T. sebifera is a prolific seed producer adapted to grow in a wide range of habitats.

The management of Chinese tallow tree (*Triadica sebifera*)

Measures and associated costs

Scientific name(s)	*Triadica sebifera* (L.) Small (ITIS Standard Report 2018) [previously *Sapium sebiferum*]
Common names (in English)	Chinese tallow tree
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Common names

BG	–
HR	Kineski pelud
CZ	Kožokvět lojonosný
DA	Kinesisk vokstræ
NL	Talgboom
EN	Chinese tallow
ET	Hiina rasvapuu
FI	Kiinantalipuu
FR	Arbre à suif
DE	Chinesischer Talgbaum
EL	–
HU	–
IE	Crann geire Síneach
IT	Albero del sego
LV	–
LT	Taukinis žvakmedis
MT	Is-siġra tas-sapun
PL	Smokrzyn łojodajny
PT	Árvore-do-sebo
RO	Alunul chinezesc
SK	Lojovec voskový
SL	Kitajski lojevec
ES	Árbol del sebo
SV	Kinesiskt talgträd

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

Triadica sebifera is a medium-sized deciduous tree that can grow up to 16 meters tall (CABI, 2018). The species is native to Asia, including China, Japan, and Vietnam. It has been introduced widely across the globe for its ornamental value and commercial applications in industry. The tree has most widely been introduced to the United States, but it also has been planted in Europe, South America, Africa, Asia and Australia (CABI, 2018; EDDMAPS, 2018; GBIF, 2018). Following introduction to the United States and Australia, it escaped cultivation and spread such that it is now widely naturalized in both countries (NSW Government Factsheet, 2017; USDA, 2008). *Triadica sebifera* currently does not occur in the natural environment in the European Union.

To develop effective measures to prevent the introduction and spread of the species in the EU and determine costs of such measures, the pathways and mechanisms for introduction and spread and how to detect the species must be considered. In addition, the biological characteristics of *T. sebifera* present some unique challenges for prevention of spread, eradication, and management. For example, it has been reported that more than 95% of *T. sebifera* seeds can initially be viable (Renne, Barrow, Randall and Bridges, 2002) and adult trees can produce over 100,000 seeds per year (USDA, 2008; Jubinksy and Anderson, 1996; Bruce, Cameron, Harcombe and Jubinsky,1997). Additionally, dispersal of *T. sebifera* plants can occur intentionally through ornamental or commercial plantings and additionally seeds can be spread by birds and water (Bruce, Cameron and Harcombe, 1997;Jubinksy and Anderson, 1996; Renne, Gauthreaux Jr and Gresham, 2000). However, the current lack of documented established trees in natural areas of the EU and the fact that most trees are not reproductive for 3–8 years (Duke, 1983) suggests it is possible to prevent invasions of this species in the EU.

Prevention of introductions. The primary pathway of intentional introduction is the transport of seeds or plants for planting. A ban on the import of plants and seeds and restrictions on growing the species across member states is critical to prevent intentional introduction to the EU. Unintentional introduction of *T. sebifera* is relatively unlikely due to the fairly large seed size of the species. There is a low chance that *T. sebifera* would be a contaminant of crop or horticultural seed mixes or in bird seed. Seeds are not likely to be hitchhikers on people or animals.

Prevention of secondary spread. *Triadica sebifera* is not currently known to occur in the natural environment of the EU. However, if the species were to establish in the EU, it could be spread by water along creeks, streams, or drainage canals, or overland during heavy rain and flooding events (Bruce *et al.*, 1997).

Measures to support early detection. Identifying newly established *T. sebifera* individuals or populations in natural areas will require activities to educate natural resource professionals, people interested in gardening and horticulture, and citizen scientists. Identification of the species is relatively easy due to its unique leaf structure and bark. Individual trees are reproductively mature at approximately 3–8 years old (Duke, 1983) so ‘early detection’ could include any activity within that timeframe.

Rapid eradication of new introductions. Early detection is important for preventing establishment of *T. sebifera* in natural areas because it would allow for eradication prior to seed production and dispersal. Manual or mechanical removal is the safest and most direct and effective method to rapidly eradicate newly established individuals or populations. All belowground parts of the plant need to be removed to maximize effectiveness.

Management of established populations. Manual, mechanical, and chemical options are available for management of older, more established populations of *T. sebifera*. The amount of effort, cost, and effectiveness varies widely by method.

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 *T. sebifera*.

MEASURE DESCRIPTION

Triadica sebifera is not known to currently occur in natural areas in the European Union but the species was listed as one of nearly 100 species that are likely to "arrive, establish, spread and have an impact on biodiversity or related ecosystem services in the EU over the next decade" (Roy *et al.*, 2015). In the United States and Australia, where *T. sebifera* has been repeatedly introduced and widely planted (Bruce *et al.*, 1997; Siemann and Rogers, 2003a,b; Camarillo, Stovall and Sunda, 2015), it has escaped cultivation and spread into natural areas and disturbed habitats, in particular open habitats near waterways (McCormick, 2005; Gan *et al.*, 2009; Pile *et al.*, 2017). It is unknown if invasions would have occurred had the species not been intentionally introduced and planted widely.

Intentional introduction as an ornamental plant, and subsequent escape, is the most likely mechanism by which the species could eventually occur in natural environments in the EU. The species is desirable as an ornamental in Asia but there is not currently a significant commercial value in the EU. Historically, the oil (from seed) and tallow (from the seed covering) derived from the plant was used for various purposes from candle making to machine oil to wood products, and it is still used in Chinese medicine (USDA, 2008; Gao *et al.*,2016).

Banning the import of *T. sebifera* to the EU, cultivation of the species, and trade among Member States will be critical for preventing intentional introductions. For example, as of October 2018, the species was purportedly available for purchase at multiple online seed suppliers in the UK although the volume of sales and the distribution are not known.

The objective of this measure is to prevent the intentional introduction of the species through the ornamental trade.

EFFECTIVENESS OF MEASURE

Effective.

Banning the import, cultivation, sale, and transport of *T. sebifera* should be highly effective for preventing the introduction and spread of the species in the EU. As unintentional introductions of the species is relatively unlikely (see *Unintentional introduction* section below), banning intentional introduction is the primary mechanism for keeping the species out of EU natural areas.

The effectiveness of a ban on import, sale, and transport is dependent on sufficient enforcement, including education regarding the ban, monitoring of sales and movement of species, and penalties for noncompliance. Assuming such actions are taken, an import ban should be highly effective. Little evidence exists to support the effectiveness of bans for preventing the introduction of species, likely because data on lack of species occurrences is usually not often reported.

SIDE EFFECTS

Environmental: Neutral or mixed
Social: Neutral or mixed
Economic: Neutral or mixed

Preventing the intentional introduction and spread of *T. sebifera* should have neutral (no) environmental side effects.

A ban on import and transport will have neutral or very minimal social effects. The only conceivable effect would be on a cultural group that relies on the species for a specific social purpose. For example, although products derived from the species are used in Chinese medicine (Gao *et al.*, 2016), the products are available elsewhere and do not need to be produced in the EU from plants grown in the EU.

Preventing the import, cultivation, and spread of *T. sebifera* will have neutral or very little economic effect. The species was once very valuable for production of oil and tallow products, woodcrafts and furniture, and other products (Lin *et al.*, 1958; Scheld and Cowles, 1981; USDA, 2008), which is why it was widely planted in the United States (Bruce *et al.*, 1997;Siemann and Rogers, 2003a,b; McCormick, 2005; Camarillo *et al.*, 2015), but there is not currently an industry that relies on *T. sebifera*. There is also no evidence that the species is widely traded in the EU for horticultural purposes.

ACCEPTABILITY TO STAKEHOLDERS

Given how few stakeholders appear to deal in *T. sebifera* seeds, plants, or products, it is likely that there would be little to no negative response from stakeholders regarding a ban on importing, keeping, or selling the species

ADDITIONAL COST INFORMATION

Invasions of *T. sebifera* can significantly affect native plant communities, and may affect ecosystem nutrient cycling (Cameron and Spencer, 1989; Bruce *et al.*, 1995; Jubinksy and Anderson, 1996; Bruce *et al.*, 1997; Neyland and Meyer, 1997; Pile *et al.*, 2017) thus the cost of inaction could be quite high. The species tolerates a wide range of environmental conditions from wetlands to grasslands to forests in its invasive range in North America (Webster, Jenkins and Jose, 2006; Langeland and Enloe, 2015) so many habitats in the EU could be vulnerable to invasions.

The cost-effectiveness of implementing a ban on the species should be very high. Enforcement would require some resources but they would be shared across other species that are also banned. The primary cost would be in educational materials to inform citizen scientists and the public. The benefits could be quite high if a ban prevents invasions, which would be very difficult to determine (Zenni and Nunez, 2013), and is not always true (Diaz *et al.*, 2012).

Apart from the species in the ornamental plant trade in the EU, which is quite minimal, there are no current socio-economic benefits of importing or keeping the species in the EU. There is little information available on the value of the species in horticulture but it appears to be minimal given the few sites that list it for sale in the EU.

LEVEL OF CONFIDENCE[1]

Established but incomplete.

Information on the establishment and spread of the species in natural areas of the United States is well documented and thought to be reliable. The impacts of *T. sebifera* invasions also have been researched extensively. What is less known is how introductions might occur in the EU – currently, a couple of online sites sell the species, but less is known about the availability of plants for planting, for example, at local nurseries who might cultivate and propagate the species. Historically there has been some interest in keeping and cultivating the tree for landscaping purposes because it grows quickly and has somewhat attractive foliage and fall colour.

1 See Appendix

Adoption of 'weed free' certification for bird feed and crop seeds.

MEASURE DESCRIPTION

There is little information available on the unintentional introductions and spread of *T. sebifera*. Given its large seed size, it is unlikely to be accidentally introduced to the EU. However, introduction as a contaminant of bird seed or in a crop seed mix might be possible. Multiple species of birds in North America readily feed on *T. sebifera* seeds (McCormick, 2005) and seeds remain viable for many years (Cameron, Glumac and Eschelman, 2000) so it is conceivable that viable seeds could be introduced as a contaminant and spread. However, no evidence exists that such an introduction has happened or is likely to occur.

To prevent the unintentional introduction of *T. sebifera* as a contaminant of bird seed or crop seed for planting, the primary measure is to implement a required certification of "weed-free" seed for any seed that is imported for bird food or crop seeds for planting.

The objective of this measure is to prevent the unintentional introduction of *T. sebifera* as a contaminant of bird food or crop seeds for planting.

SCALE OF APPLICATION

This measure would need to be applied to all Member States that import seed from the US, Asia, Australia, and other areas where *T. sebifera* is present.

No information is available on the largest scale at which this measure has been successfully applied.

T. sebifera *has high tolerance to drought, flooding and a degree of salinity. © KENPEI. CC BY-SA 3.0*

EFFECTIVENESS OF MEASURE

Neutral.

No information is available on the effectiveness of this measure for preventing unintentional introduction of non-native species.

EFFORT REQUIRED

No quantitative information is available, but it is expected that substantial effort would be required to implement a requirement that all imported bird food and crop seeds are "weed-free." Non weed-free products would need to be banned and imported products would need to be examined to ensure effectiveness of the weed-free certification.

RESOURCES REQUIRED

The primary resource required would be staff to educate sellers and buyers that all products are required to be weed-free. Staff also would be needed to enforce the ban on non weed-free products and to ensure that weed-free products are actually free from contaminants. It has been shown that bans may not always be effective (Diaz *et al.*, 2012).

SIDE EFFECTS

Environmental: Positive
Social: Neutral or mixed
Economic: Negative

Banning non weed-free bird food and crop seed products would also prevent additional potential invasive alien plants from being introduced.

If the cost of bird food or crop seeds increases due to a requirement that all products are certified weed-free then there may be negative social and economic effects, but no information is available on whether or not such effects would occur.

ACCEPTABILITY TO STAKEHOLDERS

Stakeholders that are interested in preventing invasions would likely be receptive to a requirement for weed-free products. However, businesses that import/sell bird food and crop seed products may have a negative response if the margin of profit is less for weed-free products but if the profit margin is actually larger for weed-free products, then they may have a positive response to the restriction.

ADDITIONAL COST INFORMATION

No information available.

LEVEL OF CONFIDENCE[1]

Inconclusive.

Very little information is available that is relevant to the possibility that *T. sebifera* might be unintentionally introduced via bird food or crop seed contamination, or otherwise.

1 See Appendix

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

Removal of populations occurring along waterways.

MEASURE DESCRIPTION

If *T. sebifera* were to be introduced to natural areas in the EU, the primary mechanism for secondary spread would be movement by water. The species often occurs along waterways, including streams, creeks, rivers, ponds, and in wetlands (Bruce *et al.*, 1997; McCormick, 2005; Pile *et al.*, 2017) and seed can be transported by water via waterways or during flood events.

Dispersal of *T. sebifera* seeds can also occur biotically via animals, primarily birds. For example, in the southern part of the US, the introduced starling has been shown to eat the seed and spread them widely (Renne, Gauthreaux and Gresham, 2000; Renne, Spira and Bridges, 2001; Renne *et al.*, 2002; Jubinksy and Anderson, 1996).

To prevent secondary spread by water, *T. sebifera* that occurs near water or in lowlands prone to flooding should be rapidly eradicated prior to reproductive maturity (see *Rapid eradication* section below).

The objective of this measure is to prevent secondary spread of *T. sebifera* through waterways or during flood events.

SCALE OF APPLICATION

For this measure to be effective at preventing secondary spread, all *T. sebifera* trees along waterways or in lowlands prone to flooding would need to be removed.

EFFECTIVENESS OF MEASURE

Effective.

If all reproductive trees are removed, then the measure should be very effective at preventing secondary spread of *T. sebifera*.

EFFORT REQUIRED

The effort required to eradicate newly established individuals is determined by the size of plants and the number of plants in a given area. Larger plants or more individuals would take more time and effort. Herbicide treatment would require the least effort.

RESOURCES REQUIRED

As with measures for rapid eradication and management, resources to prevent secondary spread include staff to locate and conduct the eradication measures, and equipment and/or chemicals to remove *T. sebifera*.

SIDE EFFECTS

Environmental: Neutral or mixed
Social: Neutral or mixed
Economic: Neutral or mixed
See section below on *Rapid eradication*.

ACCEPTABILITY OF STAKEHOLDERS

There are no stakeholders in the EU who currently rely on *T. sebifera* so preventing secondary spread of the species via waterways should be acceptable.

ADDITIONAL COST INFORMATION

No information available.

LEVEL OF CONFIDENCE[1]

Well established.

There are multiple reports (Bruce *et al.*, 1997; McCormick, 2005; Pile *et al.*, 2017) that *T. sebifera* occurs near waterways and may be transported by water. Therefore, removing reproductive trees from near water should prevent secondary spread of the species by water.

1 See Appendix

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

Surveillance of the natural environment by natural resources professionals, gardeners, and citizens.

MEASURE DESCRIPTION

The species is sold online and occurs under limited cultivation in the EU but the species is not known to occur in natural areas so early detection will be critical to prevent invasions. An effective surveillance system for early detection should include education of amateur and professional botanists, natural resource professionals, people interested in gardening and horticulture, and citizen scientists so they can identify and report occurrences of the species in natural areas.

Education about *T. sebifera* identification could be accomplished through pamphlets, email, web sites (for example, www.bsbi.org), or social media. Systematic surveillance of susceptible habitats could focus specifically on *T. sebifera* but are not likely to be cost-effective given the relatively unlikely chance the species would be encountered. Instead, regular biological recording for Atlases and Floras is likely to capture occurrences of the species given that they already exist at a reasonable scale across the EU (for example, Pescott *et al.*, 2015).

Triadica sebifera is relatively easy to identify based on its unique leaf morphology. There are no congeneric species within the EU. The Flora of China provides the following identification (edited): "Bark is grey, brown, and rough. Exudes a milky sap. Twigs slender. Petioles 2–6 cm long, with 2 sessile disc-shaped glands at the apex. Leaf-blades broadly rhombic-ovate, 2–7.5 x 1.5–7 cm, abruptly acutely acuminate, broadly cuneate to rounded, subtruncate at the base, entire, lateral nerves 7–12 pairs, glaucous beneath. Stipules 1–2 mm long, obtuse."*Triadica sebifera* flowers from April to June, producing both male and female flowers. Fruits are 1 cm three-lobed capsules expected to mature in the autumn. Seeds are 8 mm long and chalky white (covered by a white wax) (Flora of China, 1972; Bruce *et al.*,1997; Scheld, Cowles, Engler, Kleiman and Schultz, 1984). Providing pictures of leaves, seedlings, mature trees, flowers, and fruit should therefore be sufficient for land managers, gardeners, and citizen scientists to identify the species.

Triadic sebifera can tolerate a relatively wide range of habitat conditions in the introduced range such as moderately closed-canopy forests, open fields, wetlands, and coastal prairie, as well as disturbed sites such as old fields and margins such as fencerows (Bruce *et al.*,1997; McCormick, 2005; Webster *et al.*, 2006; Camarillo *et al.*, 2015; Langeland and Enloe, 2015). Such habitats should be the primary focus for surveillance efforts.

SCALE OF APPLICATION

Triadica sebifera has been cultivated and kept in botanical gardens in the EU for many years, including in the UK, France, Germany, the Netherlands, Italy, Portugal, Spain (Hortus Paddingtonensis, 1797; Antonelli, 1830; Dillwwyn and Collinson, 1843; Hortus Collinsonianus, 1843; Banfi and Visconti, 2013; Batchelor, 2017), thus surveillance efforts need to cover these Member States as a priority. Within Member States where *T. sebifera* is known to occur, natural areas should be surveyed for the species, with a particular focus on areas near cultivated *T. sebifera*. Preferably, *T. sebifera* would be included in surveillance efforts throughout the temperate EU Member States.

EFFECTIVENESS OF MEASURE

Neutral.

It is very difficult to determine the effectiveness of particular surveillance measures for early detection because such efforts are relatively new (within the last couple decades) and documentation of efforts are not widely disseminated. Also, as the species is not widely distributed and is likely to be new to most managers and citizens, people participating in surveillance are less likely to immediately recognize seedlings, although the species is relatively unique (as compared to, for example, a grass). However, amateur and professional botanists are likely to recognize the plant is unique and regular biological recording already occurs in much of the EU and is known to be effective at identifying new species occurrences (Pescott *et al.*, 2015).

EFFORT REQUIRED

If surveillance measures for *T. sebifera* were to be combined with efforts for other species of concern then the effort required for any one species, including *T. sebifera*, would be relatively low. Species already listed by the EU that occur in the same or similar habitats include *Asclepias syriaca*, *Heracleum mantegazzianum*, *Microstegium vimineum*, and *Pueraria lobata*.

RESOURCES REQUIRED

Surveillance of the natural environment for *T. sebifera* should require few resources – simply educational materials such as web sites, smartphone apps (which often are already produced for other IAS), and educational handouts. Overall, the implementation cost is expected to be minimal because regular biological recording already occurs in many areas of the EU (for example, Pescott *et al.*, 2015).

SIDE EFFECTS

Environmental: Positive
Social: Positive
Economic: Neutral or mixed

Surveillance for *T. sebifera* could have significant positive environmental side effects if search efforts in natural areas result in identification of other invasive species or documentation of other environmental issues that need to be reported to natural resource managers.

The positive social effects of surveillance are that citizen scientists will be more aware of environmental issues and they will have the opportunity to spend time in natural areas during search efforts.

No economic side effects of *T. sebifera* surveillance efforts are expected.

ACCEPTABILITY TO STAKEHOLDERS

Surveillance of natural areas for *T. sebifera* is expected to be acceptable to stakeholders because it will not impact economic activities or have consequences for animal welfare. Public perception should be neutral or possibly positive because participants will experience and become more aware of the natural environment.

ADDITIONAL COST INFORMATION

As described under *Rapid eradication* below, the cost of inaction could be very high if surveillance efforts are not implemented for *T. sebifera* as invasions can spread rapidly once individuals reach maturity and the species can have significant impacts on biodiversity and ecosystem functions.

If surveillance efforts for *T. sebifera* are combined with surveys of other species the measure should be cost-effective.

LEVEL OF CONFIDENCE[1]

Established but incomplete.

There is growing evidence on the application of surveillance, and citizen science as a tool for early detection.

1 See Appendix

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

Mechanical removal.

MEASURE DESCRIPTION

If a new occurrence of *T. sebifera* is found in the EU in the natural environment, the most direct and effective method to rapidly eradicate newly established individuals or populations is by physical removal. To achieve eradication, it is critical to remove individuals before they are mature and produce seed. The species has been documented to reach reproductive maturity in as little as one year under ideal greenhouse conditions (Jubinsky and Anderson, 1996), although typically, plants in natural areas are mature in 3–8 years (Duke, 1983). Given the relatively rapid maturation of *T. sebifera*, newly identified invasions will require quick action to prevent seed production and achieve eradication.

Triadica sebifera creates a long-lived seedbank, which may complicate management efforts and further motivate rapid removal to prevent second spread. Cameron *et al.* (2000) showed that germination success peaked after two years in their experiment but that there was little loss in viability (only 3%) even after seven years.

To remove an individual tree or small populations prior to maturity, mechanical or manual removal is preferred. Although multiple herbicides have been tested and utilized effectively on *T. sebifera* (see below), it is simpler, easier, and in many ways safer to remove seedling trees without the use of herbicides. Seedlings may be hand pulled or dug (such as, "grubbed") out but in either case, the entire plant must be removed because the species readily resprouts from root fragments. Machinery such as bulldozers or scrapers also can be used but, again, such techniques must remove all plant parts to prevent resprouting and ensure eradication.

SCALE OF APPLICATION

Removal of *T. sebifera* with mechanical or manual methods is labour intensive and can be time consuming. No information is available on the scale at which this measure has been applied successfully but it is likely to be restricted to areas of approximately 1 ha or less and with a limited number and size of stems, due to the difficulty of implementation and need for complete removal of all plant parts to achieve eradication. Invaded areas larger than 1 ha will require chemical control methods, especially if plants are mature and seed has been dispersed.

EFFECTIVENESS OF MEASURE

Effective.

Removal of entire plants can be highly effective for eradication. However, because of the scale at which manual or mechanical removal can be implemented is quite limited, chemical control must be considered for larger infestations. Simply cutting a plant at the soil surface is ineffective because "cutting results in the immediate production of multiple small, independent shoots" (Jubinsky, 1993). Cut-stump application of herbicides will greatly increase eradication success so when to use manual or mechanical methods and when to implement chemical control should be carefully considered.

EFFORT REQUIRED

The intensity of effort required to eradicate a population with mechanical or manual methods is determined by the size of plants and the number of plants in a given area. Larger plants will require more work to pull or dig out and the larger the plant, the greater the likelihood some plant parts will be missed and the plant will resprout. Larger areas or more dense populations will increase the chances that an individual will be missed and potentially reach reproductive maturity. Because seed dispersal of *T. sebifera* can occur through both bird and water dispersal, and mature individuals can produce up to 100,000 seeds annually (Jubinksy and Anderson, 1996; Bruce *et al.*, 1997; USDA, 2008), eradication will require exponentially more effort if seed production occurs.

RESOURCES REQUIRED

The cost of *T. sebifera* eradication using manual and mechanical methods is relatively low, although perhaps higher than the cost of using chemical herbicides. The cost is predominantly for personnel to locate, identify, map, and remove individuals. Gloves and hand tools (for example, shovels, spades) are all that is needed for seedlings and small trees. Larger trees will require chemical control (see below).

SIDE EFFECTS

Environmental: Negative
Social: Neutral or mixed
Economic: Neutral or mixed

There may be negative environmental side effects because of disturbance of the natural environment when larger individuals are dug out, but the effects can be minimized by replacing soil and taking care to not disturb native vegetation. The amount of disturbance would depend on the number and size of individuals. Few, if any, social, or economic effects are expected with manual or mechanical removal of *T. sebifera*.

ACCEPTABILITY TO STAKEHOLDERS

Manual or mechanical eradication of *T. sebifera* is likely to be acceptable to stakeholders because there is no commercial value of the species in the EU and little evidence that it is used in landscaping.

ADDITIONAL COST INFORMATION

Given the rapid spread and significant impacts of *T. sebifera* invasions in the Southern US (see *Prevention* above) the cost of not eradicating newly established populations could be profound (McCormick, 2005). The population growth and long-distance dispersal potential of *T. sebifera* once a population establishes indicates that early detection and rapid eradication are absolutely critical for preventing widespread invasions. Once individuals or populations are found – and assuming plants are still small – manual or mechanical removal should be cost-effective with few socio-economic impacts

LEVEL OF CONFIDENCE[1]

Well established.

It is well-known that larger, mature *T. sebifera* trees readily resprout when felled. However, there is a high level of confidence that at the earliest stage of invasion when plants are still small, manual or mechanical removal can be highly effective.

T. sebifera *is useful in production of biodiesel. © KENPEI. CC BY-SA 3.0*

1 See Appendix

Chemical control.

MEASURE DESCRIPTION

While rapid eradication of *T. sebifera* seedlings and small trees with manual or mechanical measures can be effective, larger trees that cannot be completely removed by hand or with hand tools or machinery will require chemical control. In addition, the difficulty of removing individual trees means that rapid eradication of larger infestations with many individuals will be impractical without chemicals.

Chemical control for rapid eradication, can be achieved with foliar, basal bark, or cut stump application of herbicides. Foliar applications of herbicides for seedlings and small trees should occur during the growing season (July through October in most Member States). Products for foliar application should contain imazapyr (1% water-solution of products such as Arsenal ™ or Habitat ™), fosamine-containing herbicide (30% water solution of Krenite ™ S), or triclopyr ester-containing herbicide (2% water-solution of Garlon ™ 4) (Jubinsky and Anderson, 1996; Langeland and Enloe, 2015; NSW Government Factsheet, 2017).

If it is acceptable for standing dead trees to remain in place, then basal bark application of herbicides is easier and more cost-effective than either foliar applications or cut-stump treatment. A 20% dilution in oil of triclopyr ester-containing herbicide such as Garlon ™ 4 or Pathfinder ™ II is effective for trees up to 15 cm.

For cut stump application a 50% dilution of triclopyr ester or triclopyr amine containing herbicide such as Garlon ™ 3A can be used immediately after cutting. Stumps may coppice and resprouts will need to be treated according to cut-stump recommendations. Herbicides that contain imazapyr can help to reduce resprouting (Jubinsky and Anderson, 1996; Langeland and Enloe, 2015; NSW Government Factsheet, 2017).

Recent research showed that herbicides containing aminocyclopyrachlor or fluroxypyr were much more effective in controlling resprouting than products containing the traditionally used triclopyr amine and ester formulations (Enloe, Loewenstein, Streett and Lauer, 2015). Therefore, these herbicides should be used.

It is illegal to use an herbicide in a manner inconsistent with the label's instructions; therefore, read the label carefully and follow the instructions. 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.

The objective of this measure is to rapidly eradicate new introductions of *T. sebifera* using chemical control methods

SCALE OF APPLICATION

No information is available on the scale at which the chemical control of *T. sebifera* or other woody invaders has been successfully implemented. But, given the method of applying either as basal bark or cut stump, widespread applications could be feasible given sufficient resources.

EFFECTIVENESS OF MEASURE

Effective.

Enloe *et al.* (2015) conducted an extensive study of the effectiveness of chemical herbicide treatments to kill *T. sebifera*, including their effects on root and stump sprouting post treatment. They found that many treatments were more than 80% effective in preventing resprouts:

“Aminopyralid reduced total sprouting by 95% compared with the untreated control and was different from all other herbicide treatments. Fluroxypyr reduced total sprouting by 79 and 88% at the low and high rates, respectively. Imazamox reduced total sprouting by 61 and 64% at the low and high rates, respectively, and triclopyr reduced total sprouting by 37%.”

For basal bark treatment, multiple chemicals were effective against *T. sebifera*, including for inhibition of resprouting. The most effective chemical was aminocyclopyrachlor (Enloe *et al.*, 2015).

EFFORT REQUIRED

The effort required to apply cut stump and basal bark chemical treatments is relatively low compared to manual or mechanical treatments. Basal bark application of chemicals is significantly easier than cut stump treatment because individuals do not need to be cut prior to treatment. When individuals are seedlings or small trees, the difference in application effort is relatively minor but for large trees, particularly those requiring chainsaws, the difference in effort is substantial.

Chemical measures can be quite effective for rapid eradication of *T. sebifera* with only a single treatment but when resprouts occur they must be treated again. It has been suggested that infested sites be revisited for at least

3-5 years to ensure eradication (Jubinksy and Anderson, 1996; Bruce *et al.*, 1997; Meyer, 2011).

RESOURCES REQUIRED

Basal bark application requires fewer resources than cut stump application because trees are left in place. For basal bark, chemical, oil surfactant, sprayer, and personal protective equipment (for example gloves) are required. For cut stump application of chemicals, tools are also needed to cut the trees – hand pruners or loppers for smaller trees and a chainsaw for larger (such as, >5cm) trees.

More staff resources are required for cut stump than basal bark application and cut stump treatments may require specialized training, such as the use of chainsaws. In either case, the applicator would need safety training in the use of chemical herbicides.

SIDE EFFECTS

Environmental: Neutral or mixed
Social: Neutral or mixed
Economic: Neutral or mixed

Cut stump and basal bark chemical measures to rapidly eradicate *T. sebifera* are likely to have few side effects. Few, if any, negative environmental side effects are expected because the amount of chemical used is relatively small (Enloe *et al.*, 2015) and is applied in a very targeted manner directly to the base of trees or cut stumps.

Given that currently there are no significant social or economic uses of *T. sebifera* in the EU, any social or economic side effects are expected to be minimal or non-existent.

ACCEPTABILITY TO STAKEHOLDERS

Both basal bark and cut stump application of herbicides for rapid eradication should be acceptable for stakeholders because the amount of herbicide is relatively low and there should be a low number of treated plants. However, the public may object to rapid eradication of *T. sebifera* if the treated trees are prominent such as near hiking trails or parks and they are removed or if trees are treated with basal bark applications and left standing.

ADDITIONAL COST INFORMATION

As described above for rapid eradication using manual or mechanical control, the cost of inaction could be quite high if small populations spread and create larger invasions. Chemical eradication measures are often thought to be highly cost-effective but the costs of detection, application, and monitoring have not been quantified.

One concern that might need to be addressed is that the physical removal of trees or leaving standing dead trees may not be acceptable to local people who pass by or use natural areas. These concerns may be addressed with educational campaigns.

LEVEL OF CONFIDENCE[1]

Well established.

It is well established that cut stump and basal bark chemical measures are effective for killing *T. sebifera* (for example, Enloe *et al.*, 2015), thus these measures are expected to be effective for rapid eradication of the species in the EU.

1 See Appendix

Measures for the species' management.

Chemical control.

MEASURE DESCRIPTION

Triadica sebifera is not known to currently occur in natural areas within the EU. Thus, surveillance, early detection, and rapid eradication should be top priorities. However, if widespread invasions of *T. sebifera* are found in a Member State(s), the optimal management measure is chemical control. Other measures, including fire, alteration of hydrology, and mechanical removal (mulching) have been attempted where the species has invaded over large areas but they are not effective because of the ability of the *T. sebifera* to resprout from roots. Because little information is available on each of these measures, no specific tables have been produced for these measures. Here the focus is on the same chemical treatments of cut stumps and basal bark applications outlined above under *Rapid Eradication*.

The seed's white waxy aril is used in soap making.
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In brief, chemical control can be achieved by primarily foliar (seedlings or small trees only), basal bark, or cut stump application of herbicides. Foliar applications of herbicides for seedlings and small trees should occur during the growing season (July through October in most EU Member States). Products for foliar application should contain imazapyr (1% water-solution of products such as Arsenal ™ or Habitat ™), fosamine-containing herbicide (30% water solution of Krenite ™ S), or triclopyr ester-containing herbicide (2% water-solution of Garlon ™ 4) (Jubinsky and Anderson, 1996; Langeland and Enloe, 2015; NSW Government Factsheet, 2017). If it is acceptable for standing dead trees to remain in place, then basal bark application of herbicides is easier and more cost-effective than either foliar applications or cut-stump treatment. A 20% dilution in oil of triclopyr ester-containing herbicide such as Garlon ™ 4 or Pathfinder ™ II is effective for trees up to 15 cm. For cut stump application a 50% dilution of triclopyr ester or triclopyr amine containing herbicide such as Garlon ™ 3A can be used immediately after cutting. Stumps may coppice and resprouts will need to be treated according to cut-stump recommendations. Herbicides that contain imazapyr can help to reduce resprouting (Jubinsky and Anderson, 1996; Langeland and Enloe, 2015; NSW Government Factsheet, 2017).

Recent research showed that herbicides containing aminocyclopyrachlor or fluroxypyr were much more effective in controlling resprouting than products containing the traditionally used triclopyr amine and ester formulations (Enloe *et al.*, 2015).

It is illegal to use an herbicide in a manner inconsistent with the label's instructions; therefore, read the label carefully and follow the instructions. 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.

The objective of this measure is to manage established invasions of *T. sebifera* using chemical control methods.

SCALE OF APPLICATION

No information is available on the scale at which management of *T. sebifera* with chemical measures has been applied. However, as treatment is conducted on a per-individual basis there is little benefit for large-scale compared to local control. That is, there is not significant economy of scale as there would be with a measure that uses larger equipment for more extensive invasions (such as aerial application of herbicides). Similarly, there is little disadvantage of larger scale management of *T. sebifera* using basal bark and cut stump chemical methods other than the amount of area that needs to be mapped, treated, and monitored.

EFFECTIVENESS OF MEASURE

Effective.

Multiple fact sheets (for example, McCormick, 2005; NSW Government Factsheet, 2017; Meyer, 2011) and the extensive study by Enloe *et al.* (2015) document the effectiveness of basal bark and cut stump chemical measures for the management of *T. sebifera*.

EFFORT REQUIRED

The effort required for management of *T. sebifera* using basal bark and cut stump chemical methods scales directly with the size of the infestation. Treatments per individual tree require relatively little effort but invasions covering multiple hectares would require significant person hours, equipment, and chemicals, particularly if trees cannot be treated with basal bark applications and left as standing dead. Results will be apparent within the first year but invaded areas will need to be retreated for resprouts for at least 3–5 years for full control of a population.

RESOURCES REQUIRED

Resources required for management of established stands of *T. sebifera* invasions are similar to resources required for rapid eradication, except that it is likely that more people, time, and chemicals are needed depending on the area invaded, density of *T. sebifera* individuals, and size distribution of trees.

SIDE EFFECTS

Environmental: Neutral or mixed
Social: Neutral or mixed
Economic: Neutral or mixed

Broad scale management of *T. sebifera* could have both positive and negative environmental side effects. It is well-established that invasions of the species in the southern US cause substantial biodiversity loss and alter ecosystem functions (Bruce *et al.*, 1995; Bruce *et al.*, 1997; Jubinksy and Anderson, 1996; Cameron and Spencer, 1989; Neyland and Meyer, 1997; Pile *et al.*, 2017). If such invasions also occurred in the EU, similar effects are expected. Removal of those invasions would thus have some positive environmental benefit. However, it is not known to what extent native biodiversity in the EU would utilize the new habitat created by large stands of *T. sebifera*. If invasive stands create habitat or provide a significant food source then removal of those stands could have negative environmental side effects. Such effects are not understood for *T. sebifera*.

Given the current lack of economic activity or cultural or social uses associated with *T. sebifera* in the EU, no social or economic side effects are expected.

ACCEPTABILITY TO STAKEHOLDERS

No significant economic activities are associated with *T. sebifera* in the EU currently so chemical management measures are expected to be acceptable to stakeholders.

ADDITIONAL COST INFORMATION

As with the cost of inaction for rapid eradication, the cost of not conducting management of *T. sebifera* could be substantial given the known ecological impacts of invasions in the Southern US.

LEVEL OF CONFIDENCE[1]

Well established.

There is a reasonable amount of information on the effectiveness, costs, and resources required for basal bark and cut stump chemical management techniques for *T. sebifera*, thus there is a high level of confidence in the information provided here.

1 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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