Information on measures and related costs in relation to species included on the Union list

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This technical note provides information on the effectiveness of measures, alongside the required effort and resources, used to prevent the introduction, and to undertake early detection, rapid eradication, and management for the invasive alien species under review. Each table represents a separate measure.

Species (scientific name)	*Microstegium vimineum* (Trin.) A.Camus, Fl. Indo-Chine [P.H. Lecomte *et al.*] 7: 260. 1922
Species (common name)	stiltgrass, Japanese stiltgrass, Mary's grass, Chinese packing grass, Nepalese browntop
Author(s)	S. Luke Flory, University of Florida, USA
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Reviewer	Giuseppe Brundu, Department of Agriculture. University of Sassari. Viale Italia

Summary Highlight of measures that provide the most cost-effective options to prevent the introduction, achieve early detection, rapidly eradicate and manage the species, including significant gaps in information or knowledge to identify cost-effective measures.
<u>Prevention</u>

Presently *M. vimineum* is absent from the EU, however there currently are few established populations of *M. vimineum* in Europe (i.e., reported only from Turkey). There is little evidence from its invaded range in the US about how it is dispersed long distances, thus it is difficult to predict a likely mode of introduction or mechanism of dispersal in the EU. The best information suggests it could be introduced to the EU as a contaminant in bird seed or in plants for planting, or on machinery (e.g., mowers or graders used along roadsides), farm equipment, recreational equipment (e.g., mountain bikes, horse hooves), or by hikers and travelers. Monitoring these pathways and vectors and implementing measures such as equipment cleaning and inspection of nursery plants should help prevent the introduction of *M. vimineum* to the EU, but more information is needed on mechanisms responsible for long-distance dispersal in the current invasive range in the US.

Early detection

Early detection of established populations will require diligent scouting by natural resource professionals or citizen scientists. Training is needed to identify *M. vimineum* seedlings, which can closely resemble some native species, but experienced individuals can readily detect new populations. Smartphone and tablet applications can be effective for citizen science reporting of new *M. vimineum* populations, but people would need to be aware of the species and educated on identification, and natural resource professionals, botanists, or ecologists would need to confirm identification.

Rapid eradication

Multiple methods can be used to rapidly eradicate new *M. vimineum* populations, including hand weeding, broad-spectrum herbicides, and post-emergent grass-specific herbicides. Hand weeding is only practical for eradicating small populations of a few square meters, but the method requires no equipment or chemicals, and trained individuals can be selective so there are relatively few non-target effects on native species. Broad-spectrum herbicides are highly effective for removing *M. vimineum,* but they are not selective (i.e., they eliminate all vegetation), which may allow other invasive species to colonize treated sites. Thus, they only should be used when total vegetation control is desired (e.g., in gravel parking areas or along railways). Grass-specific herbicides efficiently remove *M. vimineum* without harming native forbs and trees, resulting in greater diversity of native species following invader eradication. Both broad-spectrum and grass-specific herbicides can be used for management of *M. vimineum* but whenever possible, grass-specific herbicides should be used because they are equally effective and allow native broadleaf species to return. The advantage of broad-spectrum herbicides is that they are more cost-effective and control all vegetation, while grass-specific herbicides are more expensive but promote native species recovery.

Management

Mowing or string trimming can be used for managing *M. vimineum,* but because mowing is not at all selective and string trimming is minimally selective, and their use is limited by terrain and habitat conditions, they are not practical for most natural areas. There is limited evidence that prescribed fire can be used for *M. vimineum* management but its use is restricted to applications during the growing season when it likely would be difficult to carry fire through actively growing invader populations. Additionally, there is strong evidence that *M. vimineum*-fueled fires are more intense and damage native species during the dormant season and may promote *M. vimineum* populations. Hand weeding is not practical for management of larger established *M. vimineum* populations due to the time and effort required.

In summary, the introduction of *M. vimineum* can be prevented through monitoring of likely pathways, new populations can be detected with diligent

surveillance, and populations can be rapidly eradicated or managed with herbicides, hand weeding, and mowing or trimming. Proper application of appropriate measures can effectively remove invasive *M. vimineum* populations and allow native species recovery.

Prevention – 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. **This table is repeated for each of the prevention measures identified.**	
Measure description Provide a description of the measure	**Inspection of plants for planting.** *M. vimineum* is a warm-season (C4) annual plant from eastern Asia that is widely invasive throughout the eastern US. As an annual species, it germinates in spring and completes its life cycle in a single growing season. It grows in very dense patches in a wide variety of habitat conditions. It is unique among C4 species in that it can tolerate very low light conditions (Wilson, *et al.* 2015). It produces very large numbers of seed (Wilson, *et al,* 2015) from chasmogomous (i.e., potentially outcrossed) or cleistogomous (i.e. selfed) flowers (Cheplick, 2006). Cleistogomous flowers are located in leaf sheaths low to the ground and can be dispersed with senesced plant material. It does not reproduce vegetatively. It can be misidentified with *Leersia, Polygonum, Elymus,* and other woodland grasses and small forb species. The misidentification with forb species often occurs when *M. vimineum* seedlings are small and the leaves are broad – it then resembles small bamboo plants or *Polygonum* seedlings. *M. vimineum* seed is very small and can be a contaminant of nursery stock that is transported among territories, regions, or countries. Seedlings or adult plants might establish within potted plants that have been grown outdoors in areas that are invaded by *M. vimineum.* Planting nursery stock that is contaminated with live *M. vimineum* outdoors may result in dispersal to surrounding natural areas and invasion. In addition, the species has a mixed mating system with seed produced from both chasmogamous (outcrossed) and cleistogamous (selfed) flowers (Cheplick, 2006), which are located at the end of tillers and within leaf sheaths, respectively. The cleistogamously produced seeds located in the leaf sheaths can be transported in senesced plant material found in plant containers, even if no loose seed or live plants are present.
Effectiveness of measure e.g. has the measure previously worked, failed	There are no documented cases of inspecting plants for planting for *M. vimineum* specifically but inspection of nursery stock is a common practice given the large increase in global movement of live plants in recent decades (Liebhold, Brockerhoff, Garrett, Parke, & Britton, 2012) and the known problems of nursery stock contamination with non-native pests, pathogens, and invasive plants. The effectiveness of the measure is unknown.
Effort required e.g. period of time over which measure need to be applied to have results	Inspection of nursery stock for seeds and senesced and live plant material would need to be implemented for plants being transported from regions where *M. vimineum* is currently established (for example from Turkey) and would need to continue as long as those sites remain contaminated and plants are shipped from those areas. Such inspections could be combined with inspections for other species, thereby minimizing the additional effort required.

Resources required [1] e.g. cost, staff, equipment etc.	Staff will be needed to conduct inspections and some training is necessary to educate inspectors who are looking for *M. vimineum* because seeds are small and immature plants can be inconspicuous (Kleczewski, Flory, & Nice, 2011).
Side effects (incl. potential) i.e. positive or negative side effects of the measure on public health, environment, non-targeted species, etc.	None.
Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	Given that inspection of plants for planting is routine in many cases when species are being transported among territories or states, the practice of inspecting for *M. vimineum* is likely acceptable for most stakeholders.
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	The implementation cost is unknown but is expect to be minimal if nursery stock inspections are already occurring. If inspections are not already occurring, then costs could be substantial but difficult to predict. The cost of inaction could be profound if lack of inspection results in *M. vimineum* invasions in natural areas. *M. vimineum* has significant ecological and economic impacts, including effects on forest regeneration, native plant and animal diversity, and ecosystem processes such as carbon and nitrogen cycling (Barden, 1987; Brewer, 2011; S. L. Flory & Clay, 2010a, 2010b; S Luke Flory, Clay, Emery, Robb, & Winters, 2015; S.L. Flory, Rudgers, & Clay, 2007; McGrath & Binkley, 2009; C. M. Oswalt, Clatterbuck, W.K., Oswalt, S.N., Houston, A.E., & Schlarbaum, S.E.; C. M. Oswalt, Oswalt, & Clatterbuck, 2007; Simao, Flory, & Rudgers, 2010; Robert J. Warren, II, Wright, & Bradford, 2011). The cost effectiveness should be high given that expenses are low (assuming inspections already are occurring) and the payoff could be high if potential introductions are prevented. However, it is difficult to quantify the number of cases where introductions are prevented. If invasions do occur, removal of *M. vimineum* and restoration of natural areas is extremely time consuming and expensive (S. L. Flory, 2010; S. L. Flory & K. Clay, 2009; Tu, 2000).
Level of confidence [2] See guidance section	Medium. Although *M. vimineum* has been observed growing in dense stands in close proximity to nursery stock in the US and is found as a contaminant of soil stockpiles (SL Flory, personal observation), there are no known cases of nursery stock contamination by *M. vimineum* in the US or in Europe.

Prevention – 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. **This table is repeated for each of the prevention measures identified.**	
Measure description Provide a description of the measure	**Inspection of contaminated bird seed.** The introduction of invasive alien plants as contaminants of bird seed for caged or wild birds is relatively common (Vitalos & Karrer, 2008), especially when invader seed closely resembles species intended for bird seed mixes. In two cases *M. vimineum* was found as a contaminant of bird seed in Britain (Hanson & Mason, 1985; Ryves, Clement, & Foster, 1996) by identifying seedlings that germinated from seed found in bird seed mixes. The process of inspecting bird seed for contamination may be difficult given the resemblance if *M. vimineum* seed to common grass species, thus specific protocols would need to be developed to either germinate random lots of bird seed to determine if *M. vimineum* is present and/or to inspect sites where seed is collected for bird seed mixes to determine if *M. vimineum* is present at those sites.
Effectiveness of measure e.g. has the measure previously worked, failed	No information was located on the effectiveness of bird seed mix inspections to prevent introduction of non-native species. However, USDA-APHIS provides a manual that outlines regulations to prevent the introduction of problematic non-native species (USDA-APHIS "Seeds Not For Planting" manual, https://www.aphis.usda.gov/import_export/plants/manuals/ports/downloads/seeds_not_for_planting.pdf
Effort required e.g. period of time over which measure need to be applied to have results	Inspections of seed lots would need to be ongoing from seed production regions where *M. vimineum* occurs unless pre-export inspections could certify the seed lots as "weed free" by inspecting production locations.
Resources required [1] e.g. cost, staff, equipment etc.	Staff, and potentially equipment (greenhouses to germinate seed) to conduct inspections. Identification of *M. vimineum* seed is very difficult, thus seed would likely need to be germinated for identification, which would be time consuming.
Side effects (incl. potential) i.e. positive or negative side effects of the measure on public health, environment, non-targeted species, etc.	None.
Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	Requiring inspection of bird seed mixes or seed production sites might be cost-prohibitive and unacceptable to stakeholders.
Additional cost information [1]	If *M. vimineum* is introduced via bird seed mixes and causes widespread invasions in natural areas the

When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	consequences could be severe (as described above). However, relatively little is known about the likelihood of invasive plant dispersal and introduction due to contaminated bird seed mixes. Thus, the recommendation is to first conduct wide-ranging tests of bird seed mixes to ascertain the likelihood that they will contain seed of problematic species (*M. vimineum* or other species) before enacting any broad scale seed inspection programs.
Level of confidence [2] See guidance section	Medium. There is little information available on the likelihood that bird seed mixes are contaminated with *M. vimineum* (or other weedy or invasive species) and no information was found on the effectiveness of inspection activities for detecting contaminants.

Prevention – 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. **This table is repeated for each of the prevention measures identified.**	
Measure description Provide a description of the measure	**Inspection and cleaning of used machinery and equipment.** The seed of *M. vimineum* is transported among sites in the US when farming, maintenance, and construction equipment is moved among sites (Mortensen, Rauschert, Nord, & Jones, 2009). Seed adheres to equipment tires and other parts of machinery, especially when sites are muddy. *M. vimineum* is known to be facilitated by disturbance of plant communities and the leaf litter layer (Marshall & Buckley, 2008; C. M. Oswalt & Oswalt, 2007; Schramm & Ehrenfeld, 2010), thus the combination of dispersal by equipment and the disturbance created by road maintenance, farming practices, and construction activities can result in widespread invasions (Veldman & Putz, 2010). For example, a state-owned forest was overrun by *M. vimineum* following logging practices that caused soil disturbance and dispersed seed (SL Flory, personal observation). In addition, road and trail sides in the US are primary locations where *M. vimineum* first establishes before spreading into nearby undisturbed natural areas (Mortensen, et al., 2009; R. J. Warren, II, Bahn, Kramer, Tang, & Bradford, 2011).
Effectiveness of measure e.g. has the measure previously worked, failed	Although little research has quantified the effectiveness of equipment cleaning procedures for preventing the spread of invasive species, there are well-developed Best Management Practices that putatively prevent the spread of invader propagules (e.g., "Equipment Cleaning to Minimize the Introduction and Spread of Invasive Species: Heavy Equipment used on Land" http://files.dnr.state.mn.us/natural_resources/invasives/terrestrialplants/equipment_cleaning_to_minimize.pdf) The key to effectiveness of equipment cleaning to prevent the introduction of *M. vimineum* is diligent cleaning of equipment used in invaded areas. Currently, the distribution of *M. vimineum* is very restricted in Europe (i.e., only in Turkey), thus this method is only needed on a limited basis for equipment coming from the US where *M.*

	vimineum is widespread.
Effort required e.g. period of time over which measure need to be applied to have results	All equipment coming from invaded areas (e.g., the US, Turkey) should be inspected and cleaned. The measure would need to be implemented indefinitely.
Resources required [1] e.g. cost, staff, equipment etc.	Pressure washing equipment in a quarantined area, staff to conduct inspections and cleanings, and preferably equipment and facilities for collecting material to test if the practice is preventing the introduction of seed. Collected material would need to be placed in a glasshouse under ideal growing conditions to germinate seed and identify and count species. Such data could be very useful for determining if the measure is cost-effective.
Side effects (incl. potential) i.e. positive or negative side effects of the measure on public health, environment, non-targeted species, etc.	Equipment cleaning sites should be located where runoff would not enter streams or other waterways because washing water could contain pollutants such as engine or hydraulic oil. Ideally, water would remain on site or would be directed into wastewater treatment facilities.
Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	The cost of cleaning exported/imported equipment could be substantial but might be highly effective. Stakeholders may be resistant to implementing such measures depending on the associated costs and location of cleaning facilities, which might introduce transportation costs. Costs should not be prohibitive, although disposal of wash water may require construction of specialized facilities so water can be transported to wastewater treatment facilities or treated onsite.
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	Costs of inaction could be substantial if *M. vimineum* is introduced and invades natural areas (see above). Cost-effectiveness is dependent on the proportion of cleaning events that result in seeds being removed from equipment (see above suggestion on data collection).
Level of confidence [2] See guidance section	Medium. Certainly *M. vimineum* is transported by equipment in its invaded US range given that local populations spread slowly but invasions have spread rapidly at the landscape scale (Rauschert, Mortensen, Bjørnstad, Nord, & Peskin, 2010). Some evidence suggests *M. vimineum* also is spread by water (Tekiela & Barney, 2013). However, very little specific data is available on how much seed and how far seed is transported by equipment, so the effectiveness of this measure for prevention is difficult to quantify.

Prevention – 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. **This table is repeated for each of the prevention measures identified.**	
Measure description Provide a description of the measure	**Inspection and cleaning of outdoor recreation equipment, including hiking shoes and mountain bikes, and horse hooves.** The transport of *M. vimineum* seed by recreational activities has not been well researched but recent surveys demonstrate that populations in South Carolina, USA are associated with trail heads and near trails in forests used by hikers, bikers, and horseback riders (Hagan *et al.*, *unpublished data*). More generally, it is well-known that recreation and travel can result in movement of viable plant seeds (Ware, Bergstrom, Müller, & Alsos, 2012), including invasive species (Wells & Lauenroth, 2007; Whinam, Chilcott, & Bergstrom, 2005). Cleaning recreation equipment can be as simple as installation of boot brush stations at trail heads or more involved by installing bike washing stations or facilities for cleaning hooves of horses near camp sites or at trail heads. Because *M. vimineum* does not currently occur in EU Member States, such measures only need to be implemented when recreational users are arriving from the US or from Turkey, where *M. vimineum* is present and highly invasive, or from eastern Asia where *M. vimineum* is native. However, because such measures also would prevent the introduction of other seed-borne invaders, they could be highly cost effective.
Effectiveness of measure e.g. has the measure previously worked, failed	The use of boot brush stations are widespread in natural areas subjected to frequent recreation activities (CAL-IPC, 2012) but little quantitative information is available on their effectiveness. Anecdotally, natural areas managers indicate that such practices often result in removal of many invasive plant seeds (SL Flory, personal observation), but little is known about the proportion of seeds removed. That is, are enough seeds removed to prevent the spread of invasions to other areas?
Effort required e.g. period of time over which measure need to be applied to have results	Boot brush stations and facilities to clean bikes and horse hooves are relatively inexpensive and would only need to be used for *M. vimineum* specifically when recreational users are coming from infested areas. However, as with equipment cleaning, the practices likely would prevent the introduction of other non-native invasive plants.
Resources required [1] e.g. cost, staff, equipment etc.	Knowledge of travel patterns would be helpful for determining where and when boot brush cleaning stations, and bike and horse cleaning facilities are needed. Given the limited distribution of *M. vimineum* in Member States, such facilities would receive little use specifically for *M. vimineum* but would likely prevent the spread of other invaders. Staff would be needed to construct and maintain the facilities, and ideally to collect data on seeds removed by these measures.
Side effects (incl. potential) i.e. positive or negative side effects of the measure on public health, environment, non-targeted species, etc.	A positive side effect of implementing these measures for *M. vimineum* is that other invasive plants likely would be prevented from introduction and spread.

Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	The public may be resistant or ambivalent about the use of boot brush stations and other cleaning facilities. However, with proper signage such facilities alternatively could provide a good opportunity for education about invasive plant species.
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	Because boot brush and cleaning facilities are low cost to construct and maintain they might be highly cost effective. However, given the limited distribution of *M. vimineum* in Member States they would do more to prevent the introduction of species other than *M. vimineum.*
Level of confidence [2] See guidance section	Medium. Few data exist on the effectiveness of boot brush stations and bike and horse cleaning stations for preventing the spread of invasive plants, although it is understood that people and horses often disperse *M. vimineum* and other invaders. More information is needed on where *M. vimineum* occurs in member states and the likelihood that the species will be transported by recreational users of natural areas.

Early detection - Measures to achieve early detection and run an effective surveillance system for achieving an early detection of a new occurrence (cf. Article 16 of the IAS Regulation). This section assumes that the species is not currently present in a Member State, or part of a Member State's territory. **This table is repeated for each of the early detection measures identified.**	
Measure description Provide a description of the surveillance method	**Field scouting by natural resources professionals.** Early detection of *M. vimineum* will required diligent scouting by natural resources professionals who have been trained to identify the species and to focus on areas most likely to be colonized. *M. vimineum* seedlings are inconspicuous to untrained personnel and resemble other grasses and forbs such as *Elymus* spp.*, Polygonum* spp.*,* and *Leersia* spp. Personnel should be familiar enough with the growth form of the plant and common population characteristics so they have imbedded search images during scouting. *M. vimineum* most often first colonizes along roads, trails, and waterways (Cole & Weltzin, 2004, 2005; S. L. Flory, 2010), thus those sites should be scouted first. In addition, areas subjected to recent disturbances such as mowing, tree harvesting, or construction are likely to be colonized early, particularly if equipment, construction materials, or landscaping materials (e.g., soil, mulch, gravel) are transported from infested areas.
Effectiveness of the surveillance e.g. has the surveillance previously worked, failed	Once personnel are trained to identify *M. vimineum* they can quickly locate new populations and the measure can be highly effective. However, experience is critical for scouting effectiveness, and failure to locate even small

	populations of only a few *M. vimineum* individuals can result in widespread invasions in subsequent years because of the very high reproduction rate of *M. vimineum,* even under low light conditions (Wilson, Caughlin, Civitello, & Flory, 2015) such as forest understories (S. Luke Flory, Long, & Clay, 2011a, 2011b).
Effort required e.g. required intensity of surveillance (in time and space) to be sufficiently rapid to allow rapid eradication	Natural areas only need to be surveyed once or twice per year because as an annual species *M. vimineum* reproduces only once per year. A single survey about midday through the growing season likely would suffice to locate new populations, assuming personnel are well-trained and diligent in surveying all areas that might be invaded. If surveys are conducted early in the growing season when plants are small they likely would need to be repeated to be sure all individuals are located. Consequences of missing individuals that reproduce can be severe because seed can be dispersed to new areas.
Resources required [1] e.g. cost, staff, equipment etc.	No equipment is required but many person hours may be needed to conduct surveys depending on the size of the natural area.
Side effects (incl. potential) i.e. positive or negative side effects of the method on public health, environment, non-targeted species, etc.	None
Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	Given the relatively low cost of surveillance, and because effort could be combined with surveillance for other invasive plant species, stakeholders likely would find this measure acceptable.
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	Little cost information is available for invasive plant scouting. One estimate provided by Erick Smith at Kestrel Ecological Services (www.kestreleco.com; Gainesville, FL) was that scouting costs approximately $125 USD per hectare. Note that costs associated with scouting for a species can vary widely based on region, terrain, habitat, vegetation type, and the number of species being scouted simultaneously.
Level of confidence [2] See guidance section	Medium. With experience, personnel should be able to readily identify even small populations of *M. vimineum.* However, no quantitative data was available on the effectiveness of invasive plant scouting for early detection, and personnel may become fatigued and less effective after many hours of searching.

Early detection - Measures to achieve early detection and run an effective surveillance system for achieving an early detection of a new occurrence (cf. Article 16 of the IAS Regulation). This section assumes that the species is not currently present in a Member State, or part of a Member State's territory. **This table is repeated for each of the early detection measures identified.**	
Measure description Provide a description of the surveillance method	**Field scouting by citizen scientists.** The use of citizen science programs for identifying and reporting invasive species has increased rapidly in recent years as technology has improved. Smartphones and tablets are now common among people from most backgrounds and age groups, and applications (e.g. eddmaps.org; EASIN - https://easin.jrc.ec.europa.eu/CitizenScienceBecome) include the ability to upload photos, communicate with experts, and provide lat/long locations, greatly improving the quality and amount of data collected (Crall et al., 2011; Gallo & Waitt, 2011). Citizens could scout for invasive species either casually while conducting recreation or work activities or intentionally during targeted events designed to map (and often to remove) invasive species.
Effectiveness of the surveillance e.g. has the surveillance previously worked, failed	Reporting on occurrences of invasive species requires that citizen scientists are aware of the species for which information is needed. If species are common and charismatic (e.g., pythons in South Florida, USA), many people likely to participate in citizen science programs will be familiar with the species. However, for emerging and less conspicuous species such as *M. vimineum,* education and awareness programs will be needed to inform citizens. Once citizen scientists are familiar with a species they ideally also would be knowledgeable about the basic biology and ecology of the species so they are searching at the time of year and in locations where the species is most likely to be found. For example, *M. vimineum* is most conspicuous in July and August (late in the growing season) in eastern North America, and is often first found along roads, trails, and water ways (Cole & Weltzin, 2004; Kleczewski, et al., 2011; Tu, 2000). Searching at the appropriate time and place will greatly increase the effectiveness of scouting for early detection by citizen scientists. No information is available specifically for *M. vimineum* citizen science scouting but recent publications suggest that the measure can be highly effective for detection and identification of other invasive plant species (Crall, et al., 2011).
Effort required e.g. required intensity of surveillance (in time and space) to be sufficiently rapid to allow rapid eradication	Although citizen scientists can be highly effective at identifying invasive species, *M. vimineum* may pose a unique challenge because it is not a conspicuous species and it is not yet present in the EU. If a sufficiently large number of citizen scientists are involved in searching for *M. vimineum* or other species, the effort per person – and certainly the effort required by regulatory agencies – would be relatively little. A small amount of effort could have a high payoff if new populations are located early and eradicated.
Resources required [1] e.g. cost, staff, equipment etc.	Few resources are required other than a smartphone or tablet application that can be modified to include *M. vimineum.*

Side effects (incl. potential) i.e. positive or negative side effects of the method on public health, environment, non-targeted species, etc.	A positive side effect of including *M. vimineum* in citizen science invasive plant search efforts would be that other species could be identified during the search process, which may ultimately result in better early detection and eradication of emerging invaders.
Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	Stakeholders should be supportive of citizen science scouting, assuming citizens obey the regulations of properties they visit (e.g., remain on trails when required). There may be a strong positive effect on public perception of government and natural resource agencies.
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	The cost of implementing citizen science programs for early detection of invasive species is minimal because most of the work is done by citizens on a volunteer basis. The primary cost is the development and maintenance of software (e.g., smartphone applications) to gather the information. Collected data also needs to be verified by experts who are familiar with the species, database managers are needed to curate the information that is collected, and natural resource professionals are needed to take action for invader removal.
Level of confidence [2] See guidance section	High. There is strong evidence that citizen scientists can effectively identify invasive plants and there are good electronic applications for reporting on the location of invaders. Proper training on identification, ecology, and biology of *M. vimineum,* and awareness that it is a species that needs to be located during scouting of natural areas, is needed. If training and awareness are sufficient, citizen science scouting should help prevent invasions.

Rapid eradication - Measures to achieve rapid eradication after an early detection of a new occurrence (cf. Article 17). This section assumes that the species is not currently present in a Member State, or part of a Member State's territory. **This table is repeated for each of the eradication measures identified.**	
Measure description Provide a description of the measure	**Application of broad-spectrum plant protection products (PPP).** PPPs can be applied with hand pump sprayers, backpack sprayers, or CO2 or gas-powered sprayers mounted on ATVs or trucks. Any PPP should be applied according to manufacturer's instructions and in accordance with EU and national regulations. Briefly, *M. vimineum* is highly sensitive to broad-spectrum herbicides such as glyphosate (Judge, Neal, & Shear, 2008) and may be eliminated at rates below the recommended dose. Herbicides should be applied until runoff. Do not over apply and be as selective with applications as possible. Note that broad-spectrum herbicides can kill all types of vegetation and are less effective than grass-specific herbicides for removing *M. vimineum* while also allowing native species to recover (Judge, et al., 2008). Herbicides should be applied when plants are 10-15 cm tall, after self-thinning of the population occurs. Early in

	the life cycle of *M. vimineum* plants can occur at extremely high densities but later in the growing season many individuals die and the remaining individuals are larger (Robert J. Warren, II, Bahn, & Bradford, 2012) can be more effectively treated. Treating too early in the year can result in some individuals being missed, allowing them to recover and produce seed by the end of the year (Flory, personal observation). If those individuals are not treated, the population may persist. EU/national/local legislation on the use of PPPs needs to be respected.
Effectiveness of measure e.g. has the measure previously worked, failed	Broad-spectrum herbicides (e.g., glyphosate) are highly effective on *M. vimineum* (Judge, et al., 2008) and can eliminate all individuals if applied at the appropriate time of year.
Effort required e.g. period of time over which measure need to be applied to achieve rapid eradication	*M. vimineum* populations can be eradicated with as little as one application of a broad-spectrum herbicide, assuming it is applying carefully to all plants at the appropriate time of year (mid growing season). Multiple applications over one season also can be effective.
Resources required [1] e.g. cost, staff, equipment etc.	Application of any type of herbicide requires staff who are trained in how to apply herbicides safely, equipment (e.g., backpack sprayers, ATV sprayers), herbicides, and potentially surfactants depending on the product being used and the specific formulation. Costs for applying herbicides vary widely based on region, habitat, and terrain. The following are estimates provided by Erick Smith at Kestrel Ecological Services (www.kestreleco.com; Gainesville, FL). Costs do not include the price of chemicals. 1. Applying herbicide via backpack sprayer $250-750/ha for 1%-25% cover class 2. Applying herbicide via ATV $125-1,100/ac for 1%-100% cover
Side effects (incl. potential) i.e. positive or negative side effects of the measure on public health, environment, non-targeted species, etc.	By definition, broad-spectrum herbicides can kill most types of vegetation and should be applied with care so sensitive and desirable vegetation is not damaged. Non-target effects on other species, including via herbicide drift and runoff may also be of concern. Follow manufacturer and government regulations.
Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	Given the very high effectiveness of broad-spectrum herbicides on *M. vimineum* and their ready availability they can be a good option for emerging, small invasive populations, and stakeholders may find them acceptable. However, because of the many side effects (e.g., non-target effects on desirable vegetation), the stigma surrounding the use of herbicides, and the “scorched earth” appearance of treated areas, they may not be acceptable, particularly in natural areas used for recreation or those containing threatened or endangered

	species.
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	Some broad-spectrum herbicides have a very low price-point, making them highly cost-effective over very large areas. However, their use in natural areas may be limited by their non-target effects on native species. In addition to the direct effects of broad-spectrum herbicides on native species, a secondary concern is the colonization of habitats by other invaders once the primary invader has been removed (Kettenring & Adams, 2011). In many cases, it is likely more effective, both in terms of long-term costs and effects on native species, to use a grass-specific herbicide (see below).
Level of confidence [2] See guidance section	High. There is clear evidence that broad-spectrum herbicides can rapidly eradicate *M. vimineum* (Judge, et al., 2008) in the US and similar results are expected in the EU.

Rapid eradication - Measures to achieve rapid eradication after an early detection of a new occurrence (cf. Article 17). This section assumes that the species is not currently present in a Member State, or part of a Member State's territory. **This table is repeated for each of the eradication measures identified.**	
Measure description Provide a description of the measure	**Application of post-emergent grass-specific PPPs (plant protection products).** Post-emergent grass-specific herbicides (e.g., fluazifop-p-butyl, fenoxaprop-P, imazapic, and sethoxydim) can be applied with hand pump sprayers, backpack sprayers, or CO2 or gas-powered sprayers mounted on ATVs or trucks, similar to application of broad-spectrum herbicides. Herbicide should be applied according to manufacturer's instructions and in accordance with EU and national regulations. Surfactants may need to be added. *M. vimineum* is highly sensitive to grass-specific herbicides and can be controlled at rates below the recommended dose (S. L. Flory, 2010; S. L. Flory & K. Clay, 2009; C. A. Judge, J. C. Neal, & J. E. Derr, 2005a; C. A. Judge, J. C. Neal, & J. F. Derr, 2005b; Judge, et al., 2008). For example, Flory et al applied 0.21 kg active ingredient (ai) per hectare of fluazifop-P-butyl (12 oz/ac Fusilade DX; Syngenta Crop Protection, Inc., Greensboro, NC, U.S.A.) mixed with 14.8 mL of a nonionic adjuvant surfactant (Surf Plus 584; Townsend Chemical Division, Muncie, IN, U.S.A.) and found that there was 99% less *M. vimineum* in herbicide treated plots than in untreated controls. Herbicides should be applied until runoff and should not be over applied. Applications should be as selective as possible so there are minimal non-target effects on native grass species. Grass-specific herbicides should be applied when plants are 10-15cm tall, after self-thinning of the population occurs. Early in the life cycle of *M. vimineum* plants can occur at extremely high densities but later in the growing

	season many individuals die and those that remain can be more effectively treated. Treating too early in the season can result in some individuals being missed, allowing them to produce seed by the end of the year and promoting population persistence. Alternatively, populations treated early in the year would need to be revisited to treat any *M. vimineum* that survived the first herbicide application. EU/national/local legislation on the use of PPPs needs to be respected.
Effectiveness of measure e.g. has the measure previously worked, failed	*M. vimineum* can be effectively controlled with multiple types of grass-specific herbicides (Judge, et al., 2005a; Judge, et al., 2005b; Judge, et al., 2008) and across varies habitat conditions (S. L. Flory, 2010; S. L. Flory & K. Clay, 2009) with consistent results (emery, demographic paper). Flory et al 2010 showed that Fusilade resulted in more than 99% percent control after a single treatment.
Effort required e.g. period of time over which measure need to be applied to achieve rapid eradication	Small populations of *M. vimineum* that are detected early in the invasion process can be rapidly eradicated with as little as one grass-specific herbicides treatment, although follow-up monitoring should be conducted to be sure all plants have been removed. Applying herbicide to small populations (i.e., 1-4 square meters) requires only a few minutes and little effort. However, treating a large number of populations, even if they are small, over rough terrain can require considerable time and effort.
Resources required [1] e.g. cost, staff, equipment etc.	Application of any type of herbicide requires staff who are trained in how to apply herbicides safely, equipment (e.g., backpack sprayers, ATV sprayers), herbicides, and potentially surfactants depending on the product being used and the specific formulation. Costs for applying herbicides vary widely based on region, habitat, and terrain. The following are estimates provided by Erick Smith at Kestrel Ecological Services (www.kestreleco.com; Gainesville, FL). Costs do not include the price of chemicals. 1. Applying herbicide via backpack sprayer $250-750/ha for 1%-25% cover class 2. Applying herbicide via ATV $125-1,100/ha for 1%-100% cover
Side effects (incl. potential) i.e. positive or negative side effects of the measure on public health, environment, non-targeted species, etc.	Compared to broad-spectrum herbicides, post-emergent grass-specific herbicides have much fewer side effects on native species. Flory et al 2009 demonstrated that removal of *M. vimineum* with grass-specific herbicide was very effective and allowed native herbaceous plants and trees to recolonize. Forb and graminoid plant abundance increased significantly, herbaceous plant diversity increased by 21%, and tree seedling regeneration increased by 123% after removal of *M. vimineum* with grass-specific herbicide. Application of a pre-emergent herbicide did not allow for recolonization by native species, and similar results would have been expected with a broad-spectrum herbicide (e.g., glyphosate), which would have eliminated all vegetation. Native grasses and some sedges can be damaged by grass-specific herbicides but applying at rates below the lowest label rate allows some native perennial grasses to survive. Thus, the side effects of post-emergent grass-specific herbicides

	are relatively minimal compared to using broad-spectrum herbicides for rapid eradication of *M. vimineum*.
Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	The relatively small side effects of grass-specific herbicides should make it an attractive rapid eradication methods for stakeholders. However, some natural areas may have restrictions on the use of herbicides, which may include specific lists of allowable active ingredients. Because the chemicals in grass-specific herbicides (e.g., fluazifop-p-butyl, fenoxaprop-P, imazapic, and sethoxydim) are less commonly applied, less data is available on their side effects and environmental fate, and they may be more environmentally damaging, they may not be on approved use lists. Such is the case at Duke University Forest (Durham, North Carolina, USA) where glyphosate can be used but fluazifop-p-butyl (trade name Fusilade DX) is not approved (Flory, personal communication).
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	Grass-specific herbicides are considerably more expensive than broad-spectrum herbicides because in most cases there are not generic formulations available. Regardless, the much lower side-effects on native species of grass-specific herbicides make them an attractive option for rapid eradication of *M. vimineum.*
Level of confidence [2] See guidance section	High. Multiple published studies have demonstrated that post-emergent grass-specific herbicides are highly effective for rapidly eradicating *M. vimineum* while also allowing native trees and herbaceous species to recover (S. L. Flory & K. Clay, 2009; Judge, et al., 2008).

Rapid eradication - Measures to achieve rapid eradication after an early detection of a new occurrence (cf. Article 17). This section assumes that the species is not currently present in a Member State, or part of a Member State's territory. **This table is repeated for each of the eradication measures identified.**	
Measure description Provide a description of the measure	**Hand weeding.** Rapidly eradicating *M. vimineum* with hand weeding simply involves pulling seedlings from the ground and placing them on the soil/litter surface. Because *M. vimineum* is an annual species and individual plants are not particularly hardy, pulled plants do not need to be bagged or removed from invaded sites. Weeding should occur when plants are 5-20 cm tall, preferably around the mid-point of the growing season but well before flowering or seed set, because larger individuals are easier to locate and pull. Care must be taken to properly identify *M. vimineum* seedlings since they closely resemble some native species (e.g., *Polygonum* spp., *Oplismenus* spp.) when they are small.
Effectiveness of measure e.g. has the measure previously worked, failed	Weeding can be highly effective for removing *M. vimineum.* Flory *et al.* 2009 found that hand weeding was 98% effective for removing *M. vimineum* compared to untreated controls. However, see Flory and Lewis (2009) who found in another study that hand weeding was less effective. They difference in results is likely due to the timing

	of hand-weeding, density of the seed bank at the sites, or weather during the growing season. Care must be taken to monitor invaded sites for seedlings after initial hand weeding treatments have been applied.
Effort required e.g. period of time over which measure need to be applied to achieve rapid eradication	The biggest drawback of hand weeding is that it is very labour intensive. Flory *et al.* (2009) conducted hand weeding in plots that were only four square meters but found that densely invaded plots could take up to an hour or more to weed (Flory, personal observation). Plots that required the most time and effort were those where invasions were dense and co-occurred with many desirable native herbaceous species or trees. Carefully removing *M. vimineum* seedlings without damaging native species can be time-intensive, but weeding is faster when few native species are present.
Resources required [1] e.g. cost, staff, equipment etc.	Very little equipment is required (e.g., possibly gloves if poisonous/irritant plants are present at invaded sites)
Side effects (incl. potential) i.e. positive or negative side effects of the measure on public health, environment, non-targeted species, etc.	Removing *M. vimineum* with hand weeding has a significant positive effect on native species by allowing native species to return, and promoting native plant diversity. However, despite careful application of hand-weeding treatments, Flory *et al.* (2009) found that native tree seedlings did not recruit into hand weeded areas (note that post-emergent grass-specific herbicide was the only removal treatment to promote tree seedling recruitment compared to untreated invaded areas).
Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	Stakeholders should be accepting of this measure because it does not require chemical application or equipment and can be highly effective for removing *M. vimineum* without causing significant damage to native species.
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	Implementation of hand weeding for rapidly eradicating *M. vimineum* is highly cost effective with minimal side effects. It can be applied by almost anyone, including school children or recreational users of natural areas, although monitoring by natural resource professionals is required to ensure complete removal. The hands-on educational experience provided by participating in hand weeding is an additional benefit.
Level of confidence [2] See guidance section	High. There is clear experimental evidence that hand-weeding can be effective for rapidly eradicating small populations of *M. vimineum* with minimal negative effects on native species (S. L. Flory, 2010; S. Luke Flory & Keith Clay, 2009) but see (S. L. Flory & Lewis, 2009). The time and intense effort required limits the scale of invasions that can be controlled with this method but there are few negative side effects and no equipment or chemicals are required.

Management - Measures to achieve management (cf. Article 19). This section assumes that the species is already established in a Member State, or part of a Member State's territory. **This table is repeated for each of the management measures identified.**	
Measure description Provide a description of the measure	**Application of broad-spectrum PPPs.** Herbicides can be applied with hand pump sprayers, backpack sprayers, or CO2 or gas-powered sprayers mounted on ATVs or trucks. Herbicide should be applied according to manufacturer's instructions and in accordance with federal regulations. Briefly, *M. vimineum* is highly sensitive to broad-spectrum herbicides such as glyphosate (Judge, et al., 2008) and may be eliminated at rates below the recommended dose. Herbicides should be applied until runoff. Do not over apply and be as selective with applications as possible. Note that broad-spectrum herbicides can kill all types of vegetation and are less effective than grass-specific herbicides for managing *M. vimineum* while also allowing native species to recover (Judge, et al., 2008). Herbicides should be applied when plants are 10-15cm tall, after self-thinning of the population occurs. Early in the life cycle of *M. vimineum* plants can occur at extremely high densities but later in the growing season many individuals die and the remaining individuals are larger (Robert J. Warren, II, et al., 2012) can be more effectively treated. Treating too early in the year can result in some individuals being missed, allowing them to recover and produce seed by the end of the year (Flory, personal observation). If those individuals are not treated, the population may persist. In additiona EU/national/local legislation on the use of PPPs needs to be respected.
Effectiveness of measure e.g. has the measure previously worked, failed	Broad-spectrum herbicides (e.g., glyphosate) can be effective for managing *M. vimineum* in that all invasive plants can be removed. However, because all vegetation is eliminated by such herbicides, this measure should not be used when non-target native vegetation is present and grass-specific herbicide is available.
Effort required e.g. period of time over which measure need to be applied to have results	*M. vimineum* populations can be managed with as little as one application of a broad-spectrum herbicide, assuming it is applying carefully to all plants at the appropriate time of year (mid growing season). Multiple applications over one season also can be effective.
Resources required [1] e.g. cost, staff, equipment etc.	Application of any type of herbicide requires staff who are trained in how to apply herbicides safely, equipment (e.g., backpack sprayers, ATV sprayers), herbicides, and potentially surfactants depending on the product being used and the specific formulation. Costs for applying herbicides vary widely based on region, habitat, and terrain. The following are estimates provided by Erick Smith at Kestrel Ecological Services (www.kestreleco.com; Gainesville, FL). Costs do not include the price of chemicals. 1. Applying herbicide via backpack sprayer $250-750/ha for 1%-25% cover class

	2. Applying herbicide via ATV $125-1,100/ha for 1%-100% cover
Side effects (incl. potential) i.e. positive or negative side effects of the measure on public health, environment, non-targeted species, etc.	Management of *M. vimineum* with broad-spectrum herbicides is not ideal because of the severe side effects on native vegetation. By definition, broad-spectrum herbicides can kill most types of vegetation and should be applied with care so sensitive non-target vegetation is not damaged. Herbicide drift and runoff may also be of concern. Follow manufacturer and government regulations to minimize effects on the environment.
Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	Repeat applications of broad-scale herbicides for managing *M. vimineum* may be unacceptable to stakeholders because of the "scorched earth" appearance of treated areas and the undesirable side effects on non-target species.
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	Some broad-spectrum herbicides have a very low price-point, making them highly cost-effective for managing *M. vimineum* over very large areas. However, their use in natural areas may be limited by their effects on native species such that they only are used in areas without desirable vegetation or where all vegetation needs to be removed. In addition to the direct effects of broad-spectrum herbicides on native species, a secondary concern is the colonization of habitats by other invaders once the primary invader has been removed. In many cases, it is likely more effective, both in terms of long-term costs and effects on native species, to use a grass-specific herbicide.
Level of confidence [2] See guidance section	High. Broad spectrum herbicides are used to manage *M. vimineum* in the US (Flory, personal observation) because the herbicides are often affordable and readily accessible, but other measures such as post-emergent grass-specific herbicides can be just as effective for removing the invader while also allowing native species to return. The use of broad-spectrum herbicides should be limited to areas without desirable species or where all vegetation needs to be removed (e.g., agricultural settings, along railways, parking lots, or other gravel areas).

Management - Measures to achieve management (cf. Article 19). This section assumes that the species is already established in a Member State, or part of a Member State's territory. **This table is repeated for each of the management measures identified.**	
Measure description Provide a description of the measure	**Application of post-emergent grass-specific herbicide.** Post-emergent grass-specific herbicides (e.g., fluazifop-p-butyl, fenoxaprop-P, imazapic, and sethoxydim) can be applied with hand pump sprayers, backpack sprayers, or CO2 or gas-powered sprayers mounted on ATVs or trucks, similar to application of broad-spectrum herbicides. Herbicide should be applied according to manufacturer's instructions and in accordance with EU/national/local legislation. Surfactants may need to be

	added. Note that these products have been tested, and some have been approved, for use on *M. vimineum* in the US but these or similar substances need to be tested and approved in the EU. *M. vimineum* is highly sensitive to grass-specific herbicides and can be controlled at rates below the recommended dose (S. L. Flory, 2010; S. L. Flory & K. Clay, 2009; Judge, et al., 2005a; Judge, et al., 2005b; Judge, et al., 2008). For example, Flory *et al.* applied 0.21 kg active ingredient (ai) per hectare of fluazifop-P-butyl (12 oz/ac Fusilade DX; Syngenta Crop Protection, Inc., Greensboro, NC, U.S.A.) mixed with 14.8 mL of a nonionic adjuvant surfactant (Surf Plus 584; Townsend Chemical Division, Muncie, IN, U.S.A.) and found that there was 99% less *M. vimineum* in herbicide treated plots than in untreated controls. Herbicides should be applied until runoff and should not be over applied. Applications should be as selective as possible so there are minimal non-target effects on native grass species. Grass-specific herbicides should be applied when plants are 10-15cm tall, after self-thinning of the population occurs. Early in the life cycle of *M. vimineum* plants can occur at extremely high densities but later in the growing season many individuals die and those that remain can be more effectively treated. Treating too early in the season can result in some individuals being missed, allowing them to produce seed by the end of the year and promoting population persistence. Alternatively, populations treated early in the year would need to be revisited to treat any *M. vimineum* that survived the first herbicide application.
Effectiveness of measure e.g. has the measure previously worked, failed	*M. vimineum* can be effectively managed with multiple types of grass-specific herbicides (Judge, et al., 2005a; Judge, et al., 2005b; Judge, et al., 2008) and across varies habitat conditions (S. L. Flory, 2010; S. L. Flory & K. Clay, 2009) with consistent results (emery, demographic paper). Flory *et al.* (2010) showed that fluazifop-p-butyl resulted in more than 99% percent control after a single treatment.
Effort required e.g. period of time over which measure need to be applied to have results	Large populations of *M. vimineum* can be managed with grass-specific herbicides when applied with backpack sprayers, ATVs, or gas-powered pumps mounted on trucks. Follow-up monitoring and spot treatment on at least an annual schedule should be conducted to be sure all plants are removed and no additional applications are needed.
Resources required [1] e.g. cost, staff, equipment etc.	Application of any type of herbicide requires staff who are trained in how to apply herbicides safely, equipment (e.g., backpack sprayers, ATV sprayers), herbicides, and potentially surfactants depending on the product being used and the specific formulation. Costs for applying herbicides vary widely based on region, habitat, and terrain. The following are estimates provided by Erick Smith at Kestrel Ecological Services (www.kestreleco.com; Gainesville, FL). Costs do not include the price of chemicals. 1. Applying herbicide via backpack sprayer $250-750/ha for 1%-25% cover class

	2. Applying herbicide via ATV $125-1,100/ha for 1%-100% cover
Side effects (incl. potential) i.e. positive or negative side effects of the measure on public health, environment, non-targeted species, etc.	Compared to broad-spectrum herbicides, post-emergent grass-specific herbicides have much fewer side effects on native species. Flory *et al.* (2009) demonstrated that removal of *M. vimineum* with grass-specific herbicide was very effective and allowed native herbaceous plants and trees to recolonize. Forb and graminoid plant abundance increased significantly, herbaceous plant diversity increased by 21%, and tree seedling regeneration increased by 123% after removal of *M. vimineum* with grass-specific herbicide. Application of a pre-emergent herbicide did not allow for recolonization by native species, and similar results would have been expected with a broad-spectrum herbicide (e.g., glyphosate), which would have eliminated all vegetation. Native grasses and some sedges can be damaged by grass-specific herbicides but applying at rates below the lowest label rate allows some native perennial grasses to survive. Thus, the side effects of post-emergent grass-specific herbicides are relatively minimal compared to using broad-spectrum herbicides for rapid eradication of *M. vimineum*.
Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	The relatively few side effects of grass-specific herbicides should make it an attractive management option for stakeholders. However, some natural areas may have restrictions on the use of herbicides, which may include specific lists of allowable active ingredients. Because the chemicals in grass-specific herbicides are less commonly used, they may not be on approved use lists. Such is the case at Duke University Forest (Durham, North Carolina, USA) where glyphosate can be used but fluazifop-p-butyl (trade name Fusilade DX) is not approved (SL Flory, personal observation).
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	Grass-specific herbicides are considerably more expensive than broad-spectrum herbicides because in most cases there are not generic formulations available. Regardless, the much lower side-effects of grass-specific herbicides on native species make them an attractive option for management of *M. vimineum.* *Pre-emergent herbicides (Pendimethalin) can be used independently or in combination with post-emergent grass-specific herbicides for *M. vimineum* management. Such herbicides are highly effective for preventing the germination and establishment of *M. vimineum* (S. L. Flory, 2010) but because they lack specificity to plant species or functional groups and can limit the recovery of native species (S. L. Flory & K. Clay, 2009), their use should be limited to large, dense infestations that have a large seedbank.
Level of confidence [2] See guidance section	High. Experience in USA in similar conditions indicate that *M. vimineum* can be effectively managed with grass-specific herbicides such that the invader is removed and native species recover.

Management - Measures to achieve management (cf. Article 19). This section assumes that the species is already established in a Member State, or part of a

Member State's territory. **This table is repeated for each of the management measures identified.**	
Measure description Provide a description of the measure	**Mowing or string trimming.** *M. vimineum* can be managed with standard rotary mowers or with gas-powered string trimmers (i.e., "weed eaters"). Mowing close to the ground (<5cm) or repeatedly throughout the year will be most effective for suppressing plants to the point where they will not produce seed for the season (recall that *M. vimineum* is an annual plant and must complete its life cycle each year). Large pull-behind or tractor mounted mowers are unlikely to be as effective because they often do not mow low enough and may miss plants that will then produce seed.
Effectiveness of measure e.g. has the measure previously worked, failed	There is good evidence that established populations of *M. vimineum* can be effectively managed with repeated mowing or string trimming. Shelton (2012) showed that mowing any time after June in Indiana, USA was effective for reducing percent cover, biomass, and seed production but that mowing later in the season was marginally more effective. Flory and Lewis (2009) found that mowing decreased *M. vimineum* cover by 70% and biomass by 95% after only a single application. When conducted after the mid-point of the growing season, but before seed set, mowing can greatly reduce seed production, and after multiple years, can cause populations to retract or even be eradicated (R. Richardson, *personal communication*). However, missing even a few plants can greatly reduce the effectiveness of this measure because individual plants can produce hundreds or thousands of seeds (Wilson, et al., 2015). The mixed-mating system of *M. vimineum* presents a challenge because even if plants are mowed close to the ground they can cleistogamously produce seed in the leaf sheaths near ground level.
Effort required e.g. period of time over which measure need to be applied to have results	Depending on the size of the population being managed, landscape conditions (e.g., slope, soil stability), and habitat conditions (e.g., presence of trees, shrubs, rocks, or fallen logs), mowing or trimming may be relatively easy or could require considerable effort and time. Additionally, mowing or trimming will require repeated annual applications until the *M. vimineum* seed bank is exhausted (~2-5 years or more).
Resources required [1] e.g. cost, staff, equipment etc.	Mowing or trimming will require staff and equipment. Personnel who are trained to drive tractors/mowers or use gas powered string trimming equipment will be necessary to utilize this measure. Staff will need to be trained to conduct these activities on potentially steep slope and rough terrain where *M. vimineum* invades. Safety training and equipment (e.g., protective face mask, boots) will be necessary, particularly for string trimming. Costs for mowing and string trimming vary widely based on region, habitat, and terrain. Erick Smith at Kestrel Ecological Services (www.kestreleco.com; Gainesville, FL) estimates the cost of string trimming or mowing $125-750/ha.
Side effects (incl. potential) i.e. positive or negative side effects of the measure on public health, environment,	Both measures are destructive for almost all types of vegetation. String trimming can be conducted in a semi-selective manner where certain species or functional groups (e.g. trees, shrubs) are avoided but native herbaceous vegetation will be destroyed by trimming and mowing, particularly when *M. vimineum* is

non-targeted species, etc.	interspersed with native species.
Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	Stakeholders may be willing to employ mowing and, more likely, string trimming, particularly if they are averse to the use of herbicides and invasions occur in areas where mowing would improve appearance. However, the non-selective nature of the measures could be problematic and may not be suitable for certain terrain.
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	If invaded sites are already subjected to mowing/trimming regimes then this could be a cost-effective measure to employ. However, if sites are not already being mowed, if staff and equipment are not available, if terrain or habitat conditions are unfavourable, or if there are desirable plants in the habitat then other measures are likely more suitable for managing *M. vimineum.*
Level of confidence [2] See guidance section	Medium. Published research (S. L. Flory & Lewis, 2009; Shelton, 2012) and anecdotal experiences by land managers (R. Richardson, SL Flory, personal communications) suggest mowing or string trimming can be effective for managing established populations of *M. vimineum.* Note that in most cases other measures such as herbicides will be more effective at removing the invader, cost less, and allow for greater native species recovery, but may not be acceptable to stakeholders.

Management - Measures to achieve management (cf. Article 19). This section assumes that the species is already established in a Member State, or part of a Member State's territory. **This table is repeated for each of the management measures identified.**	
Measure description Provide a description of the measure	**Prescribed fire.** The use of prescribed fire to manage invasive plants has had mixed success. Fire can be used to remove built-up litter and to top-kill invaders so that herbicide applications can be more effective, and, less commonly, fire can be used to directly kill invaders without significant harm to native species. However, more often fire and invasive plants have interacted to have strong adverse effects on native plant communities and ecosystems, and such interactions can result in fire-invasion feedbacks that result in intense, damaging fires and more widespread invasions (Brooks et al., 2004; Carla M. D'Antonio, Hughes, & Tunison, 2011; C. M. D'Antonio & Vitousek, 1992). The key to success in using fire as a management tool for invasive plants is to apply fire at a time when it will have strong negative effects on the invasive plant species without causing significant harm to native species. This technique relies on timing such that native species are dormant and invaders are susceptible when fire is applied, or on differences in fire tolerance, such as when a fire intolerant invader establishes in a fire tolerant

	system.
Effectiveness of measure e.g. has the measure previously worked, failed	There is little evidence that fire can be used for management of *M. vimineum* invasions. One study demonstrated that when fire is applied during the growing season it can suppress *M. vimineum* populations (S. L. Flory & Lewis, 2009), however that study relied on the application of fire with a propane-fueled torch. There is little evidence that fire will carry through invaded areas during the growing season, which would be necessary to suppress adult *M. vimineum* plants. In contrast, there is clear evidence that fire applied to *M. vimineum* populations during the dormant spring or fall seasons results in more intense fires with higher peak fire temperatures and hotter fires that burn longer, greater negative effects of fire on native species (S Luke Flory, et al., 2015), and greater *M. vimineum* biomass the following growing season (Flory *et al.*, *in revision*). There is little lasting effect of dormant season fire on *M. vimineum* population dynamics (Emery, Luke Flory, Clay, Robb, & Winters, 2013).
Effort required e.g. period of time over which measure need to be applied to have results	A single application of a prescribed fire during the growing season can alter the population size of *M. vimineum* but additional research is needed to determine if fires will naturally carry through invasive populations when the species is green and growing actively.
Resources required [1] e.g. cost, staff, equipment etc.	Applying prescribed fires can be labour, equipment, and time intensive. Planning, executing, managing, and collecting data on the effectiveness of prescribed fires can require significant funding. There might be several legal restrictions in EU Member States concerning the use of prescribed fires, for the timing and for the personnel that can apply this method.
Side effects (incl. potential) i.e. positive or negative side effects of the measure on public health, environment, non-targeted species, etc.	Applying prescribed fires to invaded areas, especially during the dormant season, can have profound negative side effects if fires are unnaturally intense and harm native species, such as tree seedlings (S Luke Flory, et al., 2015).
Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	Enhanced use of prescribed fire when it otherwise would not be used to manage an ecosystem is likely not acceptable to stakeholders. If fire would have been used regardless, then increasing frequency or extent of fires to help manage invaders may be acceptable.
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	There are many socio-economic considerations of applying prescribed fires, including the 'blacked' look that is evident immediately after fire is applied, the fate of smoke generated by fires (e.g. drifting into residential areas or across roads), and the effects of fire on native plant and wildlife species.

Level of confidence [2] See guidance section	High. There is limited information on the effectiveness of fire for managing *M. vimineum* during the growing season, but the available information suggests it could be effective (S. L. Flory & Lewis, 2009). During the dormant season, however, fire interacts with *M. vimineum* to create more intense fires that exacerbate the independent effects of fire and invasion on native species (S Luke Flory, et al., 2015). More research is needed on the targeted use of fire to manage *M. vimineum* but it is unlikely to be a primary method for management because of the difficulty in applying fire during the growing season.

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Notes

1. Costs information. The cost information depends on the information available.

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

- **High**: Information comes from published material, or current practices based on expert experience applied in one of the EU countries or third country with similar environmental, economic and social conditions.
- **Medium**: Information comes from published data or expert opinion, but it is not commonly applied, or it is applied in regions that may be too different from Europe (e.g. tropical regions) to guarantee that the results will be transposable.
- **Low**: data are not published in reliable information sources and methods are not commonly practiced or are based soley on opinion; This is for example the case of a novel situation where there is little evidence on which to base an assessment.

3. Citations and bibliography. The APA formatting style for citing references in the text and in the bibliography is used.
e.g. Peer review papers will be written as follows:
In text citation: (Author & Author, Year)
In bibliography: Author, A. A., & Author, B. B. (Publication Year). Article title. *Periodical Title*, Volume(Issue), pp.-pp.

(see http://www.waikato.ac.nz/library/study/referencing/styles/apa)