Humulus scandens *has been introduced as an ornamental in both Europe and North America.*

The management of Japanese hop (*Humulus scandens*)

Measures and associated costs

Scientific name(s)	*Humulus scandens* (Lour.) Merr.
Common names (in English)	Japanese hop
Other designation	Other sources indicate this species as *Humulus japonicus* Siebold & Zucc.
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Common names

BG	Японски хмел
HR	Japanski hmelj
CZ	Chmel japonský
DA	Japansk humle
NL	Oosterse hop
EN	Japanese hop
ET	Jaapani humal
FI	Japaninhumala
FR	Houblon du Japon
DE	Japanischer Hopfen
EL	–
HU	Japán komló
IE	Hopa Seapánach
IT	Luppolo del Giappone
LV	Japānas apini
LT	Japoninis apynys
MT	Il-ħops il-ħażin
PL	Chmiel japoński
PT	Lúpulo
RO	Hamei japonez
SK	Chmeľ japonský
SL	Enoletni hmelj
ES	Lúpulo japonés
SV	Japansk humle

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

Humulus scandens[1] is a dioecious herbaceous annual[2] vine that germinates in early spring. The species is native to Asia (China, Taiwan, Japan, Korea, Russian Far East, and Vietnam) and has been introduced as an ornamental in both Europe and North America where it is becoming an invasive alien species in several regions (EPPO, 2018). In both its native range and introduced range, *H. scandens* occurs mostly on riverside, particularly on the loose, bare surfaces of alluvial bars formed by river and stream-sides by temporary floods (Fried *et al.*, 2018). In the current area of distribution, *H. scandens* has a high magnitude of impact on biodiversity, moderate impact on ecosystem services and a moderate socio-economic impact. The Pest Risk Analysis performed by EPPO (2018) concluded that *H. scandens* presents a high phytosanitary risk for the endangered area within the Union with a low uncertainty and that further spread within and between countries is likely. While *H. scandens* can potentially be problematic in some upland ruderal habitats (roadsides, wastelands, abandoned and disturbed areas), the present note will mainly focus on management of infestations in rivers/streams which represent 99% of the cases. Management strategy per se will not change across habitats, with the difference that considerations of negative environmental side-effects will be less important in the choice of the method for ruderal habitats.

A ban on keeping, importing, selling, and growing *H. scandens* in accordance with Article 7 of the EU IAS Regulation 1143/2014 could effectively prevent new intentional introductions into the European Union. Phytosanitary inspections could be performed together with similar measures for other species of Union concern (*Impatiens glandulifera*, *Parthenium hysterophorus*), especially on certain commodities such as soil or machinery, but there is no clear evidence that *H. scandens* could be introduced unintentionally in the Union. Rather, as the species is already present and cultivated in many regions of the Union, it is of utmost importance to raise public awareness in order that the plant is not cultivated anymore and in order to launch an eradication campaign within private gardens to avoid secondary spread to suitable habitats such as river banks.

Surveillance of suitable areas and catchments where *H. scandens* has been detected, followed by rapid eradication of small populations at early stages of invasion is the most cost-effective strategy.

Once the species is established, its impacts can be mitigated by classical management, including manual, mechanical, chemical and ecological controls or a combination of all these methods. Currently, few trials of Japanese hop control methods have been conducted in Europe: the only feedback is from the experiments carried out in Gardon Valley, France (Smage des Gardons, 2014; Sarat *et al.*, 2015). The methods described below are therefore also based on tests carried out in the United States of America (Panke and Renz, 2013; Pannill *et al.*, 2009), and methods developed in Europe to manage fast-growing annual species such as *Impatiens glandulifera* (Tanner, 2017).

Hand pulling is best suited for fairly small infested areas (up to 100–500 m^2) because it is slow, labour-intensive and expensive (EUR 10/m^2). Manual control is also the most targeted method, with the least likelihood of damage to other plants. For larger infested areas (500–10,000 m^2 or more), mechanical or chemical control will be more cost-effective (EUR 0.6–1.1/m^2). However, these methods will have more unintended effects on resident vegetation and there can be significant restrictions in use of herbicides on river banks in close vicinity of water, which is the most suitable habitat of *H. scandens*. All these methods will need to be conducted at least two times during the growing season to control potential regrowth, new seedlings and prevent seed set. Considering that seed longevity in the soil is about three years (Krauss, 1931), repeated removal treatments over at least three years are typically needed to eradicate an infestation and exhaust the short-lived seed bank.

All these curative management measures (especially mechanical and chemical control) have the disadvantage of increasing disturbances on the established native vegetation, leaving bare soils and promoting the recolonization of

1 There are still opposing views on the "correct" name for this species (the other option is *Humulus japonicus* Siebold & Zucc). However, there is no discussion on the proper identity of the species as such. Everyone agrees on what this annual species looks like and how it can be distinguished from the European and Asian native *Humulus lupulus* L. It is all about a contested validity of the description by Loureiro and the omission to nominate a neotype. For pragmatic reasons we follow the approach as taken by EPPO (2018) to choose *H. scandens* as the preferred name for this species.

2 In the literature, there are some mentions that the plant may have the ability to act as a perennial in specific habitats. In fact, in response to stress conditions, such as flooding, the stems can produce adventitious roots (Reygrobellet J.P., pers. comm.). There is however no evidence of a perennial life cycle and reproduction is only by seed.

the site by *H. scandens* and/or other invasive species. Therefore, it is highly recommended that all the measures are accompanied by broader restoration of the riparian ecosystem. Given that *H. scandens* is an opportunistic invasive species favoured by high level of resources, a sustainable long term management would consist in manipulating the environment to make it less suitable for *H. scandens*. This could be achieved by: planting grasses or sedges to increase resident vegetation cover at the local level (biotic resistance), (re)planting shrubs and trees to increase shade at the landscape level, and work with stakeholders (farmers) to reduce fertilization runoffs and other pollution in the river system to reduce eutrophication at the catchment level.

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 *H. scandens*.

MEASURE DESCRIPTION

A significant pathway for entry or spread of Japanese hop (*Humulus scandens*) into the EU, or between Member States, is through the purchase or exchange of seed material (EPPO, 2018). Currently, the plant is not widely sold in the major garden centre chains. However, for garden amateurs, seeds of *H. scandens* are available in specialized nurseries and it can also be ordered through the internet. According to gardener forums and websites, the plant is widely used and exchanged by gardeners and horticulturists. The species is also traded between Member States via internet suppliers. Its presence is very likely in gardens throughout the whole European Union (see Section *Prevention of secondary spread*). A ban from sale would help to regulate this pathway for the species.

The objective of this measure is to prevent the entry of the species in Member States where it is still absent in the wild and to prevent new introductions in Member States where the species is already naturalized.

EFFECTIVENESS OF MEASURE

Effective.

As for many invasive plants, prevention by prohibition of keeping, importing, selling, and growing the plant in the Union is the most efficient measure to prevent new introductions (Simberloff *et al.*, 2013). It could happen that seeds of *H. scandens* are labelled and traded under the name of *Humulus lupulus* (Fried G., pers. comm.). Careful controls should therefore be applied by phytosanitary inspectors not only based on the labels but on the seed material (see Section *Prevention of un-intentional introductions and spread*).

If prohibition measures are not implemented by all countries, they will not be effective since the species could be planted and may spread from one country to another especially where river systems are shared by more than one country (EPPO, 2018). For example, it is highly probable that the entry of *H. scandens* in Serbia was due to the spread of the species along the Danube River with source populations coming from Hungary (EPPO, 2018). Therefore, national measures should be combined with international measures, and it is highly recommended to set up international coordination of management of the species between countries (EPPO, 2018).

SIDE EFFECTS

Environmental effects: Neutral or mixed.
Social effects: Positive.
Economic effects: Negative.

Potential negative side effects include a loss to the trade of Japanese hop (*Humulus scandens*). However, this is likely to be of very minor impact to the trade. As stated previously, the trade of *H. scandens* in the major garden centre chains is very marginal (EPPO 2018). Most of the business in sales of *Humulus* comes from the sale of the native perennial hop *Humulus lupulus* (Manceau R., pers. comm., 2018).

The plant has allergenic pollens (Park *et al.*, 1999) with potential health impact in Europe comparable to common ragweed (EPPO, 2018), therefore preventing its introduction to new areas within the EU will offset potential negative health issues.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

A regulation of Japanese hop may be viewed negatively by a very minor fraction of the public strictly opposed to any form of regulation applied on plants and animals. There is an increasing number of people influenced by the books of landscape gardeners such as Gilles Clément (Clément, 2002) or from ecologists such as Jacques Tassin (Tassin, 2014) who promote the use of alien or even invasive plants, or stressed their positive effect, respectively. Therefore, some members of the public may still think that the balance is positive between the positive effects of *H. scandens*, for example, through its use as an ornamental for growing over trellises, arbours or fences, and its negative effects through its invasive behaviour. Some botanists may also find the plant an attractive addition to the European flora.

However, as discussed above, the plant has allergenic pollens (Park *et al.*, 1999) so that it is expected that any form of management of the species will be largely accepted by people.

Public awareness campaigns may highlight the risk of the species and prevent further spread of the species from existing populations (see Section *Prevention of secondary spread of the species*).

ADDITIONAL COST INFORMATION

Member States will have to set up border controls and ensure that stakeholders are following the ban. This will result in some enforcement costs. A ban from sale requires financial resources, staff time and the development of communication material from a number of sectors, including governmental, regulators, horticulture and horticultural suppliers, the general public, and environmental NGOs (Tanner, 2017).

For a species that is mostly traded through small specialized nurseries, via the internet or exchanged between amateurs, it would be of utmost importance to raise public awareness to disseminate the message that *Humulus scandens* is banned from sale and explain why by giving detailed information highlighting the negative impacts of the species. Environmental NGOs can assist in information dissemination to the public.

The cost for an awareness raising campaign is estimated to be EUR 10,000 per year for each Member State (Tanner, 2017). However, sectors of society may bear some of these costs themselves. These costs will be shared between all species regulated by the Union.

Cost of inaction:

Based on the current area where the species was recorded in 2012–2013 (19,949 m^2) and estimated in 2015 (29,924 m^2) on the Gardon River (southern France), the cost of managing all populations would be 580,000 EUR over only 2 years (Sarat *et al.*, 2015). Higher figures could therefore be expected for Hungary and Italy where the species is also naturalized but has a more scattered distribution over a larger territory. Reported at the national scale of each Member State, it is clear that long-term management costs of this species will rapidly exceed several dozen millions of euros.

Cost effectiveness of the measure:

A ban from sale is usually considered as the most cost-effective measure in the prevention of entry of an invasive species to new regions (Simberloff *et al.*, 2013). It is particularly expected for *Humulus scandens* given its high environmental impact in riparian habitats, its potential human health impact and its minor economic values in the horticultural trade (EPPO, 2018).

Socio-economic aspects:

Negative socio-economic impacts would include a loss for the horticultural trade of *Humulus scandens*. However, this is not likely to be significant as it is only seeds that are traded (EPPO 2018). Positive social aspect includes a higher air quality through a reduction of the allergenic pollen of the plant in the air.

LEVEL OF CONFIDENCE*

Established but incomplete.

Outside some states of the United States where *H. scandens* is prohibited (EPPO, 2018), there are no specific data associated to banning this species. There are few documents to support the information given but all the information is consistent with the general knowledge of such a measure (Simberloff *et al.*, 2013), so the information is established but may be incomplete.

* See Appendix

Phytosanitary inspection related to movement of soil, equipment and vehicles.

MEASURE DESCRIPTION

According to EPPO (2018), although unintentional introduction as a contaminant of machinery cannot be totally excluded, it is highly unlikely to occur for *Humulus scandens*. Due to the presence of *H. scandens* on river banks, transport of seeds with topsoil used as gravel is probable although no evidence exists for this. This has been shown in Germany for another species, *Impatiens glandulifera*, which occurs in the same habitat (Hartmann *et al.*, 1995).

Phytosanitary inspections and associated measures developed for other species of Union concern (for example, *Impatiens glandulifera*, *Parthenium hysterophorus*) which can spread with the same type of commodities (especially soil originating from river banks) can act to prevent the unintentional entry of *Humulus scandens* into specific countries/regions.

To prevent the import and movement of contaminated soil with *H. scandens* seeds into and between EU Member States, soil management plans, identification guides, factsheets, and codes of conduct should be developed (Tanner, 2017).

More specifically, an ISPM Standard, no. 41 (IPPC, 2017) has been recently drafted and adopted on 'International movement of used vehicles, machinery and equipment'. This focuses on reducing the risks of transporting contaminants (soil, seeds, plant debris, pests) associated with the international movement (either traded or for operational relocation) of vehicles, machinery and equipment (VME) that may have been used in agriculture, forestry, as well as for construction, industrial purposes, mining and waste management, and military.

For those VMEs that represent a contaminant risk, the phytosanitary measures recommended are detailed in the ISPM, and cover cleaning, prevention and disposal requirements. These include cleaning using pressure washing or compressed air cleaning, chemical or temperature treatments, storing and handling VMEs that prevent contact with soil, and keeping vegetation short around storage areas of ports.

The objective of this measure is to prevent unintentional introductions and spread of *H. scandens*.

SCALE OF APPLICATION

This measure should be applied at the EU scale for all commodities at risk (especially, vehicles, machinery, equipment, as well as soil and gravel from river banks) coming from a country or area where *H. scandens* is already established. This measure would need to be applied across the EU, as once VME or soil/gravel have been imported into the EU, they could be moved to high risk areas.

EFFECTIVENESS OF MEASURE

Neutral.

Any inspection of commodities at risk could reduce potential unintentional introductions. However, given the volume of commodities introduced in the Union and moved within the Union, and given that no instances have been found where seeds of *H. scandens* have been intercepted as a contaminant (nor evidence of unintentional introduction of *H. scandens*), it seems that this measure will not be very cost-effective for this species.

It is difficult to assess whether VMEs present a risk, and therefore when to apply the relevant phytosanitary measure (IPPC, 2017). The ISPM provides a number of elements to consider when assessing risk; distance of movement (shorter distances are a lower risk), complexity of VME structure (more complex are a higher risk), origin and prior use (VME in close proximity to vegetation are a higher risk), storage (VME stored outside near vegetation are a higher risk), intended location or use (VME for use in agriculture, forestry, or close proximity to vegetation are a higher risk).

In addition, the inspection, cleaning and treatment will normally take place in the exporting country to meet import requirements. However, there are no EU regulations on phytosanitary requirements for imports of VMEs. Therefore, for the measure to be effective either regulations need to be developed to regulate VME imports, or inspections and phytosanitary measures would need to be applied at EU ports and also at EU/non-EU border facilities.

EFFORT REQUIRED

This measure needs to be applied all year-round and for a long period (as VMEs and soil at risk can be imported at any time of the year).

RESOURCES REQUIRED

The resources required include the staff time of an inspector and identification material for seed identification. This measure would need to produce identification keys for seeds and train phytosanitary inspectors to identify seeds of *H. scandens*. The seeds of *H. scandens* have a large size (4–5 mm), are yellow-brown, ovoid-orbicular, inflated to lenticular, glandless. They are very typical so identification should not be an issue. However, the measure will need repeated effort to detect the seeds among the commodities (soil for example) and continually inspect consignments and commodities at risk. In this respect, there may be the potential for developing eDNA technologies as suggested by Tanner (2017) for *Impatiens glandulifera*, but these would need to be developed as there are no known projects currently researching this technology for the species.

Facilities required for the inspection, cleaning, and treatment of VME may include: – surfaces that prevent contact with soil, including soil traps and wastewater management systems – temperature treatment facilities – fumigation or chemical treatment facilities (IPPC, 2017). In addition trained staff are needed to undertake the inspections and phytosanitary measures, and suitable disposal facilities especially if implemented within the EU.

SIDE EFFECTS

Economic effects: Negative.
Environmental effects: Positive.
Social aspects: Neutral or mixed.
Increased effort will be required to inspect all commodities at risk (for example, machinery, soil). Public works contractors, gravel operators, and all economic sectors involved in international or national VMEs and soil transportations may be negatively impacted by this measure.

Seeds of other invasive plants, including at least two other species of Union concern (*Impatiens glandulifera*, *Parthenium hysterophorus*) could be included in the measures (same commodities) and therefore also intercepted and destroyed.

ACCEPTABILITY TO STAKEHOLDERS

Neutral or mixed.
This kind of measure could receive large acceptance from the public who can see that Member States are acting pre-emptively against invasive alien species. Stakeholders involved in international or national VMEs and soil transportations may be negatively impacted by this measure. If equipment would be required to be cleaned and inspected on a regular basis, some organizations would not approve of it and this measure would be met with lots of negativity by private companies.

ADDITIONAL COST INFORMATION

Implementation cost for member States:
Implementation costs for Member States are likely to be high, as significant amounts of staff time from phytosanitary inspectors would be required. Member States would be required to maintain monitoring over a long period. Note, however, that these costs will be shared over several species, at least *Impatiens glandulifera* and *Parthenium hysterophorus* for the commodities identified at risk for *Humulus scandens*.
Cost of inaction:
See section *Prevention of intentional introductions and spread*.
Cost effectiveness of the measure:
As detailed in the sections *Measure description* and *Effectiveness of the measure*, phytosanitary inspections are not likely to be cost effective, due to both the large volume of commodities that are exchanged and the low probability of unintentional introduction of *Humulus scandens* through these pathways.
Socio-economic aspects:
None to detail.

LEVEL OF CONFIDENCE*

Established but incomplete.
There are few documents to support the information given for this measure but the main source is an official standard (IPPC, 2017) with high generic value, so even if no specific information is available for *H. scandens*, we consider that the information provided is established but may be incomplete.

* See Appendix

Measures to prevent the species spreading once they have been introduced.

Targeted engagement with public who cultivate individuals in gardens, in response to new infestations.

MEASURE DESCRIPTION

All wild populations in Europe and North America are the results of garden escapes (EPPO, 2018). Once *H. scandens* is introduced and cultivated in a new area, the next step is escape from confinement, here horticulture. Even if there were a ban on trading the species, it may still enter (through internet purchases) and it is already present as casual and/or cultivated individuals in several countries (EPPO, 2018).

Containment measures are therefore needed to avoid, above all, that introduced populations spread to areas that are not yet invaded. Containment measures may be needed to prevent spread from already established populations in natural areas to new areas, or to prevent escape from gardens where the species has been planted, into natural areas. We only considered this second case here, as the measures described in *Unintentional introductions* section above (as a contaminant of soil, and hichiker on VMEs) and also in the section *Rapid eradication for new introductions* can address the first case.

The objective of the measure is to engage with the public that cultivate individuals in gardens, to raise awareness of the species and its potential impacts and provide guidance on how to remove it appropriately. This could be targeted at the local scale in response to records of new infestations, especially when located near watercourses that will act as a corridor for dispersal. The following actions are included in this measure:

At the scale of the Union:

- raise awareness with the general public and horticultural sector that *H. scandens* is an IAS and a major threat to biodiversity etc.;
- provide guidance on how to remove *H. scandens* from their gardens (with a protocol describing hand pulling methods and including how to dispose of the plant material following uplifting).

At the scale of specific catchments in response to new infestations:

- each time a new introduced population is detected in a catchment: undertake engagement activities with local communities and stakeholders (especially those upstream of the infestation) with information on the threat posed by the species and methods of removal, and also on the need to not use or transport top soil or gravel from infested areas. In the case where *H. scandens* would be detected in non-riparian habitats, similarly investigate the presence of the species in gardens of the near surroundings;
- start controlling upstream populations to avoid recolonization of downstream invaded sites (see the section *Rapid eradication* below);

SCALE OF APPLICATION

This measure should be applied at the scale of the whole Union and at the scale of the whole catchment where the species has been detected.

EFFECTIVENESS OF MEASURE

Neutral.

While eradication measures in private gardens are technically feasible, it could be difficult to encourage all those that cultivate the species to remove it (this may be more effective if the species were listed on the EU IAS Regulation). Therefore, if gardens are connected to river systems (fences near riparian habitats), there is a significant probability that recolonization and further spread will occur. Because large portions of river banks are not regularly monitored by botanists able to identify *H. scandens* at first sight, it is also likely that *H. scandens* will be detected long after first introduction – as observed in southern France (Fried G., pers. comm.). In this case, secondary spread cannot be prevented.

Such actions of eradication in private gardens have been performed in South Africa (Foxcroft *et al.*, 2008) and are currently done for *Cortaderia selloana* on Reunion Island with good results (Julliot C., pers. comm., 2015).

The overall effectiveness of the measure is expected to be neutral. While high effectiveness is expected when infestations are isolated to areas under the control of a few landowners, efficacy could be greatly reduced because the success of the measure partly depends on people to remove plants from private property voluntarily and monitoring long stretches of river to detect new establishments with limited resources.

EFFORT REQUIRED

The eradication and control actions in private gardens would need to be applied during spring and summer. The monitoring of the (private gardens of the) whole catchment can be done during the entire period when the plant is visible (from February to late November) but more active monitoring should be performed in summer when the plant reaches its full vegetative development (see *Early detection* section).

Considering that seed longevity of *H. scandens* in the soil is about three years (Krauss, 1931), and considering that cultivated individuals could have formed a seed bank in the private gardens, it is recommended that repeated visits to managed garden sites should be continued for at least three years.

RESOURCES REQUIRED

The resources required include means of communication to reach the general public (inserts in the press, advertising, posters, and videos), staff time to monitor the catchment and manage the primary focus of introductions in private gardens. The cost of advertising the presence of the species could be shared with similar measures for other terrestrial invasive plants of Union concern that are still cultivated in gardens (*Asclepias syriaca*, *Baccharis halimifolia*, *Gunnera tinctoria*, *Heracleum* spp., *Pennisetum setaceum*, *Pueraria lobata*).

SIDE EFFECTS

Environmental effects: Positive.
Social effects: Neutral or mixed.
Economic effects: Neutral or mixed.
Engagement individuals with private gardens provides a form of education to the general public that could help with understanding the issue of invasive species in general and result in more positive action with other invasive species.

Preventing secondary spread will strongly limit the impact of the allergenic pollen of *H. scandens* on human health in the primary focus of introduction. Some people may consider negatively the removal of an ornamental plant in their garden.

ACCEPTABILITY TO STAKEHOLDERS

Neutral or mixed.
While this measure could be positively perceived by the general public, it might be difficult to convince people to allow their properties to be accessed in order to check for cultivated individuals of *Humulus scandens*.

ADDITIONAL COST INFORMATION

Communication material detailing the negative impacts of the species, why it should not be cultivated in gardens and how to eradicate it safely would be essential to educate the public and support actions to prevent secondary spread from private gardens. It is estimated that the cost for an awareness raising campaign could be up to EUR 10,000 per year for each Member State (Tanner, 2017). However, sectors of society may bear some of these costs themselves.
Cost of inaction:
See *Prevention of intentional introductions and spread* section.
Cost effectiveness of the measure:
Preventive measures such as ban from sale or eradication of source populations in gardens are usually considered as the most cost-effective measures (Simberloff *et al.*, 2013). It is particularly expected for *Humulus scandens* given its high environmental impact in riparian habitats, its potential human health impact, its minor economic value in the horticultural trade and the possibility for people to use similar non-invasive vines alternatively (EPPO, 2018).
Socio-economic aspects:
Negative socio-economic impacts would include a loss of *Humulus scandens* for people who appreciate this species in their gardens for covering fences or trellises. Positive social aspect includes a higher air quality through a reduction of the allergenic pollen of the plant in the air.

LEVEL OF CONFIDENCE*

Established but incomplete.
An "Established but incomplete" rating has been chosen as a general agreement in the literature has been found, although only a limited number of studies exist on this measure with no comprehensive synthesis and no specific studies that address the question for *H. scandens*.

* See Appendix

Measures for early detection of the species and to run an effective surveillance system for an early detection of a new occurrence.

Visual detection of existing populations.

MEASURE DESCRIPTION

Visual detection of plants in the field is the only feasible early detection method for new occurrences of *Humulus scandens* in the Union. It is possible to identify the species in the field with very little training, mainly to avoid confusion with the native *Humulus lupulus*.

A significant network of stakeholders is required to monitor all potential areas where *Humulus scandens* may occur, though sites most at risk are riparian habitats up and downstream of known infestations, that could be more specifically targeted. The staff involved could come from government agencies and/or citizen scientists.

One example in Europe is the surveillance of the Gardon River. Following the detection of invasive stands of *H. scandens*, the local River Trust (Smage des Gardons) delegated the surveillance of 80 km of river (~ 20 km upstream and ~60 km downstream of the primary focus detected) to a small firm of engineering consultants. This action enabled to detect several dozen established populations of *H. scandens*. This also showed that the plant can be present and not detected if no specific monitoring is undertaken.

SCALE OF APPLICATION

This measure can be undertaken at the sub-catchment level, but needs to be applied over the area of the Union where *H. scandens* is not yet present but has a high probability of establishment according to bioclimatic modelling (EPPO, 2018). Priority should be given to the monitoring of areas near established populations and within these areas in habitats most at risk such as riparian habitats.

EFFECTIVENESS OF MEASURE

Effective.

The different stages of *Humulus scandens* are relatively easy to identify. Readily available field guides (for example Fried, 2017) can be used to identify the species. With some training, the plant can be identified as soon as it is at the seedling stage.

Together with *Sicyos angulata*, *Humulus scandens* is the tallest European annual vine. The stem is branched and can reach a length of 0.5 to 5.0 m (Small, 1997; Balogh and Dancza, 2008), or even 9–11 m (Fried G., pers. comm.; Panke and Renz, 2013). Leaves are opposite, palmately lobed with 5–7 (–9) lobes, 5–12 cm long with petioles longer than the blade (Small, 1997; Balogh and Dancza, 2008). The male inflorescences form an erected branched panicle, 15–25 cm, while the female inflorescences are ovoid cone-like spikes.

Visual detection is commonly used by amateur and professional botanists and naturalists for recording *Humulus scandens* in the field.

EFFORT REQUIRED

The period of surveillance would be from March (seedling stage) to October (fruiting stage) with more intensive surveillance during summer months (June–September) when the plant has reached its full vegetative development and is more easily detectable.

If identified before flowering, there is the opportunity to eradicate the population (see section *Rapid eradication*). If the plant has released the seeds, the population would need to be monitored and further control measures would be needed the following seasons.

RESOURCES REQUIRED

Resources would involve staff time, travel costs and health and safety measures. Actual costs of a monitoring programme will depend on the area surveyed. Efforts could be shared with the monitoring of other invasive alien species of Union concern requiring similar surveillance in riparian habitats, especially *Impatiens glandulifera* and *Parthenium hysterophorus*.

SIDE EFFECTS

Environmental effects: Positive.
Social effects: Neutral or mixed.
Economic effects: Neutral or mixed.

As part of an early detection and rapid response strategy, this measure will have a positive effect to protect native plant communities from invasion by *H. scandens*. The surveillance of *H. scandens* can lead to the detection of other invasive alien species. The measure per se has low environmental impact and low cost to implement. Obtaining access to discrete areas of land may, however, be problematic with the division of land ownership. Thus, despite intensive surveys, if the species is not controlled at a catchment scale, seeds of remaining undetected populations can become incorporated into the waterbody and spread to colonise new areas (see Section *Prevention of secondary spread*).

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

The visual detection of *Humulus scandens* is likely to be acceptable to stakeholders and no significant impacts are envisaged. However, it should also be noted that local stakeholders may choose not to report findings to avoid associated management costs (Tanner, 2017).

ADDITIONAL COST INFORMATION

Implementation cost for Member States:

Depending on the area to survey, the implementation costs will vary considerably. In southern France, 80 km of river have been surveyed to detect *H. scandens* in 2012 and 2014, for a total cost of EUR 13,000 (Smage des Gardons, 2014). Engagement with the local environmental NGOs, citizen scientists and utilization of volunteer networks can partly reduce these costs. Finally, some regional training workshops would probably be needed to train stakeholders in identification, management and safety aspects. It is estimated that each training workshop may cost EUR 3,000 (Tanner, 2017).

Cost of inaction:

See section *Prevention of intentional introductions and spread*.

Cost effectiveness of the measure:

This measure has the potential to be very cost effective if Member States can cooperate with local natural history or botanical societies, local Wildlife Trusts or River Trusts and utilize their expertise. Regional funding should be made available to local NGOs to monitor all potential invasive alien plants. The monitoring of *H. scandens* on the Gardon river by a team of two people has been estimated at EUR 167/km to survey.

Socio-economic aspects:

There are no socio-economic aspects to detail for this measure.

LEVEL OF CONFIDENCE*

Established but incomplete.

Few documents exist but the information provided is consistent.

The height of plant has been reported to range between 0.5 and 5.0 m, but it can grow to heights of 9–11 m. © Siebold & Zucc. Public domain

* See Appendix

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

Manual and/or mechanical control of small populations at an early stage of invasion.

MEASURE DESCRIPTION

This measure involves the physical pulling of all individual *Humulus scandens* plants as well as mowing or cutting multiple times a year to prevent seed production. The objective of this measure is to achieve eradication at an early stage of invasion of small populations of *Humulus scandens*.

The following actions should also be included in this measure. When a newly introduced population is detected in a catchment:

- eradicate the population or, if not possible during the first year, manage the population to prevent seed formation and secondary spread;
- investigate and identify the source of the initial infestation (for example, presence of the plant upstream along the river), giving priority to areas near the dispersal corridors of rivers (see Section *Prevention of secondary spread of the species*);
- control source populations to avoid recolonization of invaded sites;
- communicate with stakeholders to avoid top soil river being used as gravel to prevent unintentional seed dispersal and communicate with the general public to stress that the plant is regulated and should be eradicated in private gardens.

SCALE OF APPLICATION

Given that this measure is recommended for eradication at an early stage of invasion, it is clearly implied that it applies to small areas between a few dozen m^2 up to a few hundred m^2. On the Gardon River, isolated individuals at the vegetative stage are regularly eradicated with the largest covered area by this measure reaching about 10 m^2 (Reygrobellet J.-P., pers. comm.).

EFFECTIVENESS OF MEASURE

Effective.

Combining mechanical and manual control is a very effective measure to control small infestations of *H. scandens* (Pannill *et al.*, 2009; Pank and Renz, 2013; Sarat *et al.*, 2015). If the newly introduced populations consist of only a few individuals (<50 individuals), hand pulling is sufficient and will be effective.

If the newly introduced populations are of larger size over a larger area (dense stands over 100–500 m^2), mechanical control (combined or not with manual control) will be effective. Cutting or mowing the vines as close to the ground as possible will enable the control of most individuals of the newly introduced population as long as the cutting is started early (late spring) and the entire site is thoroughly cut. The effectiveness of the mowing/cutting will be improved if the practice is repeated frequently until the plants die back in fall and/or if it is combined with hand pulling of the remaining individuals by taking care to remove the root and not just break the stem off at ground level (Pannill *et al.*, 2009; Pank and Renz, 2013).

EFFORT REQUIRED

If the plant has been detected before seed set and it is certain that it is the first year of establishment in the site (due to regular survey of the site), eradication can be achieved in one year. However, most of the time it is difficult to ascertain that a plant is still in the first year of establishment (even with annual surveys, some individuals can be missed), therefore a follow-up of the eradication is always advisable. If management occurred after seed set, the measures should be repeated the following years.

Most probably, newly introduced populations will be found several growing seasons after establishment so that *Humulus scandens* has already produced seeds stored in the soil seedbank. Considering that seed longevity in the soil is about three years (Krauss, 1931), repeated removal treatments over three years are typically needed to eradicate an infestation and exhaust the short-lived seed bank. Thus, it is recommended that repeated visits to managed sites should be continued for at least three years.

Additional effort will be required to dispose of the plant material following removal. In this case, as a part of the seeds produced in previous year are expected to have been dispersed by river floods, it is highly recommended to survey at least the next 1-km portion of the river in order to identify and eradicate potential satellite populations.

RESOURCES REQUIRED

If the newly introduced populations consist only of one to ~50–100 individuals and manual removal is intended, the costs are negligible. It has been estimated at EUR 10/m² in southern France for a total of 340m² (Smage des Gardons, 2014). At very early stages of invasion, control costs could even be lower if the hand pulling is only for a dozen scattered individuals (this would be integrated in the surveillance measures).

If the new introductions consist of already dense stands of *Humulus scandens*, mechanical control will require a mower and/or a brush cutter equipped with a grinder disk. The costs will range between EUR 0.6/m² to EUR 1.1/m² according to the method used (Sarat *et al.*, 2015).

In all cases, resources should also include safety clothes; especially, it is important to wear gloves, long pants and long sleeves due to irritating prickles on the stems and leaves of *H. scandens* (Panke and Renz, 2013).

In southern France, the manual control of *Humulus scandens* by three people has been estimated to take:
- 5h for 100 m²;
- 3h for 50 m² with lot of seedlings;
- 2h for 30 m² in an area where *H. scandens* was mixed with *Urtica dioica*;
- 1h30' for 17 m² in an area where *H. scandens* was mixed with *Arundo donax* and where *Humulus lupulus* (native) was sorted to avoid negative side-effects on these plants;
- 4h for 70 m² in a *Phragmites australis* stand where *H. scandens* was removed by taking care not to damage *Phragmites australis*.

The cost per m² controlled has been estimated to 10.40 EUR (Sarat *et al.*, 2015).

In the same area, the mechanical control of *Humulus scandens* by three people has been estimated to take:
- 1.6h for 250 m² with a simple mowing (at 15 cm above the soil);
- 1.5h for 200m² with a with a brush cutter equipped with a grinder disk close to the soil.

The cost per m² controlled has been estimated to 0.6 EUR for the simple mowing and 1.1 EUR for the grinding method (Sarat *et al.*, 2015). Thus, mechanical control is much less expensive than manual control.

SIDE EFFECTS

Environmental effects: Neutral or mixed.
Social effects: Neutral or mixed.
Economic effects: Neutral or mixed.
The process of hand-pulling can create disturbance to the soil which can have a range of negative effects to the environment (erosion, establishment of other invasive plants, etc.). If applied on few individuals, the negative side-effects are negligible but over large populations this side-effect could become severe.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.
Such proactive actions that limit costs and environmental side-effects of management generally receive a good perception by the public. If the communication actions to increase awareness about the impact and risks of the plant have not been carried out, there is nevertheless a risk of misunderstanding in relation to the management of populations that do not yet have impacts at an early stage of the invasion process.

ADDITIONAL COST INFORMATION

Implementation cost for Member States:
Implementation costs can be relatively low and engagement with the local environmental NGOs and utilization of the volunteer network can further reduce costs. Control costs range from EUR 1.1/m² (mechanical control) to EUR 10/m² (manual control) (Smage des Gardons, 2014).
Cost of inaction:
See section *Prevention of intentional introductions and spread*.
Cost effectiveness of the measure:
Mechanical and manual control methods are cost effective when controlling small populations of the species.
Socio-economic aspects:
Positive effects could include uninvaded rivers thereby enhancing cultural services and recreation activities. *Humulus scandens* can restrict access to waterbodies thus impacting on recreational activities such as fishing.

LEVEL OF CONFIDENCE*

Established but incomplete.
An "Established but incomplete" rating has been chosen as we found a general agreement in the literature although no specific studies exist that address the question for *H. scandens*.

* See Appendix

Manual control (hand pulling).

MEASURE DESCRIPTION

Manual control methods consist in the physical pulling of individual *Humulus scandens* plants. *Humulus scandens* can be pulled any time of the year. It does not develop an extensive or deep root system and as a result is fairly easy to pull or dig early in the season, especially when the soil is moist. Ideally, however, this should be done between the seedling stage and the beginning of flowering. The most favourable period seems to be the end of spring (April – May) while the roots are small and before the vines become tangled with other vegetation (Pannill *et al.*, 2009). Moreover, at this period, intra-specific competition has reduced the number of individuals (compared to the "seedling" stage), while the biomass is not yet too important.

If the intervention takes place on individuals that are climbing in the canopy, an uprooting of the underground part can be enough to stop the development of the species. When the species forms relatively dense "mats" within open vegetation, the manual uprooting of the aerial part is facilitated by the possibility of "wrapping and rolling" the plant material. However this method will have more negative side effects on other resident species. A second passage should remove the remaining roots in order to stop the recolonization of the species. The torn biomass (above and below ground) should be destroyed.

The objective is to control small populations at the front of colonisation or where access for other control methods is difficult.

SCALE OF APPLICATION

Hand pulling is slow and labor-intensive and best suited for fairly small infested areas (Pannill *et al.*, 2009). Examples in France ranges between 10 and 100 m² (Sarat *et al.*, 2015).

EFFECTIVENESS OF MEASURE

Effective.

This is an effective method but care must be taken to remove the root and not just break the stem off at ground level (Pannill *et al.*, 2009). The effectiveness in season has been estimated between 70 and 90% by Panke and Renz (2013).

EFFORT REQUIRED

Within a growing season, regular staggered emergences of *H. scandens* seedlings occur between February and May. Therefore, either a monthly pulling and monitoring is required, or at least two passages in the middle and at the end of the period to ensure that the current infestation is eradicated. Considering that seed longevity in the soil is about three years (Krauss, 1931), repeated removal treatments over three years are typically needed to eradicate an infestation and exhaust the short-lived seed bank. Thus, it is recommended that repeated visits to managed sites should be continued for at least three years. In areas subject to flooding that may receive influx of seed from upstream infestations, longer-term monitoring and management will be necessary.

Hand pulling can be labour intensive and often teams of volunteers spend full days in the field pulling plants. Additional effort is also required to dispose of the plant material following uplifting.

RESOURCES REQUIRED

Little specific material is needed for this management method compared to chemical or mechanical control. Safety clothes should be worn, especially it is important to wear gloves, long pants and long sleeves due to irritating prickles on the stems and leaves (Pannill *et al.*, 2009; Panke and Renz, 2013). See also the section on *Rapid eradication for new introductions* above.

SIDE EFFECTS

Environmental effects: Neutral or mixed.
Social effects: Positive.
Economic effects: Neutral or mixed.

Manual control is the most targeted method, with the least likelihood of damage to other plants (Pannill *et al.*, 2009). However when growing together with the native *Humulus lupulus* it is sometimes difficult to separate the two species (Sarat *et al.*, 2015). When controlling dense stands with the technique of "rolling the vine's mats", it is clear that part of other resident plant species will also be pulled out (Sarat *et al.*, 2015).

One adverse consequence of manual control is that it can leave banks bare and without root systems to hold soil in place, thereby adding to the potential for erosion as well as for new colonisation by *H. scandens* and/or other invasive alien species. This is why manual control should be accompanied by restoration measures (see *Management* section, *Ecological control: manipulating the environment for restoring ecosystem to increase bottom-up and top-down regulations*).

Any control of *Humulus scandens* can be viewed as positive for public health. The pollen of *H. scandens* is allergenic (Park *et al.*, 1999), so control of *Humulus scandens* will improve air quality for people that are sensitive. Note that currently, there is no evidence of allergies due to *H. scandens* in Europe. The social effects described here are potential positive effects based on impact in the native area of the plant.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

Manual control would be perceived as more environmentally acceptable to stakeholders compared to chemical applications, especially for environmental NGOs involved in management actions but also for the general public.

ADDITIONAL COST INFORMATION

Implementation costs for Member States:

Among the available methods, manual control is the most expensive (10EUR/m^2) and it is rarely considered at large scales. However, implementation costs for Member States will be relatively low based on the possibilities to develop engagement with local environmental NGOs and/or the utilization of volunteer networks that can reduce costs.

Cost of inaction:

See section *Prevention of intentional introductions and spread*.

Cost-effectiveness:

Manual control is a cost-effective method for controlling small populations of an annual invasive plant such as *H. scandens* especially when this measure is coordinated by NGOs.

Socio-economic aspects:

Positive effects could include uninvaded rivers thereby enhancing cultural services and recreation activities. *H. scandens* can restrict access to waterbodies thus impacting on recreational activities such as fishing.

LEVEL OF CONFIDENCE*

Established but incomplete.

Currently, few trials of *Humulus scandens* control methods have been conducted in Europe and in the world. However, all the sources that provide feedback on control methods (Pannill *et al.*, 2009; Pank and Renz, 2013; Sarat *et al.*, 2015) are consistent. Thus, there is a high degree of confidence in the relevance of the information given for this measure, though it may still be incomplete.

* See Appendix

Mechanical control.

MEASURE DESCRIPTION

Mechanical control includes mowing or cutting the plants. As for manual control, the most favorable period seems to be the end of spring. Grinding with a brushcutter equipped with a grinder disk can effectively stop the growth of the species (Sarat *et al.*, 2015). Depending on the development of the species in the two following years, a new mechanical treatment and/or manual grubbing-up (if there are few new individuals) should be planned to stop the recovery of the population. According to tests carried out by the Smage des Gardons in southern France (Sarat *et al.*, 2015), a simple mowing does not allow effective control of the species because of the rapid regrowth of plants and the many inflorescences observed at the end of the season, despite a mowing in early July. A second passage would therefore be necessary to achieve a good control level.

If seed are present, it is recommended to use a mower that bags cut material, or rake and bag the cut material after mowing, and finally to dispose of cut material in a landfill or burn it to avoid spreading seeds to other areas (Panke and Renz, 2013).

The objective is to control established populations of large size (>100 m²).

SCALE OF APPLICATION

This method can be applied for larger infested areas than manual control, typically between 100 and 1,000 m² or more. In southern France 450 m² have been controlled by three people in two hours (Sarat *et al.*, 2015).

EFFECTIVENESS OF MEASURE

Effective.

Cutting or mowing the hop vines as close to the ground as possible could be an effective control method as long as the cutting is started early (late spring), the entire site is thoroughly cut, and the practice is repeated frequently until the plants die back in fall (Pannill *et al.*, 2009). According to tests carried out by the Smage des Gardons, a simple mowing at 15 cm above the soil does not allow effective control of the species because of the rapid regrowth (Sarat *et al.*, 2015). The population of *Humulus scandens* can quickly re-grow from the cut stems (new stems growing from lateral meristems) and from uncut vines. If successful, mowing tends to retain and promote the development of perennial grasses.

EFFORT REQUIRED

Cutting or mowing is not appropriate for young stages of the plant. The best timing for the first passage would be in late spring (May–June) and it should be followed by a second passage in summer (July) to control the lateral re-growth of the cut stems or uncut stems (for example, not well controlled at first passage). A unique passage with a brush cutter equipped with a grinder disk seems possible in July (Sarat *et al.*, 2015). Considering that seed longevity in the soil is about three years (Krauss, 1931), repeated removal treatments over three years are typically needed to eradicate an infestation and exhaust the short-lived seed bank. Thus, it is recommended that repeated visits to managed sites should be continued for at least three years. In areas subject to flooding that may receive influx of seed from upstream infestations, longer-term monitoring and management will be necessary.

Additional effort will be required to dispose of the cut plant material following in order they cannot re-root or disperse seeds.

RESOURCES REQUIRED

The equipment needed includes a mower and/or a brush cutter equipped with a grinder disk. Safety clothes should be worn, to protect the body against the projection of pebbles, small objects, or dust. Similarly to manual control, it is important to wear gloves, long pants and long sleeves due to irritating prickles on the stems and leaves (Panke and Renz, 2013).

In southern France, the mechanical control of *Humulus scandens* by three people has been estimated to take:

- 1.6h for 250 m² with a simple mowing (at 15 cm above the soil);
- 1.5h for 200m² with a with a brush cutter equipped with a grinder disk close to the soil.

The cost per m² controlled has been estimated to EUR 0.6 for the simple mowing and EUR 1.1 for the grinding method (Sarat *et al.*, 2015). Thus, mechanical control is much less expensive than manual control.

SIDE EFFECTS

Environmental effects: Neutral or mixed.
Social effects: Positive.
Economic effects: Neutral or mixed.

If *Humulus scandens* is present in an area of conservation value with non-targeted species of interest, mechanical control can have adverse effects on these species. Attempts to mow through tree planting sites with tangles of hop vines covering the trees can result in the vines pulling out trees and breaking tree shelters (Pannill *et al.*, 2009).

One adverse consequences of mechanical control is that it can leave banks bare and without root systems to hold soil in place, thereby adding to the potential for erosion as well as for new colonisation by *H. scandens* or other invasive alien species. This is why mechanical control should be accompanied by restoration measures (see *Management* section, *Ecological control: manipulating the environment for restoring ecosystem to increase bottom-up and top-down regulations*)

Any control of *Humulus scandens* can be viewed as positive for public health. The pollen of *H. scandens* is allergenic (Park *et al.*, 1999), so control of *Humulus scandens* improve air quality for people that are sensitive. Note that currently, there is no evidence of allergies due to *H. scandens* in Europe. The social effects described here are potential positive effects based on impact in the native area of the plant.

None to detail outside from the cost of management.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

Similarly to manual control, mechanical control of the species would be more acceptable to stakeholders compared to chemical control, especially for environmental NGOs involved in management actions but also for the general public.

ADDITIONAL COST INFORMATION

Implementation costs for Member States:

Control costs ranged from EUR 0.6 to 1.1 per m² for relatively small stands (200–250 m²). Implementation costs for Member States are expected to be relatively low based on the possibilities to develop engagement with local environmental NGOs and/or the utilization of volunteer networks that can further reduce costs.

Cost of inaction:

See section *Prevention of intentional introductions and spread*.

Cost-effectiveness:

Mechanical control is a cost-effective method for controlling medium-sized populations of *H. scandens* especially when this measure is coordinated by NGOs.

Socio-economic aspects:

Positive effects could include uninvaded rivers thereby enhancing cultural services and recreation activities. *H. scandens* can restrict access to waterbodies thus impacting on recreational activities such as fishing. If the control program is done by teams of previously unemployed people it can also have a positive effect on employment.

LEVEL OF CONFIDENCE*

Established but incomplete.

Currently, few trials of *Humulus scandens* control methods have been conducted in Europe and in the world. However, all the sources that provide feedback on control methods (Pannill *et al.*, 2009; Pank & Renz, 2013; Sarat *et al.*, 2015) are consistent. Thus, there is a high degree of confidence in the relevance of the information given for this measure, though it may still be incomplete.

Humulus scandens *germinates in early spring.*
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* See Appendix

Chemical control.

MEASURE DESCRIPTION

Note: There is no information available for chemical control of *Humulus scandens* in Europe. All the information given below is from the United States of America.

Chemical control of *Humulus scandens* can be obtained by controlling seedlings as they germinate (pre-emergent herbicides), actively growing plants (post-emergent herbicides) or a combination of the two.

Pre-Emergent Herbicides. The use of pre-emergent herbicides is potentially valuable in controlling *Humulus scandens* (Pannill *et al.*, 2009). However, seeds of *Humulus scandens* are large (about 4–5 mm) and it is therefore harder to prevent their successful germination than it is for weed species with smaller seeds. Calibration of spray equipment and uniform application of the targeted rate (amount per ha) is crucial when using pre-emergent herbicides (see Table below).

Post-Emergent Herbicides. Post-emergent herbicides are products that kill emerged, growing plants in seedlings to adult stages. It is the most common approach for weed control and it has also been found to be effective for management of *Humulus scandens* (Pannill *et al.*, 2009). Two treatments (mid and late summer) are recommended in order to prevent seed production.

Pre-emergent applications can be combined with post-emergent herbicides applied later in the season in order to provide a longer period of control and preventing production of seeds before frost. To be fully effective in preventing the fall seed set, such combinations should include a pre-emergent herbicide in early March (or even slightly later if using a product with post-emergent properties), followed by post-emergent application in mid-summer (Pannill *et al.*, 2009).

The herbicide options can also be combined with efforts to pull vines (manual control) or regularly mowing (mechanical control).

The information on chemical control included in the following Table was adapted from Panke & Renz (2013), completed with Pannill *et al.* (2009).

It is important to note that EU/national/local legislation on the use of plant protection products and biocides needs to be respected and authorities should check to ensure chemicals are licensed for use in their respective countries/regions. A column has been added to indicate if the active ingredient has an EU approval or not.

These active ingredients also provide a pre-emergent activity on *Humulus scandens*.

Compared to manual and mechanical control, the advantage of chemical control is that it is a less expensive method, and it can be carried out later in the season (mid and late summer with a post-emergence strategy), and long lance sprayer may enable to spray in less accessible areas. Another point is that plant dies in situ so that no management of plant material is needed after treatment. Finally, a positive aspect of herbicide application is reduced soil disturbance.

However, there are numerous disadvantages that can minimize the effectiveness of this method: i) application's effectiveness depends on weather conditions, ii) operators can easily miss some plants, iii) herbicides may only be applied by licensed herbicide applicators. Moreover, they can be significant restrictions in use of herbicides, and this will especially be the case in the most suitable habitat of *Humulus scandens* on river banks in close vicinity of water. Also it could be problematic to use herbicides in publicly accessible areas.

SCALE OF APPLICATION

This measure could be applied from small to relatively large stands of *H. scandens*. A land manager may choose to use herbicides in small infestations if preventing soil disturbance is of concern, and desirable plants are present that the herbicide selected would not harm. Due to lower management cost per m^2 compared to manual or mechanical control, a land manager could use herbicides in large infestations. There are no detailed figures available but several thousands of square meters could be a good rough estimation of large scale applications. However, it should be kept in mind that *H. scandens* mostly develop on river banks and that it is often forbidden to spray herbicides close to water surfaces. This could significantly reduce the scale of application of this measure.

EFFECTIVENESS OF MEASURE

Effective.

Depending on the product used and the field conditions, chemical control showed 70 to 100% effectiveness (Pank & Renz, 2013). Among pre-emergence herbicides, sulfometuron methyl (Oust® XP at a rate of 70 g/ha) was found in trials to have the most long-lasting control (through July). Metsulfuron methyl, simazine, pendimethalin, and imazapic also provided good pre-emergent control but did not control seeds germinating after June (Pannill *et al.*, 2009).

Of the post-emergent products tested in the USA, metsulfuron methyl (Escort XP® at 70 g/ha) and glyphosate (Accord Concentrate® at 2.33 l/ha) provided the greatest control (Pannill *et al.*, 2009). However, when only one application was applied at least some seeds were produced in all plots, even where the treatments were most effective. More research would be needed to identify the best timing and herbicides to manage Japanese hop.

EFFORT REQUIRED

Pre-emergent applications should be made in mid-March, although products that possess both pre- and early post-emergent properties may be used through mid-April. Alternatively, if the window of opportunity for pre-emergent application is missed, a combination of a pre-emergent herbicide plus a fairly low rate of a post-emergent herbicide, thoroughly applied to reach the tiny hop plants and seedlings through other vegetation or debris, may be very effective in controlling new growth.

Ideally, the first application of post-emergent herbicides would be made after most seeds have germinated (mid-April to mid-May) and before hop vines are covering shrubs or trees (early June to late July, depending on tree size) or before seed formation starts (August). Treatments in August or later can lessen the damage from hop vines and reduce seed production. Applications timed closer to the initiation of seed formation are more likely to prevent seed production before frost. In study plots in the USA where post-emergent treatments were applied in June, no newly germinated hop seedlings were observed for the remainder of the growing season (Pannill *et al.*, 2009)

Effective combinations include a pre-emergent herbicide in early March, or slightly later if using a product with post-emergent properties, followed by post-emergent application in mid-summer, or two post-emergent treatments (mid and late summer) to prevent the fall seed set.

Due to the staggered emergences of *H. scandens* between February and May, one treatment is not sufficient and two treatments within a growing season are required (see above). Considering that seed longevity in the soil is about three years (Krauss, 1931), repeated chemical treatments over 3 years are typically needed to eradicate an infestation and exhaust the short-lived seed bank. In areas subject to flooding that may receive influx of seed from upstream infestations, longer-term monitoring and management will be necessary (Pannill *et al.*, 2009).

RESOURCES REQUIRED

Resources required for chemical control include equipment, for example sprayer backpack (EUR 150), staff time, travel costs, safety equipment. Repeated visits would be needed over at least two or three seasons. Detailed costs of chemical control for *H. scandens* have not been found.

SIDE EFFECTS

Environmental effects: Negative.
Social effects: Neutral or mixed.
Economic effects: Neutral of mixed.
Often there are restrictions on the chemicals that can be used, if any, due to the sensitivity of the invaded habitat. Non-target damage of native plants is a negative side effect of this control method. Many herbicides which are effective on *Humulus scandens*, such as Glyphosate® will also kill other plants growing close by 1–2 m from the target plant.

In this respect, the advantage of pre-emergent herbicides (that control plants as they germinate) are that, depending on product, rate and timing, pre-emergents may be used safely early in the season on bare soils where the presence of dense stands of *H. scandens* is known, generally causing minimal or no damage to other perennial vegetation. However, this will still have non-intended effects on other annual species present in the seed bank.

Another adverse consequence of chemical control is that it can leave banks bare and without root systems to hold soil in place, thereby adding to the potential for erosion as well as for new colonisation by *H. scandens* and/or other invasive alien species. This is why chemical control should be accompanied by restoration measures (see *Management* section, *Ecological control: manipulating the environment for restoring ecosystem to increase bottom-up and top-down regulations*).

Any control of *Humulus scandens* can be viewed as positive for public health. The pollen of *H. scandens* is allergenic (Park *et al.*, 1999), so control of *Humulus scandens* improves air quality for people that are sensitive. Note that currently, there is no evidence of allergies due to *H. scandens* in Europe. The social effects described here are potential positive effects based on impact in the native area of the plant. On the other hand, the use of pesticides to control invasive alien species may be perceived negatively by the general public and decrease public acceptance of the need to regulate and manage invasive alien species (Tassin *et al.*, 2014).

ACCEPTABILITY TO STAKEHOLDERS

Unacceptable.
Chemical control may be viewed negatively by stakeholders due to numerous potential non-target damages on resident vegetation and due to contamination of water. In addition, there will be many areas where chemical application is not allowed for example in the near vicinity of standing water, for example, along rivers, sites of conservation value, etc.

Type of herbicides	Recommended rate	Effectiveness in season (%)	Effectiveness after treatment (%)	Timing	EU approval
Pre-emergence					
pendimethalin	100–134 fl oz/A (3.0–4.0 lb a.i./A)	70-90	50-70	Apply prior to germination of seedlings. Spring applications will maximize control, autumn or winter applications may suppress seedlings the following spring.	Yes
simazine	No detailed information available	–	–	–	No
Post-emergence					
2,4-D	broadcast: 1.0–2.0 lb a.e./A spot: For a 3.8 lb a.e./ gal product. 0.5–2.0% (0.02–0.08 lb a.e./gal)	70-90	70-90	Apply when target species is actively growing and fully leafed out. Reapply if additional seedlings germinate after application.	Yes
aminopyralid*	broadcast: 32 fl oz/A (1.0 lb a.e./A), spot: Equivalent to broadcast rates.	90-100	70-90	Apply when target species is actively growing and fully leafed out. Reapply if additional seedlings germinate after application.	Yes
dicamba	broadcast: 32 fl oz/A (1.0 lb a.e./A), spot: Equivalent to broadcast rates.	70-90	50-70	Apply when target species is actively growing and fully leafed out. Reapply if additional seedlings germinate after application.	Yes
glyphosate	broadcast: 0.75–1.0 lb a.e./A, spot: For a 3 lb a.e./ gal product. 1.0–2.0% (0.03–0.06 lb a.e./gal)	70-90	50-70	Apply when target species is actively growing and fully leafed out. Reapply if additional seedlings germinate after application.	Yes

Type of herbicides	Recommended rate	Effectiveness in season (%)	Effectiveness after treatment (%)	Timing	EU approval
triclopyr	broadcast: 16 fl oz/A (0.5 lb a.e./A), spot: 1–2% (0.04–0.08 lb a.e./gal)	70-90	70-90	Apply when target species is actively growing and fully leafed out. Reapply if additional seedlings germinate after application.	Yes
Metsulfuron-methyl*	broadcast: 1 oz/A (0.6 oz a.i./A), spot: 0.04 oz/gal (0.02 oz a.i./gal)	90-100	70-90	Apply when target species is actively growing and fully leafed out.	Yes
Sulfometuron-methyl*	broadcast: 1.0 oz/A (0.75 oz a.i./A), spot: Equivalent to broadcast rates.	70-90	70-90	Apply when target species is actively growing and fully leafed out.	Yes
Imazapic*	No detailed information available	–	–	–	No

*These active ingredients also provide a pre-emergent activity on *Humulus scandens*.

ADDITIONAL COST INFORMATION

Implementation cost for Member States:
Based on the costs information available for another annual invasive species (*Impatiens glandulifera*), it could range from EUR 0.6/m^2 (for chemical application) to EUR 11.6/m^2 when habitat restoration is included (Tanner, 2017).

Cost of inaction:
See section in *Prevention of intentional introductions and spread*.

Cost effectiveness of the measure:
Chemical control is cost effective when controlling small to medium-sized populations.

Socio-economic aspects:
See section in *Rapid Eradication*.

LEVEL OF CONFIDENCE*

Well established.
Several documents summarizing the experience of chemical control of *H. scandens* in the USA are consistent in their content so that the level of confidence is well established.

* See Appendix

In Europe, flowering occurs from July to September.

Ecological control: manipulating the environment for restoring ecosystems to increase bottom-up and top-down regulation.

MEASURE DESCRIPTION

Previous curative management measures (especially mechanical and chemical control) have the disadvantage of disturbing all (or almost all) the vegetation and in so doing promote the recolonization of the site by *H. scandens* and/or other invasive alien species (MacDougall and Turkington, 2005). More generally, it is known that *H. scandens* will more easily establish and invade disturbed and eutrophic riparian habitats with bare soil and low tree canopy cover. A study conducted in southern France showed that establishment success of *H. scandens* was highest where spring resident vegetation was less than 25% cover (measured over 4 m^2), tree canopy cover was <35% and soil N content was > 1.1g/kg (Fried *et al.*, 2018). In sites with higher vegetation level on the ground, higher tree canopy cover and poorer soil resources, *H. scandens* germinated but failed to establish. Therefore, manipulating the environment to reduce sites' suitability for *H. scandens* can be effective as a sustainable control strategy of *H. scandens* (Pannill *et al.*, 2009).

At the catchment scale, partnerships with farmers need to be developed to reduce fertilization levels and/or avoid fertilization runoffs from cultivated plots to the river systems. This could reduce eutrophication and limit the development of opportunistic invasive alien species such as *H. scandens* whose performance becomes higher than native analogue species particularly when resources become abundant (Fried *et al.*, 2018).

Where the riparian forests have been degraded, replanting trees and shrubs can prevent the establishment of *H. scandens*, which needs high levels of light (heliophilous species) to grow correctly and to display its invasive behaviour (Fried *et al.*, 2018). As soon as the tree canopy closes, the hop will cease to be a problem (Pannill *et al.*, 2009). Practices that favour fast tree growth, early crown closure, and heavy shade will help the new stand survive and outgrow the Japanese hop. These include planting fast-growing tree species that are adapted to the site and that will create dense shade in spring and summer and spacing the plants close together (Pannill *et al.*, 2009).

Where herbaceous vegetation on the ground has been disturbed (for example, during mechanical or chemical management of *H. scandens*), seeding grasses and/or sedges can be an effective way to prevent recolonization from the seedbank or from upstream sites (Panke and Renz, 2013).

These measures should be combined at the different scale of the catchment, site and plot levels.

The objective of these measures could be i) specifically to prevent re-colonization of *H. scandens* after curative management by mechanical or chemical means, or more generally ii) to prevent establishment of *H. scandens* in riparian habitats, especially where human activities have degraded the riparian habitats.

Note: as there are currently no known biological control agents for *H. scandens* we do not include biological control as a distinct measure for management. However, this would be part of a comprehensive ecological management in the broad sense for example, including an increase of top-down regulations (by natural enemies) in addition to bottom-up regulation (competition with resident vegetation as developed above). Therefore we include here a short note on the current knowledge on biological control of *H. scandens*.

The U.S. Forest Service has been investigating natural enemies of plants of Asian origin that are invasive in the U.S. (Zheng *et al.*, 2004). They have identified two moths (*Epirrhoe sepergressa* and *Chytonix segregata*) and one fungus (*Pseudocercospora humuli*), as potential natural enemies of Japanese hop and will continue research on those species. The Japanese beetle (*Popillia japonica*) has also been observed to feed on hop but did not cause extensive damage. Zheng *et al.* (2004) reviewed the natural enemies feeding on *H. scandens*. Nine fungi are known to infect species of the genus *Humulus* with only one, *Pseudocercospora humuli*, that may be specific to *H. scandens*. Of the 27 insects associated with plants of the genus Humulus, two species, *Epirrhoe sepergressa* and *Chytonix segregata*, may have narrow host ranges (Zheng *et al.*, 2004). In its native range, *H. scandens* is considered as one of the two main host of *Apolygus lucorum* (Heteroptera: Miridae) (Lu *et al.*, 2012). *Amara gigantea*, a granivorous beetle was observed to feed particularly on *H. scandens* seed in Japan (Sasakawa, 2010). Other herbivorous animals feeding on *H. scandens* in the native range include *Polygonia c-aureum* Linné (Nymphalidae), the major Lepidopteran pest of *H. scandens*, the mite *Armascirus taurus* (Kramer) collected in Shanghai (Balogh and Dancza, 2008).

SCALE OF APPLICATION

This measure should be applied at large scale (10–100 km^2), at the level of the whole catchment in which *H. scandens* is present (in the case of restoration after management) or potentially present (in the case of preventive management).

EFFECTIVENESS OF MEASURE

Effective.

As an annual species, *H. scandens* is very sensitive to competition with established (perennial) vegetation in the early stage of its development (seedling stage). A study and several management reports indicated that in sites where established vegetation is well developed on the ground in early spring, the development of *H. scandens* will be limited in the following summer (Pannill *et al.*, 2009; Fried *et al.*, 2018). This is consistent with a study that showed in another context (serpentine grasslands in California) that the establishment of spring germinating annual invaders (such as *H. scandens*) was lower when resident communities were composed of perennial and autumn-germinating annuals (Hooper and Dukes, 2010). Areas with dense cover of perennial grasses such as *Agrostis stolonifera* were unsuitable for the establishment of *H. scandens* (Fried *et al.*, 2018). Therefore, seeding grasses and/or sedges seems an effective, long-term measure that has the potential to lower the suitability of the environment for *H. scandens*.

EFFORT REQUIRED

Seeding grasses and/or sedges as well as planting trees should be done in autumn or in spring depending on the region, in all cases before the rain period in order to facilitate the rooting of the sowing or plantations.

This measure will necessitate a strong initial effort (seeding grasses/sedges, planting trees, working with farmers and other stakeholders at the catchment scale to reduce pollutions in the river system) but if actions are successful, this measure does not need to be repeated over numerous years as for curative management. A simple survey to check that *H. scandens* establishment is prevented would be sufficient during the following years.

RESOURCES REQUIRED

Restoring ecosystems could represent a large amount of staff, equipment and costs (for seeding and replanting native vegetation). The cost of grass seeds for sowing 1ha is about EUR 150–200. Most of the cost will correspond to the time for staff to sow the herbaceous species and plant the sedges and/or the trees. However, these costs could be considered as largely shared with the sustainable management of many if not all other invasive alien plants of Union concern.

SIDE EFFECTS

Environmental effects: Positive.
Economic effects: Neutral or mixed.
Social effects: Positive.

Seeding native herbaceous species and replanting trees to restore riparian forests will not only have a positive effects for controlling invasive alien plants but will improve ecosystem services associated with riparian habitats, such as the provision of food, moderation of stream water temperature via evapotranspiration and shading, provision of a buffer zone that filters sediments and controls nutrients, and stabilization of stream banks. It also provides a corridor for the movement of biota (Hood & Naiman, 2000).

Any control of *Humulus scandens* can be viewed as positive for public health. The pollen of *H. scandens* is allergenic, so control of *Humulus scandens* improve air quality for people that are sensitive.

Although initial investment may be perceived as high, this is the only management measure that does not need to be repeated each year if revegetation is successful. On the medium-long term, it has rapidly positive economic effects with the cost of curative management saved. This likely would be less expensive in most cases compared to management exclusively.

ACCEPTABILITY TO STAKEHOLDERS

Neutral or mixed.

Public perception of this measure is expected to be positive. However, there may be problems with economic sectors who exploit gravel and could disturb riparian habitats (including tourism), and with the agricultural sector who might be reluctant to regulate the level of fertilisation inputs.

ADDITIONAL COST INFORMATION

Implementation cost for member States:

Detailed costs of ecological restoration for *H. scandens* have not been found. Based on the costs information available for another annual invasive species (*Impatiens glandulifera*), it could represent EUR 11/m^2 (Tanner, 2017). It should be kept in mind that these costs will be largely shared with the sustainable management of many if not all other invasive alien plants of Union concern.

Cost of inaction:

See section in *Prevention of intentional introductions and spread*.

Cost effectiveness of the measure:

Ecological control is very cost effective when managing large populations over large scale. Moreover, it will be efficient for regulating several other invasive alien species (at least *Impatiens glandulifera*, *Parthenium hysterphorus*).

Socio-economic aspects:

Positive effects could include uninvaded rivers thereby enhancing cultural services and recreation activities.

LEVEL OF CONFIDENCE*

Established but incomplete.

Although there are few case studies of integrated ecological management so far, and no specific examples for *H. scandens*, the confidence level of the information provided is established but incomplete. Biotic resistance is a well-established mechanism to explain unsuccessful establishment of invasive alien plants (Levine *et al.*, 2004).

* See Appendix

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Appendix

Level of confidence provides an overall assessment of the confidence that can be applied to the information provided for the measure.

- **Well established:** comprehensive meta-analysis[1] or other synthesis or multiple independent studies that agree.
- **Established but incomplete:** general agreement although only a limited number of studies exist but no comprehensive synthesis and/or the studies that exist imprecisely address the question.
- **Unresolved:** multiple independent studies exist but conclusions do not agree.
- **Inconclusive:** limited evidence, recognising major knowledge gaps.

1 A statistical method for combining results from different studies which aims to identify patterns among study results, sources of disagreement among those results, or other relationships that may come to light in the context of multiple studies.

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