Cardiospermum grandiflorum. © *Ewen Cameron. CC BY 4.0.*

The management of balloon vine (*Cardiospermum grandiflorum*)

Measures and associated costs

Species (scientific name)	*Cardiospermum grandiflorum* Sw., Prodr. Veg. Ind. Occ. 64 (1788)
Species (common name)	Balloon vine
Author(s)	Nicola Schoenenberger (Innovabridge Foundation, Switzerland)
Date Completed	06/11/2017
Reviewer	Giuseppe Brundu (Department of Agriculture, University of Sassari, Italy)
Reference	Schoenenberger, N. 2017. Information on measures and related costs in relation to species considered for inclusion on the Union list: *Cardiospermum grandiflorum*. Technical note prepared by IUCN for the European Commission.

Table of contents

Common names

BG	–
HR	Velika korinda
CZ	Srdcovnice
DA	Storblomstret hjerteranke
NL	Ballonrank
EN	Balloon vine
ET	Suureõieline südaseemnik
FI	Ilmapallоköynnös
FR	Corinde à grandes fleurs
DE	Ballonwein
EL	–
HU	–
IE	Féithleog bhalúnach
IT	Cardiospermo a fiori grandi
LV	–
LT	Stambiažiedis širdvis
MT	L-isfineġ is-sufi
PL	–
PT	Corriola-de-balões
RO	–
SK	Balónovec veľkokvetý
SL	Velika korinda
ES	Farolillo trepador
SV	Stor ballongranka

Summary of the measures, emphasizing the most cost-effective options.

Cardiospermum grandiflorum Sw. (Sapindaceae) is an herbaceous, perennial, seed propagated climber plant (vine). The species also spreads vegetatively by suckering and root fragments (Pasiecznik, 2014). Its wide Neotropical native range spreads from southern Mexico to the Caribbean (type specimen from Jamaica) and Brazil (Carrol *et al.*, 2005). It's nativeness to tropical Africa has been questioned and remains to be confirmed (Gildenhuys *et al.*, 2013; EPPO, 2016). The species is invasive in South Africa, Australia, Cook Islands, Fiji, French Polynesia, New Zealand and Malta; it is introduced to Sri Lanka, naturalized in the USA and its casual presence has been recorded in France (Landes and Alpes-Maritimes) and Italy (Sicily); non-native records exist for the Canary Islands (Spain) and Madeira (Portugal), with unknown invasion status (EPPO, 2016).

C. grandiflorum is invasive in riparian habitats, along forest margins, and is also found in rocky habitats, disturbed sites such as urban areas, transport infrastructure and agricultural fields (EPPO, 2017). *C. grandiflorum* performs best in subtropical climates with mean annual temperature between 15 °C and 25 °C (Pasiecznik, 2014), the only extensive invasion reported in a Mediterranean climate refers to Malta (Ameen, 2013).

C. grandiflorum is principally introduced through ornamental trade (Henderson, 2001; Pasiecznik, 2014), although it is infrequently listed in online nursery catalogues. Moreover, its seed-carrying inflated capsules can float for extensive periods in watercourses (for example, along rivers and across the sea) and thus can cover substantial distances over short time scales (Gildenhuys, 2015a). A trade ban, combined with awareness campaigns aimed *inter alia* at collectors exchanging seeds non-commercially (such as botanical gardens), early detection and rapid eradication measures, would prevent spread and negative impacts in balloon vine-free areas.

Mechanical, often combined with chemical control has proven to be efficient to eradicate *C. grandiflorum*, especially at initial stages of the infestation (BRAIN, 1997; Biosecurity Queensland, 2013; PIER, 2013; Weedbusters, 2017), also considering its relatively short lived seed bank. Biological control by the seed-feeding weevil *Cissoanthonomus tuberculipennis* is being implemented in South Africa since 2013, and first results indicate efficient establishment and spread of the agent and a significant decrease in seed production by *C. grandiflorum*.

Measures for preventing the species being introduced, intentionally and unintentionally.

This section assumes that the species is not currently present in a Member State, or part of a Member State's territory.

A ban on importing (pre-border measure), selling, breeding, growing, and cultivation, as required under Article 7 of the IAS Regulation, targeting intentional introduction of plants and propagules of *C. grandiflorum*.

MEASURE DESCRIPTION

Ornamental trade is the main pathway of introduction of *C. grandiflorum* around the world (Henderson, 2001; Pasiecznik, 2014). Avoidance of new introductions or further spread through the promulgation of trade bans is thus considered the most efficient and cost-effective prevention measure. In online nursery catalogues**,** *C. grandiflorum* is relatively infrequently listed, whereas the congeneric *C. halicacabum* is more readily available.

In South Africa and the Australian states of New South Wales and Queensland, *C. grandiflorum* is currently listed as a noxious weed, and in New Zealand as an 'Unwanted Organism' under state legislation. Listing implies the obligation to contain or control populations according to specified management plans issued by the authorities (Australia), the execution of a government sponsored management programme (South Africa), or the possible eradication following extensive management efforts. Moreover, regulation prohibits ownership, import, sale, propagation, distribution and dumping into the environment (EPPO, 2016).

Risk assessments classifying *C. grandiflorum* as a 'High Risk' species have been conducted for the USA (USDA, 2013), and for Hawaii and other Pacific Islands (PIER, 2013). In the EPPO region, the likelihood of establishment and the potential impact were assessed as being moderate, with a moderate to high uncertainty. However, it was added to the EPPO Alert List in 2012 and transferred to the List of Invasive Alien Plants in 2013. In the framework of the LIFE project IAP-RISK, EPPO has prepared a full PRA (Pest Risk Analysis) and scored *C. grandiflorum* as a 'High Risk' species under future climatic scenarios and therefore recommended it for regulation as a quarantine pest (EPPO, 2016).

EFFECTIVENESS OF MEASURE

The promulgation of trade bans and listings generally occurred decades after introduction and invasion, limiting the effectiveness of the measure. In Australia, first records of *C. grandiflorum* date back to 1923 (Carroll *et al.*, 2005a) but regulation was put into force in 1999 (Environment Protection and Biodiversity Conservation Act). In South Africa, the species was introduced around 100 years ago (Simelane *et al.*, 2011) and became listed in 1982 (under Conservation of Agricultural Resources (CARA) Act 43), long after its rapid spread to several of the country's provinces (Henderson, 2001; Simelane *et al.*, 2011). In New Zealand, it was listed in 1999 under the country's Biosecurity Act, and following extensive management efforts, is now rare or even possibly eradicated from the country (EPPO, 2016). This was also possible thanks to public awareness and educational campaigns (http://www.weedbusters.org.nz).

If trade bans are introduced *a priori*, such as before invasive spread of the species, they can be expected to be effective measures against invasion. However, given the species' desirable characteristics as an ornamental, it could be likely moved around non-commercially. Therefore, the potential for further human-assisted spread cannot be ruled out (EPPO, 2016). If the measure is not implemented by all European countries (for example, only in countries most prone to invasion), it may not be effective since the species could be moved from one country to another, either intentionally or unintentionally.

EFFORT REQUIRED

To be effective, trade bans must be enforced indefinitely. This is particularly true for European countries where the species' potential range is expected to expand significantly under future climate change scenarios (EPPO, 2016). Moreover, accompanying measures to avoid intentional release into the wild or export prohibition (for example, if a trade ban is implemented only in a subset of European countries), may have to be put in place to render trade bans efficient.

RESOURCES REQUIRED

Evaluations of the costs associated with the implementation of trading bans of *C. grandiflorum* are not available.

However, it is generally recognised that prevention is better than cure, with eradication of introduced species typically becoming less feasible as spread progresses (for example, Thuiller *et al.*, 2005).

In countries effectively enforcing the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), with roughly 5,000 species of animals and 29,000 species of plants whose international trade is regulated (CITES, 2017), the implementation, at least in respect of border controls, relative to one quite easily identifiable additional species may cause no or very little additional cost. However, guidance tools for proper identifications of the traded commodity are required.

SIDE EFFECTS

The promulgation of a trading ban would generally increase the awareness of the risks associated with invasive alien plants and the control measures in place to hinder their introduction.

ACCEPTABILITY TO STAKEHOLDERS

The economic impact on the ornamental plant industry is considered low, as only small volumes of the species are traded.

An online search (03.11.2017) 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.
- Germany: one botanical garden (University Duisburg Essen, Germany, Index Seminum 2016) offering *C. grandiflorum* seeds from natural habitats non-commercially and two websites selling *C. grandiflorum* seeds commercially (http://www.sunshine-seeds.de/Cardiospermum-grandiflorum-45722p.html / https://www.exot-nutz-zier.de/Samenliste/Samen_Ranker_Kletterpflanzen_C/Cardiospermum_grandiflorum/ProductDetails8848.aspx?Category=1andSubCategory=67andProductDetailsTemplate=).

Nursery professionals are generally highly aware of invasive plants, accept responsibility for horticultural introductions and are willing to engage in preventive measures both in terms of voluntary codes of conduct (Burt *et al.*, 2007) and mandatory trade regulations (Humair *et al.*, 2014). On the other hand, in some countries, such as France, there is an increasing movement of collectors and garden lovers that decry the "unjustified fear" that leads to the interdiction of selling and cultivating invasive alien ornamental plants (Clément and Lapouge-Déjean, 2014).

ADDITIONAL COST INFORMATION

The exact costs of a trading ban for the Member States are unknown. It is widely accepted that prevention is highly cost effective, being much cheaper than early detection, rapid eradication or management measures (cost of inaction). Nurseries and seed producers will suffer only very moderate economic losses as *C. grandiflorum* is only very limitedly traded, and a substitutive species looking very similar (*C. halicacabum*) is already in trade.

LEVEL OF CONFIDENCE[1]

High.

Information comes from published material, or current practices based on expert experience applied in third countries with similar environmental, economic and social conditions. Moreover, a thorough PRA was recently performed for the EPPO region (which includes the EU).

Note however that collectors may continue exchanging seeds non-commercially and extreme (inter-continental) long-distance dispersal may occasionally occur.

Awareness campaigns.

MEASURE DESCRIPTION

Awareness campaigns may be set up to prevent mislabelling, dumping of garden waste, carrying around of *C. grandiflorum* curious seeds in countries at high risk, and to avoid soil movements from infested sites.

Unintentional introductions may occur through extreme long-distance dispersal (intercontinental) which is possible also naturally, thanks to its inflated fruits that remain buoyant over long periods of time (Gildenhuys *et al.*, 2015a; Carthey *et al.*, 2016; see also the *Early Detection*

1 See Appendix

section below); as a consequence of mislabelling of nursery material, such as in online nursery catalogues, confusion between *Cardiospermum* spp. occurs as traded *C. halicacabum* is frequently mislabelled as *C. grandiflorum* (presumably because of its more evocative specific epithet); dumping of garden waste (in South Africa *C. grandiflorum* is commonly observed in disturbed habitats such as abandoned agricultural fields, urban environments, and areas outside domestic gardens; EPPO, 2016); or through moving of contaminated soil by earthmoving equipment, cars etc. (Port Macquarie Landcare group, 2012).

EFFECTIVENESS OF MEASURE

It is difficult to assess the effectiveness of awareness campaigns against unintended introductions. Moreover, the identification of *C. grandiflorum* may be difficult when it is traded as seed, and misidentifications or mislabelling specially with *C. halicacabum* may occur. However, at generic level, the traded specimens are readily identifiable, being it in the form of seeds/fruits or of live plants (Cullen *et al.*, 2011).

EFFORT REQUIRED

To be successful, awareness campaigns need to be repeated over time, and additional information readily provided upon request by the public, such as identification tools, indications for correct transport and disposal, lists of composting plants and incinerators that accept invasive alien species, including eventual fees. Campaigns may have to be directed to specific stakeholder groups such as the garden industry or the construction industry (in areas where construction land is infested a cadastre of seed-contaminated soil, to be consulted prior to soil excavations may be implemented).

RESOURCES REQUIRED

No information available.

SIDE EFFECTS

General increase of the awareness of the risks associated with invasive alien plants, and the possible actions that can be taken.

ACCEPTABILITY TO STAKEHOLDERS

In general awareness campaigns are received positively.

ADDITIONAL COST INFORMATION

The exact costs are unknown.

LEVEL OF CONFIDENCE[1]

Medium.

Due to the difficulty to assess the effectiveness of awareness campaigns against unintended introductions.

1 See Appendix

Measures for early detection of the species and to run an effective surveillance system to detect efficiently new occurrences.

Monitoring of sentinel sites.

MEASURE DESCRIPTION

Early Detection and Rapid Eradication (EDRE) is key to prevent ecological harm and excessive management costs of new infestations (Davis, 2009). An Early Detection system for the species should involve both the active monitoring of sentinel (high risk) sites by experts (discussed in this section), alongside the citizen science (discussed in the following *Early Detection* sections).

Monitoring of sentinel sites involves active surveillance in areas where there is a high risk the species may invade such as forest margins, along watercourses, and in disturbed urban open areas in subtropical climates (Carroll, 2005a; Gildenhuys *et al.*, 2013). In Europe, due to its scare presence, such surveillance may concentrate on areas suitable for establishment at present or under future climatic scenarios (EPPO, 2016), and particularly in the vicinity of already established populations (Malta, Sicily and southern France), of parks and botanical gardens, composting facilities where garden waste is processed, landfill sites of excavated soil and along the maritime coast lines (extreme long-distance dispersal). Modelling approaches to identify invasion hot spots may be a prerequisite (Ibáñez *et al.*, 2009).

This measure can be supported by remote sensing. Woody climber species can be mapped by hyperspectral remote sensing and digital image processing techniques (Cheng *et al.*, 2007). However, no data is available for *Cardiospermum* spp.

This vine is densely growing and can climb up to 8 m high in the canopy. © Tatters. CC BY-SA 2.0.

EFFECTIVENESS OF THE MEASURE

The effectiveness of monitoring sentinel sites as an early detection measure has the potential to be high.

Although the introduction of *C. grandiflorum* to the Cook Islands after a hurricane is interpreted as trans-oceanic dispersal (Meyer, 2004), surveillance along ocean coasts to detect extremely long-distance dispersal is most probably ineffective the event being too rare. Dispersal towards mainland Europe would imply propagule spread from the closest infested coastal areas that is the Canary Islands and Malta. The surface oceanic currents, however, are directed away from the European continent, from the Canary Islands (Canary Current) southwards along the north west African coast (Mittelstaedt, 1991) and from Malta (Mid Mediterranean Jet) south-eastwards (Incarbona *et al*., 2011).

EFFORT REQUIRED

Monitoring of sentinel sites presuppose mapping and modelling efforts to define potential hotspots of invasion.

RESOURCES REQUIRED

The measure requires trained people to undertake the monitoring, and associated transport costs. Monitoring of water courses may be burdensome and involve the need of boats, personal floatation devices, etc. However, this becomes more feasible if more than one species is monitored.

SIDE EFFECTS

The total cost of monitoring of Invasive Alien Plant species can be reduced as several species can be monitored jointly. This is true for observational monitoring and for remote sensing.

ACCEPTABILITY TO STAKEHOLDERS

There may be issues around gaining access to private land to undertake monitoring.

ADDITIONAL COST INFORMATION

The exact costs are unknown. It is a widely accepted that EDRR is cost effective, being cheaper than management measures, which have to be continued indefinitely (cost of inaction) (Clout and Williams, 2009).

LEVEL OF CONFIDENCE[1]

High.

Monitoring of risk-based hotspots (sentinel sites) has proven to be highly effective to detect early introductions of invasive plants. Information comes from current practices based on expert experience (however, not on *C. grandiflorum*).

Citizen-science.

MEASURE DESCRIPTION

An Early Detection system for the species should involve both the active monitoring of sentinel (high risk) sites by experts (discussed in the above *Early Detection* sections), alongside the citizen science (discussed in this section).

For an eye-catching and easily identifiable species as *C. grandiflorum*, using citizen-science involving the public can be an effective approach for early detection. Such programmes for invasive *Cardiospermum* spp. are being implemented like in the USA (EDDMapS, 2017) or South Africa (Cape Town Invasive Species Unit, 2017). They typically imply public awareness campaigns, fact sheets and identification keys, the use of social media, apps for mobile devices or online field-books to report geo-located sites of infested areas, and competitions for new reports implying some sort of reward (prizes or citation of the finder's name on a website or publication, for example, "Cape Town's Invasive Species Unit has launched a competition with great prizes for anyone spotting any of the 28 targeted invasive species in the City", see http://www.invasives.org.za/news-previews/item/1350-spot-invaders-and-win). For citizen-science projects involving IAS in Europe see https://easin.jrc.ec.europa.eu/CitizenScienceProjects.

EFFECTIVENESS OF THE MEASURE

The effectiveness of surveillance has the potential to be **high**.

Citizen-science approaches seem to be successful in South Africa (http://www.capetowninvasives.org.za) and New Zealand (http://www.weedbusters.org.nz), where, after being listed as an 'Unwanted Organism' and following extensive management efforts, *C. grandiflorum* is now rare or even possibly eradicated from the country (EPPO, 2016).

However, without an established institution able to respond rapidly and appropriately (Rapid Eradication), early warnings remain purposeless (Clout and Williams, 2009). For example, in Malta, the relatively early detection of invasive stands of *C. grandiflorum* have not induced control measures (Ameen, 2013).

1 See Appendix

In Switzerland, an app for mobile devices and an online field-book to report early findings of invasive alien plants, was well accepted by the public, the number of annual reports amounting to approximately 3,500–5,000 findings in the first two years after launching of the tool (Michael Jutzi, Pers. Comm.). There are a number of citizen science activities focused on invasive species in Europe, including an invasive species reporting mobile app developed by the JRC European Alien Species Information Network (EASIN) (https://easin.jrc.ec.europa.eu/); and the UKs Plant Tracker app which focuses on public reporting of non-native plants, though not *Cardiospermum* (http://www.planttracker.org.uk).

EFFORT REQUIRED

Citizen-science programmes need to integrate easily available technical tools for disseminating information, good communication concepts, systems for data validation, well-designed and standardized methods of data collection, feedback to volunteers on their contribution as a reward for participation (Silvertown, 2009).

RESOURCES REQUIRED

In Switzerland, an app for mobile devices (running on both Android and Mac) to report geo-located findings of invasive alien plants, and later on for all flora, was developed since 2015. Costs are estimated as following (Sibyl Rometsch and Christophe Bornand, Pers. Comm.). Development: 153,000 CHF (ca. 130,000 EUR); running costs including updates: 20,000 CHF/year (ca. 17,500 EUR).

SIDE EFFECTS

The total cost of monitoring of Invasive Alien Plant species can be reduced as several species can be monitored jointly. This is true for observational monitoring and for remote sensing.

ACCEPTABILITY TO STAKEHOLDERS

Citizen Science can be rewarding for the individuals practising it, as it conveys a feeling of usefulness and strengthens civil society participation.

ADDITIONAL COST INFORMATION

The exact costs are unknown. It is a widely accepted that EDRR is cost effective, being cheaper than management measures, which have to be continued indefinitely (cost of inaction) (Clout and Williams, 2009).

LEVEL OF CONFIDENCE[1]

High.

As shown by New Zealand's example.

1 See Appendix

Measures to achieve rapid eradication after an early detection of a new occurrence.

Manual removal.

MEASURE DESCRIPTION

Manual removal by pulling out the plant and its taproots is recommended for small infestations. Seedlings can be successfully hand pulled all year round. Plants can also be cut at the base, the root dug out, and the top growth brought down using a brush hook or similar tool, or left to die off. In case of dense curtain infestations, stems can be cut at waist height, leaving the top growth dying off and eventually falling out of the canopy (BRAIN, 1997; Biosecurity Queensland, 2013; PIER, 2013; Weedbusters, 2017).

A combination of manual and chemical control is generally advised as regrowth is common (Biosecurity Queensland, 2013), involving cutting and painting the stump with herbicides (plant protection products) or cutting and leaving the stems to re-sprout then spray the foliage with herbicides (Weedbusters, 2017), or cutting or scraping and painting very large plants (BRAIN, 1997). See *Chemical control* section (Rapid eradication) below for more information.

EFFECTIVENESS OF MEASURE

There are conflicting statements regarding the effectiveness of the measure. Simelane (2014) indicates that "mechanical control of balloon vine is extremely difficult and costly", and Pasiecznik (2014) states that control has proven difficult. Others indicate that *C. grandiflorum* is not difficult to control and large infestations can be cleared in a fairly short time with concentrated efforts, using both chemical and manual weeding methods (BRAIN, 1997). In fact, eradication of invasive alien plant infestations smaller than one hectare is usually possible, and early detection can make the difference between successful eradication, and the necessity for infinite management measures and financial commitment (Rejmánek and Pitcairn, 2002).

The European and Mediterranean Plant Protection Organisation (EPPO, 2016), advises that "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" and highlights the importance of regional cooperation to promote information exchange in identification and management methods. EPPO's Expert Working Group considers that eradication of *C. grandiflorum* is feasible at the current level of occurrence of the species in the EPPO region (EPPO, 2016).

For follow-up management seed longevity, which is estimated to last around two years (Vivian-Smith and Panetta, 2002) must be taken into consideration. However, the exact plant and seed longevity is yet to be confirmed (Global Invasive Species Database, 2017), and some websites report a much longer persistence of *C. grandiflorum* in the soil seed bank (for example, http://www.sown.com.au reports up to 11 years of persistence, without any reference cited).

EFFORT REQUIRED

As with any invasive plant species there is a need for follow-up maintenance to avoid recolonization. Spot weeding is needed to control newly germinated plants until depletion of the often relatively large soil seed bank, as seeds start to sprout responding strongly to the availability of light (BRAIN, 1997; FloraBase, 2012). Follow-up is considered critical for the first 18 months after application of the measure and correlated disturbance (CHAH, 2011), and should be dealt with quarterly check-ups (Global Invasive Species Database, 2017). Considering the uncertainty about seed longevity, efforts to guarantee permanent eradications may have to be ensured over a longer period of time.

RESOURCES REQUIRED

Manpower and simple tools for cutting and digging.

However, in the worst cases, hand pulling can cost as much as 10.00–14.00 euro/m^2 when plants are well developed, there are difficulties in site accessibility and if additional costs are included in the estimate, such as filling the gap with new soil, collecting and providing the disposal for all the removed plant material, safety costs. Very rarely can this cost be lower than 1.00–1.50 euro per square metre (Giuseppe Brundu, Pers. Comm.)

SIDE EFFECTS

Pulling of the aerial parts of the vines from the canopy can damage the native plants they are climbing on as well as disrupting a potential habitat for various species (BRAIN, 1997; Global Invasive Species Database, 2017).

After management, seeds will often mass germinate when a disturbance creates a clearing in the vegetation (Muyt, 2001; Vivian-Smith and Panetta, 2002). Densely invaded riparian systems are subject to erosion after clearing, and improved understanding of how to manage ecosystem recovery is needed (Richardson and van Wilgen, 2004).

ACCEPTABILITY TO STAKEHOLDERS

Public perception of manual management is generally positive, see also *Chemical control* (Management) sections below.

EU/national/local legislation on the use of plant protection products and biocides needs to be respected.

ADDITIONAL COST INFORMATION

Cost of inaction and consequent invasive spread of *C. grandiflorum* is presumably high, as illustrated by the example from Malta (Ameen, 2013), where the plant is smothering native Mediterranean vegetation.

LEVEL OF CONFIDENCE[1]

High.

All sources recommend manual control. Information comes from published material, or current practices based on expert experience applied in one of the EU countries or third countries with similar environmental, economic and social conditions.

Chemical control.

MEASURE DESCRIPTION

Chemical control methods include: cutting in spring or summer and painting the stump with 33% glyphosate (PIER, 2013), 50% glyphosate (Biosecurity Queensland, 2013), or with undiluted (100%) glyphosate (BRAIN, 1997); cutting the base and treat the re-sprouted leaves with 1–2% Glyphosate (BRAIN, 1997; Weedbusters, 2017); scraping and painting large plants with glyphosate (BRAIN, 1997). Vine seedlings can be successfully foliar sprayed, and the mix should be adjusted according to observed results (BRAIN, 1997). Single plants can be spot sprayed with 3–4% 2,4 D amine and 5% Fluroxypyr (Biosecurity Queensland, 2013). Other herbicides successfully used against larger plants of *Cardiospermum* spp. include paraquat (note that paraquat is not approved in the EU), glufosinate-ammonium, lactofen (not approved in the EU), carfentrazone-ethyl, or sulfentrazone (not approved in the EU) (Brighenti *et al.*, 2003).

A combination of chemical and manual control is generally advised (Biosecurity Queensland, 2013). It is important to note that EU/national/local legislation on the use of plant protection products and biocides needs to be respected.

EFFECTIVENESS OF MEASURE

Both chemical and manual weeding methods can control *C. grandiflorum* (BRAIN, 1997). However, the application of herbicides may be impossible or illegal due to the frequent proximity to water of invaded stands.

EFFORT REQUIRED

See the *Manual removal* sections (Rapid eradication).

RESOURCES REQUIRED

To undertake chemical control measures trained operators, pesticides, and spraying equipment are needed. A project in Italy which developed a drone-based pesticide distribution system on corn, cost ca. 100 Euro per hectare, including the cost of a technician to operate the drone.[2]

SIDE EFFECTS

Herbicide treatments may negatively affect native species and pollute surface and groundwater (Simelane *et al.*, 2011; PIER, 2015), cause non-target effects in soil microbiota, or constitute health hazards for the workers employed in managing *C. grandiflorum*.

See also the *Manual removal* section (Rapid eradication).

ACCEPTABILITY TO STAKEHOLDERS

The use of pesticides in the environment may be perceived very negatively by the public.

ADDITIONAL COST INFORMATION

See the *Manual removal* section (Rapid eradication).

LEVEL OF CONFIDENCE[1]

High.

All sources concur on the usefulness of chemical management methods, in particular when combined with (after) mechanical methods. Information comes from published material, or current practices based on expert experience applied in one of the EU countries or third countries with similar environmental, economic and social conditions.

1 See Appendix
2 http://www.ambienteterritorio.coldiretti.it/TEMATICHE/Agricoltura-Biologica/Pagine/Arrivaildronecontrolapiralidedelmais.aspx (Italian)

Measures for the species' management.

Mechanical management.

MEASURE DESCRIPTION

See also the *Manual removal* section (Rapid eradication).

To date, managing *C. grandiflorum* invasions has mostly involved physical removal or burning (EPPO, 2016), although infestations appear daunting, they can be effectively controlled (CHAH, 2011).

EFFECTIVENESS OF MEASURE

See the *Manual removal* section (Rapid eradication). An integrated approach including both manual and chemical weeding can be effective to control large infestations (BRAIN, 1997).

For Europe, there is very little information. Only MEPA (2013) provides guidelines for managing *C. grandiflorum* and restoring native plant communities in terrestrial settings in the Maltese Islands**.**

EFFORT REQUIRED

See the *Manual removal* section (Rapid eradication).

To prevent spread and re-colonization along waterways, a catchment wide approach can be beneficial when controlling *C. grandiflorum* (CHAH, 2011). Moreover, national measures should be combined with international measures, and international coordination of management of the species between countries is recommended (EPPO, 2016).

RESOURCES REQUIRED

See the *Manual removal* section (Rapid eradication).

Once established and widespread, mechanical control of *C. grandiflorum* would potentially incur the largest costs, also because of the dead plant material which has to be removed (and disposed) to restore exposure of the understory to sunlight (Simelane, 2014). However, it is problematic to define the amount of time and money spent on an individual species as generally a number of species are managed simultaneously (David Simelane, Pers. Comm.).

SIDE EFFECTS

The removal of the dried-out vegetation from the canopy may be difficult due to the height of the infestation and herbicide spray may be an option when used with the correct equipment (CHAH, 2011). Moreover, the species' preference for sensitive riparian areas and need for multiple control treatments may make treatment expensive and ecologically damaging (USDA, 2013). In addition, thorough disposal is critical (to avoid further dispersal), if the seeds and taproots need to be removed from sites (Global Invasive Species Database, 2017).

ACCEPTABILITY TO STAKEHOLDERS

See the *Manual removal* section (Rapid eradication).

ADDITIONAL COST INFORMATION

Cost of inaction and consequent invasive spread of *C. grandiflorum* is presumably high, as illustrated by the example from Malta (Ameen, 2013), where the plant is smothering native Mediterranean vegetation.

LEVEL OF CONFIDENCE[1]

Moderate.

There is little information about control of large areas invaded by *C. grandiflorum*.

Chemical management.

MEASURE DESCRIPTION

See *Chemical control* section (Rapid eradication).

Large curtain infestations with dense stands of hundreds of stems growing together can be cut at waist height and the leaves re-sprouting from the basal stems can be foliar sprayed with Glyphosate at approximately 1–2% (BRAIN, 1997; Weedbusters, 2017). It is important to note that EU/national/local legislation on the use of plant protection products and biocides needs to be respected.

1 See Appendix

EFFECTIVENESS OF MEASURE

See the *Chemical control* section (Rapid eradication).

Chemical management of *C. grandiflorum* may be restricted where it grows close to water sources due to legal requirements.

EFFORT REQUIRED

See the *Chemical control* section (Rapid eradication).

Considering the low acceptance of the use of pesticides in the environment, considerable public outreach efforts may have to be undertaken to increase acceptance of the measure.

RESOURCES REQUIRED

See the *Chemical control* section (Rapid eradication).

SIDE EFFECTS

See the *Chemical control* section (Rapid eradication).

ACCEPTABILITY TO STAKEHOLDERS

See the *Chemical control* section (Rapid eradication).

The use of herbicides is generally the least supported method by the general public for controlling invasive alien plants (Bremner and Park, 2007). For instance, in south-western USA, a large majority (64%) of the citizens rated chemical control of invasive alien plants as being not acceptable at all or only slightly acceptable (12% rated as highly acceptable). In contrast, acceptability was much higher for mechanical methods (53 % highly acceptable, 21% not at all or slightly acceptable) and for biological control (27% not or slightly acceptable, 44% highly acceptable) (Brunson and Tanaka, 2011).

ADDITIONAL COST INFORMATION

See the *Chemical control* section (Rapid eradication).

LEVEL OF CONFIDENCE[1]

Moderate.

There is little information about control of large areas invaded by *C. grandiflorum*.

Biological control.

MEASURE DESCRIPTION

Classical biological control against *C. grandiflorum* has only been explored in South Africa. Studies started in 2003 to search for biological control agents (Simelane *et al.*, 2011). Three promising agents were identified: a seed-feeding weevil *Cissoanthonomus tuberculipennis* (further researched by Lampert *et al.*, 2013), a fruit-galling midge *Contarinia* spp., and the rust fungus *Puccinia arechavaletae* (Simelane *et al.*, 2011). Concerns about their potential impacts on non-target *Cardiospermum* species and their uncertain native status in southern Africa had initially prevented their release (Gildenhuys *et al.*, 2013). In 2013, the release of *C. tuberculipennis* was granted in KwaZulu Natal Province by the relevant regulatory authorities (Simelane *et al.*, 2014).

Neo-classical biological control (such as the use of natural enemies that are native to the introduced range), is also a possible management approach (EPPO, 2016). Soapberry bugs of the genera *Leptocoris*, *Jadera* and *Boisea* (Rhopalidae) feed exclusively on seeds of Sapindaceae and are natural seed predators of *Cardiospermum* spp. in both their native and non-native areas (Carroll *et al.*, 2005b), and native American soapberry bugs can destroy the seeds of an introduced Sapindaceae (*Koelreuteria elegans*) at a very high percentage (Carroll *et al.*, 2003). However, the genera *Leptocoris*, *Jadera* and *Boisea* are absent from the European continent (EPPO, 2016).

It should be borne in mind that the release of macro-organisms as biological control agents is currently not regulated at EU level. Nevertheless national/regional laws are to be respected. Before any release of an alien species as a biological control agent an appropriate risk assessment should be made.

EFFECTIVENESS OF MEASURE

Moderate to high. A three-year monitoring conducted since the release of the biological control agent *Cissoanthonomus tuberculipennis* in South Africa, shows that establishment and dispersal of the weevil has been rapid (33 to 37 km/year), and that populations have been increasing at almost all the study sites. By the year 2017, 50% seed predation was measured at different sites. Reduction in seed bank densities and seedling recruitment was observed at some sites, which is promising, considering that the invasiveness of *C. grandiflorum* is attributed to its prolific seed production (David Simelane, Pers. Comm.). However, the effectiveness and the host specificity under field conditions of this biological control agent remains to be further assessed (EPPO, 2016).

1 See Appendix

EFFORT REQUIRED

As the biological control agent *C. tuberculipennis* readily establishes itself and spreads naturally after establishment (Simelane *et al.*, 2014), the measure needs to be applied theoretically only once per infested area and presupposes the availability of rearing facilities and knowledge.

RESOURCES REQUIRED

On average, three years of research are required for any tested and introduced biocontrol agent against weeds. With technical support and facilities, the costs were estimated to be about 460,000 USD in 1997 (McFadyen, 1998), registration costs in the European Union, would add another >30,000 EUR (Sheppard *et al.*, 2006). However, prior use elsewhere also reduces the cost of a biocontrol programme. Taking Switzerland as an example, projects may last anything between 5 and 20 years, and depend on the size of the area where the agent will be applied, whether follow-up monitoring and evaluation is included, or if they are closely related to non-target risks. Costs of one million CHF (ca. 875,000 Euro) may be roughly estimated, but they could be significantly less or more (Tim Haye, Pers. Comm).

SIDE EFFECTS

In South Africa, emphasis was put on potential adverse effects on non-target Sapindaceae, including *Cardiospermum* spp. which are native or with doubtful native status in southern Africa, and monitoring of non-target impacts on *C. corindum* and *C. pechueli* was strongly recommended (Gildenhuys *et al.*, 2015a; 2015b; Simelane *et al.*, 2014).

In Europe (and the northern temperate hemisphere), the only native Sapindaceae belong to the genera *Acer* and *Aesculus*, both belonging to the subfamily Hyppocastanoideae which is phylogenetically quite distant from *Cardiospermum* (subfamily Sapindoideae) (Bürki *et al.*, 2010). However, several Sapindoideae are important ornamental plants in Europe, including *Koelreuteria* spp. (Cullen *et al.*, 2011), and natural enemies of *Cardiospermum* have been shown to be able to attack *Koelreuteria elegans* in Florida (Carroll *et al.*, 2003).

ACCEPTABILITY TO STAKEHOLDERS

See the *Chemical control* section above.

However, what does biological control have to do with chemical control?

In biological control, general public understanding of the scientific aspects, and the risks and potential benefits is judged to be unsatisfactory (Sheppard *et al.*, 2006).

ADDITIONAL COST INFORMATION

None available for *C. grandiflorum*.

LEVEL OF CONFIDENCE[1]

Moderate to high.

As shown by recent studies (including unpublished yet) in South Africa.

Fruits of Cardiospermum grandiflorum*, an alien plant on the Canary Islands in ruderal communities. © Bernd Sauerwein. CC BY-SA 3.0*

1 See Appendix

Bibliography

Ameen, J. (2013). Valley flora being slowly choked by invasive plant. *Times of Malta*, Allied Newspapers Ltd. Retrieved July 2017, from http://www.timesofmalta.com/articles/view/20130309/local/Valley-flora-being-slowly-choked-by-invasive-plant.460792.

ARC. (2011). Southern Africa Plant Invaders Atlas (SAPIA) News. Retrieved July 2017, from http://www.arc.agric.za/home.asp?pid=1andtoolid=2andsec=1001.

Biosecurity Queensland. (2013). Balloon vine, Heart seed vine, *Cardiospermum grandiflorum*. Pest plant fact sheet PP66. Brisbane, Australia: Department of Agriculture, Fisheries and Forestry, 2 pp.

BRAIN – Brisbane Rainforest Action and Information Network. (1997). Balloon Vine *Cardiospermum grandiflorum.* Retrieved July 2017, from http://www.brisrain.org.au/01_cms/details.asp?ID=305

Bremner, A. and Park, K. (2007). Public attitudes to the management of invasive non-native species in Scotland. *Biological Conservation*, 139, 306–314.

Brighenti, A.M., Voll, E. and Gazziero, D.L.P. (2003). Biology and management of *Cardiospermum halicacabum*. *Planta Daninda*, 21, 229–237.

Brunson, M.W. and John Tanaka, J. (2011). Economic and Social Impacts of Wildfires and Invasive Plants in American Deserts: Lessons From the Great Basin *Rangeland Ecology and Management*, 64 (5), 463–470.

Buerki, S., Lowry II, P.P., Alvarez, N., Razafimandimbison, S.G., Küpfer P. and Callmander, M.W. (2010). Phylogeny and circumscription of Sapindaceae revisited: molecular sequence data, morphology and biogeography support recognition of a new family, Xanthoceraceae. *Plant Ecology and Evolution*, 142, 148–159.

Burt, J.W., Muir, A.A., Piovia-Scott, J., Veblen, K.E., Chang, A.L., Grossman J.D. and Weiskel, H.W. (2007). Preventing horticultural introductions of invasive plants: potential efficacy of voluntary initiatives. *Biological Invasions*, 9: 909–923.

Cape Town Invasive Species Unit. (2017). *Cardiospermum grandiflorum* ID kit. Retrieved July 2017, from http://www.capetowninvasives.org.za/project/terrestrial/species/cardiospermum-grandiflorum.

Carroll S.P., Loye J.E., Dingle H., Mathieson M., Famula T.R. and Zalucki P. (2005b) And the bleak shall inherit – evolution in response to invasion. *Ecology Letters*, 8, 944–951.

Carroll, S.P., Marler, M., Winchell, R. and Dingle, H. (2003). Evolution of cryptic flight morph and life history differences during host race radiation in the soapberry bug, *Jadera haematoloma* Herrich-Schaeffer (Hemiptera: Rhopalidae). *Annals of the Entomological Society of America* 96: 135–143.

Carroll, S.P., Mathieson M. and Loye J.E. (2005a). Invasion history and ecology of the environmental weed balloon vine, *Cardiospermum grandiflorum* Swartz, in Australia. *Plant Protection Quarterly*, 20: 140–144.

Carthey, A.J.R., Fryirs, K.A., Ralph, T.J., Bu, H. and Leishman, M.R. (2016). How seed traits predict floating times: a biophysical process model for hydrochorous seed transport behaviour in fluvial systems. *Freshwater Biology*, 61: 19–31. doi: 10.1111/fwb.12672.

CHAH – Council of Heads of Australasian Herbaria (CHAH) and Department of Sustainability, Environment, Water, Population and Communities of the Government of Australia. (2011). Weeds in Australia – *Cardiospermum grandiflorum*. Retrieved July 2017, from http://www.environment.gov.au/cgi-bin/biodiversity/invasive/weeds/weeddetails.pl?taxon_id=7277#.

Cheng, Y., Tom, E. and Ustin, S.L. (2007). Mapping an invasive species, kudzu (*Pueraria montana*), using hyperspectral imagery in western Georgia. *J. Appl. Remote Sens.*, 1, 013514 (23 May 2007).

CITES. (2017). The CITES Appendices. Retrieved July 2017, from https://cites.org/eng/app/index.php.

Clément, G. and Lapouge-Déjean, B. (2014). Plantes envahissantes, pionnières ou simplement expansives ? Editions Terre Vivante, 192 pp.

Clout, M.N. and Williams, P.A. (Eds.) (2009). Invasive species management. A handbook of principles and techniques. Oxford University Press, Oxford.

Cullen, J., Knees, S. and Cubey, H.S. (2011). The European garden flora, flowering plants: A manual for the identification of plants cultivated in Europe, both out-of-doors and under glass, Second edition. Cambridge, UK: Cambridge University Press.

Davis, M.A. (2009). Invasion Biology. Oxford University Press. Oxford, UK.

EDDMapS. (2017). Early Detection and Distribution Mapping System. The University of Georgia – Center for Invasive Species and Ecosystem Health. Available online at http://www.eddmaps.org/; last accessed July 17, 2017.

EPPO. (2016). Pest risk analysis for *Cardiospermum grandiflorum*. EPPO, Paris. Retrieved July 2017, from https://www.eppo.int/INVASIVE_PLANTS/priorization/13-18617_PRIO_Cardiospermum_grandiflorum.docx.

EPPO. (2017). PQR - EPPO database on quarantine pests (available online). Retrieved July 2017, from http://www.eppo.int.

FloraBase. (2012). *Cardiospermum grandiflorum* Sw. Retrieved July 2017, from https://florabase.dpaw.wa.gov.au/browse/profile/17318.

Gildenhuys, E., Ellis, A.G., Carroll, S.P. and Le Roux, J.J. (2015a). Combining known native range distributions and phylogeny to resolve biogeographic uncertainties of balloon vines (*Cardiospermum*, Sapindaceae). *Diversity and Distributions*, 21, 163–174.

Gildenhuys, E., Ellis, A.G., Carroll, S.P. and Le Roux, J.J. (2015b). From the Neotropics to the Namib: evidence for rapid ecological divergence following extreme long-distance dispersal. *Botanical Journal of the Linnean Society*, 179, 477–486.

Gildenhuys, E., Ellis, A.G., Carroll, S. and Le Roux, J.J. (2013). The ecology, biogeography, history and future if two globally important weeds: *Cardiospermum halicacabum* Linn. and *C. grandiflorum* SW. *Neobiota*, 19, 45–65.

Global Invasive Species Database. (2017). Species profile: *Cardiospermum grandiflorum*. Retrieved July 2017, from http://www.iucngisd.org/gisd/species.php?sc=1346 on 14-07-2017

Henderson, L. (2001). Alien Weeds and Invasive Plants. Plant Protection Research Institute Handbook No. 12. Cape Town, South Africa: Paarl Printers.

Humair, F., Kueffer, C. and Siegrist, M. (2014). Are Non-Native Plants Perceived to Be More Risky? Factors Influencing Horticulturists' Risk Perceptions of Ornamental Plant Species. *PLOS ONE* 9(7), e102121 (see https://doi.org/10.1371/journal.pone.0102121).

Ibáñez, I., Silander Jr, John. A., Allen, J. M., Treanor, S.A. and Wilson, A. (2009). Identifying hotspots for plant invasions and forecasting focal points of further spread. *Journal of Applied Ecology*, 46, 1219–1228.

Incarbona, A., Ziveri, P., Sabatino, N., Manta, D.S. and Sprovieri, M. (2011). Conflicting coccolithophore and geochemical evidence for productivity levels in the Eastern Mediterranean sapropel S1. *Mar. Micropaleontol.* 81, 131e143.

Lampert, S., Savaris, M., Rosado-Neto, G.H. and Valle da Silva Pereira, P.R. (2013). Behavioral aspects and predation of seeds of *Cardiospermum grandiflorum* Swartz (Sapindaceae) by *Cissoanthonomus tuberculipennis* Hustache (Coleoptera: Curculionidae). *Insecta Mundi*, 0320, 1–4.

McFadyen, R.E.C. (1998). Biological control of weeds. *Ann. Rev. Entomol.*, 43, 369–393.

MEPA – Malta Environment and Planning Authority. (2013). Guidelines on managing non-native plant invaders and restoring native plant communities in terrestrial settings in the Maltese Islands, 88 pp.

Meyer, J.Y. (2004). Treat of invasive alien plants to native flora and forest vegetation of Eastern Polynesia. *Pacific Science* 58: 357–375.

Mittelstaedt, E. (1991): The ocean boundary along the northwest African coast: Circulation and oceanographic properties at the sea surface. *Progress in Oceanography*, 26, 307–355.

Muyt, A. (2001). Bush Invaders of South-East Australia. Published by R.G. and F.J. Richardson, Meredith Victoria, 304 pp.

Pasiecznik, N. (2014). CABI Invasive Species Compendium. Datasheet *Cardiospermum grandiflorum* (Baloon vine). Retrieved July 2017, from http://www.cabi.org/isc/datasheet/112965.

PIER. (2013). Pacific Island Ecosystems at Risk. Retrieved July 2017, from http://www.hear.org/pier/species/cardiospermum_grandiflorum.htm.

Port Macquarie Landcare group. (2012). The master Weed Whackers Manual. A compilation of the most common weeds found on Port Macquarie Landcare sites. Retrieved September 2017, from http://www.landcareportmac.com.au

Rejmánek, M. and Pitcairn, M.J. (2002). When is eradication of exotic pest plants a realistic goal? Pages 249–253 *in* M.N. Clout, C.R. Veitch (eds.). Turning the tide: the eradication of invasive species. IUCN SSC Invasive Species Specialist Group, Gland, Switzerland and Cambridge, UK.

Richardson, D.M. and van Wilgen, B.W. (2004). Invasive alien plants in South Africa: how well do we understand the ecological impacts? *South African Jour. Sci.*, 100, 45–52.

Sheppard, A.W., Shaw, R.H. and Sforza, R. (2006). Top 20 environmental weeds for classical biological control in Europe: a review of opportunities, regulations and other barriers to adoption. *Weed Research*, 46, 93–117.

Silvertown, J. (2009). A new dawn for citizen science. *Trends in Ecology and Evolution*, 24(9), 467–471.

Simelane, D. (2014). ARC-PPRI fact sheets on invasive alien plants and their control in South Africa. Retrieved July 2017, from http://www.arc.agric.za/arc-ppri/Pages/Balloon-vine,-Cardiospermum-grandiflorum-(Sapindaceae).aspx.

Simelane, D.O., Fourie, A. and Mawela, K.V. (2011). Prospective agents for the biological control of *Cardiospermum grandiflorum* Sw (Sapindaceae) in South Africa. *African Entomology*, 19, 269–277.

Thuiller, W., Richardson, D.M., Pyšek, P., Midgley, G.F., Hughes, G.O. and Rouget, M. (2005). Niche-based modelling as a tool for predicting the risk of alien plant invasions at a global scale. *Global Change Biology*, 11, 2234–2250. doi: 10.1111/j.1365-2486.2005.001018.x.

USDA. (2013). Weed risk assessment for *Cardiospermum grandiflorum* Sw. (Sapindaceae) – Balloon vine. Retrieved July 2017, from https://www.aphis.usda.gov/plant_health/plant_pest_info/weeds/downloads/wra/Cardiospermum_grandiflorum_WRA.pdf.

Vivian-Smith, G. and Panetta, F.D. (2002). Going with the flow: dispersal of invasive vines in coastal catchments. *Coast to Coast* 2002, 491–494.

Weedbusters. (2017). Information sheet on Balloon Vine – *Cardiospermum grandiflorum*. Retrieved July 2017, from http://www.weedbusters.org.nz/weed-information/cardiospermum-grandiflorum/59/.

Personal Communications – An online enquiry was sent to the following people and institutions. We express our gratitude to the respondents.

Biosecurity Queensland, Department of Agriculture, Fisheries and Forestry of the State of Queensland.

Brisbane Rainforest Action and Information Network, PO Box 443 The Gap Qld 4061, Australia.

Cape Town Early Detection and Rapid Response (EDRR) Project. www.capetowninvasives.org.za. Cape Town, South Africa.

David Simelane – Agricultural Research Council-Plant Protection Research Institute, Private Bag X134, Queenswood, 0121 South Africa.

Sibyl Rometsch, Christophe Bornand, Michael Jutzi – Info Flora. The National Data and Information Center on the Swiss Flora. Bern, Geneva, Lugano, Switzerland

Tim Haye – Head Arthropod Biological Control, CABI, Rue des Grillons, Delemont, Switzerland.

Weedbusters, c/- PO Box 1493, Waikato Mail Centre, Hamilton 3240, New Zealand.

Appendix

- **High:** Information comes from published material, or current practices based on expert experience applied in one of the EU countries or third country with similar environmental, economic and social conditions.

- **Medium:** Information comes from published data or expert opinion, but it is not commonly applied, or it is applied in regions that may be too different from Europe (for example tropical regions) to guarantee that the results will be transposable.

- **Low:** Data are not published in reliable information sources and methods are not commonly practiced or are based solely on opinion. This is for example the case of a novel situation where there is little evidence on which to base an assessment.

Your feedback is important. Any comments that could help improve this document can be sent to ENV-IAS@ec.europa.eu