Regulatory status of the pest

Australia: *Cardiospermum grandiflorum* is regulated under legislation (Environment Protection and Biodiversity Conservation Act 1999) in New South Wales and listed as Class 4: "A locally controlled weed. The growth and spread of this species must be controlled according to the measures specified in a management plan published by the local control authority and the plant may not be sold, propagated or knowingly distributed"; in Queensland as Class 3: "This species is primarily an environmental weed and a pest control notice may be issued for land that is, or is adjacent to, an environmentally significant area (throughout the entire state). It is also illegal to sell a declared plant or its seed in this state"; in Western Australia as Unassessed - "This species is declared in other states or territories and is prohibited until assessed via a weed risk assessment (throughout the entire state)".

South Africa: In South Africa control of the species is enabled by the Conservation of Agricultural Resources (CARA) Act 43 of 1983, as amended, in conjunction with the National Environmental Management: Biodiversity (NEMBA) Act 10 of 2004. Currently *C.*

grandiflorum is listed as a Category 1b “invader species” on the NEMBA mandated list of 2014 (Government of the Republic of South Africa, 2014). Category 1b means that the “invasive species that may not be owned, imported into South Africa, grown, moved, sold, given as a gift or dumped in a waterway". Category 1b species are major invaders that may need government assistance to remove. All Category 1b species must be contained, and in many cases they already fall under a government sponsored management programme.” (www.environment.gov.za).

New Zealand: *Cardiospermum grandiflorum* is currently legally listed (under the country's Biosecurity Act 1993) as an ' Unwanted Organism'.

6. Distribution

Continent	***Distribution*** *(list countries, or provide a general indication , e.g. present in West Africa)*	***Provide comments on the pest status in the different countries where it occurs*** *(e.g. widespread, native, introduced….)*	***Reference***
Africa	Algeria, Guinea-Bissau, Guinea, Sierra Leone, Angola, Benin, Botswana, Cameroon, Central African Republic, Côte d'Ivoire, Democratic Republic of Congo, Ghana, Guinea, Kenya, Liberia, Namibia, Nigeria, Rwanda, Sierra Leone, South Africa, southern Malawi, southern Mozambique, South Sudan, Swaziland, Togo, Uganda, western Tanzania, Zambia, Zimbabwe	Conflicting information exists on the status (native or introduced/invasive) of *C. grandiflorum* in Africa. While some sources consider it native to tropical regions of Africa, others note its status as an invader of the continent is unknown. For some countries (e.g. Uganda) both morphological (S. Carroll personal communication) and phylogenetic data suggest a native range distribution. The species is definitely non-native to South Africa and Namibia. Given that some accessions from tropical Africa (Uganda) are now considered native and the species' cosmopolitan distribution and dispersal capabilities, it is reasonable to assume that tropical African populations are likely native. It is also possible that the species is under cultivation in some parts of Africa. It is noteworthy that the species is considered invasive in some parts of its native East African ranges (Kenya and Uganda, A.B.R. Witt, personal communication). Areas of geographic uncertainty (native vs. introduced) include southern African distributions of the species in Zimbabwe, southern Malawi, and southern Mozambique.	Cowling *et al.* (1997), DAFF (2011), ISSG (2007), Gildenhuys *et al.* (2015), GISD (2015), Macdonald et al., 2003), McKay *et al.* (2010)
America	Argentina, Belize, Bolivia, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Guyana, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay, USA (Hawaii California, and Puerto Rico), Venezuela	The species has a wide Neotropical native range from southern Mexico to Brazil and Caribbean (type specimen from Jamaica). All central and south American countries are considered part of the species' native range distribution. Distributions in the USA represent non-native naturalised populations of the species.	Carroll *et al.* 2005a, USDA 2013
Asia	Sri Lanka	*Cardiospermum grandiflorum* is considered introduced to Sri Lanka	CABI (2016), USDA (2013)
Europe	France (only in Landes and Alpes-Maritimes departments), Italy (mainland and the Island of Sicily), Malta, Portugal (only in	Invasive species perceived to have significant environmental impacts in Malta. In France and Italy the species is considered casual and may be in the process of establishment. The status of	Ameen (2013), Celesti-Grapow et al (2010), DAFF (2011), EPPO (2012),

Continent	***Distribution*** *(list countries, or provide a general indication , e.g. present in West Africa)*	***Provide comments on the pest status in the different countries where it occurs*** *(e.g. widespread, native, introduced….)*	***Reference***
	Madeira Island), Spain (only in Canary Islands: Gran Canaria, Tenerife, La Gomera, La Palma) Biogeographical regions: Alpine, Atlantic, Macaronesia (outermost territories), Mediterranean	the situation of the species in Spain and Portugal is currently unknown.	Gómez-Bellver *et al*., (2016), Alberti (2014)
Oceania	Australia, Cook Islands, Fiji, French Polynesia, New Zealand	All are invaded regions, particularly in Australia. Uncommon in New Zealand following extensive management efforts against the weed.	Carroll *et al.* 2005a, EPPO 2012, USDA 2013, Gildenhuys *et al.* 2015, GISD (2015),

Introduction

Cardiospermum grandiflorum has a wide Neotropical native range from southern Mexico to Brazil and Caribbean (type specimen from Jamaica) (Appendix 4, Figure 1). The species has been introduced intentionally to many regions of the world as a popular ornamental plant. The species is widespread and highly invasive in subtropical regions in Australia and South Africa.

Africa

The introduction of *Cardiospermum grandiflorum* into South Africa as an ornamental plant occurred around 100 years ago (Simelane *et al.* 2011). The species has rapidly spread and is considered invasive in five of the country's nine provinces, of which the Kwazulu-Natal and the Eastern Cape provinces are the most severely affected (Henderson 2001, Simelane *et al.* 2011). Little information is available about the species' introduction history into other non-native ranges in southern Africa (Angola, Botswana, Namibia, Mozambique, Swaziland, Zimbabwe) (EWG opinion). However, some databases, for example GISD (2015) list all of the aforementioned countries as part of the native range. Some uncertainty exists about the species' status (native or introduced) in tropical Africa. For some countries (e.g., Uganda) both morphological and phylogenetic data suggest a native range distribution. In this PRA tropical regions of Africa were regarded as native range distributions. See Appendix 4, Figure 2.

Oceania

The first herbarium records of *C. grandiflorum* date back to 1923 in Australia, from around Sydney, New South Wales (Carroll *et al.* 2005a). The species is now abundant throughout the east coast of Australia between Sydney and Cairns. Inland spread of the species to forested areas such as Toowoomba (Queensland) and the Blue Mountains (New South Wales) recently has been observed (Carroll *et al.* 2005a, E. Gildenhuys, pers. obs.). The species is present in isolated populations in the north island of New Zealand around Auckland. The species is now rare (possibly eradicated) from the country following extensive management efforts. *Cardiospermum grandiflorum* is widespread and invasive on Rarotonga, Cook Islands, and Tahiti, but exact dates of introduction are not known. See Appendix 4, Figure 3.

Americas

The species has a wide Neotropical native range from southern Mexico to Brazil and Caribbean (type specimen from Jamaica). All central and south American countries are considered part of the species' native range distribution. Distributions in the USA represent non-native naturalised populations of the species. There also is a single record from California where the species is reported as restricted to a small area in urban Los Angeles (Gildenhuys *et al.* 2013). See Appendix 4, Figure 4.

Europe

In Europe, the species has non-native records from France (Landes and Alpes-Maritimes departments, considered a casual species in 2012, in the process of becoming established, EPPO, 2012). In the Alpes-Maritimes department in France, the species was first recorded in Menton in the City of Beausoleil in an urban area. In Italy, the species is recorded from Canalicchio near Catania, in Sicily (recorded in 2016, personal communication, Pietro Minissale, 2016); and for Ligura, reported as naturalized in 2013, Alberti, 2014). In Malta (considered as an invasive species) where it is reported to invade a Natura 2000 site 'Wied Babu' in Żurrieq and is considered to have devastating impacts on the native biodiversity of the island (Ameen, 2013). In Portugal, the species has been reported from the Madeira Island, reported as 'recently became a troublesome invasive species in 2014 and has been reported since 2008), and Spain (Canary Islands: Gran Canaria, Mallorca (recorded in 2004, casual record), Tenerife, La Gomera, La Palma) (Benedito and Sequeira, 2014, Borges, 2008, MEPA, 2013, Sáez et al., 2016, Verloove, 2013). See Appendix 4, Figure 5.

Asia

Some consider parts of Asia as the native range of the species (CABI 2016). The species is considered as introduced to Sri Lanka. See Appendix 4, Figure 6.

7. Habitats and their distribution in the PRA area

Habitats	**EUNIS habitat types**	**Status of habitat (eg threatened or protected)**	**Present in PRA area (Yes/No)**	**Comments (e.g. *major/minor habitats* in the PRA area)**	***Reference***
Grasslands and lands dominated by forbs, mosses or lichens	E1. Dry grassland E2: Mesic grasslands E3: Seasonally wet and wet grasslands E5: Woodland fringes and clearings and tall forb stands E7: Sparsely wooded grasslands	In Part	Yes	Major habitat within the EPPO region	EWG opinion
Woodland	G1: Broadleaved deciduous woodland (including riparian woodland) G2: Broadleaved evergreen woodland G4: Mixed deciduous and coniferous woodland G5: Lines of trees, small anthropogenic woodlands, recently felled woodland, early-stage woodland and coppice	In part	Yes	Major habitat within the EPPO region	EWG opinion
Regularly or recently cultivated agricultural, horticultural and domestic habitats	I1: Arable land and market gardens I2: Cultivated areas of gardens and parks	None	Yes	Major habitat within the EPPO region	EWG opinion
Constructed, industrial and other artificial habitats	J4: Transport networks and other constructed hard-surfaced areas J5: Highly artificial man-made waters and associated structures J6: Waste deposits	None	Yes	Major habitat within the EPPO region	EWG opinion

Habitats	EUNIS habitat types	Status of habitat (eg threatened or protected)	Present in PRA area (Yes/No)	Comments (e.g. *major/minor habitats* in the PRA area)	*Reference*
X: Habitat complexes	X06: Crops shaded by trees X07: Intensively-farmed crops interspersed with strips of natural and/or semi-natural vegetation X09: Pasture woods (with a tree layer overlying pasture) X10: Mosaic landscapes with a woodland element (bocages) X11: Large parks X13: Land sparsely wooded with broadleaved deciduous trees X14: Land sparsely wooded with broadleaved evergreen trees X15: Land sparsely wooded with coniferous trees X16: Land sparsely wooded with mixed broadleaved and coniferous trees X22: Small city centre non-domestic gardens X23: Large non-domestic gardens X24: Domestic gardens of city and town centres X25: Domestic gardens of villages and urban peripheries	None	Yes	Major habitat within the EPPO region	EWG opinion

C. grandiflorum prefers open habitat, though it may thrive in forest edges (CABI 2016). *Cardiospermum grandiflorum* thrives in well-drained soil types. Research on invasive populations of *C. grandiflorum* from Australia found soil types to vary substantially among regions of high-density populations indicating a wide edaphic tolerance by the species. It also has been noted that optimal growth takes place in well-lit (sunny) locations, although it is capable of germinating under dark conditions (Gildenhuys et al., 2013). Seeds and young plants are able to survive flooded, saturated, and dry conditions, while performing best in intermediate conditions (Dempsey 2011). In both native and introduced ranges, *C. grandiflorum* performs best in subtropical climates, in habitats such as forest margins, along watercourses, and in disturbed urban open areas (Carroll 2005a, Gildenhuys *et al.* 2013). The species also responds rapidly to environmental disturbances (Carroll *et al.* 2005a) and is commonly observed in highly disturbed habitats such as abandoned agricultural fields, urban environments, and areas outside domestic gardens (JJ Le Roux, personal observation)

8. Pathways for entry

Possible pathways	**Pathway: Plants or seeds for planting** **(CBD terminology: Escape from confinement - horticulture)**
Short description explaining why it is considered as a pathway	Ornamental trade is the main pathway of introduction of *C. grandiflorum* around the world (Henderson, 2001; CABI, 2016). Most non-native *Cardiospermum* species, including *C. grandiflorum*, primarily have been introduced as an ornamental species. These species are popular because of their ease to grow and showy fruit capsules. *Cardiospermum grandiflorum* could enter the EPPO region from online suppliers – for example from the USA.
Is the pathway prohibited in the PRA area?	No evidence of regulation within the PRA area
Has the pest already been intercepted on the pathway?	Yes, the commodity is for sale seeds
What is the most likely stage associated with the pathway?	Individual live plants (though this is mostly within the EPPO region as oppose to entry into the PRA area) or seeds (both within and from outside the EPPO region).
What are the important factors for association with the pathway?	While trade using the normal avenues (e.g. online market places like Ebay.com) currently lists *C. grandiflorum* infrequently, a congeneric species, *C. halicacabum* is readily available. It is possible that some traders may confuse these two species as the latter frequently is mislabelled as *C. grandiflorum*.
Is the pest likely to survival transport and storage in this pathway?	Yes, if the intention is to introduce propagules (plants or seeds) for ornamental purposes then survival is essential.
Can the pest transfer from this pathway to a suitable habitat?	Yes, through direct human actions. Planted individuals can easily spread via wind or water dispersed seeds. The species responds well to anthropogenic disturbances in urban (city) and rural (e.g. agriculture) areas.
Will the volume of movement along the pathway support entry?	The species is already present in the EPPO region and we found little evidence for on-going trade in the species apart from the small numbers of online suppliers already mentioned. However, based on the potential of misidentification with *C. halicacabum* coupled with the potential to enter via online suppliers the volume of movement along the pathway will support entry.

Will the frequency of movement along the pathway support entry?	See answer under 'Will the volume of movement along the pathway support entry?'		
Likelihood of entry	Low	Moderate X	High
Rating of uncertainty	Low X	Moderate	High

As the species is imported as a commodity, all European biogeographical regions will have the same likelihood of entry and uncertainty scores.

Do other pathways need to be considered?

No

9. Likelihood of establishment in the natural environment PRA area

Note: Based on the species distribution modeling, suitable areas for *C. grandiflorum* have been identified as suitable for establishment in the Mediterranean biogeographical region (See appendix 1 and 2). Areas in Portugal, Spain and Italy are suitable for the establishment of the species and areas in North Africa (Morocco and Algeria) are marginally suitable. In addition, areas of Israel and countries bordering the Adriatic and Ionian Sea provide marginally suitable areas for the establishment of *C. grandiflorum*. The authors of the PRA acknowledge that there are a number of caveats to the modelling the species distribution and for this species they include: (1) The GBIF API query used to did not appear to give completely accurate results. For example, in a small number of cases, GBIF indicated no Tracheophyte records in grid cells in which it also yielded records of the focal species. (2) We located additional data sources to GBIF, which may have been from regions without GBIF records. (3) Other variables potentially affecting the distribution of the species, such as soil nutrients, were not included in the model. Given the aforementioned caveats, the EWG consider that the model adequately describes the potential occurrence of the species under the current climatic conditions.

Cardiospermum grandiflorum is already present in the natural environment in Malta where it also shows invasive tendencies. The species is also casual and may be in the process of establishing in France and Italy. The species also has annual and perennial forms/behaviour, and it is likely that annual forms are better suited for climatic conditions within the EPPO region. In Australia and South Africa, the species does not exhibit the invasive tendencies in the Mediterranean areas that are seen in the more tropical and sub-tropical regions of these countries (personal communication JJ Le Roux 2016; CABI 2016).

Natural habitats within the endangered area include woodland, forests, wasteland, grassland, riparian systems and successional habitats.

Rating of the likelihood of establishment in the natural environment	Low ☐	Moderate X	High ☐
Rating of uncertainty	Low X	Moderate ☐	High ☐

10. Likelihood of establishment in managed environment in the PRA area

Cardiospermum grandiflorum responds well to human-mediated environmental disturbances (Personal Comunication, Le Roux). This is especially true in areas previously invaded by the species where seed banks respond to the availability of light. Irrespective, release of the species into disturbed areas, e.g. agricultural land and their boundaries, old fields, road sides, water course banks, etc. are expected to be highly suitable for establishment in areas meeting the species' climatic requirements (EWG opinion). This is shown as the species grows well along roadsides, urban areas within its non-native range where it is non-invasive. For example, in Italy (Liguria), *C. grandiflorum* is established in disturbed, peri-urban areas (Informatore Botanico Italiano, 2014).

As already mentioned, the most limiting environmental factors for establishment of *C. grandiflorum* is temperature, and the EWG considers rainfall to be a limiting factor. However, urban environments (home gardens, disturbed habitats in cities, roadsides etc.) often create microclimates that may overcome these limitations.

Managed habitats within the PRA area include old fields, road sides, water course banks, agricultural lands, home gardens and roadsides.

Rating of the likelihood of establishment in the managed environment	Low ☐	Moderate	High X
Rating of uncertainty	Low X	Moderate ☐	High ☐

11. Spread in the PRA area

Natural spread

Cardiospermum grandiflorum fruits (balloons) and seeds are well adapted for extreme (i.e. inter-continental) long-distance dispersal (Gildenhuys *et al.* 2015a). That is, seed-carrying balloons can float for extensive periods in watercourses and so cover substantial distances over short time scales, e.g. along rivers and even across the sea. Previous research has shown balloons floated in seawater for 6 months to carry viable seeds (Gildenhuys *et al.* 2013). Within balloons individual seeds are attached to circular sails that may deploy once the fruit dehisces, further aiding in wind dispersal. The known presence of the species within the EPPO region makes natural dispersal the most likely mode of spread within the region. If natural spread is from a dense population, the volume of movement is likely to support the establishment of new populations. Individuals would be able to spread via wind or water dispersed seeds transferring to suitable habitats.

Human assisted spread

The main pathway historically for this species has been the ornamental industry and the use of the species as a garden plant (Henderson, 2001; CABI, 2016). Online vendors still sell seeds of the genus, but mostly for *C. halicacabum*. Within the EPPO region several traders do list the species. Many of these traders may misidentify the species, i.e. selling *C. halicacabum* under the name *C. grandiflorum* (EWG opinion). It is possible that the species may still be in the horticultural trade within the PRA area since it is already present in several EPPO countries and may therefore be traded as whole plants. In some instances, a congeneric species, *C. halicacabum*, may have been mislabelled as *C. grandiflorum* by these traders

(EWG opinion). However, given the species' known occurrences within the EPPO region and its desirable characteristics as an ornamental, it remains likely that it could be moved around non-commercially, and therefore, we cannot rule out the potential for further human-assisted spread. From planted populations, spread would be facilitated via wind or water dispersed seeds. Schoenenberger (2017) details only small volumes of the species are traded and thus propagule pressure within the EPPO region is limited. Therefore, coupling both natural spread and human assisted spread, a moderate rating of spread has been given.

Rating of the magnitude of spread	Low ☐	Moderate **X**	High ☐
Rating of uncertainty	Low **X**	Moderate ☐	High ☐

12. Impact in the current area of distribution

12.01 Impacts on biodiversity

In its invasive range *C. grandiflorum* typically forms dense draping carpets/mats, smothering large areas of underlying vegetation (Ameen, 2013; McKay *et al.* 2010). For example, in Australia these carpets can cover native vegetation in riparian ecosystems in uninterrupted stands sometimes several kilometres in size, including trees of up to 20 m high (Carroll *et al.* 2005a). The resultant exclusion of sunlight negatively impacts photosynthesis, leading to the competitive exclusion of other species, including natives. *Cardiospermum grandiflorum* therefore has the potential to negatively affect overall ecosystem processes and plant communities (Ameen 2013, Coutts-Smith and Downey 2006). While empirical data on the species' impacts are currently lacking, its potential impacts can be deduced from similar invasive growth forms elsewhere in the world. For example, the woody vine *Clematis vitalba* is a vigorous climber that, similar to balloon vine, smothers vegetation. In New Zealand *C. vitalba* has had serious biodiversity impacts (Ogle *et al.* 2000). In South Africa *C. grandiflorum* is considered a 'transformer' species (Henderson 2001, Carroll *et al.* 2005a) where it is a major weed in riparian zones (banks of watercourses).

In Malta, there is evidence of impacts on biodiversity as the species has formed extensive invasive populations (EWG opinion). The invaded area in Malta may present unique micro-climatic conditions for the species due to it being a steep-sided dry valley (EWG opinion).

An intriguing example of the possible long-term impacts of invasive balloon vines on native biodiversity includes an evolved increase in rostrum length of the Australian soapberry bug, *Leptocoris tagalicus,* in response to feeding preferentially on invasive *C. grandiflorum* rather than its native Sapindaceae host (Carroll *et al.* 2005b). This impact is unlikely to be replicated in the EPPO region, as the region falls outside the native range distributions of soapberry bugs.

To-date there are no impacts recorded on red list species and species listed in the Birds and Habitats Directives.

Rating of the magnitude of impact in the current area of distribution	*Low* ☐	*Moderate* X	*High*
Rating of uncertainty	*Low*	*Moderate* X	*High* ☐

12.02. Impact on ecosystem services

Ecosystem service	**Does the IAS impact on this Ecosystem service?** Yes/No	**Short description of impact**	**Reference**
Provisioning	Yes	In East Africa, dense populations of invasive *C. grandiflorum* have been reported to hinder the free movement of wildlife and livestock (BioNET International 2016). These impacts are well documented for congeneric species such as *C. halicacabum* that can reduce soybean crop yields by up to 26%.	BioNET International 2016, Johnston *et al.* 1979, Jolley *et al.* 1983, Voll *et al.* 2004, Subramanyam *et al.* 2007, Murty and Venkaiah 2011, Dempsey *et al.* 2011, Brighenti *et al.* 2003.
Regulating	Yes	Impediment on photosynthesis, reducing biodiversity Relative primary production by competitive displacement of native vegetation. Possibly could interfere with stability of riparian habitats when displacing native flora, e.g. increased bank erosion	Carroll *et al.* 2005a, Ameen, 2013, McKay *et al.* 2010
Cultural	Yes	Aesthetic impacts can occur when the species smothers natural areas	EWG opinion

Ecosystem service impacts are rather hard to assess, given that many descriptions in the literature are based on observational rather than empirical data, with the current status of impacts in any particular area unknown. The assessment is therefore given a “moderate” uncertainty rating.

Rating of the magnitude of impact in the current area of distribution	*Low* ☐	*Moderate* **X**	*High*
Rating of uncertainty	*Low* ☐	*Moderate* **X**	*High* ☐

12.03. Describe the adverse socio-economic impact of the species in the current area of distribution

Dense stands of *C. grandiflorum* have been reported as being able to restrict the free movement of wildlife and livestock (BioNET International 2016). The largest potential costs would potentially lie in the control of this species once established and widespread. Mechanical control of balloon vine is extremely difficult and costly, as dead plant material has to be removed to restore exposure of the understory to sunlight (Gildenhuys et al., 2013). Such costs would be escalated by the need to prevent contamination of watercourses, along which the species are most likely to establish, when using chemical control. Using novel methods of control, such as biological control may be costly and as an example, research costs for biological control in South Africa are typically over 500,000 Euros per target species (van Wilgen *et al*. 2004).

Cardiospermum (note this relates to several species) invasions also have substantial economic impacts on sugarcane and soybean production (Johnston *et al.* 1979, Jolley *et al.* 1983, Subramanyam *et al.* 2007, Murty and Venkaiah 2011). For example, in Brazil *C. halicacabum* can reduce soybean crop yields by up to 26% (Dempsey *et al.* 2011, Brighenti *et al.* 2003). The problem with controlling *Cardiospermum* infestations in soybean crops is the difficulty of mechanically excluding their seeds, which represent soybean seeds in size and shape (Brighenti *et al.* 2003). It is foreseeable that, when climatic requirements are met, the species may pose an economic threat to agricultural crop yields.

There are no human health impacts associated with this species (EWG opinion).

The EWG are unaware of any quantitative costs on the adverse socio-economic impacts of *C. grandiflorum* either in the EPPO region or third countries.

Control methods

The species can be controlled using mechanical, chemical and biological control methods (see section 3. Risk management).

Rating of the magnitude of impact in the current area of distribution	*Low*	*Moderate* X	*High* ☐
Rating of uncertainty	*Low* ☐	*Moderate* X	*High* ☐

13. Potential impact in the PRA area

Will impacts be largely the same as in the current area of distribution? No

Magnitude of impact is hard to assess due to the conflicting information on the species. For example, in Australia and South Africa, countries with both subtropical and Mediterranean-type regions, the species does not exhibit the invasive tendencies in the Mediterranean areas that are seen in the more tropical and sub-tropical regions of these countries (personal communication JJ Le Roux, 2016; CABI 2016).

In Malta, there is evidence of impacts on biodiversity as the species has formed extensive invasive populations (EWG opinion, (Ameen 2013). The invaded area, in Malta may present unique micro-climatic conditions for the species due to it being a steep-sided dry valley (EWG opinion). *C. grandiflorum* is reported to invade a Natura 2000 site 'Wied Babu' in Żurrieq and is considered to have devastating impacts on the native biodiversity of the island (Ameen, 2013). Malta is the only region invasive populations of the species are reported as widespread in natural areas where they smother and outcompete native plant communities (Ameen 2013).

The impacts on ecosystem services detailed in section 12.03 are relevant to the PRA area for those impacts detailed under regulating, supporting and cultural services. For regulating, in the PRA area, *C. grandiflorum* has the potential to impede photosynthesis of native vegetation and reduce native biodiversity and for supporting ecosystem services, relative primary production may be negatively impacted on by competitive displacement of native vegetation. For cultural services, dense monocultures may impact on the aesthetic value of natural habitats, and there is evidence that this is already happening in Malta (EWG opinion).

The EWG consider that the impacts described in the current area of distribution will be similar to that in the PRA area, though the level of uncertainty will increase from moderate to high for all categories as the species currently has a limited distribution within the PRA area and there are a lack of scientific studies evaluating impacts.

Potential impacts in the PRA area will be greatest where the climate is conducive for establishment and the phenology of the species (see endangered area). Temperature seems to impact phenology of *C. grandiflorum*, with warmer climates supporting longer flowering periods (JJ Le Roux, personal observation). Therefore, the Mediterranean biogeographical region will experience the greatest impacts compared to other EU biogeographical regions.

In the absence of specific data on impacts in the PRA area the rating of magnitude of impact is given as moderate (there is already evidence the species is having an impact) but the uncertainty is raised to high as it is not clear if these impacts will be realised throughout areas of potential establishment in the PRA area.

The text within this section relates equally to EU Member States and non-EU Member States in the EPPO region.

At present one species, *Rhamnus alaternus* (protected by law Schedule II of Legal notice LN200/2011) has been highlighted as being vulnerable to *C. grandiflorum* in Malta (Ameen, 2013).

The following endemic species in Islas Canarias are considered to be affected by *C. grandiflorum: Aeonium urbicum* (Crassulaceae), *Allagopappus dichotomus* (Asteraceae), *Argyranthemum frutescens* (Asteraceae), *Artemisia thuscula* (Asterceae), *Ceballosia fruticosa* (Boraginaceae), *Echium leucophaeum* (Boraginaceae), *Euphorbia canariensis* (Euphorbiaceae), *Euphorbia lamarckii* (Euphorbiaceae, listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora), *Kleinia neriifolia* (Asteraceae), *Lavandula canariensis* (Lamiaceae), *Rubia fruticosa* (Rubiaceae), *Rumex lunaria* (Polygonaceae) (EPPO, 2013).

In Madeira, the following endemic species are considered to be affected by *C. grandiflorum: Aeonium glandulosum* (Crassulaceae), *Aeonium glutinosum* (Crassulaceae), *Crambe fruticosa*

(Brassicaceae), *Erica platycodon* subsp. *maderincola* (Ericaceae), *Euphorbia piscatoria* (Euphorbiaceae), *Genista tenera* (Fabaceae), *Helichrysum melaleucum* (Asteraceae), *Matthiola maderensis* (Brassicaceae), *Olea;europaea* subsp. *maderensis* (Oleaceae), *Sedum nudum* (Crassulaceae) and *Sinapidendron angustifolium* (Brassicaceae). In addition, in Madeira, the following species included in the Habitats Directive are also affected by *C. grandiflorum*: *Chamaemeles coriacea* (Rosaceae), *Convolvulus massonii* (Convolvulaceae), *Dracaena draco* (Asparagaceae), *Jasminum azoricum* (Oleaceae), *Echium candicans* (Boraginaceae), *Musschia aurea* (Campanulaceae), *Maytenus umbellata* (Celastraceae) and *Sideroxylon mirmulans* (Sapotaceae) (EPPO, 2013).

<u>New rating for impacts within the EPPO region:</u>

Impacts on biodiversity

Rating of the magnitude of impact in the area of potential establishment	*Low* ☐	*Moderate* X	*High* ☐
Rating of uncertainty	*Low* ☐	*Moderate* ☐	*High* X

Impacts on ecosystem services

Rating of the magnitude of impact in the area of potential establishment	*Low*	*Moderate* X	*High* ☐
Rating of uncertainty	*Low* ☐	*Moderate* ☐	*High* X

Socio-economic impacts

Rating of the magnitude of impact in the area of potential establishment	*Low*	*Moderate* **X**	*High* ☐
Rating of uncertainty	*Low* ☐	*Moderate*	*High* **X**

14. Identification of the endangered area

Based on the species distribution modeling, suitable areas for establishment of *C. grandiflorum* have been identified in the Mediterranean biogeographical region, including Portugal, Spain, and Italy and outside of the EU in the Macaronesia biogeographical region. Areas in Portugal, Spain, Malta and Italy are suitable for the establishment of the species and areas in North Africa (Morocco and Algeria) are marginally suitable. In addition, areas of Israel and countries bordering the Adriatic and Ionian Sea (specifically Greece) provide marginally suitable areas for the establishment of *C. grandiflorum*.

Habitats within the endangered area include woodland, forests, wasteland, riparian systems, old fields, fallow gardens, successional habitats, roadsides, urban habitats.

15. Climate change

15.01. Define which climate projection you are using from 2050 to 2100*

Climate projection RCP 8.5 2070

Climate change

By the 2070s, under climate change scenario RCP8.5 (RCP8.5 is the most extreme of the RCP scenarios, and may therefore represent the worst case scenario for a reasonably anticipated climate change), projected suitability for *C. grandiflorum* increases, most notably in Italy and northwards into the Atlantic Biogeographic Region as far north as The Netherlands and southern Britain (Fig. 6). Presumably this is driven by increases in summer and winter temperatures. There is little increase in suitability around the Mediterranean coastlines, which may be because of reduced predicted precipitation The extent of suitable areas will increase in the Atlantic biogeographical region (France, Germany, Belgium, Netherlands and England), even including a very small area of the Continental biogeographical region.

15.02 Which component of climate change do you think is most relevant for this organism?

*Temperature **(yes)***	*Precipitation **(yes)***	*C0$_2$ levels (**yes**)*
*Sea level rise **(no)***	*Salinity **(no)***	*Nitrogen deposition **(yes)***
*Acidification **(no)***	*Land use change **(yes)***	*Other (please specify)*

Are the **introduction pathways** likely to change due to climate change? **(If yes, provide a new risk and uncertainty score)**	**Reference**
The introduction pathways are unlikely to change as a result of climate change. Therefore, the scores will remain the same. All European biogeographical regions will have the same likelihood of entry and uncertainty scores. Scores = Plants for planting: Moderate with a low uncertainty	EWG opinion
Is the **risk of establishment** likely to change due to climate change? **(If yes, provide a new risk and uncertainty score)**	**Reference**
Yes, temperature is an important factor in the reproductive cycle (e.g. seed germination) of the species. Under predicted future climate conditions (using scenario RCP 8.5 (2070)) in general, the potential area for establishment in the EPPO region will increase. The extent of suitable areas will increase in the Atlantic biogeographical region (France, Germany, Belgium, Netherlands and England), even including a very small area of the Continental biogeographical region. Therefore, the score (for establishment in natural areas) will change from moderate to high and the uncertainty rating changes from low to high	(Johnston *et al.* 1979, Jolley *et al.* 1983, Dempsey 2011)
Is the **risk of spread** likely to change due to climate change? **(If yes, provide a new risk and uncertainty score)**	**Reference**
Yes, temperature impacts the phenology of *C. grandiflorum*, with warmer climates supporting longer flowering periods. This will potentially lead to higher reproductive output under predicted future climate conditions (using scenario RCP 8.5 (2070)). Increased flood events resulting from climate change could	FloraBase 2012

facilitate the spread of seeds into new regions. The extent of suitable areas for spread will increase in the Atlantic biogeographical region (France, Germany, Belgium, Netherlands and England), even including a very small area of the Continental biogeographical region. Therefore, the score (for spread) will change from moderate to high and the uncertainty rating changes from low to high	
Will **impacts** change due to climate change? **(If yes, provide a new risk and uncertainty score)**	**Reference**
Yes, it is expected that a larger part of the EPPO region will be suited to the climatic requirements of the species, and thus that the area occupied by the species, and performance of the species will increase. Under climate change, and if the species establishes monocultures the potential impacts are likely to be similar in the Atlantic, Continental and Mediterranean biogeographical regions. The score (for impact in the PRA area for all categories: biodiversity, ecosystem services and socio-economic impacts) will change from moderate to high with uncertainty remaining as high	EWG opinion

16. Overall assessment of risk

Cardiospermum grandiflorum presents a moderate phytosanitary risk to the endangered area with a moderate level of uncertainty. The overall likelihood of *Cardiospermum grandiflorum* continuing to enter into the EPPO region is moderate with a moderate uncertainty. There is some evidence that the plant is available from a small number of horticultural suppliers within the EPPO region. The overall likelihood of *C. grandiflorum* establishing in the EPPO region is moderate with a low uncertainty - the species is already present within the EPPO region, in particular in Malta where there is evidence that the species shows invasive tendencies. The overall potential impact of the species is moderate with a high uncertainty for the PRA area. The high uncertainty reflects the difficulty in assessing impacts due to the lack of published research and the apparent differences in performance across climatic regions. In Australia and South Africa, countries with both subtropical and Mediterranean-type regions, the species does not exhibit the invasive tendencies in the Mediterranean areas that are seen in the more tropical and sub-tropical regions of these countries (personal communication, JJ Le Roux, 2016; CABI 2016). However, in Malta, there is evidence of impacts on biodiversity as the species has been reported to have formed invasive populations.

The most limiting environmental factors for the establishment of *C. grandiflorum* are temperature and rainfall. In specific situations, e.g. urban environments, Insubria (Great Lakes in Northern Italy and Southern Switzerland), meso-climatic conditions may exist that help overcome these limitations.

Pathways for entry:

Plants for planting

Rating of the likelihood of entry for the pathway, plants or seeds for planting	*Low*	*Moderate* **X**	*High*
Rating of uncertainty	*Low* **X**	*Moderate*	*High*

Rating of the likelihood of establishment in the natural environment in the PRA area

Rating of the likelihood of establishment in the natural environment	*Low*	*Moderate* **X**	*High*
Rating of uncertainty	*Low* **X**	*Moderate*	*High*

Rating of the likelihood of establishment in the managed environment in the PRA area

Rating of the likelihood of establishment in the natural environment	*Low*	*Moderate*	*High* **X**
Rating of uncertainty	*Low* **X**	*Moderate*	*High*

Magnitude of spread

Rating of the magnitude of spread	*Low*	*Moderate* **X**	*High*
Rating of uncertainty	*Low* **X**	*Moderate*	*High*

Impact on biodiversity

Rating of the magnitude of impact in the current area of distribution (Biodiversity)	*Low*	*Moderate* X	*High*
Rating of uncertainty	*Low*	*Moderate* X	*High*

Impact on ecosystem services

Rating of the magnitude of impact in the current area of distribution (ecosystem services)	*Low*	*Moderate* X	*High*
Rating of uncertainty	*Low*	*Moderate* X	*High*

Impact on socio-economics

Rating of the magnitude of impact in the current area of distribution (ecosystem services)	*Low*	*Moderate* X	*High*
Rating of uncertainty	*Low*	*Moderate* X	*High*

Will impacts be largely the same as in the current area of distribution? **No**

New rating for impacts within the EPPO region:

Impact on biodiversity

Rating of the magnitude of impact in the current area of distribution (Biodiversity)	*Low* ☐	*Moderate* X	*High* ☐
Rating of uncertainty	*Low* ☐	*Moderate* ☐	*High* X

Negative impact the pest may have on categories of ecosystem services

Rating of the magnitude of impact in the current area of distribution (ecosystem services)	*Low*	*Moderate* X	*High* ☐
Rating of uncertainty	*Low* ☐	*Moderate* ☐	*High* X

Socio-economic impact of the species

Rating of the magnitude of impact in the current area of distribution (ecosystem services)	*Low*	*Moderate* X	*High* ☐
Rating of uncertainty	*Low* ☐	*Moderate*	*High* X

Stage 3. Pest risk management

17. Phytosanitary measures

The results of this PRA show that *Cardiospermum grandiflorum* poses a moderate risk to the endangered area (Mediterranean biogeographical region) with a moderate uncertainty.

The major pathway(s) being considered:

(1) Plants for planting

Given the significant impact of the species in other parts of the world and the identified risk to the PRA area, the EWG recommends the following measures for the endangered area:

International measures:

For the pathway plant for planting:

Prohibition of import into and movement within countries in the endangered area, of plants and seeds labeled or otherwise identified as *Cardiospermum grandiflorum*,

Recommend that *Cardiospermum grandiflorum* is banned from sale within the endangered area,

Cardiospermum grandiflorum should be recommended as a quarantine pest within the endangered area.

National measures

Cardiospermum grandiflorum should be monitored and eradicated, contained or controlled where it occurs in the endangered area. In addition, public awareness campaigns to prevent spread from existing populations or from botanic gardens in countries at high risk are necessary. If these measures are not implemented by all countries, they will not be effective since the species could spread from one country to another. National measures should be combined with international measures, and international coordination of management of the species between countries is recommended.

The EWG recommends the prohibition of selling and movement of the plant. These measures, in combination with management plans for early warning; obligation to report findings, eradication and containment plans, and public awareness campaigns should be implemented.

Containment and control of the species in the PRA area

Eradication measures should be promoted where feasible with a planned strategy to include surveillance, containment, treatment and follow-up measures to assess the success of such actions. As highlighted by EPPO (2012), regional cooperation is essential to promote phytosanitary measures and information exchange in identification and management methods. Eradication may only be feasible in the initial stages of infestation, and this should be a priority. The EWG considers that this is possible at the current level of occurrence the species has in the EPPO region.

General considerations should be taken into account for all potential pathways, where, as detailed in EPPO (2014), these measures should involve awareness raising, monitoring, containment and eradication measures. NPPOs should facilitate collaboration with all sectors to enable early identification including education measures to promote citizen science and linking with universities, land managers and government departments.

Import for plant trade
Prohibition of the import, selling, planting, and movement of the plant in the endangered area.

Unintended release into the environment
The species should be placed on NPPO's alert lists and a ban from sale would be recommended in countries most prone to invasion. Export of the plant should be prohibited within the EPPO region. Management measures would be recommended to include an integrated management plan to control existing populations including manual and mechanical techniques, targeted herbicides and proven biological control techniques. Monitoring and surveillance including early detection for countries most prone to risk. NPPOs should report any finding in the whole EPPO region in particular the Mediterranean area.

Intentional release into the environment
Prohibition on planting the species or allowing the plant to grow in the wild.

Natural spread (method of spread within the EPPO region):
Increase surveillance in areas where there is a high risk the species may invade. NPPO's should provide land managers and stakeholders with identification guides and facilitate regional cooperation, including information on site specific studies of the plant, control techniques and management.

See Standard PM3/67 'Guidelines for the management of invasive alien plants or potentially invasive alien plants which are intended for import or have been intentionally imported' (EPPO, 2006).

17.01 Management measures for eradication, containment and control

Manual control

Management
To date, managing *C. grandiflorum* invasions has mostly involved manual removal or burning. Manual removal involves cutting plants at the base. Roots are dug up after the above ground biomass has died off to avoid resprouting. This method of management is effective where the species is not widely spread.

Chemical control of larger plants includes treatment with paraquat (please note that paraquat is banned in some EPPO countries), glufosinate-ammonium, lactofen, carfentrazone-ethyl, sulfentrazone, glyphosate or 2, 4-dichloraphenoxy acetic acid (see Brighenti *et al.* 2003). This does not mean the chemicals are available or legal to use and countries should check to ensure chemicals are licensed for use in their country. In addition, the use of chemical control could potentially be problematic for two reasons, firstly because of non-target impact on underlying vegetation and, secondly, the high risk of environmental contamination because of the species' typical proximity to waterways (Simelane *et al.* 2011). A potential problem with both manual and chemical management is the species' ability to form relatively large seed banks (potentially hundreds per plant), so that once the weedy canopy is cleared or died off, seeds start to sprout as they respond strongly to the availability of light (FloraBase 2012).

Classical biological control has only been explored against the species in South Africa. Since the inception of a biological control program in 2003, ten insects and two fungal agents have either been recorded on the target weed in the native South American range or have been undergoing host-specificity testing in South Africa (Fourie and Wood 2007, McKay *et al.* 2010, Simelane & Mawela 2013). Eight of these insects displayed wider host ranges, capable of feeding and developing on other cosmopolitan *Cardiospermum* species in South Africa, in particular *C. halicacabum* and *C. corindum*. This is problematic for the region because, while both *C. grandiflorum* and *C. halicacabum* are non-native in South Africa, *C. corindum* is considered native (Gildenhuys *et al.* 2015a, 2015b). Of those potential biological control agents tested to date, most were largely restricted to its taxonomic family (Sapindaceae) or genus, but not necessarily to the species *Cardiospermum grandiflorum*. One promising seed-feeding Curculionid weevil, *Cissoanthonomus tuberculipennis*, was released in South Africa's KwaZulu Natal Province in late 2013 (Simelane *et al.* 2014). The effectiveness of this biological control agent and its host specificity under field conditions remains to be assessed.

“Neoclassical” biological control, that is, the use of natural enemies that are native to the introduced range, represents a possible management approach worthwhile to mention with regards to *C. grandiflorum*. Soapberry bugs (genera *Leptocoris*, *Jadera* and *Boisea* from the family Rhopalidae) feed exclusively on seeds of Sapindaceae and are natural seed predators of *Cardiospermum* species in both their native and non-native regions (Carroll *et al.* 2005b). Soapberry bugs co-occur with the widespread distribution of *Cardiospermum* and thus may be a factor in the genus' reproduction globally. For example, native American soapberry bugs can destroy ca. 95% of introduced balloon vine seed crops there (Carroll *et al.* 2003). A treatment of soapberry bugs that feed on *C. halicacabum* and *C. grandiflorum* can be found in Carroll and Loye (2012). In the European context such neoclassical biological might occur if insects utilising native Sapindaceae shift onto balloon vine. However, the genera *Leptocoris*, *Jadera* and *Boisea* are absent from the continent.

As the populations in the EPPO region (and the EU) are limited the implementation costs for Member States would be relatively low. The cost of inaction could significantly increase potential costs in the future as any management programme would have to take place on a larger scale and this would reduce the cost-effectiveness of any measures.

18. Uncertainty

Uncertainty should also be considered in the context of species distribution modelling (SDM). Here records for *C. grandiflorum* and synonyms were retrieved from GBIF and other online sources, and were also digitised from occurrences that were either mapped or clearly georeferenced in published sources. This may mean that the realised climatic niche of *C. grandiflorum* is under-characterised. In addition, georeferenced records used in our SDMs were usually without information on population persistence – if records within the EPPO area, or in climatically similar areas, are typically of ‘casual’ occurrences, rather than established populations, it may be that our SDMs over-emphasise the likelihood of establishment in climatically marginal habitats.

To remove spatial recording biases, the selection of the background sample was weighted by the density of Tracheophyte records on the Global Biodiversity Information Facility (GBIF). While this is preferable to not accounting for recording bias at all, a number of factors mean this may not be the perfect null model for species occurrence:

- The GBIF API query used to did not appear to give completely accurate results. For example, in a small number of cases, GBIF indicated no Tracheophyte records in grid cells in which it also yielded records of the focal species.
- We located additional data sources to GBIF, which may have been from regions without GBIF records.

Other variables potentially affecting the distribution of the species, such as soil nutrients, were not included in the model.

Level of uncertainty per sections:

Pathway for entry: Low

Likelihood of establishment: Low

Establishment in natural areas: Low

Establishment in managed areas: Low

Spread: Low

Impacts (current area): Moderate

Potential impacts in PRA area: High

19 Remarks

- ***Inform EPPO or IPPC or EU***
- The EWG recommends a PRA is conducted on the closely related species *Cardiospermum halicacabum*.

- ***Inform industry, other stakeholders***
- Ask industry to confirm if there is mislabelling between *Cardiospermum halicacabum* and *Cardiospermum grandiflorum*

- ***Specify if surveys are recommended to confirm the pest status***
- Assess the current impact of *Cardiospermum grandiflorum* in Malta and other regions where the species is considered established/invasive.
- Also specific studies on the species biology are necessary given that most of the information refers to *C. halicacabum*.
- Specific studies on the species biology are necessary.

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Appendix 1. Projection of climatic suitability for *Cardiospermum grandiflorum* establishment

Aim

To project the suitability for potential establishment of *Cardiospermum grandiflorum* in the EPPO region, under current and predicted future climatic conditions.

Data for modelling

Climate data were taken from 'Bioclim' variables contained within the WorldClim database (Hijmans *et al.*, 2005) originally at 5 arcminute resolution (0.083 x 0.083 degrees of longitude/latitude) but bilinearly interpolated to a 0.1 x 0.1 degree grid for use in the model. Based on the biology of the focal species, the following climate variables were used in the modelling:

- Mean temperature of the warmest quarter (Bio10 °C) reflecting the growing season thermal regime. The USDA APHIS risk assessment mentions 4 °C as a minimum growth temperature (USDA APHIS, 2013), so low temperatures should limit growth.
- Mean minimum temperature of the coldest month (Bio6 °C) reflecting exposure to frost. Reports suggests that *C. grandiflorum* requires coldest month temperatures above 0°C (CABI, 2015).
- Mean annual precipitation (Bio12 ln+1 transformed mm), as a measure of moisture availability. Minimum precipitation requirements of 250 mm are reported (USDA APHIS, 2013).
- Precipitation of the driest quarter (Bio17 ln + 1 transformed) as a further measure of drought stress.

To estimate the effect of climate change on the potential distribution, equivalent modelled future climate conditions for the 2070s under the Representative Concentration Pathway (RCP) 8.5 were also obtained. This assumes an increase in atmospheric CO_2 concentrations to approximately 850 ppm by the 2070s. Climate models suggest this would result in an increase in global mean temperatures of 3.7 °C by the end of the 21st century. The above variables were obtained as averages of outputs of eight Global Climate Models (BCC-CSM1-1, CCSM4, GISS-E2-R, HadGEM2-AO, IPSL-CM5A-LR, MIROC-ESM, MRI-CGCM3, NorESM1-M), downscaled and calibrated against the WorldClim baseline (see http://www.worldclim.org/cmip5_5m). RCP8.5 is the most extreme of the RCP scenarios, and may therefore represent the worst case scenario for a reasonably anticipated climate change.

In the models we also included measures of habitat availability:

- Density of permanent rivers was estimated from the Vector Map (United States National Imagery Mapping Agency, 1997). River vectors were rasterised at 0.02 x 0.02 degree resolution. Then, we calculated the proportion of these grid cells containing rivers within each of the 0.1 x 0.1 degree cells used in the model. River banks are a primary habitat of *C. grandiflorum* (USDA APHIS, 2013, CABI, 2015).
- Tree cover was estimated from the MODerate-resolution Imaging Spectroradiometer (MODIS) satellite continuous tree cover raster product, produced by the Global Land Cover Facility (http://glcf.umd.edu/data/vcf/). The raw product contains the percentage cover by trees in each 0.002083 x 0.002083 degree grid cell. We aggregated this to the mean cover in our 0.1 x 0.1 degree grid cells. *C. grandiflorum* prefers open habitat, though it may thrive in forest edges (CABI 2015).

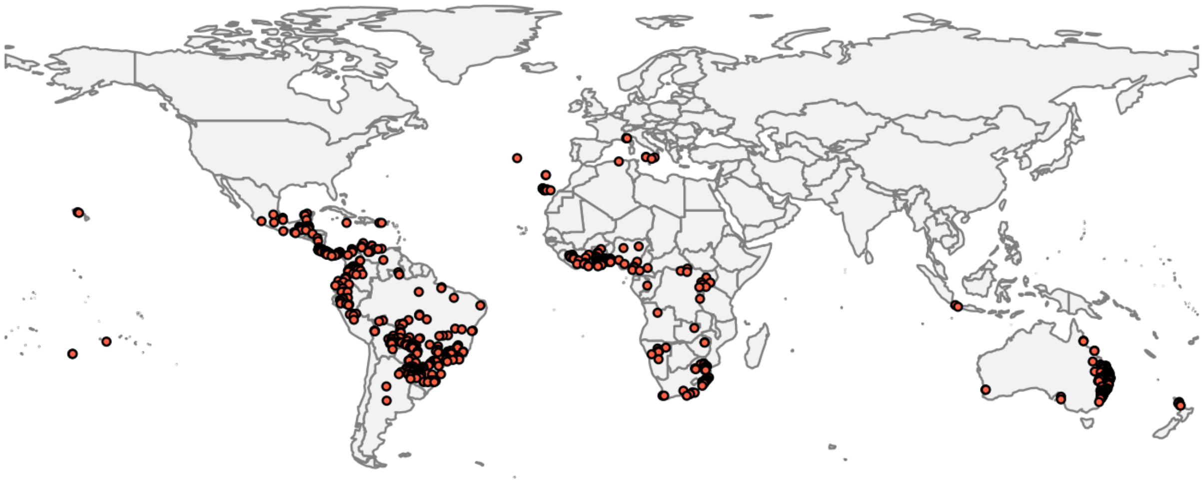
- Human influence index as *C. grandiflorum*, like many invasive species, is known to associate with anthropogenically disturbed habitats (USDA APHIS, 2013). We used the Global Human Influence Index Dataset of the Last of the Wild Project (Wildlife Conservation Society - WCS & Center for International Earth Science Information Network - CIESIN - Columbia University, 2005), which is developed from nine global data layers covering human population pressure (population density), human land use and infrastructure (built-up areas, nighttime lights, land use/land cover) and human access (coastlines, roads, railroads, navigable rivers). The index ranges between 0 and 1 and was log+1 transformed for the modelling to improve normality.

As detailed in the main text, *C. grandiflorum* may have wide edaphic tolerances. Nevertheless, we included two soil variables, derived from the GIS layers available from SoilGrids (Hengl *et al.*, 2014). Each soil property is provided at depths of 0, 5, 15, 30, 60, 100 and 200 cm as 0.002083 x 0.002083 degree rasters. These were aggregated as the mean soil property across all depths on the 0.1 x 0.1 degree raster of the model. The soil variables obtained were:

- Soil pH in water, which may affect nutrient availability to plants.
- Soil sand percentage, which affects soil drainage.

Species occurrences were obtained from the Global Biodiversity Information Facility (www.gbif.org), supplemented with data from the literature and the Expert Working Group. Occurrence records with insufficient spatial precision, potential errors or that were outside of the coverage of the predictor layers (e.g. small island or coastal occurrences) were excluded. The remaining records were gridded at a 0.1 x 0.1 degree resolution (Figure 1).
In total, there were 707 grid cells with recorded occurrence of *C. grandiflorum* available for the modelling (Figure 1).

Figure 1. Occurrence records obtained for *Cardiospermum grandiflorum* used in the model, after exclusion of casual and thermally-anomalous records.



Species distribution model
A presence-background (presence-only) ensemble modelling strategy was employed using the BIOMOD2 R package v3.3-7 (Thuiller *et al.*, 2014, Thuiller *et al.*, 2009). These models contrast the environment at the species' occurrence locations against a random sample of the global background environmental conditions (often termed 'pseudo-absences') in order to

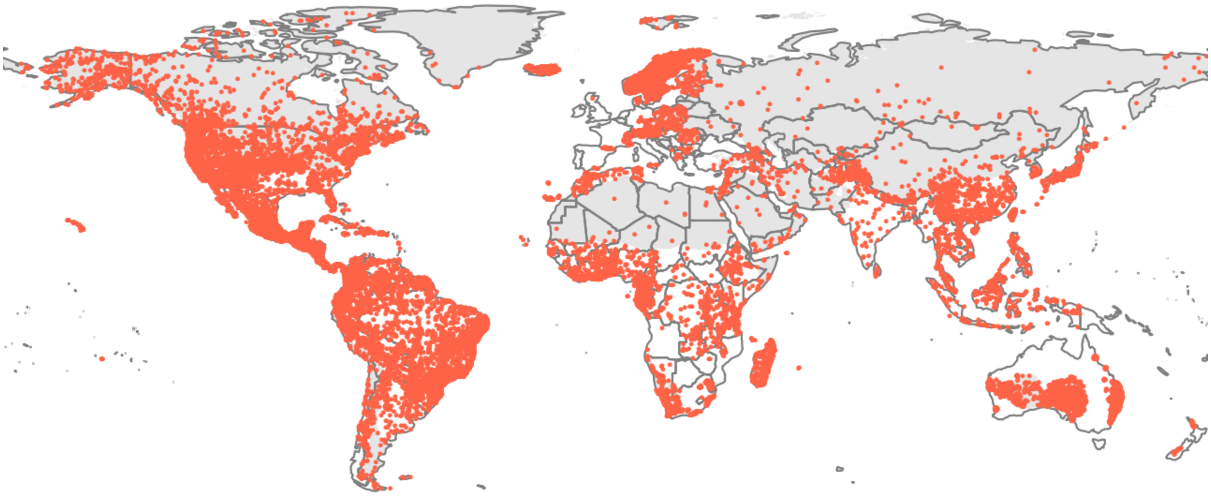
characterise and project suitability for occurrence. This approach has been developed for distributions that are in equilibrium with the environment. Because invasive species' distributions are not at equilibrium and subject to dispersal constraints at a global scale, we took care to minimise the inclusion of locations suitable for the species but where it has not been able to disperse to. Therefore the background sampling region included:

- The native continents of *C. grandiflorum*, in which the species is likely to have had sufficient time to cross all biogeographical barriers. For the model we assumed the native range to be South and north America, Asia and Africa, but excluding South Africa, Namibia, Angola, Zimbabwe, Mozambique, Botswana, Swaziland and Lesotho; AND
- A relatively small 50 km buffer around all non-native occurrences, encompassing regions likely to have had a high propagule pressure for introduction by humans and/or dispersal of the species; AND
- Regions where we have an *a priori* expectation of high unsuitability for the species (see Fig. 2). Absence from these regions is considered to be irrespective of dispersal constraints. The following rules were applied to define the region expected to be highly unsuitable for *C. grandiflorum*:
    - Mean minimum temperature of the coldest month (Bio6) < -5 °C. There is little information on frost tolerance of *C. grandiflorum*, but the coldest location with a presence in our dataset has Bio6 = 1.1 °C. The USDA APHIS risk assessment suggests *C. grandiflorum* can tolerate USDA plant hardiness zone 9, with the average most extreme minimum temperature no lower than -6.7 °C (USDA APHIS, 2013).
    - Annual precipitation (Bio12) < 250 mm. There is little information on precipitation requirements, but the APHIS risk assessment suggests a minimum requirement of approximately 250 mm (USDA APHIS, 2013). In our data, two occurrences were in drier locations (one in the Canary Islands and one in Namibia). It is possible that they are associated with wet microhabitats such as riverbanks.

Within this sampling region there was a substantial spatial biases in recording effort, which may interfere with the characterisation of habitat suitability. Specifically, areas with a large amount of recording effort will appear more suitable than those without much recording, regardless of the underlying suitability for occurrence. Therefore, a measure of vascular plant recording effort was made by querying the Global Biodiversity Information Facility application programming interface (API) for the number of phylum Tracheophyta records in each 0.1 x 0.1 degree grid cell. The sampling of background grid cells was then weighted in proportion to the Tracheophyte recording density. Assuming Tracheophyte recording density is proportional to recording effort for the focal species, this is an appropriate null model for the species' occurrence.

To sample as much of the background environment as possible, without overloading the models with too many pseudo-absences, five background samples of 10,000 randomly chosen grid cells were obtained (Figure 2).

Figure 2. Randomly selected background grid cells used in the modelling of *Cardiospermum grandiflorum*, mapped as red points. Points are sampled from the native continents, a small buffer around non-native occurrences and from areas expected to be highly unsuitable for the species (grey background region), and weighted by a proxy for plant recording effort.



Each dataset (i.e. combination of the presences and the individual background samples) was randomly split into 80% for model training and 20% for model evaluation. With each training dataset, ten statistical algorithms were fitted with the default BIOMOD2 settings, except where specified below:

- Generalised linear model (GLM)
- Generalised boosting model (GBM)
- Generalised additive model (GAM) with a maximum of four degrees of freedom per smoothing spline.
- Classification tree algorithm (CTA)
- Artificial neural network (ANN)
- Flexible discriminant analysis (FDA)
- Multivariate adaptive regression splines (MARS)
- Random forest (RF)
- MaxEnt
- Maximum entropy multinomial logistic regression (MEMLR)

Since the background sample was much larger than the number of occurrences, prevalence fitting weights were applied to give equal overall importance to the occurrences and the background. Variables importance was assessed and variable response functions were produced using BIOMOD2's default procedure. Model predictive performance was assessed by calculating the Area Under the Receiver-Operator Curve (AUC) for model predictions on the evaluation data, that were reserved from model fitting. AUC can be interpreted as the probability that a randomly selected presence has a higher model-predicted suitability than a randomly selected absence. This information was used to combine the predictions of the different algorithms to produce ensemble projections of the model. For this, the three algorithms with the lowest AUC were first rejected and then predictions of the remaining seven algorithms were averaged, weighted by their AUC. Ensemble projections were made for each dataset and then averaged to give an overall suitability.

Results
The ensemble model had a better predictive ability (AUC) than any individual algorithm and suggested that suitability for *C. grandiflorum* was most strongly determined by the minimum temperature of the coldest month, mean temperature of the warmest quarter, soil pH, annual precipitation and precipitation of the driest quarter (Table 1). From Fig. 3, the ensemble model estimated the optimum conditions for occurrence at approximately:

- Minimum temperature of the coldest month > 9.2 °C (>50% suitability with > 2.9 °C)
- Mean temperature of the warmest quarter = 24.3 °C (>50% suitability from 19.5 to 30.0 °C)
- Soil pH = 6.0 (>50% suitability from 4.9 to 8.1)
- Annual precipitation = 1364 mm (>50% suitability from 315 to 3728 mm)
- Precipitation of the driest quarter = 414 mm

These optima and ranges of high suitability described above are conditional on the other predictors being at their median value in the data used in model fitting.

The model also characterised slight preferences for low tree cover, high human influence, and non-sandy soils (Table 1, Fig. 3). However, river density had a very low contribution to the model fit.

There was substantial variation among modelling algorithms in the partial response plots (Fig. 3). In part this will reflect their different treatment of interactions among variables. Since partial plots are made with other variables held at their median, there may be values of a particular variable at which this does not provide a realistic combination of variables to predict from. It also demonstrates the value of an ensemble modelling approach in averaging out the uncertainty between algorithms.

Global projection of the model in current climatic conditions (Fig. 4) indicates that the native and known invaded records generally fell within regions predicted to have a high suitability. Major regions without records of the species, but that are projected as suitable include Carribbean islands, south east USA, and southeast Asia. Tropical Asia is considered as part of the native range of the species, while absence from the USA may be because the species is not commonly available for purchase there (USDA APHIS, 2013).

In Europe and the Mediterranean region the model predicts that, in the current climate, there may be areas moderately suitable for establishment of the species around the Atlantic coastline from southwest France southwards and around much of the northern Mediterranean coastline up to Israel. Some of the northern African coastline of Morocco, Algeria and Tunisia also appear marginally suitable for the species. Inland regions predicted with marginal suitability are found throughout southwest Iberia and in Sardinia.

By the 2070s, under climate change scenario RCP8.5, projected suitability for *C. grandiflorum* increases, most notably in Italy and northwards into the Atlantic Biogeographic

Region as far north as The Netherlands and southern Britain (Fig. 6). Presumably this is driven by increases in summer and winter temperatures. There is little increase in suitability around the Mediterranean coastlines, which may be because of reduced predicted precipitation.

Table 1. Summary of the cross-validation predictive performance (AUC) and variable importance of the fitted model algorithms and the ensemble (AUC-weighted average of the best performing seven algorithms). Results are the average from models fitted to five different background samples of the data.

Algorithm	**Predictive AUC**	**Variable importance**								
		Minimum temperature of coldest month	**Mean temperature of warmest quarter**	**Annual precipitation**	**Precipitation of driest quarter**	**Human influence index**	**River density**	**Tree cover**	**Soil pH**	**Soil sand content**
GBM	0.8932	63.2%	20.5%	3.5%	4.5%	0.6%	0.0%	7.0%	0.4%	0.3%
ANN	0.8906	42.3%	20.6%	9.1%	8.6%	3.5%	0.3%	9.1%	3.4%	3.1%
RF	0.8818	34.5%	13.7%	10.6%	13.3%	4.0%	0.6%	9.6%	4.3%	9.3%
MaxEnt	0.8800	37.2%	21.4%	9.0%	8.3%	0.5%	0.1%	12.8%	1.9%	8.8%
GAM	0.8784	62.7%	21.3%	3.4%	4.5%	0.3%	0.0%	5.9%	0.4%	1.4%
MARS	0.8702	69.3%	12.9%	4.1%	5.1%	0.0%	0.0%	7.6%	0.4%	0.6%
GLM	0.8642	54.1%	27.7%	5.4%	4.9%	0.5%	0.1%	5.3%	0.2%	1.7%
FDA	0.8616	45.8%	15.0%	6.3%	13.6%	0.0%	0.0%	11.3%	3.2%	4.9%
CTA	0.8502	47.4%	17.0%	11.4%	6.6%	0.8%	0.0%	13.4%	2.3%	0.9%
MEMLR	0.8074	39.3%	9.4%	10.0%	14.5%	8.5%	0.7%	7.0%	0.6%	9.9%
Ensemble	0.8924	51.9%	19.7%	6.5%	7.1%	1.3%	0.2%	8.2%	1.6%	3.6%

Figure 3. Partial response plots from the fitted models, ordered from most to least important. Thin coloured lines show responses from the seven algorithms, while the thick black line is their ensemble. In each plot, other model variables are held at their median value in the training data. Some of the divergence among algorithms is because of their different treatment of interactions among variables.

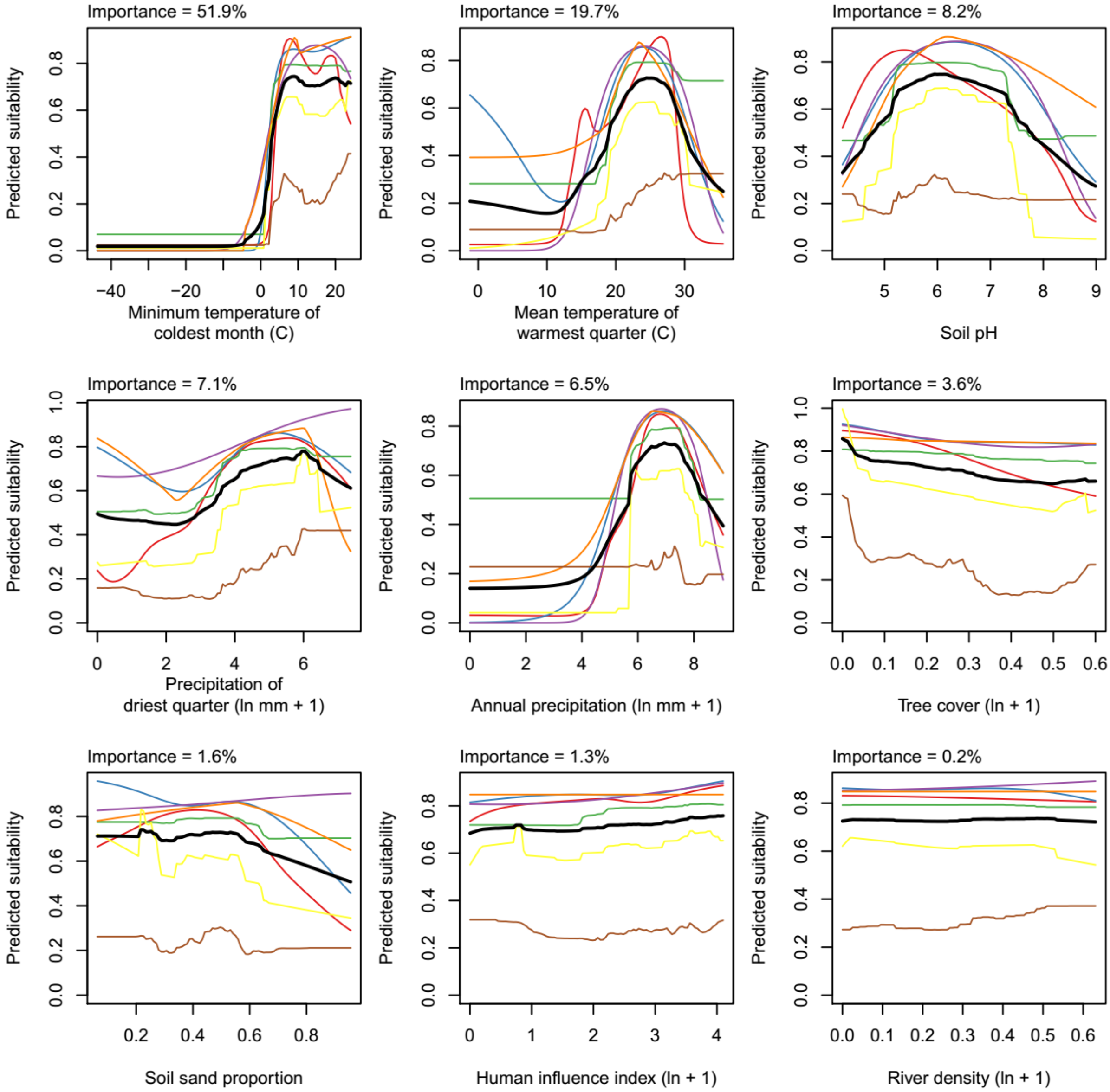


Figure 4. Projected global suitability for *Cardiospermum grandiflorum* establishment in the current climate. For visualisation, the projection has been aggregated to a 0.5 x 0.5 degree resolution, by taking the maximum suitability of constituent higher resolution grid cells. Values > 0.5 may be suitable for the species. The white areas have climatic conditions outside the range of the training data so were excluded from the projection.

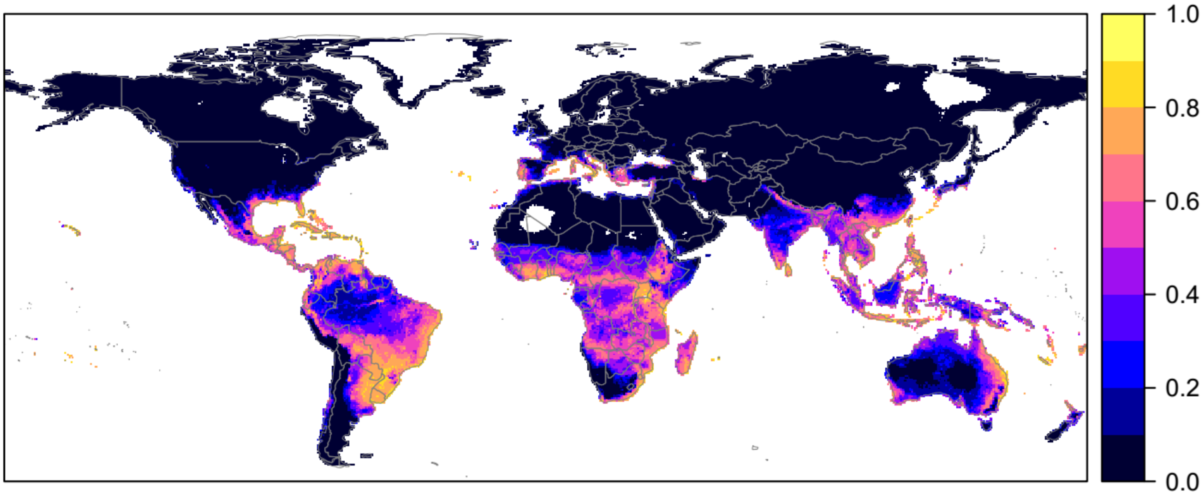


Figure 5. Projected current suitability for *Cardiospermum grandiflorum* establishment in Europe and the Mediterranean region. For visualisation, the projected suitability has been smoothed with a Gaussian filter with standard deviation of 0.1 degrees longitude/latitude. The white areas have climatic conditions outside the range of the training data so were excluded from the projection.

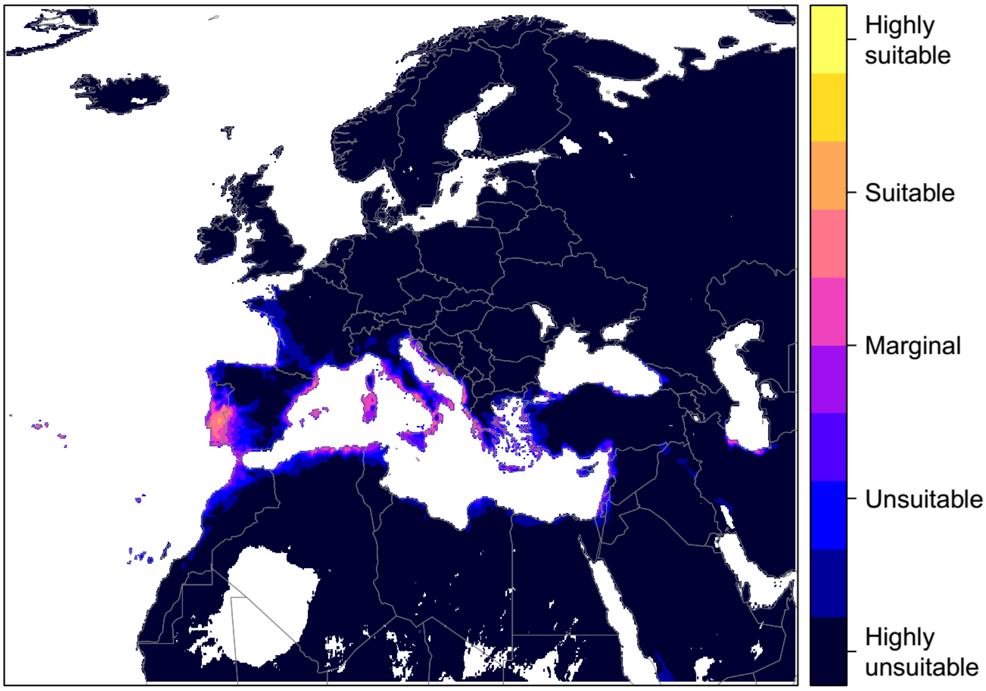
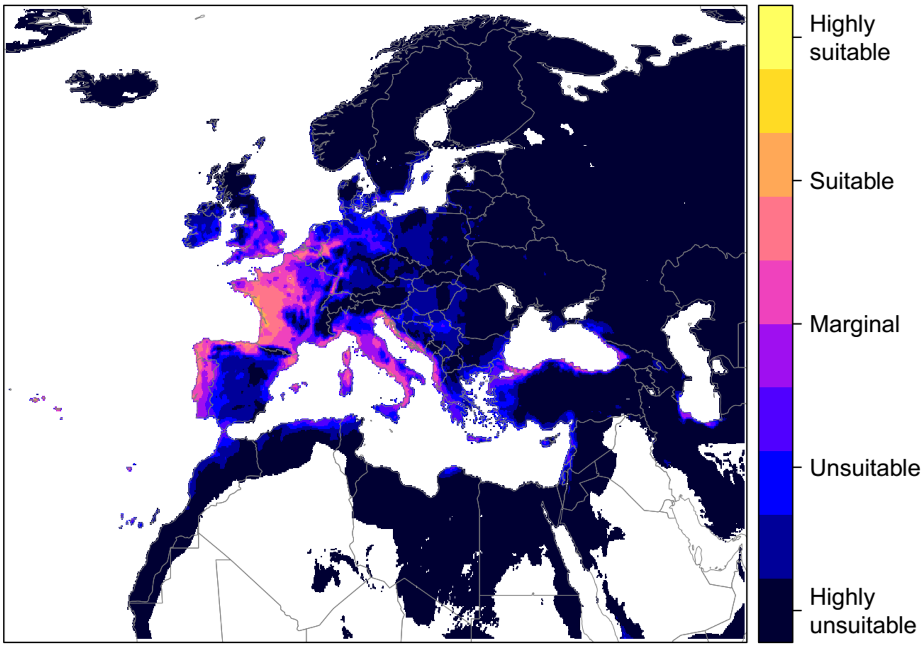


Figure 6. Projected suitability for *Cardiospermum grandiflorum* establishment in Europe and the Mediterranean region in the 2070s under climate change scenario RCP8.5, equivalent to Fig. 5.



Caveats to the modelling

To remove spatial recording biases, the selection of the background sample was weighted by the density of Tracheophyte records on the Global Biodiversity Information Facility (GBIF). While this is preferable to not accounting for recording bias at all, a number of factors mean this may not be the perfect null model for species occurrence:

- The GBIF API query used to did not appear to give completely accurate results. For example, in a small number of cases, GBIF indicated no Tracheophyte records in grid cells in which it also yielded records of the focal species.
- We located additional data sources to GBIF, which may have been from regions without GBIF records.

Other variables potentially affecting the distribution of the species, such as soil nutrients, were not included in the model.

The climate change scenario used is the most extreme of the four RCPs. However, it is also the most consistent with recent emissions trends and could be seen as worst case scenario for informing risk assessment.

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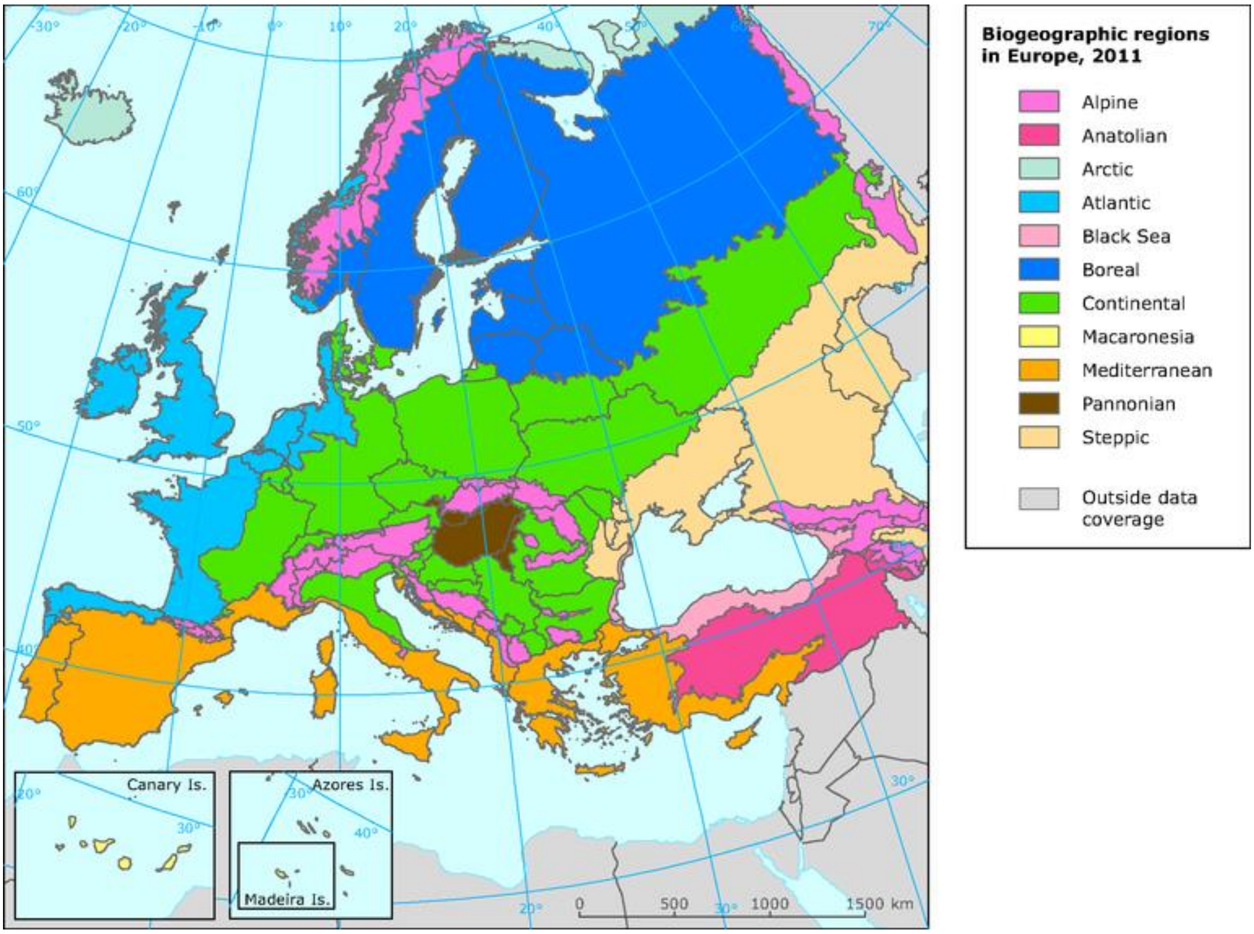
Appendix 2 Biogeographical regions in Europe



Appendix 3. Relevant illustrative pictures (for information)

Figure 1. *Cardiospermum grandiflorum* growing up supporting vegetation.

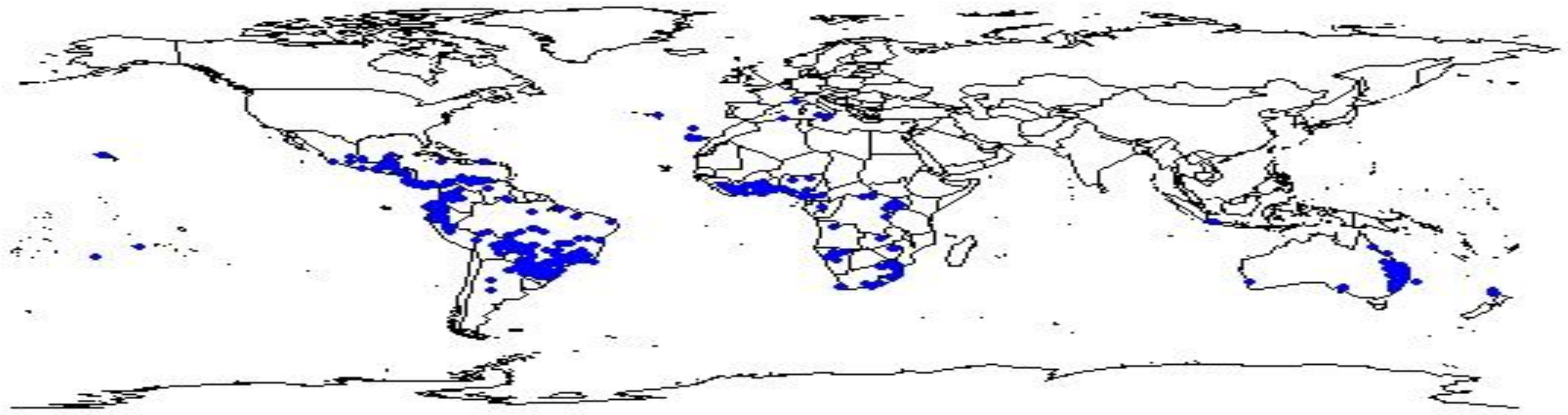
Figure 2. *Cardiospermum grandiflorum* flowers

Figure 3. *Cardiospermum grandiflorum* smothering native vegetation in South Africa

Figure 4. *Cardiospermum grandiflorum* growing along riparian habitat

Appendix 4. Distribution maps of *Cardiospermum grandiflorum*[4]

Figure 1. Global distribution (from GBIF)



[4] Note that these maps may contain records, e.g. herbarium records, that were not considered during the climate modelling stage

Figure 2. Distribution maps of *Cardiospermum grandiflorum* in Africa (from GBIF)

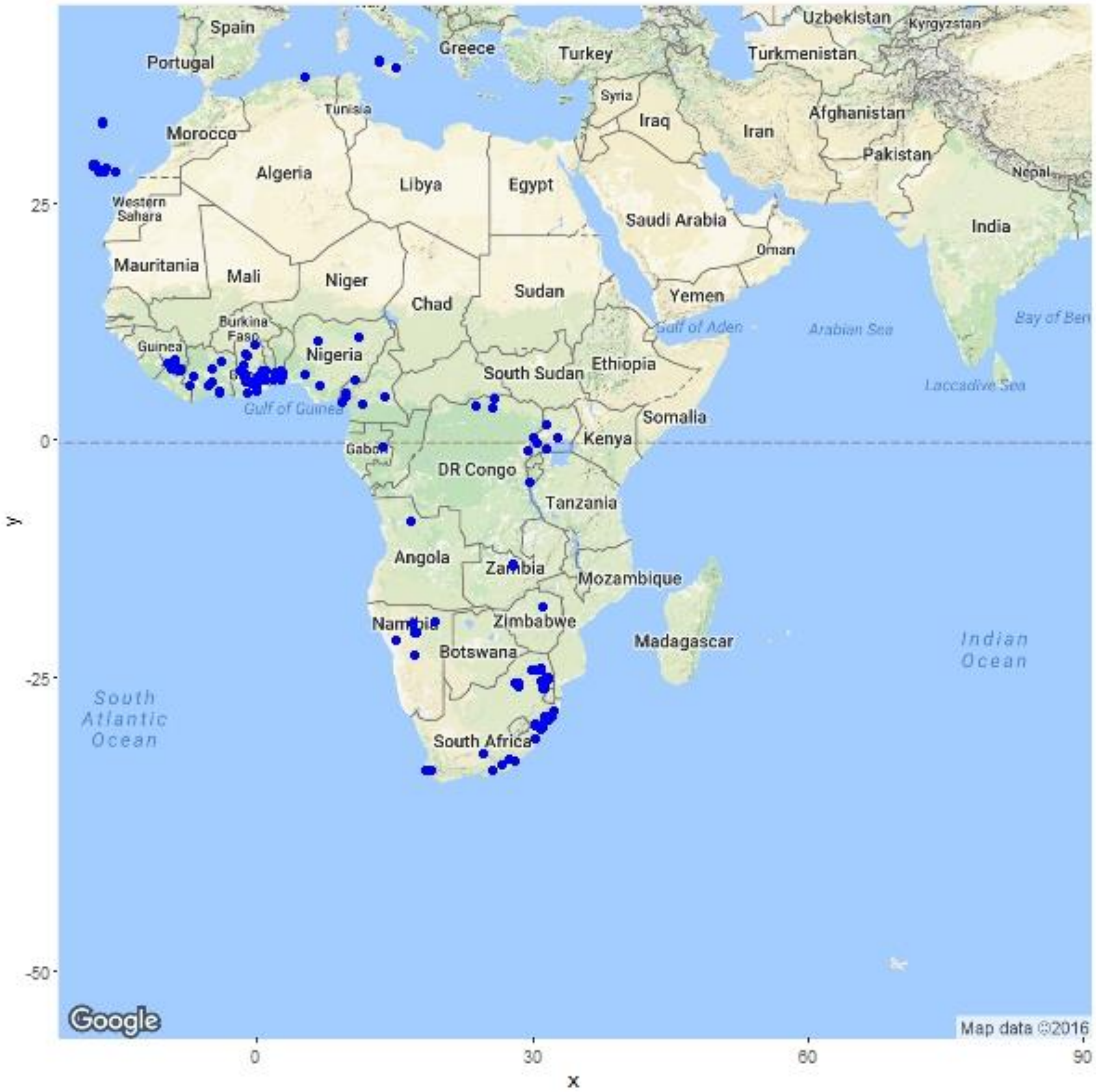


Figure 3. Distribution maps of *Cardiospermum grandiflorum* in Oceania (from GBIF)

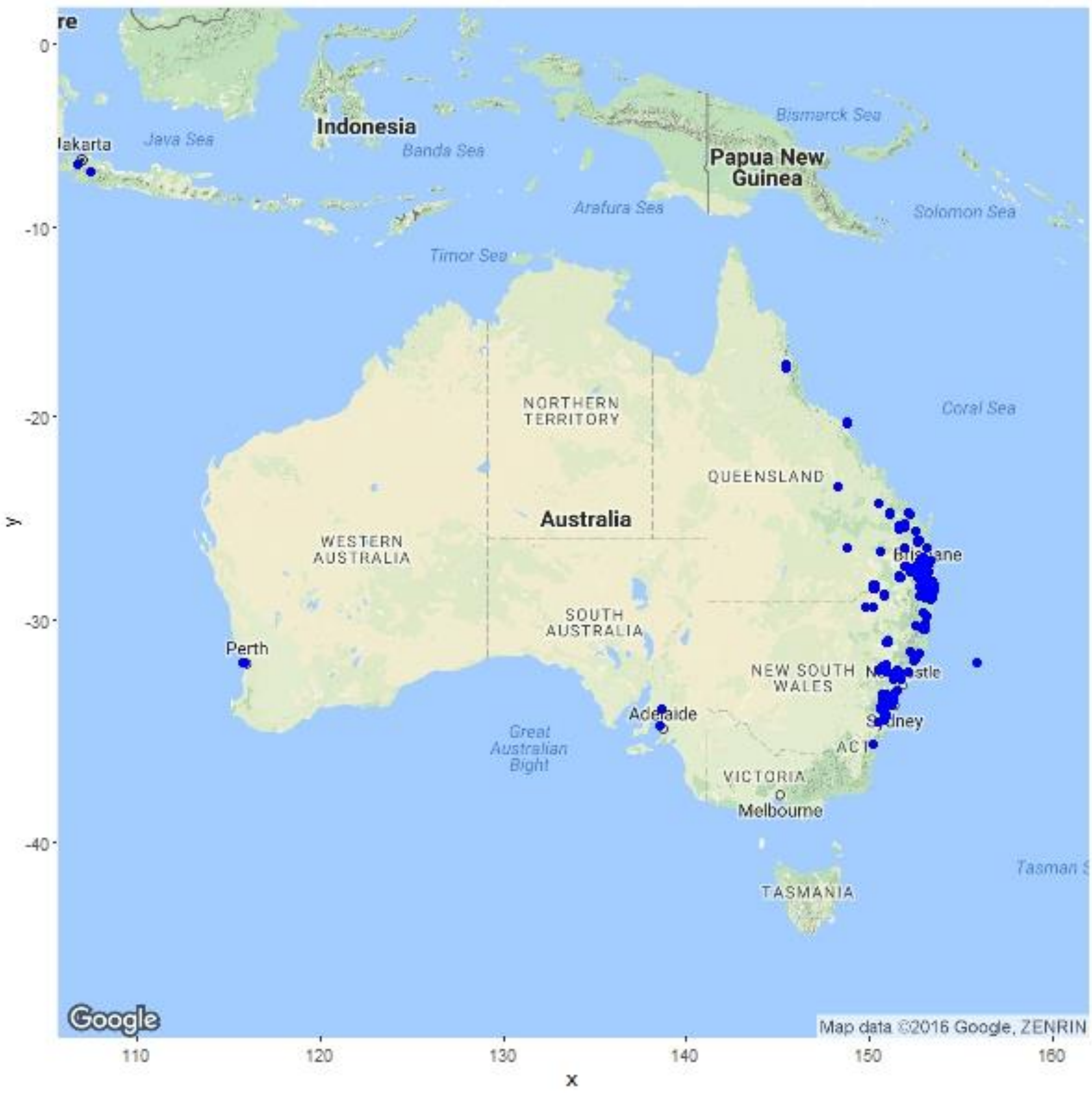


Figure 4. Distribution maps of *Cardiospermum grandiflorum* in South America (from GBIF)

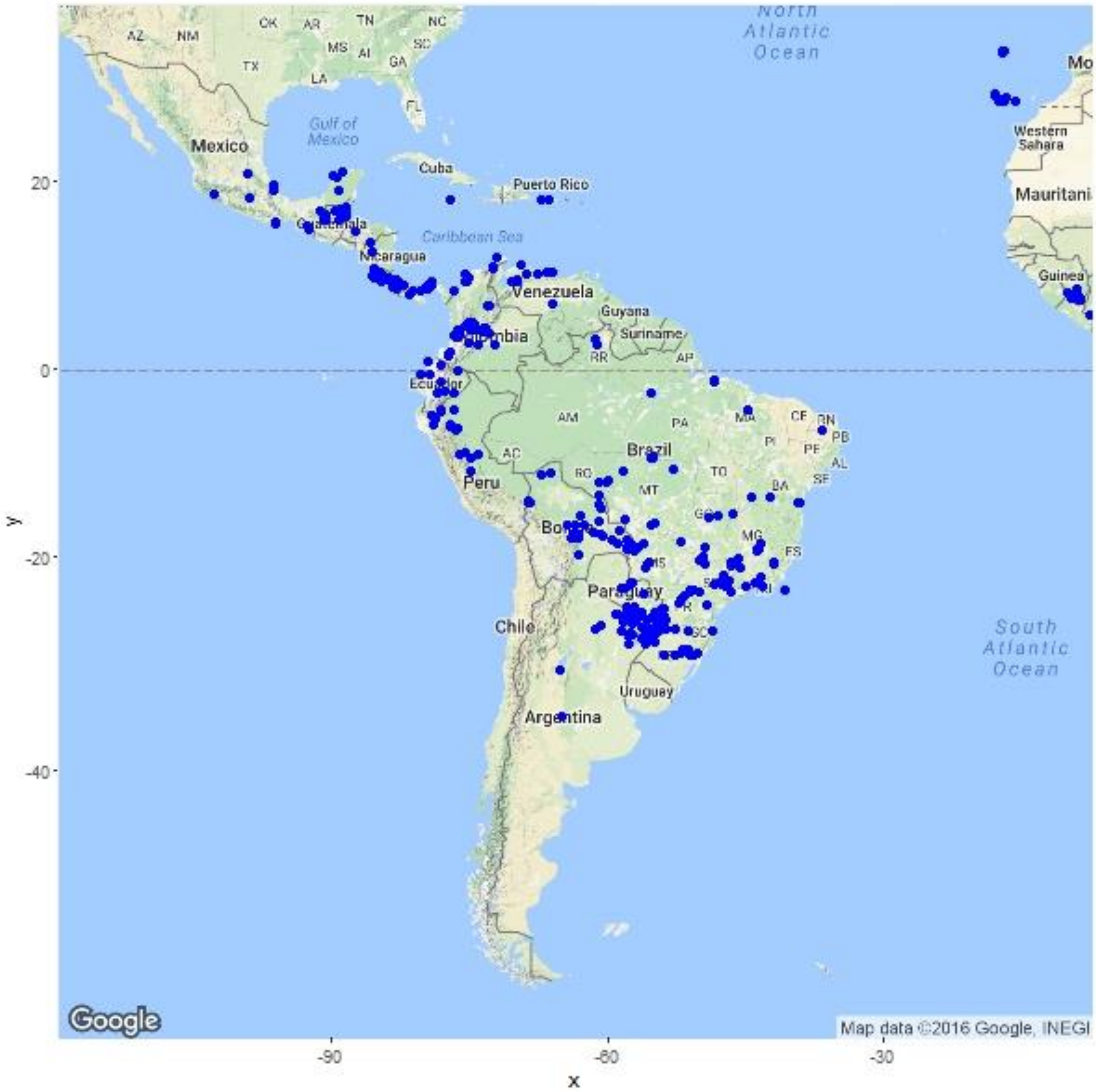


Figure 5. Distribution maps of *Cardiospermum grandiflorum* in Europe (from GBIF)

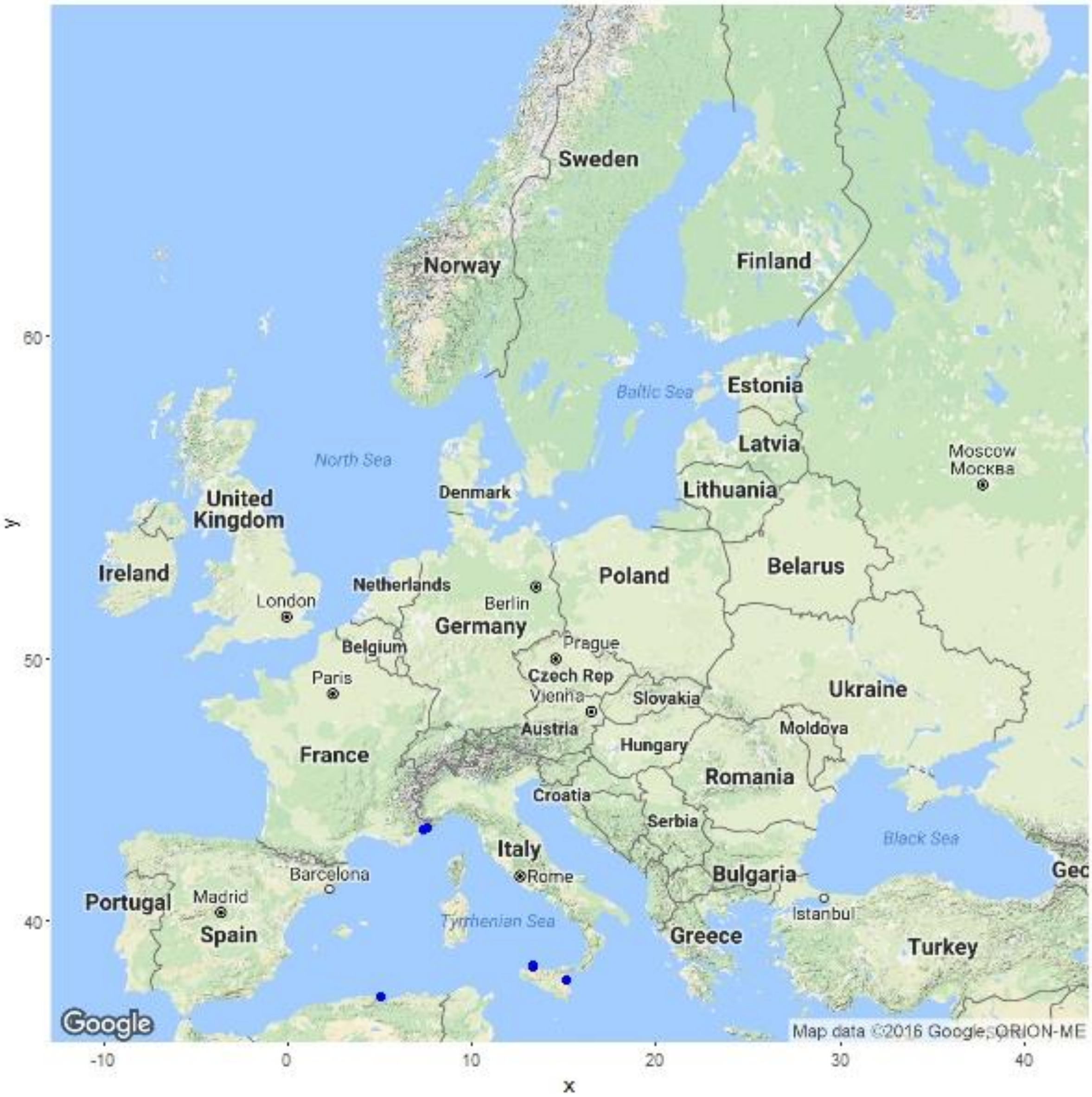


Figure 6. Distribution maps of *Cardiospermum grandiflorum* in Asia (from GBIF)