Lespedeza cuneata is an aggressive, warm-season, perennial legume. © Dalgial. CC BY-SA 3.0.

The management of Chinese bushclover (*Lespedeza cuneata*)

Measures and associated costs

Scientific name(s)	*Lespedeza cuneata* (Dum.Cours.) G.Don
Common names (in English)	Chinese bushclover
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Common names

BG	–
HR	Lespedeza
CZ	Lespedézie hedvábitá
DA	Kinesisk buskkløver
NL	Chinese struikklaver
EN	Chinese bushclover
ET	Siidine lespedeetsa
FI	Kiinanpensasapila
FR	Lespédéza soyeux
DE	Chinesischer Buschklee
EL	–
HU	–
IE	Tom seamaireach síneach
IT	Lespedeza
LV	–
LT	Šilkinė lespedeza
MT	Ix-xnien tas-siġra
PL	–
PT	Quebracho
RO	–
SK	lespedéza trváca
SL	Kitajska grmasta detelja
ES	Lespedeza perenne
SV	Kinesisk buskklöver

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

Lespedeza cuneata has various common names (for example, bushclover, perennial lespedeza, sericea lespedeza) and synonyms (for example, *Lespedeza juncea* var. *sericea* (Thunb.) Lace and Hauech (Ohashi *et al.*, 2009; Flora of China, 2010; The Plant List, 2017; CABI, 2018). Here we identify the species as *Lespedeza cuneata* (Dum.Cours.) G. Don. It is an upright perennial herbaceous legume that is native to eastern Asia and eastern Australia and invasive throughout the Midwest and Southeast U.S.A. It occupies disturbed areas, old fields, and open woodlands in its invasive range in the U.S. totalling more than 8 million acres (Duncan *et al.*, 2004) where it can have significant ecological effects (for example, Brandon *et al.*, 2004; Ohlenbusch, 2007). Currently, *L. cuneata* is not known to occur in the natural environment in the EU, although it is listed as a horticultural species in European garden floras (Cullen, 1995).

Preventing the introduction, spread, and impacts of *L. cuneata* in the EU will require measures that address both intentional (as plants for planting) and unintentional (as hay contaminant) pathways of introduction and spread. Because of its biological characteristics and dispersal and establishment mechanisms, early detection and rapid eradication are particularly important for preventing widespread invasions and impacts of *L. cuneata*. The species produces large numbers of seeds, can colonise disturbed and undisturbed areas, form a seed bank, thrive on low nutrient sites, and impact native species (reviewed by Gucker, 2010 and Ohlenbusch, 2007). Importantly, mechanical management techniques such as mowing or tilling, fire, and currently available biological controls are ineffective for eradication or management and techniques that cause disturbance such as mowing and fire perhaps even exacerbate the spread of *L. cuneata* invasions (Gucker, 2010). Some chemical control measures have been developed that are moderately successful at removing *L. cuneata* but they can significantly damage native species (Ohlenbusch, 2007), thus the species is particularly difficult to control.

Prevention of intentional introductions: Given that *L. cuneata* does not currently occur in natural areas in the EU, restricting the introduction of the species is critical for preventing establishment and spread in nature. Primary uses of the species have been for forage (Hoveland and Donnelly, 1985), soil erosion control, and wildlife habitat in the Midwest and Southeast U.S. where it has been in use since the early 1900s. Currently, *L. cuneata* is bred and utilised for forage (Ohlenbusch, 2007) and it may still be in use for erosion control (for example, in road cuts, S. L. Flory pers. obs.), and seeds are available via online retailers in the EU. Thus, stopping the import and sale of *L. cuneata* in the EU is a top priority for preventing introductions.

Prevention of unintentional introductions: A second pathway by which *L. cuneata* might be introduced to the EU is through seed contamination of hay imported from the U.S. Although the volume of hay traded between the EU and U.S. is relatively small, the species was widely planted and is now invasive in many hay producing areas in the Midwest and Southeast of the U.S. Thus, hay imported to the EU from the U.S. where *L. cuneata* is invasive should be certified as 'weed-free', including from *L. cuneata*. Alternatively, all hay imports from infested areas could be banned.

Prevention of secondary spread: There is no evidence that *Lespedeza cuneata* currently occurs in the natural environment of the EU. However, if the species were to establish then measures to limit the spread to non-contiguous areas would include inspection and cleaning of vehicles and equipment, and possibly the banning of movement of manure from infested areas. In addition, efforts should focus on early detection and rapid eradication to prevent the introduction and spread of *L. cuneata* in the EU.

Measures to support early detection: If *L. cuneata* is introduced to the EU for forage production or erosion control, as has been the case in the U.S. (Ohlenbusch, 2007), then surveillance efforts should focus on forage production areas and disturbed sites near road or other construction projects to support early detection. If *L. cuneata* is introduced unintentionally via contaminated hay imported from invaded areas in the U.S., surveillance efforts for early detection should focus on livestock production or horse boarding areas. In either case, amateur and professional botanists and managers of natural areas should be educated on the identification of *L. cuneata* and the habitats most susceptible to invasion by the species.

Rapid eradication of new introductions: It is difficult to eradicate *L. cuneata* because of its tolerance to disturbance, including mowing and clipping (Brandon *et al.*, 2004), and its deep roots and abundant belowground resources (Guernsey, 1977), which allow it to persist under a wide range of conditions and disturbance regimes. The most promising measure to rapidly eradicate newly established populations of *L. cuneata* is through spot spraying with chemical herbicides (for example, Altom *et al.*, 1992).

Management of established populations: To achieve management of *L. cuneata* if it were to become widespread in the EU would require concerted efforts to map and monitor invasive populations, control dispersal to prevent further spread, and treat satellite infestations and then the core invasive population by broadcasting chemical herbicides, fire, and/or mowing (reviewed by Vermeir *et al*., 2002; Ohlenbusch, 2007).

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 keeping, 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 *L. cuneata.*

Note that if L. cuneata is listed as an invasive alien species of Union concern, the measures that would automatically apply in accordance with Article 4(6) of the EU IAS Regulation 1143/2014 would include the suggested measures described here.

MEASURE DESCRIPTION

Lespedeza cuneata is not known to currently occur in the natural environment of the EU but the species was listed as one of nearly 100 species that were considered likely to "arrive, establish, spread and have an impact on biodiversity or related ecosystem services in the EU over the next decade" by a group of invasion biologists (Roy *et al.*, 2015).

The species was first introduced to the U.S. in 1896 at an agricultural experiment station in North Carolina. It was then used widely for mine reclamation and erosion control in the 1920s-30s and then promoted as a forage starting in the 1940s. In recent decades the species still has been promoted for re-vegetation of mined areas in the eastern U.S. (Carter and Ungar, 2002). *Lespedeza cuneata* was bred for forage production (Hoveland and Donnelly, 1985; Min *et al.*, 2005; Terrill *et al.*, 2009) and planted throughout many cattle, goat, and sheep producing areas in the U.S. (Guernsey, 1977).

Lespedeza cuneata can have high tannin levels that deter feeding by cattle and horses (Hoveland and Donnelly, 1985), in particular when plants are at a late stage of development (Fechter and Jones, 2001). However, the species also can provide a reasonably valuable source of protein (Hoveland and Donnelly, 1985) and tannin levels drop when plants dry, such as during the haying process (Terrill *et al.*, 1989; Ohlenbusch *et al.*, 2007). As a result, hay produced entirely from *L. cuneata* or containing a significant component of the species is considered to have value as fodder.

Some still recommend *L. cuneata* as a forage species in the U.S. (Fair, 2014) and it is available for sale in very large (>20kg) quantities, despite its known problems as an invader in many areas. Thus, the species could be intentionally introduced to the EU to be used as a forage species (Cummings *et al.*, 2007), especially because it is drought tolerant and performs well on poor quality (low nutrient) and other variable soils (Cope, 1966; Plass and Vogel, 1973; Guernsey, 1977; Ohlenbusch *et al.*, 2007).

Examples of online suppliers:
- http://www.pepinieredesavettes.com/pepiniere/lespedeza-cuneata,1697,theme==0,page==1?noclear
- http://b-and-t-world-seeds.com/carth.asp?species=Lespedeza%20cuneataandsref=40202

Banning the importation, sale, cultivation of *L. cuneata* would prevent the intentional introduction and spread of the species.

The objective of this measure is to prevent the intentional introduction of *L. cuneata* to the EU as plants for planting and banning trade in the species among Member States.

EFFECTIVENESS OF MEASURE

Effective.

The extensive problem with *L. cuneata* as an invasive species in the U.S. is thought to be almost entirely due to its intentional introduction as a forage, erosion control, and wildlife species (reviewed by Gucker, 2010 and Ohlenbusch, 2007). This same pathway – plants for planting – is expected to be the most likely mechanism by which the species would be introduced to the EU and spread among Member States. Thus, a ban on such import, planting, selling, etc should be highly effective in preventing invasions of the species in the EU.

SIDE EFFECTS

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

There are no known environmental side effects.

There are few known social benefits to *L. cuneata* except for limited availability in horticulture (Cullen 1995) so banning the species from the EU should have neutral or mixed social side effects.

There are economic benefits of the use of *L. cuneata* in the U.S. The species can be highly productive on marginal lands and provide reasonably good quality forage. Hoveland and Donnelly (1983) demonstrated that total hay production could be 6-11 t ha^{-1}, and others have shown that the high tannin levels can be beneficial for goat and sheep de-worming and other purposes (Terrill *et al.*, 2009) and increase milk quality (Min *et al.*, 2005). However, others have noted that its problems as an invasive species override its potential benefits because other species are excluded (Weber, 2017) and mature plants can have a negative impact on cattle and horses (Fechter and Jones, 2001). There are other available forages for use in the EU, thus the economic side effects of a ban are expected to be neutral or mixed.

ACCEPTABILITY TO STAKEHOLDERS

Currently, *L. cuneata* is not known to be used as a forage or erosion control species in the EU, thus a ban on import and sale of the species should be acceptable to stakeholders. For those that manage and seek to conserve natural areas, the ban is likely to be welcomed. However, if individuals are interested in promoting new horticultural species such as *L. cuneata* there may be a negative view of a ban and potentially loss of income.

ADDITIONAL COST INFORMATION

The cost of inaction on banning the introduction of *L. cuneata* could be very high. If the species is widely introduced as a forage species and results in invasions, there could be significant ecological damage. For example, although *L. cuneata* was initially promoted as a benefit for wildlife in the U.S. (Schneider *et al.*, 2006; Gucker, 2010) there appears to be little evidence that the species is more beneficial to wildlife than native plant species (Vogel, 1981). In fact, one study found that the species contained insufficient resources to facilitate bird survival during winter months (Newlon *et al.*, 1964) and although the species provides habitat, it is thought to be of lower quality than native species dominated areas (Unger *et al.*, 2015). Furthermore, invasions of *L. cuneata* in the U.S. can result in disruption of pollinator networks (Woods *et al.*, 2012) and suppression of native plant diversity and abundance (Eddy and Moore, 1998; Brandon *et al.*, 2004; Allred *et al.*, 2010; Bauman *et al.*, 2015).

The cost of implementation of an import and sales ban is relatively low and could be combined with other listed species, but the benefit of preventing invasions may be quite high, thus the measure is expected to be highly cost-effective.

No additional socio-economic aspects were considered.

LEVEL OF CONFIDENCE[1]

Well established.

There is strong evidence that *L. cuneata* has been planted widely as a forage in the U.S. and that the species has become highly problematic in the Midwest and eastern U.S., thus banning introduction to the EU is well-supported.

1 See Appendix

Imports of hay from infested areas to be banned.

MEASURE DESCRIPTION

Currently, although no evidence exists suggesting that *L. cuneata* has been a contaminant of hay imported to the EU from the U.S., hay imports to the EU do occur (https://apps.fas.usda.gov/gats/default.aspx), and they could contain *L. cuneata* as a contaminant.

Lespedeza cuneata is a prolific seed producer and hay is produced throughout the invasive range of the species in the U.S. Stems of *L. cuneata* can produce more than 1,000 seeds each and individuals can have dozens of stems. In total, seed production can be 130-390 kg of seed per acre with approximately 770,000 seeds per kg (Ohlenbusch, 2007). In total, seed production can be 300 million per acre. Additionally, plants can produce seeds at a very young age, as little as 15 weeks (Farris, 2006). *Lespedeza cuneata* has been planted in pastures and for erosion control in road cuts and has escaped and invaded natural grasslands, woodlands, fencerows, margins, and pastures where it was not planted (Weber, 2017), providing ample opportunity for *L. cuneata* seeds to be incorporated into hay, including hay for export.

It is expected that *L. cuneata* seeds would survive the haying process and could be introduced as viable propagules in the EU. Seeds could then be spread through the hay transport process, feeding of livestock, or in the dung of animals, including trail-riding horses (Campbell *et al.*, 2001; Stroh *et al.*, 2009) but also native animals that might consume the seed (Eddy *et al.*, 2003; Blocksome, 2006; Cummings *et al.*, 2007; Quick *et al.*, 2017).

"Weed free" hay (and straw) is described as "...hay, straw or mulch that is not known to contain propagative plant parts and seeds of noxious weeds" (Clines, 2005). It is required for use in many parts of the U.S., including for feeding horses on National Forest lands. Importing only weed free hay to the EU from the U.S. could greatly reduce the likelihood of *L. cuneata* unintentional introduction, but there is evidence that "weed free" hay may not always be free from invasive plant propagules (Dombeck *et al.*, 2004; Clines, 2005).

Alternatively, hay may be banned as an import from the U.S. to the EU or imports may be restricted so that they only originate from outside the invasive range of *L. cuneata* in the U.S., although the latter policy would be difficult to enforce given the rapid range expansion of the species.

The objective of this measure is to prevent the unintentional introduction of *L. cuneata* through contaminated hay.

SCALE OF APPLICATION

Weed free hay is commonly used in much of the U.S. (https://standleeforage.com/company/standlee-difference/certified-noxious-weed-free) and also recommended as fodder for horses when using public lands for recreation in Canada (https://bcinvasives.ca/resources/programs/play-clean-go/trail-users). No information was found on the use of weed free hay in Europe but the measure would need to be applied at the European level because if 'non' weed free hay from contaminated areas could be imported to anywhere within the EU it could be moved elsewhere.

EFFECTIVENESS OF MEASURE

Effective.

Demonstrating prevention is difficult because there often is not a good comparison once a policy is implemented. But, it is reasonable to expect that requiring imported hay to be free of weed contaminants could reduce the likelihood of unintentional introduction of *L. cuneata* (Clines, 2005), but effectiveness would depend on the degree to which "weed free" hay actually was free from *L. cuneata* seed.

EFFORT REQUIRED

Requiring that all hay imported to the EU from the U.S. or other *L. cuneata* infested areas would need to be maintained indefinitely. To ensure that weed free hay is in fact not contaminated by *L. cuneata* or other invasive species would require a monitoring programme. However, a weed free hay requirement would apply to all noxious weeds and invasive species that might occur in the same habitats such as *Asclepias syriaca*, *Heracleum mantegazzianum*, and *Microstegium vimineum*, which could greatly increase the efficiency of the measure.

RESOURCES REQUIRED

The cost of implementing a weed free hay requirement to reduce the likelihood of unintentional introduction of species is not known. Resources required would include staff to develop, implement, and monitor the programme. Inspections of hay imports would require staff time, and staff would need to be educated on how to examine shipments. The programmes also would require communication with exporters in the U.S. to ensure that hay was produced on weed free land because it would be difficult to detect small seeded species such as *L. cuneata* once the shipment reached the EU.

SIDE EFFECTS

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

Restricting hay imports to only weed free hay could prevent

L. cuneata, and other potential invasive species, invasions from occurring. If introductions from additional invasive species are reduced, which is difficult to measure, it is expected that there would be neutral or positive environmental effect. However, it is important to note that species native to the U.S. that may not be classified as 'weeds' in the weed free certification could still pose a potential threat as invasive species to countries in the EU.

There are no known social benefits to *L. cuneata*, so banning the species from the EU should not have social side effects.

Presumably, there are economic benefits to importing hay from the U.S. and restricting hay to only what can be certified as weed free (Clines, 2005) would increase costs and have a negative economic benefit.

ACCEPTABILITY TO STAKEHOLDERS

The current volume of hay imports to the EU from the U.S. is not particularly large but imports do occur on a regular basis (https://apps.fas.usda.gov/gats/default.aspx). Stakeholders who benefit from importation of hay would suffer a negative effect on a weed free requirement because the cost of weed free hay is substantially higher given the necessity to monitor, identify, and remove weeds and invasive plants from hay producing areas. However, EU stakeholders who are interested in natural areas preservation and conservation, invasive plant management, and native species biodiversity will find the weed free requirement to be quite acceptable. Broad support is likely because the measure would prevent the introduction of *L. cuneata* to the EU as well as other invasive plant species.

ADDITIONAL COST INFORMATION

The cost of inaction on preventing the unintentional introduction of *L. cuneata* through hay contamination could be high because invasions of the species cause significant ecological impacts (Newlon *et al*., 1964; Unger *et al*., 2015; Woods *et al*., 2012; Eddy and Moore, 1998; Brandon *et al*., 2004; Allred *et al*., 2010; Bauman *et al*., 2015). In addition, *L. cuneata* can replace more palatable and higher quality forage species under some conditions.

One study showed that yearly losses in forage in part of Kansas, U.S. exceeded $29 million, and another showed that invasion reduced the 30-year value of grazing land by more than $500 per ha (Fechter and Jones, 2001).

LEVEL OF CONFIDENCE[1]

Established but incomplete.

The idea behind the use of weed free hay and straw is reasonable and the measure is widely used in the U.S. to help prevent the spread of invasive plants (https://www.fs.usda.gov/detail/deschutes/learning/nature-science/?cid=stelprdb5300707) but more information is needed on how often "weed free" hay is actually free from invasive plant propagules.

1 See Appendix

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

Phytosanitary measures to inspect and clean mud, plant debris and equipment from infested areas.

MEASURE DESCRIPTION

While the species is not yet established within the EU, the secondary spread of the species in the U.S. has been attributed to seed dispersal by machinery and vehicles, livestock (through manure), wildlife (for example, deer, rodents and birds) (Gucker, 2010), and wind. The only aspect that can be realistically managed is to reduce the risk of secondary spread to non-contiguous areas, by applying phytosanitary measures to inspect and clean mud and plant debris from vehicles and equipment being transported from infested areas, and possibly to ban the movement of manure from areas where the species is established. These activities would need to be coupled with targeted awareness raising activities with key sectors (for example, agriculture and construction).

There are a number of best practices often focused at specific sectors that can be applied to target the inspection and cleaning of equipment and vehicles (for example, Halloran *et al.*, 2013; IPPC, 2017).

The objective of this measure is to prevent the secondary spread of *L. cuneata* through movement of seed by machinery and vehicles, manure, and wildlife.

SCALE OF APPLICATION

These inspection and cleaning measures can be applied at an individual site level, but would need to cover the entire infested area.

EFFECTIVENESS OF MEASURE

Neutral.

If the inspection and cleaning activities are rigorously and consistently applied, it is presumed they would be effective in reducing the risk of secondary spread, however it is unlikely that they will stop secondary spread altogether.

EFFORT REQUIRED

These activities would need to be put in place indefinitely, or until the species was eradicated.

RESOURCES REQUIRED

The ISPM (IPPC, 2017) state that facilities required for inspection, cleaning, and treatment of vehicles may include: surfaces that prevent contact with soil, including soil traps and wastewater management systems, temperature treatment facilities, and fumigation or chemical treatment facilities. Halloran *et al.*, (2013) detail equipment required for cleaning seed from vehicles including a pump and high pressure hose (minimum water pressure should be 90 pounds per square inch), air compressor and blower or vacuum, shovel, pry bar, and a stiff brush or broom. 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

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

The measure would not just target *L. cuneata* but also other invasive plant species. However, if suitable disposal facilities are not installed there is a risk of environmental impacts, for example to freshwater systems, in the local area from the cleaning and treatment processes.

ACCEPTABILITY TO STAKEHOLDERS

The sectors required to undertake the inspections and cleaning will bear the brunt of the costs for implementing the measures, so there could be some resistance. This issue can be addressed through effective communication and awareness raising activities.

ADDITIONAL COST INFORMATION

No information available.

LEVEL OF CONFIDENCE[1]

Established but incomplete.

While there is some information on these measures (best practices, etc.) little is known about their effectiveness.

1 See Appendix

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

Surveillance system focusing on expert amateur and professional botanists and land managers for early detection.

MEASURE DESCRIPTION

New occurrences of *L. cuneata* in natural areas of the EU are most likely to be found either near forage production areas where the species has been planted or near where livestock and horses are fed hay imported from the U.S. The most susceptible habitats in these areas would be roadsides, field margins, disturbed areas (Cope, 1966; Plass and Vogel, 1973; Hoveland and Donnelly, 1983; Ohlenbusch *et al.*, 2007), and along trails used for horseback riding (Campbell *et al.*, 2001; Stroh *et al.*, 2009).

It will be important for amateur and professional botanists and land managers to properly identify the species (for example, see https://www.invasive.org/browse/subinfo.cfm?sub=3033 for photos). It is a perennial herbaceous legume that can grow to a height of 0.5-1.0 m. The species has trifoliate leaves along the entire length of the stem, and stems can be sparse or denser depending on growing conditions. The leaflets are narrow and long with a small indent at the end. The length to width ratio of leaflets is diagnostic with *L. cuneata* having a ratio of 4:1-6:1 (Pramanik and Thothathri, 1983; Flora of China, 2010). *Lespedeza cuneata* flowers are off white to purple and are produced on short pedicels in leaf axils. The flower season in the U.S. is mid-summer to early autumn (Hoveland and Donnelly, 1983; Ohlenbusch *et al.*, 2007). The species has a mixed mating system with both chasmogamous and cleistogamous flowers (Cope, 1966).

Education of amateur and professional botanists and land managers about *L. cuneata* identification could be accomplished through pamphlets, email, websites (for example, www.bsbi.org), or social media. Systematic surveillance of susceptible habitats could focus specifically on *L. cuneata* 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. However, it would be efficient to combine educational efforts of *L. cuneata* with other listed or proposed species likely to occur in the same habitats (Althoff *et al.*, 2006; Pitman, 2006), include *Ailanthus altissima*, *Asclepias syriaca*, *Heracleum mantegazzianum*, and *Microstegium vimineum*.

The objective of this measure is to facilitate early detection of *L. cuneata* in the EU through enhanced surveillance measures in cooperation with efforts to detect species already listed.

SCALE OF APPLICATION

Surveillance efforts for invasive species can occur at a wide range of scales, from scouting and monitoring efforts at local natural areas by land managers to nation-wide efforts aimed at educating the general public (for example, EDDMaps.org). Here, education about *L. cuneata* to enhance detection should occur across all of the EU but any targeted surveillance efforts should be focused specifically in areas likely to be susceptible such as near livestock and horse use areas where imported hay is utilised, or near forage production areas if the species is planted for grazing or hay production in the EU.

EFFECTIVENESS OF MEASURE

Neutral.

Certainly, surveillance efforts have been successful but it often is difficult to gauge success and surveillance efforts do not always result in improved management (Rout *et al.*, 2014). Different surveillance protocols have been modelled to test their effectiveness (Fox *et al.*, 2009) but no such models exist for *L. cuneata*. It would be difficult to develop such models, which would need to include habitat use data for the species that could be reliably applied to the EU, but such an effort could increase the effectiveness and efficiency of surveillance.

EFFORT REQUIRED

The frequency and volume of hay imports from the U.S. to the EU is relatively low but imports do occur on a regular basis. Importantly, *Lespedeza cuneata* is widespread in the U.S. from as far north as New Jersey and Michigan, as far south as Florida and Texas, and as far west as Nebraska and Oklahoma. In addition, seed of the species is available online at multiple sites in the EU. So, there are multiple opportunities for *L. cuneata* propagules to be unintentionally or intentionally introduced to the EU. Surveillance measures will need to remain in place as long as hay is imported and seed is sold online, which should occur in most EU Member States where general botanical recording is an ongoing activity and should capture new occurrences of *L. cuneata* (Pescott *et al*., 2015).

RESOURCES REQUIRED

Resources required to educate botanists and land managers conducting surveillance about *L. cuneata* include pamphlets, websites, and social media, plus possibly some staff time to conduct education workshops. Such resources and events could be efficiently produced if they are combined with materials and presentations on other species likely to occur in the same habitats such as *Ailanthus altissima*, *Asclepias syriaca*, *Heracleum mantegazzianum*, and *Microstegium vimineum*.

L. cuneata *blooms from July through October. © Dalgial. CC BY-SA 4.0.*

SIDE EFFECTS

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

The process of conducting surveillance efforts that include searches for *L. cuneata* are not expected to have direct effects on the environment.

Social side effects of surveillance efforts are expected to be neutral given that they already exist at a reasonable scale across the EU (for example, Pescott *et al*., 2015).

No economic side effects of surveillance are expected.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

Surveillance for early detection of *L. cuneata* should not impact economic activities and the public likely would be supportive and even encouraging, thus the measure is expected to be acceptable to stakeholders.

ADDITIONAL COST INFORMATION

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).

Given the significant ecological cost of *L. cuneata* invasions in the U.S. and the economic costs of management for the species, inaction could result in considerable costs if surveillance does not facilitate early detection and rapid eradication.

No socio-economic costs are expected beyond those already described.

LEVEL OF CONFIDENCE[1]

Well established.

The information here on biology of *L. cuneata* and the most likely pathways for introduction (intentionally via plants for planting and unintentionally via hay contaminant) and where it might be found is reasonably well established, but it is not known how useful such information is for conducting effective surveillance measures. 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).

1 See Appendix

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

Spot treatment with chemical herbicides.

MEASURE DESCRIPTION

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.

To spot treat *L. cuneata*, herbicides are applied with a hand-pump or CO_2 pressurised backpack sprayer (Altom *et al*., 1992; Koger *et al*., 2002; Farris and Murray, 2009) or other hand operated spray equipment such as a tank mounted on the back of an ATV unit. Plants should be sprayed to run-off and applied only to the target plant while avoiding overspray onto co-occurring desirable species.

Multiple herbicides have been evaluated for their effectiveness at controlling *L. cuneata* (for example, Altom *et al*., 1992; Koger *et al*., 2002; Farris and Murray, 2009). Results vary among different chemicals and across *L. cuneata* plant life history stages. Triclopyr and fluroxypyr have provided the most consistent control of the species across different life stages, including seedlings and adult plants (Altom *et al*., 1992; Koger *et al*., 2002; Farris and Murray, 2009).

Various herbicide concentrations have been tested. Altom *et al*. (1992) tested triclopyr at 0.56 and 1.12 kg per ha and fluroxypyr at 0.56 kg per ha on variably sized *L. cuneata* plants that ranged from 10-50 cm in height in a pasture setting. Both herbicides provided effective control, usually with >90% plant necrosis. Koger *et al*. (2002) found similar results when testing triclopyr at 560 and 840 g ae/ha and fluroxypyr at 210 and 560 g ae/ha. – less than 4% of plot density remained compared to controls. Farris and Murray (2009) demonstrated that triclopyr, metsulfuron-methyl, glyphosate, and 2,4-D amine plus picloram (tank-mix) all controlled more than 80% of *L. cuneata* after 4 months but that only triclopyr, applied when the plants were larger controlled 100% of seedlings.

Herbicides for spot treatment are generally mixed with a crop oil concentrate at 1.0% (v/v) or a non-ionic surfactant at 0.25% (v/v). It is illegal to use a herbicide in a manner inconsistent with the label's instructions; therefore, read the label carefully and follow instructions.

SCALE OF APPLICATION

Research has been conducted on herbicides for *L. cuneata* control on plots that ranged from 5-15 sq m plots (Altom *et al*., 1992; Koger *et al*., 2002; Farris and Murray, 2009) but there is no reason to believe that the effectiveness of treatments would vary based on the scale of applications as long as products could be applied homogenously throughout the treated area. Larger invaded areas likely would be treated more effectively with CO_2 pressurised backpack sprayers or with tanks and booms mounted on all-terrain vehicles (ATVs).

EFFECTIVENESS OF MEASURE

Effective.

There is strong evidence that spot treatment of *L. cuneata* with herbicides is effective for rapid eradication. The most consistently effective chemicals are triclopyr and fluroxypyr, which can result in 90-100% control of seedlings and adult plants 4 to 12 months after treatment (Altom *et al*., 1992; Koger *et al*., 2002; Farris and Murray, 2009).

EFFORT REQUIRED

Spot treatment can achieve eradication of *L. cuneata* in as little as 4 months if the plants are at the seedling stage (Farris and Murray, 2009) but the measure is less effective on mature, more established individuals so returning to an invaded area for retreatment probably will be necessary. Furthermore, because *L. cuneata* can create a persistent seedbank, sites may need to be monitored for 3-5 years (Ohlenbusch, 2007) to determine if new seedlings emerge and need to be treated. Preemergence herbicides may be considered for infested areas with large seed banks (Farris and Murray, 2009).

RESOURCES REQUIRED

Certified pesticide applicators, chemical herbicides, adjuvants such as crop oil or nonionic surfactant to improve application and effectiveness, spraying equipment and personal protective equipment are required. Costs vary widely based on the pay rate of staff, price of herbicide and other chemicals, and the type of spraying equipment used. One study from 1997 estimated costs at \$6.15-15.75 per acre (ca. €5.35-13.70), depending on the chemical used (Vermeire *et al*., 2002). There is also cost involved in mapping infested areas and returning to the area for retreatment.

SIDE EFFECTS

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

Eradicating *L. cuneata* by spot treating with herbicides can have positive environmental side effects if native species are released from competition with the invader and more widespread invasions are prevented. In one study, removal of *L. cuneata* by spot treating with triclopyr allowed more desirable forage grass species to return to the previously invaded area compared to untreated control plots, however, another weedy species also colonised the plots (*Ambrosia psilostachya*, Altom *et al*., 2002). Thus, as with many invasive plant species removal efforts, control of secondary invaders may be necessary to achieve restoration of native species or success of forage species. As with many herbicides, there may be nontarget effects on co-occurring native species but no such effects have been documented in the literature. Instead, the positive response of desirable species (for example, Altom *et al*., 2002) suggests that any non target effects are less than the positive response of desirable species when they are released from competition with *L. cuneata*.

No social side effects of spot treatment for eradication of *L. cuneata* such as herbicide runoff have been documented.

There could be positive economic side effects of spot treatment with herbicides if eradication of newly established *L. cuneata* is achieved and desirable species, such as more palatable forages, positively respond to removal of the invasive competitor (Altom *et al*., 2002).

ACCEPTABILITY TO STAKEHOLDERS

Neutral or mixed.

The general public may have a negative view on the use of chemical herbicides to control invasive *L. cuneata*, particularly if newly established populations are large and require extensive applications. The image of a manager in personal protection gear applying chemicals can generate fear, especially if the public is unaware of why chemicals are being applied. Thus, it is important to provide interpretative signs and to inform the public as to what is being done and why.

If citizens understand that the invader, including *L. cuneata* or other species that may be treated in the same habitat can cause significant ecological damage, and that it is increasingly difficult, expensive, and damaging to treat the larger the infestation, concerns can be alleviated.

ADDITIONAL COST INFORMATION

As with inaction for preventing introductions and not quickly identifying new occurrences through surveillance, failing to rapidly eradicate populations can result in widespread populations that are costly to manage.

Because the cost of herbicide applications are strongly correlated with the size of the infestation, it is much more cost-effective to locate and treat populations when they are small (Kettenring and Adams, 2011). In addition, it is more cost-effective to treat other species likely to occur in the same habitats such as *Ailanthus altissima*, *Asclepias syriaca*, *Heracleum mantegazzianum*, and *Microstegium vimineum*. Of course, specific treatment protocols will need to be followed for each species.

No socio-economic aspects are expected beyond those already described.

LEVEL OF CONFIDENCE[1]

Well established.

Measures to rapidly eradicate *L. cuneata* with herbicides are well established and have been tested across multiple habitats, plant life history stages, and geographic areas (Altom *et al*., 1992; Koger *et al*., 2002; Farris and Murray, 2009). Studies consistently show that triclopyr and fluroxypyr can result in 90-100% control of seedlings and adult plants less than a year after treatment. Moreover, under some conditions such as higher fertility desirable species can return to treated areas, assuming other secondary invaders are controlled (Koger *et al*., 2002).

1 See Appendix

Broadcast application of herbicides.

MEASURE DESCRIPTION

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.

If *L. cuneata* were to become widespread in a Member State, the only known management measure likely to be effective focuses on the use of herbicides, although other integrated measures can be helpful under particular circumstances. Fire has been explored as a management tool (see separate section below) but it is not effective because it removes plant residue that would otherwise inhibit *L. cuneata* germination and establishment and does not affect established *L. cuneata* plants. However, an appropriate use of fire could be to remove senesced plant material and residue so that returning *L. cuneata* plants are exposed and can be more effectively treated.

Thus, herbicide applications alone or in combination with fire or mowing are thought to be most effective for management of widespread invasions. The same products and rates used for spot treatment in rapid eradication should be effective at the management scale:

Altom *et al.* (1992) tested triclopyr at 0.56 and 1.12 kg per ha and fluroxypyr at 0.56 kg per ha on variably-sized *L. cuneata* plants that ranged from 10-50 cm in height in a pasture setting. Both herbicides provided effective control, usually with >90% plant necrosis. Koger *et al.* (2002) found similar results when testing triclopyr at 560 and 840 g ae/ha and fluroxypyr at 210 and 560 g ae/ha. – less than 4% of plot density remained compared to controls. Farris and Murray (2009) demonstrated that triclopyr, metsulfuron-methyl, glyphosate, and 2, 4-D amine plus picloram (tank-mix) all controlled more than 80% of *L. cuneata* after 4 months but that only triclopyr, applied when the plants were larger controlled 100% of seedlings. Herbicides for management are generally mixed with a crop oil concentrate at 1.0% (v/v) or a nonionicsurfactant at 0.25% (v/v).

It is illegal to use a herbicide in a manner inconsistent with the label's instructions; therefore, read the label carefully and follow instructions. Local and federal regulations on the use of chemical herbicides also may apply.

The objective of this measure is to manage widespread and established populations of *L. cuneata* through the use of chemical herbicides.

SCALE OF APPLICATION

Management of *L. cuneata* with herbicides has been tested on plots that ranged in size from 5-15 sq m (Altom *et al.*, 1992; Koger *et al.*, 2002; Farris and Murray, 2009) with similar results. The effectiveness of treatments should not vary based on the scale of applications as long as products can be applied homogenously throughout the treated area. Larger invaded areas likely would be treated more effectively with equipment mounted on all-terrain vehicles (ATVs) or trucks than with backpack sprayers on foot.

EFFECTIVENESS OF MEASURE

Effective.

There is good evidence that *L. cuneata* can be managed with herbicides. The most consistently effective chemicals are triclopyr and fluroxypyr, which can result in 90-100% control of seedlings and adult plants 4 to 12 months after treatment (Altom *et al.*, 1992; Koger *et al.*, 2002; Farris and Murray, 2009). However, depending on the scale of the established invasion, the abundance of co-occurring species, and the difficulty of the invaded terrain, initial treatment efforts over large areas may not be as successful as has been demonstrated on small research plots and retreatment probably will be required.

EFFORT REQUIRED

Repeated monitoring and followup treatments would likely be needed to achieve effective management of *L. cuneata* (Ohlenbusch, 2007; Gucker, 2010). There is evidence that control of populations can be achieved in as little as 4 months if the plants are at the seedling stage (Farris and Murray, 2009) but the measure is less effective on mature, more established individuals. Furthermore, because *L. cuneata* can create a persistent seedbank, sites may need to be monitored for 3-5 years (Ohlenbusch, 2007) to determine if new seedlings emerge and need to be treated. Pre-emergence herbicides may be considered for infested areas with large seed banks (Farris and Murray, 2009) or fire might be effective at reducing seed bank size (Gucker, 2010; Ohlenbusch, 2007).

RESOURCES REQUIRED

To manage widespread established *L. cuneata* invasions, certified pesticide applicators, chemical herbicides, adjuvants such crop oil or nonionic surfactant to improve application and effectiveness, spraying equipment and personal protective equipment are required. Costs vary widely based on the pay rate of staff, price of herbicide and other chemicals, and the type of spraying equipment used. One estimate suggests the cost of herbicide application for treating *L. cuneata* is $18-$36 U.S.D/acre (ca. €16-31) (Alexander *et al*., 2018), although these numbers may underestimate total costs associated with mapping infested areas and returning to the area for monitoring and retreatment.

SIDE EFFECTS

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

Managing *L. cuneata* with herbicides may have positive environmental side effects if native species are released from competition with the invader and more widespread invasions are prevented. In one study, removal of *L. cuneata* by spot treating with triclopyr allowed more desirable forage grass species to return to the previously invaded area compared to untreated control plots, however, another weedy species also colonised the plots (*Ambrosia psilostachya*, Altom *et al*., 2002). Thus, as with many invasive plant species removal efforts, control of secondary invaders may be necessary to achieve restoration of native species or success of forage species.

No social side effects of broadcast application of *L. cuneata* such as herbicide runoff have been documented.

There could be positive economic side effects of treatment with herbicides if eradication of newly established *L. cuneata* is achieved and desirable species, such as more palatable forages, positively respond to removal of the invasive competitor (Altom *et al*., 2002).

ACCEPTABILITY TO STAKEHOLDERS

Neutral or mixed.

There may be a negative public perception of broad scale management of *L. cuneata* with herbicides, particularly if invasions are in visible areas and treatments result in dead vegetation when the surrounding resident plants are green – which is likely. In addition, applicators in personal protection gear applying chemicals can generate fear and concern, especially if the public is unaware of why chemicals are being applied. Thus, it is important to provide interpretative signs and to inform the public as to what is being done and why.

Conversely, if people are educated about the impacts of *L. cuneata* and other problematic species and that it is increasingly difficult, expensive, and damaging to treat the larger the infestation, concerns may be alleviated.

ADDITIONAL COST INFORMATION

Inaction on management of widespread invasions of *L. cuneata* will likely result in greater ecological damage and invasions in new areas.

It is more cost-effective to locate and rapidly eradicate populations but even when management level is reached it is important to treat satellite populations to prevent them from growing and dispersing seed to additional areas.

No socio-economic aspects are expected beyond those already described.

LEVEL OF CONFIDENCE[1]

Established but incomplete.

Information on how to manage *L. cuneata* invasions at local scales is well established and there is little reason to believe larger scale management would differ significantly. Some considerations for broader scale management are the total area invaded (with larger areas more plants are more likely to be missed in the treatment process), the abundance of co-occurring species (that might make finding and treating plants difficult), and the difficulty of the invaded terrain. Recommendations are available on management measures (Ohlenbusch, 2007; Gucker, 2010) but they have not been well quantified for established populations over large areas.

1 See Appendix

Use of prescribed fire.

MEASURE DESCRIPTION

The use of prescribed fire for managing invasive plants often has been considered (Brooks *et al.*, 2004) but in many cases the effectiveness of the measure for invasive plant management produces mixed results (Keeley, 2006). The same is true for *L. cuneata* – some studies have shown that fire can reduce germination or kill seedlings but other studies have shown that fire promotes *L. cuneata* (Gucker 2010; Vermeire *et al.*, 2002). It is known that adult *L. cuneata* plants readily resprout after fire (Diller, 2002; Vermeire *et al.*, 2002), indicating that fire is not a useful management measure for mature plants. A recent comprehensive study demonstrated that under lab conditions *L. cuneata* seed germination was inhibited but in the field, fire promoted germination (Wong *et al.*, 2012). In addition, they found only minimal effects of fire on seedlings. Altogether, Wong *et al.* (2012) concluded that fire may be helpful for controlling seedlings that emerge after adult plants have been removed with herbicide but that otherwise fire was not a particularly useful management measure for *L. cuneata*.

In a separate study where fire was applied to management units that were ~5.5 ha (14 acres) in size researchers found that fire applied during the summer resulted in very good control of *L. cuneata* and other invasive plants compared to fires applied during the spring (Alexander *et al.*, 2018).

The objective of using fire as a management measure is to reduce the size of *L. cuneata* populations and inhibit seed dispersal.

SCALE OF APPLICATION

Prescribed fire generally can be applied at large scales (10s of km^2). The largest scale where fire has been used successfully to achieve some level of control of *L. cuneata* is ~5.5 ha (14 acres) but there is no reason to believe that application at larger scales would produce different results.

EFFECTIVENESS OF MEASURE

Neutral.

The use of fire to manage *L. cuneata* has produced mixed results (Gucker, 2010) and some studies have shown that invasive populations may actually be promoted by fire (Wong *et al.*, 2012), thus a further study is needed about the timing, intensity, and other aspects of fire before it is widely implemented as a management measure.

EFFORT REQUIRED

The appeal of fire as a management tool is that it requires relatively little time to complete a management treatment given the scale at which it can be applied and the cost to conduct treatments. A single treatment may reduce seedling numbers (Wong *et a*l., 2012) although repeated burning may be needed to reduce the abundance of *L. cuneata* and other invasive plants (Alexander *et al.*, 2004).

RESOURCES REQUIRED

Extensive resources may be required to conduct prescribed fires, including trained staff, specialised equipment, and machinery (to install fire breaks).

SIDE EFFECTS

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

If fire inhibits other invasive plants (for example, Alexander *et al.*, 2004), or if the targeted ecosystem is fire adapted such that application of fire promotes native species diversity independent of invasive plant suppression, then fire would have a positive environmental effect. However, if fire is applied to an ecosystem that is not fire adapted then native species may be harmed.

Fire may be viewed positively if people understand the conservation value of fire in particular ecosystems but more likely, fire would be viewed negatively, especially if access to areas is restricted when the measure is applied or if smoke drifts into nearby residential or commercial areas (McCaffrey, 2006). Additionally, the visual appeal of burned areas would temporarily be reduced.

ACCEPTABILITY TO STAKEHOLDERS

Neutral or mixed.

Some stakeholders may consider fire to be an acceptable management practice if they are well-educated on the conservation value of fire such as how it can maintain diversity and native plant communities in fire-adapted systems (for example, Brockaway and Lewis, 1997). However, more likely, recreational users such as hikers and bird watchers, might view fire as unacceptable (McCaffrey, 2006).

ADDITIONAL COST INFORMATION

The cost of applying prescribed fire is very low on a per area basis, assuming that trained staff and equipment area available. In one case, the cost was estimated at only $1U.S.D/acre (ca. €0.87) (Alexander *et al.*, 2004).

LEVEL OF CONFIDENCE[1]

Established but incomplete.

There is good evidence that fire may both inhibit (Alexander *et al.*, 2004) and promote (Wong *et al.*, 2012) *L. cuneata*, thus more information is needed to determine where, when, and under what conditions fire is an effective measure to manage this invasive species.

1 See Appendix

Mowing.

MEASURE DESCRIPTION

Mowing with a string trimmer or rotary mower that is self-propelled or tractor mounted has variable results for the control of *L. cuneata*. Mowing may be combined with herbicide application so that adult plants can be removed and herbicide application is more effective on resprouting plants or germinating seedlings (Gucker, 2010). However, mowing is non-selective so establishment of desirable native species may be difficult (Vermeir *et al.*, 2002; Ohlenbusch, 2007).

The objective of using mowing as a management measure is to reduce the size of *L. cuneata* populations and inhibit seed dispersal.

SCALE OF APPLICATION

Mowing can be applied at large scales – up to many ha – depending on the size of the mowing equipment available.

EFFECTIVENESS OF MEASURE

Repeated mowing multiple times per year at low heights (<30 cm, preferably lower; Vermeire *et al.*, 2007) can reduce seed production (Barnewitz *et al.*, 2002) but may result in rapid resprouting, and possibly increased vigor of adult plants (Diller, 2002).

EFFORT REQUIRED

Significant effort is required to repeatedly apply mowing multiple (3-4) times per year. The amount of time required to complete each mowing event depends on the scale of the invasion and the size of the equipment used.

RESOURCES REQUIRED

Mowing requires trained staff who can operate equipment safely and equipment such as a string trimmer, manual or self-propelled rotary mower, or tractor mounted mower.

SIDE EFFECTS

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

Mowing can have significant negative environmental effects by causing damage to non-target species such as native forbs, grasses, and tree seedlings (Vermeir *et al.*, 2002; Ohlenbusch, 2007).

Mowing may have positive social effects if people consider mowed areas to have a desirable appearance. However, mowing may suppress desirable native species that are important to botanists or bird watchers.

If areas invaded by *L. cuneata* are used as pasture then mowing may reduce desirable grasses used for forage, resulting in a negative economic effect.

ACCEPTABILITY TO STAKEHOLDERS

Given the widespread use of mowing to maintain areas, the measure likely would be acceptable to stakeholders unless the goal for an area is to promote high native plant diversity or natural succession to forest (such as mowing would suppress tree seedling establishment).

ADDITIONAL COST INFORMATION

The implementation cost for mowing would be relatively low because many land managers likely already have trained staff and equipment to apply the measure. However, the measure may not be particularly cost-effective because it may have to be repeated indefinitely for an established invasion (Vermeir *et al.*, 2002; Ohlenbusch, 2007).

LEVEL OF CONFIDENCE[1]

Established but incomplete.

There is significant information demonstrating that repeated mowing at low heights can reduce the performance and seed production of adult *L. cuneata* plants. However, there also exists evidence that plants readily resprout after mowing and that seedlings emerge quickly after treatment. More information on how best to integrate mowing with herbicide applications to achieve effective management of *L. cuneata* would be helpful.

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 or other synthesis or multiple independent studies that agree. *Note:* a meta-analysis is 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.
- **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.

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