Acacia saligna © *Jean-Marc Dufour-Dror.*

The management of golden wreath wattle (*Acacia saligna*)

Measures and associated costs

Scientific name(s)	*Acacia saligna*
Common names (in English)	Golden wreath wattle
Synonym	*Acacia cyanophylla Lindl.*
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Common names

BG	–
HR	Akacija
CZ	Akácie modrolistá
DA	Tåre-akacie
NL	Wilgacacia
EN	Golden wreath wattle
ET	Pajuakaatsia
FI	Siniakaasia
FR	Mimosa à feuilles de saule
DE	Weidenblatt-Akazie
EL	Ακακία κυανόφυλλη
HU	–
IE	Acáise shailduilleach
IT	Acacia saligna
LV	Vītollapu akācija
LT	Siauralapė akacija
MT	L-akaċja
PL	–
PT	Acácia
RO	Salcâm saligna
SK	Akácia vŕbovitá
SL	Vrbolistna akacija
ES	Acacia de hoja azul
SV	Tårakacia

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

The present Technical Note addresses "*Acacia saligna*" and/or "*Acacia saligna* s.l." (s.l. = sensu lato - in the broad sense) (also abbreviated as *A. saligna*) both indicating the species complex, for example, the whole group of subspecies (or lower taxa, such as cultivated varieties, cultigens and provenances) that have been described for the entity *Acacia saligna* (Labill.) H.L.Wendl., Comm. Acac. Aphyll. 26. 1820. *Acacia cyanophylla* Lindl. is a synonym of *Acacia saligna* (Labill.) H.L.Wendl. and has been frequently used, mostly in the past, in many countries of the European Union.

When addressing an alien woody plant species that is introduced mostly intentionally (such as an ornamental and forestry tree) and not yet present in the territory of the European Union, a ban on keeping, importing, selling, breeding, and growing the species is expected to be an effective measure against invasion. However, *A. saligna* is already present in many countries of the European Union (Croatia, Cyprus, France, Greece, Italy, Malta, Portugal, Spain), therefore such a measure is likely to only limit further introduction (such as introduction in new Member States (MS), or introduction of new provenances of *A. saligna*), further spread and re-invasion in sites where removal or control intervention are taking place (such as in the framework of LIFE projects).

Most of the uses and benefits provided by *A. saligna* can be provided in the European Union by alternative native woody species, such as in the case of slope/sand dunes stabilisation and reduction of soil erosion risk, shade and other landscaping uses. The economic impact on the ornamental plant industry is likely to be very low, as only small volumes of the species are traded. In addition, the negative effects of *A. saligna* on ecosystem services in the invaded range are generally considered far greater than its positive effects.

The measures that can prevent unintentional introduction and spread should be based on a comprehensive analysis of the pathways of unintentional introduction and spread of *A. saligna* within the territory of the European Union and identify those pathways which require priority action. These preventive measures include the application of best management practices for habitats and land uses that are at risk of invasion and for the construction and management of roads. In addition, awareness campaigns to prevent mislabelling, dumping of garden waste and soil and seed movements from infested sites, as well as targeting key stakeholder groups, will be needed. It is important to note that all these measures addressing unintentional introductions and secondary spread need to be addressed within a single action plan.

The measures for the prevention of secondary spread should include, for example: (1) awareness campaigns in the horticultural and forestry sectors to promote nursery best practices, prevent mislabelling, prevent dumping of garden waste and prevent the movement of contaminated soil or seeds from infested sites; (2) public awareness campaigns to raise awareness so that the public are able to identify *A. saligna*, and have knowledge of its impacts and its management, including information on seed spread and the need for correct vendor identification; and (3) target awareness campaigns at landholders in areas at risk of invasion so they can recognise *A. saligna* and prevent its establishment.

The measures to achieve early detection and run an effective surveillance system of new occurrences of *A. saligna* should consider the pathways of introduction and spread, the location and distribution of existing infested areas, and the susceptibility of diverse habitats and land uses to invasion. Early Detection and Rapid Eradication (EDRE) are critical for preventing establishment of *A. saligna*. Coordination efforts should be made between land managers, the local public (citizen-science) and road crews on identification of *A. saligna* so suspected infestations can be reported. EDRE can detect and eradicate incipient populations of *A. saligna* before they have a chance to become widely established, thus eliminating the need for costly and resource-intensive control programmes. If prevention measures fail, EDRE is the next and most cost-effective line of defence against invasive alien species. The measures to achieve rapid eradication of *A. saligna* are the same as described in the section on Management, for example, rapid eradication should follow an integrated control methodology.

The management (control) of *A. saligna* needs to make use of an integrated control strategy within a dedicated management plan. Different measures may be required at an individual site, and management should be frequently site-specific and include measures for the restoration of the natural vegetation and the reduction of disturbance. Although *A. saligna* is not found in association with any of the 23 invasive alien plants of Union concern, Regulation (EU) No. 1143/2014, many of them can be found in similar habitats along roads, in riparian networks and close to urban settlements, so that management measures could be, only in part, incorporated into existing management measures for species of Union concern.

Conceptually, the management of *A. saligna* needs to include a range of technologies and tools rather than only plant protection products (herbicides) and/or mechanical interventions alone. Different types of habitats and land uses are invaded by *A. saligna* in the European Union, and even within a single country or region. Therefore, management of *A. saligna* requires the integration of different measures including biological, chemical and mechanical control options, along with various forms of cultural control including, for example, grazing management, dedicated guidelines on prescribed burning, and restoration programmes. The extensive and long-lived seed bank of *A. saligna* allows it to regenerate long after clearing, cutting, wildfires or other disturbances. As such, seed banks (and its germination rate) represent a fundamental challenge to its management. Several techniques have been proposed to reduce the size of existing seed banks, most of them being unfortunately highly destructive, resource intensive or unsuitable for use in natural areas. Although biological control is an option to be considered for inclusion in the integrated management plan, potential impacts on non-target organisms and ecosystems have to be adequately assessed before any introduction of biocontrol agents in the European Union.

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

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

A ban on importing, keeping, breeding, growing and selling.

MEASURE DESCRIPTION

Acacia saligna (Labill.) H.L.Wendl., Comm. Acac. Aphyll. 26. 1820 (Family Leguminosae; LPWG, 2017) is native, and endemic, to Western Australia. It is either a very polymorphic species (Maslin, 1974) or a species complex (Millar and Byrne, 2012) and the identification of *A. saligna* at the subspecific level is challenging (Le Houérou and Pontanier, 1987; Maslin and McDonald, 2004; Millar *et al.,* 2008b; Millar *et al.,* 2011).[1] Therefore, in the present Technical Note, the terms "*Acacia saligna*" and/or "*Acacia saligna* s.l." (s.l. = *sensu lato* - in the broad sense) (also abbreviated as *A. saligna*) both indicate the species complex, for example, the whole group of subspecies (or lower taxa, such as cultivated varieties, cultigens and provenances) that have been described for the entity *Acacia saligna* (Labill.) H.L.Wendl., Comm. Acac. Aphyll. 26. 1820. Whenever the present Technical Note refers solely to a subspecific entity, its full name is reported. Therefore, the present Technical Note provides Information on measures and related costs in relation to *Acacia saligna* s.l.

The species is an alien woody shrub or small tree species that is introduced mostly intentionally as an ornamental, forestry or agro-forestry tree and already present in many countries of the European Union (Croatia, Cyprus, France, Greece, Italy, Malta, Portugal, and Spain). Therefore, to address any additional intentional introductions and consequent spread of *A. saligna* a **ban on importing, keeping, breeding, growing and selling at an EU level would be needed (as would be required under Article 7 of the EU IAS Regulation 1143/2014).**

Importantly, in some European Union countries or regions or in protected areas, the legislation in force poses limitations to the use of *A. saligna*. For example, in the Tuscany region of **Italy** (according to the DGR n. 1223, dated 15 December 2015, Annex B, conservation measure RE_I_11). In **Malta**, the "Trees and Woodland Protection Regulations, 2011" (LN 200 of 2011) lists a number of species of trees deemed to cause damage to biological diversity of native trees or woodlands in Malta, or to the natural environment in general. The propagation, sowing, planting, import/export, transport and selling of these 24 species (including *A. saligna*) are hence prohibited (MEPA 2013). In **Portugal** *A. saligna* is listed in the annex I of Decreto-Lei n. 565/99, of the 21st December 1999 (under the name of *Acacia cyanophylla* Lindley), which regulates the introduction of non-native species and lists the non-native species in Portugal, indicating which are considered invasive and prohibiting the introduction of new species (with some exceptions). Furthermore, this legislation prohibits the possession, cultivation, growing and the trade of species that are considered invasive or of ecological risk. In **Cyprus**, in an effort to minimise the impacts of invasive plant species on biodiversity, the Department of Forests has banned the use of known invasive species (such as *A. saligna, Ailanthus altissima, Dodonaea viscosa*) in all kinds of plantations, including those in inhabited areas and disturbed sites (Tsintides and Christou, 2011).

1 *Acacia saligna* (Labill.) H.L.Wendl., Comm. Acac. Aphyll. 26. 1820, is currently circumscribed by four to five informal subspecies (Millar *et al.,* 2008a, b, 2011; WorldWideWattle ver. 2, 2018) as follows: *Acacia saligna* (Labill.) H.L.Wendl. subsp. saligna (autonym), *Acacia saligna* (Labill.) H.L.Wendl. subsp. *stolonifera* M.W.McDonald and Maslin ms, *Acacia saligna* (Labill.) H.L.Wendl. subsp. *pruinescens* M.W.McDonald and Maslin ms and *Acacia saligna* (Labill.) H.L.Wendl. subsp. *lindleyi* (Meisn.) M.W.McDonald and Maslin ms (Maslin *et al.,* 2006; https://florabase.dpaw.wa.gov.au/) The taxonomy and nomenclature of *Acacia saligna* s.l. is under ongoing revision in Australia. At the same time, the concept of 'variant' is found in the scientific literature and in technical reports, or in provenance trials. Importantly, (1) subsp. *lindleyi* is also referred to as the 'typical' variant; (2) subsp. *pruinescens* is referred to as the 'Tweed River' variant; (3) subsp. *saligna* is referred to as the 'cyanophylla' variant and (4) subsp. *stolonifera* is referred to as the 'forest' variant (Maslin *et al.,* 2011). The *A. saligna* subspecies can be distinguished by a combination of morphological differences including phyllode appearance, the shape of the inflorescence bud, the length of racemes and the diameter, colour and number of flower heads (Millar *et al.,* 2008b and references cited therein); however, these characteristics can only be assessed when plants are suitably mature and only while plants are developing buds or flowering (Millar *et al.,* 2008b and references cited therein). In addition, these subspecies of *A. saligna* display variation in key traits, such as seed set, fecundity and suckering (Millar *et al.,* 2008b and references cited therein) that are all important aspects to consider both for the identification and for assessing the invasion risk and the most suitable phytosanitary measures. These four informal subspecies were recently and tentatively reclassified into three major subspecies lineages: subsp. *lindleyi*, 'subsp. *pruinescens* + subsp. *saligna*' and subsp. *stolonifera* (Maslin *et al.,* 2011; Millar *et al.,* 2011). However, according to the inflorescence characters, Maslin *et al.,* (2011) have proposed only two-groups ('subsp. *pruinescens* + subsp. *saligna*' and 'subsp. *lindleyi* + subsp. *stolonifera*').

EFFECTIVENESS OF MEASURE

Effective.

When addressing an alien woody plant species that is introduced mostly intentionally (such as an ornamental and forestry tree), and not yet present in the territory of the European Union, a ban on keeping, importing, selling, breeding, and growing the species is expected to be an effective measure against invasion. However, *A. saligna* is already present in many countries of the European Union (Croatia, Cyprus, France, Greece, Italy, Malta, Portugal, Spain), therefore such a measure is likely to only limit further intentional introduction (for example, introduction in new Member States, or introduction of new provenances[2] of *A. saligna*), further spread and re-invasion in sites where removal or control intervention are taking place (such as in the framework of LIFE projects).

A. saligna adult plants and seeds are unlikely to be confused with other species by well-trained personnel using adequate identification tools. *A. saligna* has no known close relatives in the European Union, but it resembles, superficially, a number of other introduced Acacia species including *A. pycnantha* (Maslin, 1974), however the latter is distinguished by its stouter raceme axes and peduncles, its prominently tapered phyllode bases, it smaller pulvinus, and its smaller glands. In its growth habit, phyllode morphology, glabrous raceme, and large flower heads, *A. saligna* superficially resembles *A. amplices* B.R.Maslin; however, the flowers, legumes, and seeds of these two species are quite different. Finally, *A. saligna* can occasionally be confused with *A. microbotrya* Benth. and *A. rostellifera* Benth. (Maslin, 1974) and it might also be superficially confused with *A. retinodes* Schltdl. See Queensland Government Fact Sheet on *Acacia saligna*, which provides guidance on distinguishing between these similar species[3].

SIDE EFFECTS

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

Environmental effects: There are no known environmental side effects of this measure. However the intended (direct) environmental effects of this measure could be considerable for the European Union, as *A. saligna* impacts on native biodiversity with negative consequences similar to those occurring in Mediterranean-type shrublands and littoral dunes of the current areas of distribution (South Africa, Middle East and eastern Australia). Sand dune ecosystems and riparian habitats are known to be invaded by large and dense thickets of the invasive shrub (such as the so-called 'wattle forests'). In the **European Union** *A. saligna* is tackled by many LIFE projects, such as LIFE13 NAT/CY/000176, LIFE13 NAT/ES/000586, LIFE08NAT/IT/000353, LIFE13 NAT/IT/000433, LIFE12 NAT/MT/000182 (data from Scalera *et al.,* 2017).

Social effects: The pollen of *A. saligna* is considered as a possible allergenic source (Irian *et al.,* 2013) so that a ban on importing, keeping, selling, breeding and growing *A. saligna* is potentially likely to have a positive side effect on human health. Although *A. saligna* plants and stands are usually very aesthetically appreciated during the flowering season, they are not reported to provide any exclusive documented recreational cultural ecosystem services.

Economic effects: Most of the uses and benefits provided by *A. saligna* can be provided in the European Union by alternative native woody species, such as in the case of slope/sand dunes stabilisation, short rotation forestry and reduction of soil erosion risk, shade and other landscaping uses. The economic impact on the ornamental plant industry is likely to be very low, as only small volumes of the species are traded, in particular in the Mediterranean biogeographic region of the European Union (Brundu 2018, pers. obs.).

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

To evaluate the acceptability of a ban on keeping, importing, selling, breeding and growing *A. saligna*, it is important to consider the various purposes for *A. saligna* intentional introduction and use in the European Union. In addition, acceptability can be enhanced through a correct communication campaign and a plethora of possible actions as those suggested by Wilson *et al.,* (2011, box 3 on page 1037). Introduction and use of *A. saligna* within the European Union mostly occurred in the past for afforestation/reforestation, firewood production, erosion control, soil stabilisation and protection purposes, especially in coastal dune ecosystems in the Mediterranean region and islands (Hadjikyriakou and Hadjisterkoti, 2002; Celesti-Grapow *et al.,* 2009, 2010, 2016; Marchante and Marchante, 2005, Marchante *et al.,* 2017). Honey production and other secondary uses were other reasons for its intentional introduction, including its use as an ornamental species. In recent years, its introduction for biomass production (short rotation coppicing systems) in marginal soil conditions under Mediterranean climates is under investigation in the European Union (Crosti *et al.,* 2010; Facciotto and Nervo, 2011) as in the rest of the world (Hobbs *et al.,* 2009; Griffin *et al.,* 2011). So far, few studies have specifically quantified both the re-sprouting capacity and the impact of nutrient and water availability on the biomass yields of the different subspecies of *A. saligna* (Maslin and Mc Donald, 2004). However, it is known that their growth rates and biomass production can vary markedly between and even within sites. Field trials conducted in Chile (Perret *et al.,* 2001), in

2 In the forestry terminology and legislation, origin and provenance are specifically described (for example, Council Directive 1999/105/EC of 22 December 1999 on the marketing of forest reproductive material). Origin: the geographic locality within the natural range of a species where the parent seed source or its wild ancestors grew. Provenance: the geographic locality of a stand of trees from where the seed was collected.

3 https://keyserver.lucidcentral.org/weeds/data/media/Html/acacia_saligna.htm

Israel (Zegada-Lizarazu *et al.,* 2007) and in Italy (Faccciotto and Nervo, 2011) suggest that water availability is an important limiting factor to the growth of *A. saligna* and that irrigation and potentially also fertilisation will have to be applied to guarantee a high sustained yield in short rotation coppicing systems under Mediterranean climates. As in the cases of other woody energy crops (Gasol *et al.,* 2010; Dauber *et al.,* 2012; Blanco-Canqui, 2016), it may be expected that *A. saligna* may not provide substantial economic benefits as a bioenergy crop due to limited growth and high installation costs in these conditions.

In addition, most of the uses and benefits provided by *A. saligna* described above can be provided in the European Union by alternative native woody species, such as in the case of slope/sand dunes stabilisation and reduction of soil erosion risk, shade and other landscaping uses. The economic impact on the ornamental plant industry is likely to be very low, as only small volumes of the species are traded, increasing the acceptability of this measure to the industry. In addition, in the invaded range, the negative effects of *A. saligna* on ecosystem services are generally considered far greater than positive effects.

In addition, due to the fact that besides the olive tree (*Olea europaea*), the *Xylella fastidiosa*-Codiro strain can infect *A. saligna*, there are ongoing restrictions on the movement of *A. saligna* in Europe and in the European Union. Therefore, it is assumed that this measure would be acceptable to many stakeholder groups within the European Union.

ADDITIONAL COST INFORMATION

To be effective, these restrictions and trade bans must be enforced indefinitely. Evaluations of the costs associated with the implementation of a ban on keeping, importing, selling, breeding and growing for *A. saligna* are not available. However, if a ban on *A. saligna* is part of general biosecurity policy and strategy, then resources and costs will be reduced. For example, if there is a unique biosecurity strategy for all the invasive alien plants of Union Concern, this will produce general beneficial effects and economies of scale, including for the training of staff and application of custom controls as some pathways are responsible for the introduction of more than one taxa. However, the costs of compliance and the resources required might be different across EU Member States as it would be in relation to, for example, the existing organisational framework, the total number of points of entry, the size of the borders, the size of the country and coastlines, the total number of islands, the biogeographical region, and the trade routes of the Member State. General information (not specifically concerning *A. saligna*) can be gathered through the documents and reports of those countries that have national biosecurity policies in force, such as Australia and New Zealand. Another source of general information on prevention cost is the study of Epanchin-Niell (2017). This author reports a number of economic studies that have examined optimal prevention investments based on weighing prevention investments against expected post invasion costs as well as the trade-offs between prevention and control investments. Importantly, although perfect prevention is neither feasible nor cost-effective, investing in prevention efforts nonetheless provides benefits by reducing the likelihood of invasion and delaying impacts, thereby reducing expected damages. However, even in cases where investing more in prevention may appear optimal, if decision-makers are risk averse they may nonetheless underinvest in prevention, preferring to focus on post invasion control. This could happen because prevention appears riskier as it targets an uncertain invasion possibility, whereas control addresses a known problem (Finnoff *et al.,* 2007 reported by Epanchin-Niell, 2017).

A trade ban has to be correctly communicated to all the involved stakeholders so that an information campaign would improve the effectiveness of the measure. There might be the need to implement more systematic and strategically oriented communication, via, for example, email lists or newsletters to disseminate research findings to forestry professionals and policy makers, or seminars for forestry professionals and members of industry, would also be beneficial. It is important to identify the different levels stakeholders for successful utilisation of stakeholder support (Klapwijk *et al.,* 2016 and reference cited therein).

LEVEL OF CONFIDENCE*

Well established.

There is enough scientific and technical knowledge supporting the statement and guidelines of this section on preventive measures. Therefore, there is high confidence that a ban on keeping, importing, selling, breeding and growing is certainly a very effective measure for forest trees that are mostly intentionally introduced and spread by man.

* See Appendix

General considerations on the preventive measures for unintentional introduction and spread.

MEASURE DESCRIPTION

The measures that can prevent unintentional introduction and spread should be based on a comprehensive analysis of the pathways of unintentional introduction and spread of *A. saligna* within the territory of the European Union and identify the pathways which require priority action. *A. saligna* is present and naturalised in many Mediterranean countries (such as Albania, Algeria, Libya, Egypt, Israel, Morocco, Tunisia, Turkey) so that there is the potential risk of unintentional introduction or spread to other EU Members states. However, an accurate mapping of EU-bordering regions infested and possibly a high-resolution mapping of existing foci along networks or in areas with intense human activities could help very much to set the strategy for preventing unintentional introduction and spread in the EU.

These preventive measures include the application of best management practices for the construction and management of roads, and best management practices for habitats and land uses that are at risk of invasion (discussed in this section). In addition, awareness campaigns to prevent mislabelling, dumping of garden waste, soil and seed movements from infested sites and targeting key stakeholder groups will be needed (discussed in the following Prevention section). It is important to note that all these measures addressing unintentional introductions and spread need to be addressed within a single action plan.

Unintentional introductions – Applying best management practices for the construction and maintenance of roads, and for managing habitats and land uses that are at a high risk of invasion.

A. saligna can disperse at the local scale vegetatively and by seeds. Long-distance dispersal of seeds can be mediated by natural corridors and by road transport and other human activities and infrastructures, such as through the movement of infested soil. Wind can also move dry legumes with seeds through the environment. It is assumed that due to the dynamic nature of riparian habitats, the propagules of *Acacia* species are rapidly distributed downstream of the initial invasion (Galatowitsch and Richardson, 2005).

There are many guidelines available for best management practices in road building and maintenance that help prevent the spread of invasive plants along roadsides and into agricultural or natural areas. Although these guidelines are not specifically addressed to *A. saligna*, they can be conveniently considered and applied for *A. saligna*. Importantly, activities such as mowing, grading, ditching and construction can work to either exacerbate or prevent the spread of invasive acacias and their seed bank (Spooner *et al.,* 2004). Guidelines for best management practices in roads should include: (i) prevention and management of soil movements, (ii) vegetation and green waste management plans along roads and (iii) sowing and planting after road works (to avoid leaving bare soils that are very favourable to seedling installations).

Those habitats and land uses that are more prone to invasion by *A. saligna* should be managed according to specific guidelines that focus on reducing the risk from unintentional introductions, and should include adequate forest management measures, maintenance interventions for transport corridors and urban-forest interfaces, management of riparian networks and sand dune systems, measures to reduce or to contrast land abandonment in agricultural and forest areas, and prevention of wild fires. The recently published ISPM Standard Number 41 '*International movement of used vehicles, machinery and equipment*' (IPPC, 2017) is one such standard that could be adopted, as it addresses the risks of transporting contaminants (soil, seeds, plant debris, pests) associated with the international movement (either traded or for operational relocation) of vehicles, machinery and equipment (VME). For those VMEs that represent a contaminant risk the phytosanitary measures recommended are detailed in the ISPM, and cover cleaning, prevention and disposal requirements. This is particularly important as *A. saligna* is already present and established in many Member States, so that there is a higher risk of accidental introduction and spread into these habitats from infested areas.

Importantly, forest and shrubland habitat disturbance in Mediterranean coastal areas may provide greater opportunity for invasion of *A. saligna*, thereby altering the successional trajectory of native plant communities (Del Vecchio *et al.,* 2013; Calabrese *et al.,* 2017). Forest disturbance is typically characterised by biomass removal that creates new growing space, such as through fires, removal of litter, clear cuttings, coppicing, and opening or widening of roads.

Acacia saligna © *Jean-Marc Dufour-Dror.*

SCALE OF APPLICATION

There is no available information on the application of the preventive measures for unintentional introduction and spread of *A. saligna* in the European Union. However, the LIFE projects dealing with the local eradication of *A. saligna*, which is considered feasible on small Mediterranean islands (such as the island of Pianosa, Italy, within the LIFE project LIFE08 NAT/IT/000353[4]), provide information on the monitoring and preventive actions that can be in some cases paired with the preventive measures for *Ailanthus altissima*.

Spooner *et al.,* (2004) investigated how soil disturbance from roadworks affects the population structures of roadside shrubs in an agricultural landscape of southern New South Wales, Australia. Size structures of *Acacia pycnantha*, *A. montana* and *A. decora* were assessed. Soil disturbance from previous roadworks was recorded in 88% of populations, and there was a significant relationship between major recruitment and roadworks events in *Acacia* populations situated along bitumen roads. Therefore, Spooner *et al.,* (2004) concluded that for *Acacia* species, soil disturbance from roadworks are analogous to periodic disturbance from a natural fire regime, which in conjunction with historical changes in grazing pressure, are suggested as the main causes of increased *Acacia* recruitment.

EFFECTIVENESS OF MEASURES

Effective.

The preventive measures summarised above are effective for *A. saligna* and can also prevent the entry and spread of other invasive alien plants, for example, as in the case of preventing the movement of infested soil.

EFFORT REQUIRED

To be effective, these measures must be enforced indefinitely.

4 Montecristo 2010 - Montecristo 2010: eradication of invasive plant and animal aliens and conservation of species/habitats in the Tuscan Archipelago,Italy. LIFE08 NAT/IT/000353.

RESOURCES REQUIRED

An action plan and well-trained personnel. Resources required to implement the ISPM standard on VME transport would include facilities for inspection, cleaning, and treatment of the VMEs that represent a risk (IPPC, 2017).

SIDE EFFECTS

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

Applying best construction and management practices for roads and for habitats and land uses that are at risk of invasion, awareness campaigns to prevent mislabelling, dumping of garden waste, soil and seed movements from infested sites and targeting key stakeholder groups will also limit the spread of other invasive alien species with similar ecological requirement and pathways of spread. In addition, preventive measures for *A. saligna* should be beneficial having in mind that this tree is listed in Annex 1 of the Commission Implementing Decision (EU) 2015/789 of 18 May 2015 as regards measures to prevent the introduction into and the spread within the Union of *Xylella fastidiosa* (Wells *et al.,* (notified under document C(2015) 3415) and of the Commission Implementing Decision (EU) 2015/2417 of 17 December 2015 amending Implementing Decision (EU) 2015/789 as regards measures to prevent the introduction into and the spread within the Union of *Xylella fastidiosa* (Wells *et al.*,) (notified under document C(2015) 9191). The economic costs to the private sector (such as construction) that may need to implement any best management practices are unknown.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

Please see the section on preventive measures for intentional introduction. Applying best construction and management practices for roads may incur costs for those sectors required to undertake the measures. Importantly, in some European countries or regions, the legislation in force poses limitations to the use of *A. saligna* and some funding schemes do consider ineligible the areas invaded by *A. saligna* in agricultural areas that might benefit through the EU's rural development policy 2014-2020 (such as the Malta Managing Authority, EAFRD)[5] while the species itself is eligible for control or removal[6].

ADDITIONAL COST INFORMATION

If these preventive measures are not applied, there is the risk of accidental introduction and spread taking place, with the invasion of new sites and the risk or re-invasion of sites where local eradication has been achieved. A number of scientific papers do indicate that in the European Union there is a significant area at risk of invasion, in the countries surrounding the Mediterranean basin (for example, Thompson *et al.,* 2011).

LEVEL OF CONFIDENCE*

Well established.

There is enough scientific and technical knowledge supporting the statement and guidelines of this section on preventive measures.

5 Guidance Notes for Applications for Agri-Environment Funds and Programmes, Rural Development Programme for Malta 2014 - https://eufunds.gov.mt/en/EU%20Funds%20Programmes/European%20Agricultural%20Fund/Documents/Measures/MIZURA%2010/AECM%20guidelines%20AECMs%201234%206a6b6c%20%20V%202%202.pdf

6 Guidance Notes for Applications for Funding under Measure 4.4 of the Rural Development Programme 2014-2020 –'Support for non-productive investments linked to the achievement of agri-environment-climate objectives' Version No: 1.2–10th January 2017 - https://agriculture.gov.mt/en/arpa/Documents/2017/RuralDevelopmentMeasures/Measure%204dot4Version%201dot2January%202017.pdf

* See Appendix

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

Education and awareness activities.

MEASURE DESCRIPTION

These measures include protocols to reduce both intentional and unintentional secondary spread within the European Union of *A. saligna* plants and seeds.

These measures should include, for example, (1) awareness campaigns in the horticultural and forestry sectors to promote nursery best practices, prevent mislabelling and dumping of garden waste, and prevent the movements of contaminated soil or seeds from infested sites; (2) public awareness campaigns to raise awareness so that the public are able to identify *A. saligna*, and have knowledge of its impacts and its management, including information on seed spread and the need for vendor correct identification, (3) target awareness campaigns at landholders in areas at risk of invasion so they can recognise *A. saligna* and prevent its establishment; (4) information an awareness on the best management practices for the construction and management of roads, and for habitats and land uses that are at risk of invasion (same measures as discussed in the above section).

This set of preventive measures can be adopted by EU Member States (MS) making use of specific national legislation tools or can be included in more general biosecurity policy and strategy for larger groups of invasive alien species. However, in addition to regulations, MSs or single stakeholder categories may consider and use a voluntary code of conduct as an effective alternative or complementary approach (for example, EPPO Phytosanitary Procedures, PP 3/74 (1); EPPO, 2009). Additional information can be found in the EPPO Guidelines for the management of plant health risks of bio-waste of plant origin (EPPO, 2008) and in the Council of Europe “European Code of Conduct for Invasive Alien Trees”. Concerning the cleaning of machinery or of other vectors, useful information can be found from the guidelines prepared by Biosecurity Queensland, part of the Department of Agriculture, Fisheries and Forestry, in Australia (Biosecurity Queensland, 2018)[7], the ISPM Standard Number 41 ‘*International movement of used vehicles, machinery and equipment*’ (IPPC, 2017), and similar documents.

Simple measures should not be considered as “stand alone” measures but must be integrated in more general action plans and codes of conduct, and widely disseminated and integrated with other general biosecurity and planning measures (for example, the quality of forest and horticultural reproductive materials and nursery plants weed-free, Integrated Coastal Zone Management in Europe[8], see also Buckley, 2008).

SCALE OF APPLICATION

There is no available information on the application of the preventive measures for intentional/unintentional secondary spread of *A. saligna* in the European Union. However, the LIFE projects dealing with the local eradication of *A. saligna*, which is considered feasible on small Mediterranean islands, provide information on education and awareness campaigns tackling *A. saligna* as in the case of the LIFE Project RES MARIS (LIFE13 NAT/IT/000433 - http://www.resmaris.eu/acacia/). Additional information is also available thanks the LIFE project OROKLINI - Restoration and management of Oroklini Lake SPA - CY6000010- in Cyprus (LIFE10 NAT/CY/000716). Awareness campaigns in some countries have so far been promoted by governmental agencies, for example, the “Check, Clean, Dry” initiative in New Zealand[9] and in the UK[10]. Nevertheless, as remarked by Piria *et al.,* (2017) public awareness and education about non-native invasive species issues still require considerable improvement in most EU countries.

7 For example: http://www.agriculture.gov.au/import/goods/vehicles-machinery/regulations/guides-checklists
8 Recommendation of the European Parliament and of the Council of 30 May 2002 concerning the implementation of Integrated Coastal Zone Management in Europe.
9 https://www.mpi.govt.nz/travel-and-recreation/outdoor-activities/check-clean-dry/
10 http://www.nonnativespecies.org/checkcleandry/

EFFECTIVENESS OF MEASURES

Effective.

Education activities are usually effective in raising public awareness. Schreck Reis *et al.,* (2011) report the positive results achieved in increasing awareness about biological invasions among young students during a workshop on Invasive Plant Species organised at the Botanical Museum of the University of Coimbra (Portugal). The UK's Check Clean Dry campaign found that after one year of the campaign there was a 9% increase in people carrying out the good biosecurity practices in the Broads, and that anglers and canoeists that had heard of the campaign were six times more likely to clean and dry their kit after every use than those who had not heard of the campaign (GB NNSS, 2017).

EFFORT REQUIRED

To be effective, these measures must be enforced indefinitely.

RESOURCES REQUIRED

Action plan and well-trained personnel. Importantly, education and awareness campaigns can be very effectively supported by novel tools, as in the case of LINVEXO, an interactive, digital learning application about invasive plants and animals. Students learn in a short amount of time about the spread and impact of species, but also how to constrain them from doing further harm (https://itzit.com/visual-education/).

The UK's communications IAS awareness raising activities cost on average GBP 90,000 per year (ca. 102,400 Euro) and are currently coordinated by a 0.5 post (GB NNSS, 2017). Since 2008 the following has been spent: GBP 330,000 on the Check Clean Dry campaign, GBP 60,000 on public attitudes survey, GBP 25,000 on training, GBP 10,000 to 15,000 on the website. However, they recommend that funds of GBP 200,000 to 300,000 per year are needed to expand the communications work in order to meet the new GB IAS Strategy, and that a new campaign (such as for exotic pets) would cost at least GBP 25,000 to 30,000 per year (GB NNSS, 2017). In addition, according to the GB NNSS report the New Zealand Check Clean Dry campaign received ca. NZD 1.3 million per year (ca. EUR 725,500) between 2005 and 2008.

SIDE EFFECTS

Environmental: Positive

Social: Neutral or mixed

Economic: Neutral or mixed

This preventive measure could help in reducing the secondary spread of *A. saligna*, reducing its negative impacts and also the spread of other alien plant species that share the same pathways of secondary spread.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

Education and awareness raising activities are usually accepted by relevant stakeholders when properly conducted and communicated.

ADDITIONAL COST INFORMATION

As detailed also above in the section on the trade ban, the preventive measures have to be correctly communicated to all the involved stakeholders so that an information campaign would improve the effectiveness of the measures. There might be the need to implement more systematic and strategically oriented communication, via, for example, email lists or newsletters to disseminate research findings to forestry professionals and policy makers, or seminars for forestry professionals and members of industry, would also be beneficial. It is important to identify the different levels stakeholders for successful utilisation of stakeholder support (Klapwijk *et al.,* 2016 and reference cited therein).

LEVEL OF CONFIDENCE*

Well established.

There is enough scientific and technical knowledge supporting the statement and guidelines of this section on preventive measures.

* See Appendix

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

Integrated surveys within a dedicated surveillance action plan.

MEASURE DESCRIPTION

The measures to achieve early detection and run an effective surveillance system of new occurrences of *A. saligna* should consider the pathways of introduction and spread, the location and distribution of existing infested areas, and the susceptibility of diverse habitats and land uses to invasion. Early detection and rapid eradication (EDRE) are critical for preventing establishment of *A. saligna*. Coordination efforts should be made between land managers, the local public (citizen-science) and road crews, on identification of *A. saligna* so suspected infestations can be reported.

There is not a single method that can be used, so it is advisable to frame the available measures and options in a dedicated action plan, often using integrated survey methods.

Early detection can be achieved by surveying the highest priority coastal habitats, roads, rivers, urban and peri-urban areas, burned areas, agricultural and forestry areas and natural and semi natural areas that intersect or are in close proximity to infestations (at least within 2 km of known locations of *A. saligna*). Surveys can be done on foot, by car or aerial vehicle (helicopter) and assisted with distal or proximal remote sensing tools such as unmanned aerial vehicles or systems (UAV, UAS, drones). For adult plants detection is much easier during the flowering period.

citizen-science can also play a role in the early detection, for example *A. saligna* distribution is mapped in Australia (both in its native and invasive range) by The Atlas of Living Australia, a collaborative, national project that aggregates biodiversity data from multiple sources (including citizen-science) and makes it freely available and usable online (https://www.ala.org.au/). In Portugal, citizen-science and other techniques are applied to *A. saligna* monitoring, detection, and modelling in the framework of the project INVADER-IV (PTDC/AAGREC/4896/2014, see de Sá *et al.,* 2018).

Early detection should consider the available knowledge on the type of habitats and land uses most prone to invasion, such as in Portugal[11] these are the Atlantic decalcified fixed dunes (*Calluno-Ulicetea*) (EU Habitats Directive Annex I habitat type code 2150); Coastal dunes with *Juniperus* spp. (2250); *Cisto-Lavenduletalia* dune sclerophyllous scrubs (2260); *Cistus palhinhae* formations on maritime wet heaths (5140) and West Mediterranean clifftop phryganas (*Astragalo-Plantaginetum subulatae*) (5410), but also on 2130, 2250, 2230 (Gutierres *et al.,* 2011). For Italy, *A. saligna* was described as invasive on Mediterranean scrub (habitats 2250* and 2260) and coastal *Pinus* dune wood (habitat 2270*) and it is recorded as particularly prevalent in sunny areas of habitat 2270* (Del Vecchio *et al.,* 2013). In Cyprus, the most prone to invasion is the *Juniperus phoenicea* habitat 5212 (LIFE 04 NAT/CY/000013).

SCALE OF APPLICATION

So far, the European examples of surveillance and early detection reported above (Portugal) are applied only to limited project areas, although in Portugal a smartphone App for citizen-science is available at the country level.

EFFECTIVENESS OF MEASURES

Effective.

There is plenty of literature and practical cases supporting the fact that Early Detection, followed by Rapid Eradication (EDRE) would be a very effective strategy to limit further spread of *A. saligna* within the EU. However, there is not enough information to calculate the total cost for the EU for such a strategic option.

The surveillance and ED measures would be very effective if included in a dedicated plan. However, such a dedicated plan should be based also on the knowledge of the actual distribution and abundance at Member State level, at least

11 http://invasoras.pt/wp-content/uploads/2012/10/Acacia-saligna_en.pdf

with the resolution of a 10 x 10 km grid map (or even lower for some priority sites). Such important baseline mapping dataset is presently not available, so that the precise evaluation of efforts and resources required for ED in areas not yet invaded by *A. saligna* in the EU is not possible.

EFFORT REQUIRED

To be effective, these measures must be enforced indefinitely.

RESOURCES REQUIRED

A dedicated action plan and well-trained personnel, a central national mapping data-base, and taxonomic expertise.

In general, trained staff is the key resource needed to undertake surveys on foot, boat and by vehicle. The additional costs of vehicles, including boats and helicopters (or other aerial vehicles) may also need to be considered depending upon the geography, habitats and size of the areas invaded. If remote sensing is being adopted, then drones and computer software are also needed, along with staff with the relevant skills. citizen-science programmes need to be supported by well-trained personnel and adequate hardware and software resources. Specific additional information can be found at: http://www.cost.eu/COST_Actions/ca/CA17122

SIDE EFFECTS

Environmental: Positive
Social: Positive
Economic: Neutral or mixed

There will be no negative side effects in relation to early detection measures applied to tackle *A. saligna*. However, if there was a common biosecurity/surveillance strategy for a number of invasive alien plants, this will of course produce general beneficial effects as some vectors and corridors are responsible for the spread of more than one taxa, so that land surveillance in the same localities or along the same routes or coastal areas will tackle more than one alien taxon. The same consideration applies to a common citizen-science campaign for more than one alien species that could provide significant positive effects in detection efforts.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

Surveillance measures to support early detection should be adequately communicated to relevant stakeholders. Environmental control services can access private land with or without permission depending on national and regional legislation, to monitor, control or eradicate plants that pose a significant threat to the surrounding environment, but this should always be accompanied by an adequate communication and awareness campaign.

ADDITIONAL COST INFORMATION

Although *A. saligna* is not found in association with any of the 23 invasive alien plants of union concern (Reg. EU No. 1143/2014) many of them can be found along roads, in riparian network and close to urban settlements, so that surveillance measures for *A. saligna* could be effectively incorporated into existing surveillance measures for species of Union concern.

LEVEL OF CONFIDENCE*

Well established.

There is enough scientific and technical knowledge supporting the statement and guidelines of this section on preventive measures.

* See Appendix

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

Early detection.

MEASURE DESCRIPTION

Early Detection, followed by Rapid Eradication (EDRE), can detect and eradicate incipient populations of *A. saligna* before they have a chance to become widely established, thus eliminating the need for costly and resource-intensive control programmes. If prevention fails, early detection and rapid response are the next and most cost-effective line of defence against invasive alien species. The critical threshold in the EU Mediterranean biogeographic region could be as short as 18 months as 2 years old individuals of *Acacia saligna* may begin to set seeds (Dufour-Dror, 2018 pers. comm.).

The measures to achieve rapid eradication of *A. saligna* are the same as described in the section on Management, for example, rapid eradication should follow an integrated control methodology.

Mechanical or integrated Control

In the very first phase of an *A. saligna* invasion where only seedlings are present, hand pulling (and/or manual removal using hand tools) can be applied in combination with monitoring of the site and control follow ups. In the case of larger infestations and vegetative propagation from adult individuals, rapid eradication should be conducted according to the integrated control methodology in the framework of a management plan (see Management measures section below). If rapid eradication occurs on a relatively large area (for example, more than 10–20 m^2), it is advisable to adopt specific measures for vegetation recovery of the eradicated areas. These might include the planting or sowing of local plant species, and temporary protection from grazing. For these reasons, rapid eradication cannot be applied without considering an integrated control methodology. Importantly, a successful rapid eradication should remove the aerial parts of the *A. saligna* invasive stand, the root system ("bud bank", *sensu* Klimešova and Klimeš, 2007) and the seed bank.

Eradication may only be feasible in the initial stages of infestation, and this should be a priority. The elimination of small incipient populations of *A. saligna* before they have a chance to become widely established will eliminate the need for costly and resource-intensive control programmes. It should be combined with active surveillance and early detection of new *Acacia* populations within the endangered area (such as roads, urban and peri-urban areas, riparian network, coastal areas, and natural and semi natural areas crossed or in close proximity to planted or infested sites).

SCALE OF APPLICATION

Although successful eradication of Australian acacias is rarely reported, it is possible to plan local eradication actions (the total removal of all seeds bearers, for example, adults of *A. saligna*) in recently invaded sites of special environmental importance as performed for example through the "Rizoelia National Forest Park", the "Improving lowland forest habitats for Birds in Cyprus" (Kavo Greko) and the "Montecristo 2010" LIFE projects (LIFE12 NAT/CY/000758, LIFE13 NAT/CY/000176 and LIFE08 NAT/IT/000353, respectively).

EFFECTIVENESS OF MEASURES

Effective.

Rapid eradication is expected to be very effective. Rejmánek and Pitcairn (2002) report some of the numerous examples where small infestations of invasive plant species have been eradicated by hand pulling. According to the study the same authors conducted in California, the professional eradication of exotic weed infestations smaller than one hectare is usually possible. Importantly, *A. saligna* has been successfully eradicated from the island of Pianosa (Italy, LIFE08 NAT/IT/000353)[12] and locally, in site specific interventions, also in Cyprus and Israel (Dufour-Dror 2018, pers. comm.).

EFFORT REQUIRED

To be effective, these measures must be enforced indefinitely, for example, rapid eradication should follow each new outbreak. Follow ups are required, which could be up to 50 years which is the presumed maximum lifespan of viable seeds (Dufour-Dror, 2018 pers. comm.). A methodology and plan to evaluate the effectiveness of clearing practices is also necessary.

12 http://www.montecristo2010.it/stealthV3_pubblica/0840425A0S1345033092.pdf

RESOURCES REQUIRED

Contingency action plan and well-trained personnel.

In the **European Union** *A. saligna* is managed (local eradication, control) by many LIFE projects, thus some information exists on control costs, for example, LIFE08NAT/IT/000353 (€9.40 per square meter), LIFE13 NAT/IT/000433 (€17,000.00 per ha) or LIFE13 NAT/CY/000176 (€10,000.00 per ha labour cost, excluding the costs of the herbicide) (data from Scalera *et al.,* 2017), while reports from another project from Cyprus have estimated the labour cost of control at €8,630 per ha (www.care-mediflora.eu).

Similarly, the equipment and comparative cost for eradication programmes for *Acacia nilotica* in Australia can be found in the manual from Calvert (2011). However, the cost can vary considerably due to terrain conditions, tree density, tree structure (single-stem vs multi-stems). A pair of workers can control between 100 to 150 individuals in a working day (Dufour-Dror, 2018, pers. comm.).

SIDE EFFECTS

Environmental: Positive
Social: Neutral or mixed
Economic: Positive

The elimination of small incipient populations of *A. saligna* before they have a chance to become widely established will eliminate the need for costly and resource-intensive control programmes.

The removal of *Acacia saligna* foci is a positive outcome per se, but negative side effects can be associated to that action: (1) the use of herbicides must be applied correctly and by a professional team, otherwise damages can occur to the native vegetation or to the ecosystem; and (2) secondary invasion promoted by disturbance and clearance might be a very relevant and problematic issue to address before any control is undertaken: The removal of *Acacia saligna* can lead to the establishment of other invasive species (Dufour-Dror, 2018, pers. comm.).

ACCEPTABILITY TO STAKEHOLDERS

Neutral or mixed.

The proportion of people living in urban areas in Europe continues to grow[13]. Urban trees are considered an essential component of the world's urban ecosystems and might provide a broad range of benefits to support, maintain, and improve quality of life. In numerous cases, this also applies to non-native trees and to highly urbanised areas such as the coastal areas in the Mediterranean region of Europe. For these reasons, tree cutting, and control need to be adequately communicated to local communities, private owners and relevant stakeholders. This applies specifically to *A. saligna* that is commonly considered as a beautiful ornamental tree during its flowering period, so that eradication measures need to be clearly communicated and explained.

ADDITIONAL COST INFORMATION

Depending on the age of the stand that is going to be eradicated, it might be necessary to include the control of the seed bank (see management section below) and to address possible legacy effects.

It is often assumed that the impacts of invasive plants will diminish immediately after eradication. However, in some cases the invader can have legacy effects in the soil that might persist for long periods, preventing the natural restoration of the areas managed. According to the study by Nsikani *et al.,* (2017) *A. saligna* invasion in South Africa alters overall soil characteristics but specifically raises pH by 0.6–1.8. Moreover, soil characteristics (such as pH) are not restored to natural conditions after control (soil legacy effects persist up to 10 years after clearing). Furthermore, *A. saligna* control elevates soil N levels and these can remain high up to 10 years after clearing. Elevated N often facilitates secondary invasion and/or weedy native species dominance which may hinder the restoration of functional native ecosystems. Therefore, strategies to manage areas previously invaded by *A. saligna* should take into account the removal of litter from the target invader, secondary invaders, and weedy native species.

LEVEL OF CONFIDENCE*

Well established.

There is enough scientific and technical knowledge supporting the statement and guidelines of this section on preventive measures.

Acacia saligna © *Jean-Marc Dufour-Dror.*

13 http://ec.europa.eu/eurostat/statistics-explained/index.php/Urban_Europe_-_statistics_on_cities,_towns_and_suburbs_-_executive_summary

* See Appendix

Measures for the species' management.

Physical control.

MEASURE DESCRIPTION

The management of established populations of *A. saligna* needs to make use of an **integrated control strategy** within a **dedicated management plan**. Different measures may be required at an individual site, and management should be frequently site-specific and include measures for the restoration of the natural vegetation and the reduction of disturbance (Richardson and Kluge, 2008). Although *A. saligna* is not found in association with any of the 23 invasive alien plants of union concern (Reg. EU No. 1143/2014) many of them can be found along roads, in riparian network and close to urban settlements, so that management measure could be only in part incorporated into existing management measures for species of Union concern.

Conceptually, the management of *A. saligna* needs to include a range of technologies and tools rather than only plant protection products (herbicides) and/or mechanical interventions alone. Different types of habitats and land uses are invaded by *A. saligna* in the European Union, and within a single country or region. The idea of an integrated control originates from the agricultural sector but can be very effectively applied to many invasive alien plants that impact their host environment and ecosystem services. Therefore, sustainable management of *A. saligna* demands the integration of chemical and mechanical control options, biological control, along with various forms of cultural control including, for example, grazing management, dedicated guidelines on prescribed burning, and restoration programmes (for example, Richardson and Kluge, 2008).

In addition, management measures for *A. saligna* (such as tree/phytomass removal) should be conducted having in mind that this tree is listed in Annex 1 of the Commission Implementing Decision (EU) 2015/789 of 18 May 2015 as regards measures to prevent the introduction into and the spread within the Union of *Xylella fastidiosa* (Wells *et al.,*) (notified under document C(2015) 3415) and of the Commission Implementing Decision (EU) 2015/2417 of 17 December 2015 amending Implementing Decision (EU) 2015/789 as regards measures to prevent the introduction into and the spread within the Union of *Xylella fastidiosa* (Wells *et al.,*) (notified under document C(2015) 9191).

Different methods have been proposed for control of adult *A. saligna* stands such as: (i) stem cutting very close to the ground level, such as below the coppicing point (however this rarely kill *A. saligna* trees and resprouting is almost systematic. This is considered efficient on some wattle species, such as *Acacia cyclops*), (ii) stem cutting at higher level supplemented by immediate systemic herbicide application to cut stumps (Cut Stump method), (iii) injection of systemic herbicide (such as glyphosate, fluroxypyr and triclopyr) into the base of the trunk of mature trees through the outer sapwood (drill-fill technique) or (iv) local application of herbicides into frills made around the basal section of seedlings and sapling (frilling technique) (MacDonald and Wissel, 1992; Robertson, 2005; Dufour-Druor, 2013a; Krupek *et al.,* 2016). The frilling technique is designed for small individuals (saplings). Larger ones are effectively controlled with the hack and squirt method (Dufour-Dror, 2018, pers. comm; Campbell *et al.,* 1999). New seedlings from the seed bank and potential shoot resprouts must be regularly eliminated afterwards through mechanical or chemical methods. 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.

Drill-fill and frilling techniques proved to be very effective to control *A. saligna* although being quite time-demanding for the management of large and dense populations (Dufour-Dror, 2012, 2013; Manolaki *et al.,* 2017). These techniques do not address the exhaustion of the long-lived seed bank and the recovery of native vegetation (Wilson *et al.,* 2011; Souza-Alonso *et al.,* 2017).

SCALE OF APPLICATION

The above described methodologies have been applied in the control of adult *A. saligna* stands in Italy and Cyprus, for example in the framework of a number of LIFE projects. A combination of manual, mechanical and chemical methods is described also for Malta, at Għadira (MEPA, 2013).

EFFECTIVENESS OF MEASURES

Effective.

The management (control) of *A. saligna* needs to make use of an **integrated control strategy** within a **dedicated management plan**. Different measures may be required at an individual site, and management should be frequently site-specific and include measures for the restoration of the natural vegetation and the reduction of disturbance. The dedicated management plan has to include the control of the seed bank. According to Dofour-Dror (2018, pers. comm.) the efficiency of the control by drill-fill or hack and squirt can be about 80% after the first control, but returning controls are necessary, and the efficiency of the cut-stump method is lesser, though acceptable.

EFFORT REQUIRED

Inherent characteristics of the *A. saligna*, including its rapid growth rates, copious seed production and consequent establishment of a rich soil seed bank, together with the absence of natural enemies, have given this alien tree a competitive advantage over native plant species in the Mediterranean region of the European Union. In addition, *A. saligna* resprouts vigorously from roots after fire or mechanical clearing, further complicating control (Richardson and Kluge, 2008 and references cited therein). For these reasons, control is required to be enforced indefinitely in consideration of the significant invaded range in the European Union.

RESOURCES REQUIRED

In the **European Union** *A. saligna* is managed (local eradication, control) by many LIFE projects, thus some information exists on control costs, for example, LIFE08NAT/IT/000353 (€9.40 per square meter), LIFE13 NAT/IT/000433 (€17,000.00 per ha) or LIFE13 NAT/CY/000176 (€10,000.00 per ha labour cost, excluding the costs of the herbicide) (data from Scalera *et al.,* 2017), while reports from another project from Cyprus have estimated the labour cost of control at €8,630 per ha (www.care-mediflora.eu).

Similarly, the equipment and comparative cost for eradication programmes for *Acacia nilotica* in Australia can be found in the manual from Calvert (2011), with mechanical clearing methods costing between AUD 65 to 220 (ca. €40 to 135) per hectare, and the initial clearing of 700 ha cost a total of AUD 344,681 (ca. €210,780). Note these do not cover maintenance of regrowth.

Whenever using contractors for management measures, it is advisable to meet on site the contractors, discuss the job in detail and supply them both with a distribution map of the alien tree and a contract outlining the technical guidelines of the work (Brown and Brooks, 2002). In fact, as with all invasive plants, baseline maps illustrating the distribution of *A. saligna* allow for strategic planning of control and follow-up work.

There are only limited studies or knowledge of the long-term health effects of a number of plant protection products (PPP). Herbicides can be absorbed through the skin, by inhalation or swallowing. Personal protective equipment (PPE) can limit exposure through these routes. The minimum PPE that should be worn depends on the toxicity and concentration of herbicide and the conditions in which it is used, according to European and Member States legislation and Best Practices[14]. Safety and health in agriculture is not covered by a specific EU directive but various EU directives do address certain safety and health issues in the sector (for example, Regulation (EU) 2016/425 of the European Parliament and of the Council of 9 March 2016 on personal protective equipment and repealing Council Directive 89/686/EEC). In addition, existing standards (for example, ISO and CEN standards) give detailed technical information concerning agricultural and forestry equipment, in order to prevent accidents. In general, Personal Protective Equipment for the use of PPP include adequate clothing, gloves, boots, respiratory protection, eye protection, hygiene, for example, maintaining a hygiene level that avoids as much contamination as possible is sensible (Brown and Brooks, 2002).

SIDE EFFECTS

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

Targeted and localised application of PPP, such as stem injection (see above) reduces the risk of herbicide damage or contamination to the surrounding environment. By placing the herbicide directly into the alien tree, such as direct application techniques, contamination of soil and water and damage to non-target plants is minimised. However, responses to stem injection will vary, depending on plant age, sap components and environmental conditions (Brown and Brooks, 2002).

14 https://osha.europa.eu/en/tools-and-publications/publications/protecting-health-and-safety-workers-agriculture-livestock

There are only limited studies or knowledge of the long-term effects of a number of plant protection products (PPP). Herbicide can be absorbed through the skin, by inhalation or swallowing. Personal protective equipment (PPE) can limit exposure through these routes. The minimum PPP that should be worn depends on the toxicity and concentration of herbicide and the conditions in which it is used, according to European and Member States legislation. Maintaining a hygiene level that avoids as much contamination as possible is sensible (Brown and Brooks, 2002).

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

Please see the section on Rapid Eradication, which stresses the importance of communicating the rationale for the control measures to all the relevant stakeholders. *A. saligna* cutting and control might be adequately communicated to local communities, private owners and relevant stakeholders. *A. saligna* is commonly considered as a beautiful ornamental tree during its flowering period and is used as an ornamental and shadow plant in many private gardens. In this case, eradication measures need to be clearly communicated and explained to private owners. Perceptions of invasive species, levels of awareness, and priority species for management often vary among different stakeholders (Shackleton *et al.,* 2018).

Lehrer *et al.,* (2011, 2013) have performed an economic valuation for bio-invasion in general and then examined the costs and benefits of conservation management programmes that reduce the risk of *A. saligna* invasion at the Nizzanim Long-Term Ecosystem Research (LTER) nature reserve in Israel. The study found that the annual mean willingness to pay (WTP) for containment or eradication of *A. saligna* was US$ 8.41 and US$ 8.83, respectively. The value placed on conserving the nature reserve was then compared to the cost of containment or eradication of the species, enabling a standard economic benefit–cost analysis. The result of this analysis showed that, using the most conservative method of valuation of the nature reserve, eradication of *A. saligna* gave a net benefit.

ADDITIONAL COST INFORMATION

Information related to South Africa is reported in Campbell *et al.,* (1999).

LEVEL OF CONFIDENCE*

Well established.

There is enough scientific and technical knowledge supporting the statement and guidelines of this section on preventive measures.

* See Appendix

Seed Bank Control.

MEASURE DESCRIPTION

As reported by Cohen *et al.,* (2018), many of the invasive plants possess a large persistent seed bank characterised by physical dormant (PY) seeds, which is a major obstacle to their effective and sustainable management. These plants include Australian *Acacia* species in general (Richardson and Kluge, 2008) and *A. saligna* in particular. Measures to reduce and deplete the seed bank are a fundamental part of any action plan aiming to tackle invasive acacias.

The extensive and long-lived seed bank of *A. saligna* allows it to regenerate long after clearing, cutting, wildfires or other disturbances. As such, seed banks represent a fundamental challenge to its management (Richardson and Kluge, 2008). Several techniques have been proposed to reduce the size of existing seed banks, most of them being unfortunately highly destructive, resource intensive or unsuitable for use in natural areas (Wilson *et al.,* 2011). They include the following:

(1) Prescribed fire management - This technique has been widely applied in South Africa to cause both the destruction of a significant part of buried viable seed population and the mass germination of the remaining seeds (to be complemented by subsequent treatments to kill emerging seedlings). Burning of standing trees is recommended rather than burning felled trunks to reduce the impact on and promote the recovery of native vegetation of fire-prone Mediterranean ecosystems (Holmes *et al.,* 1987, 2000; Le Maitre *et al.,* 2011);

(2) Soil Solarization (solar heating) - Areas exposed to sunlight are covered with plastic (transparent, low density polyethylene sheets), and the resulting increase in soil temperature induces germination and kills seedlings. Soil solarization is a method of pest treatment frequently used in agriculture (Kanaan *et al.,* 2018). This was found to strongly deplete *A. saligna* seed banks in experimental plots in Israel but could be only applied on limited surfaces (Cohen *et al.,* 2008, 2017, 2018). In fact, although solarization is widely used in agriculture, its application over large areas in natural ecosystems is limited, since it requires soil preparation and irrigation (Cohen *et al.,* 2018 and references cited therein);

(3) Earth covering - Seeds germinating more than 10 cm below the soil surface have a reduced chance of reaching the surface, and so covering invaded sites with 20 cm of uncontaminated soil can prevent recruitment (Richardson and Kluge, 2008). Importantly, earth covering (or comparable measures that could be used in weed control in agricultural areas such as soil inversion and removal of the topsoil) implicate major disturbances which are not suitable to sensible areas such as sand dunes, riparian areas or conservation areas.

SCALE OF APPLICATION

According to Cohen *et al.,* (2018) when applying solarization over large-scale areas, the polyethylene can be mulched by a machine, which reduces the expense of mulching. A plastic fence can provide an additional protection to the mulched area and can also be used for providing protection when active revegetation is planned following the solarization.

EFFECTIVENESS OF MEASURES

Ineffective.

Recently, Cohen *et al.,* (2018), on Israeli coastal sand dunes, demonstrated that soil solarization, particularly in combination with prescribed burning, was much more effective than prescribed burning alone, reducing seed viability to about 29% and 4%, respectively. These results were confirmed by recording seedling emergence from the natural seed bank during two successive germination years following the treatments. Only a relatively very small number of seedlings emerged in the soil solarization treatment and none in the combined treatment. Based on the above data, Cohen *et al.,* (2018) recommended to apply prescribed burning as a pre-treatment for soil solarization, or to utilise wildfires followed by soil solarization to reduce the seed bank of invasive fire-adapted plants. In situations in which fire cannot be used as a pre-treatment, soil solarization alone is considered reasonably effective. However, all of the 3 methods proposed so far and described above are very difficult to be implemented **over large areas** and out of experimental plots, due to severe constraints in practicalities, and costs, and above all because they would not be effective in large areas of natural habitats such as riparian network, sand dunes and other natural ecosystems invaded by *Acacia saligna* in the EU. Therefore, due to these constraints these measures are assessed as ineffective for controlling seedbanks in natural areas, particularly at the scale that would be required in the EU. For *Acacia saligna*, currently seed banks can only be managed by removal of seed-bearing trees as part of an integrated management plan (see Management section above).

EFFORT REQUIRED

Inherent characteristics of the *A. saligna*, including its rapid growth rates, copious seed production and consequent establishment of a rich soil seed bank, together with the absence of natural enemies, have given this alien tree a competitive advantage over native plant species in the Mediterranean region of the European Union. In addition, *A. saligna* re-sprouts vigorously from roots after fire or mechanical clearing, further complicating control (Richardson and Kluge, 2008 and references cited therein). For these reasons, control will require to be enforced indefinitely in consideration of the significant invaded range in the European Union.

RESOURCES REQUIRED

Also according to Cohen *et al.,* (2018) there are several limitations to the application of soil solarization in natural habitats. Firstly, in addition to the relatively long duration of the process and the climatic dependency, it could be applied only in flat and non-stony soils, such as agricultural areas. The application in other habitats might require soil preparation, such as uprooting tree stumps and flattening the soil surface by a bulldozer, which usually results in intensive disturbance. However, in situations in which *A. saligna* invasion occurs following soil disturbance, such as sand mining and wetland draining, or where dense stands alter the soil conditions, an abiotic manipulation is needed for returning the soil conditions to the original state in order to facilitate the regeneration of the natural vegetation (Le Maitre *et al.,* 2011, cited by Cohen *et al.,* 2018). Importantly, wetting the soil before mulching by irrigation might be an additional obstacle for application of solarization in natural habitats (Cohen *et al.,* 2018). On large-scale areas, the polyethylene can be mulched by a machine, which reduces the expense of mulching. A plastic fence can provide an additional protection to the mulched area and can also be used for providing protection when active revegetation is planned following the solarization (Cohen *et al.,* 2018). For Italy, solarization costs in agricultural areas have been quantified around €50.00 (EUR) per hectare (10,000 m^2)[15].

SIDE EFFECTS

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

The use of prescribed burning is limited due to safety, local regulations and local conditions of the various environmental ecosystems (van Wilgen *et al.,* 2010; van Wilgen *et al.,* 2012).

As reported by Cohen *et al.,* (2018) for Israel, solarization may reduce the seed banks of not only alien (*A. saligna* and other non-native species), but also of local vegetation species. This effect must be taken into consideration, especially when species of high ecological value are expected to emerge after clearance, as in most of the coastal areas of the Mediterranean Europe. On the other hand, invasive plants such as *A. saligna* commonly invade habitats that have been disturbed and whose disturbance facilitates the occurrence of other environmental weeds. Therefore, the natural seed banks in such areas include seeds of environmental weeds that tend to emerge during the active revegetation efforts that are needed to prevent reinvasion (Pretorius *et al.,* 2008 as reported by Cohen *et al.,* 2018). In this respect, the solarization advances the restoration efforts by reducing the seed banks of these weeds.

Importantly, the effects of translucent polyethylene sheeting as a thermal covering to eradicate *Pueraria montana* (kudzu) were investigated at Clemson, South Carolina in 2005-2006 (Newton *et al.,* 2008). The use of polyethylene sheeting appeared not to be cost-effective for general control of large *P. montana* infestations, but was considered to be useful for small patches. Similarly, solarization of water hyacinth (*Eichhornia crassipes*) proved successful according to the study by Ogari and van der Knaap (2002).

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

Please see the section on Rapid Eradication, which stresses the importance of communicating the rationale for the control to all the relevant stakeholders.

ADDITIONAL COST INFORMATION

Because the effect of soil disinfestation induced by solarization is not specific to the target invasive plants, and hence is expected to reduce the seed bank of native species, it is recommended to be applied at sites where active revegetation is part of the restoration programme (Cohen *et al.,* 2018).

LEVEL OF CONFIDENCE*

Well established.

There is enough scientific and technical knowledge supporting the statement and guidelines of this section on management measures. A number of studies and management actions have been conducted in areas with comparable situations to the Mediterranean region of the European Union.

15 Regolamento (CE) n. 1234/2007 - Settore ortofrutta STRATEGIA NAZIONALE 2009-2013, calcolo degli importi forfettari e valori massimi ammissibili nei programmi operativi allegato alla Circolare ministeriale n. 6152 del 24/12/2008.

* See Appendix

Classical Biological Control.

MEASURE DESCRIPTION

Two biocontrol agents were introduced in South Africa to reduce the invasiveness of *A. saligna*, such as the gall-forming rust fungus *Uromycladium tepperianum* (pathogen) and the seed-feeding weevil *Melanterius compactus*. Since 2001, the action of the fungus was supplemented by the seed-feeding weevil in order to hinder the seed production and enhance the level of control. Although this beetle is recognised as highly successful to locally reduce the seed rain, its overall impact is still unclear today (Impson *et al.,* 2011; Moran and Hoffman 2012).

SCALE OF APPLICATION

South Africa (as described above).

EFFECTIVENESS OF MEASURES

Effective.

Guidelines on how to assess the effectiveness of *A. saligna* management are provided by Kraaij *et al.,* (2017). Field surveys conducted up to 15 years after the introduction of the fungal pathogen showed that it behaves as an effective biocontrol agent against *A. saligna*. It reduces both tree and canopy density and causes of loss of vigour, a decreasing capacity to cope with environmental stresses and a reduced lifespan and fecundity of the plant (Morris, 1997, Wood and Morris, 2007; Impson *et al.,* 2011). However, its efficiency decreases with tree density and invasive plant populations can persist due to new seed production and continuous recruitment from the seed bank, especially where frequent fire perturbations promote mass-germination and strongly reduce the inoculums of *U. tepperianum* (Wood and Morris, 2007; Wood, 2012; Strydom *et al.,* 2017). In addition, there is controversial information on the effectiveness of biological control using *U. tepperianum* (Dufour-Dror, 2018, pers. comm.).

EFFORT REQUIRED

Inherent characteristics of the *A. saligna*, including its rapid growth rates, copious seed production and consequent establishment of a rich soil seed bank, together with

Acacia saligna © *Jean-Marc Dufour-Dror.*

the absence of natural enemies, have given this alien tree a competitive advantage over native plant species in the Mediterranean region of the European Union. In addition, *A. saligna* re-sprouts vigorously from roots after fire or mechanical clearing, further complicating control (Richardson and Kluge, 2008 and references cited therein). For these reasons, control is required to be enforced indefinitely in consideration of the significant invaded range in the European Union.

RESOURCES REQUIRED

Costs for initial identification and testing (including risk assessment) of biological control agents can be significant, once effective agents have been identified the costs relate to release, breeding and re-release (if required), and long-term monitoring.

SIDE EFFECTS

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

Potential impact on non-target organisms and ecosystems (van Wilgen *et al.,* 2000; Souza-Alonso *et al.,* 2017) have to be adequately assessed before any potential introduction of biocontrol agents in the European Union, as is currently being performed before the introduction of *Trichilogaster acaciaelongifoliae* for *Acacia longifolia* control in Portugal (Jeger *et al.,* 2016; Marchante *et al.,* 2017). Close attention should be paid to *U. tepperianum* due to the non-target effects it already caused to local agriculture in Indonesia and Malaysia, as reported by Dufour-Dror (2013) and Veldtman *et al.,* (2011). It is important to note that the release of macro- (or micro- in this case) organisms as biological control agents is currently not regulated at EU level. Nevertheless national/regional laws are to be respected. Before any release of an alien species as a biological control agent, an appropriate risk assessment should be made.

ACCEPTABILITY TO STAKEHOLDERS

Neutral or mixed.

A survey conducted in Canada on biological control (McNeil *et al.,* 2010) clearly shows that while biological control is preferred over pesticides, there is still a need to "educate" the general public on biological pest management. The authors remark that it would be of interest to have similar surveys carried out in both developed and developing countries, and also to see whether biocontrol is seen in a more positive light in developed countries where genetically modified plants are not as widely used as in Canada.

ADDITIONAL COST INFORMATION

Useful general information can be found in the study assessing the suitability and safety of a well-known bud-galling wasp, *Trichilogaster acaciaelongifoliae*, for biological control of *Acacia longifolia* in Portugal (Marchante *et al.,* 2011). More in general, for New Zealand, Cf. Paynter *et al.,* (2015).

LEVEL OF CONFIDENCE*

Established but incomplete.

There is enough scientific and technical knowledge supporting the statement and guidelines of this section on management measures, but so far, there is no specific study on the biological control of *A. saligna* in the European Union.

* 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 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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