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EU Legislation on Forest Plant Health: An Overview with a Focus on *Fusarium circinatum*

Anna Maria Vettraino [1,*], Roel Potting [2] and Rosa Raposo [3]

[1] Department for Innovation in Biological, Agro-food and Forest Systems (DIBAF), University of Tuscia, via S. Camillo de Lellis, snc, 01100 Viterbo, Italy
[2] Office for Risk Assessment and Research, Netherlands Food and Consumer Product Safety Authority, P.O. Box 43006 Utrecht, The Netherlands; r.p.j.potting@nvwa.nl
[3] National Institute for Agricultural and Food Research and Technology and agrifood—Forest Research Centre (INIA-CIFOR), Ctra. Coruna km. 7.5, 28040 Madrid, Spain; raposo@inia.es
* Correspondence: vettrain@unitus.it

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Abstract: The increase in arrivals of new forest pests highlights the need for effective phytosanitary legislation and measures. This paper introduces legislation targeted at prevention and management of potential introductions of forest pests and pathogens. An overview is given on plant health regulations on global and regional level with detailed information on the situation in the European Union (EU). The current and new European legislation is discussed, and a particular focus is given on eradication and contingency plans for *Fusarium circinatum*. We identified key aspects relevant for the improvement of the efficacy of measures aimed to prevent alien pests.

Keywords: EU legislation; plant health; invasive alien species; *Fusarium circinatum*; pitch canker; contingency plan; pest risk analysis (PRA); international standards for phytosanitary measures (ISPMs); EPPO standards

1. Introduction

The health of the earth's forests and urban and sub-urban green spaces is increasingly challenged by the outcomes of the recurrent introduction of invasive alien species (IAS), defined by the Convention on Biological Diversity (CBD—1993) as "species whose introduction and/or spread outside their natural past or present distribution threatens biodiversity" [1]. In the last century, the numbers of IAS in Europe greatly increased [2–4]. This proliferation is due to several reasons, some of which are within the control of regulatory authorities and some of which are not. However, the role of the plant trade as a major invasion pathway for IAS was recognised in several studies [5–7]. Alien pests arrive also by accident, in packaging material, in ship ballast tanks, shipping containers or with travellers. Interestingly, their introduction is sometimes a consequence of movement of military personnel during wars and conflicts. That was the case with *Heterobasidion irregulare*, introduced by the 85th division of the US Fifth Army in June 1944, in Central Italy [8], and *Diatrobica virgifera virgifera,* first introduced in Europe in 1990 by military air transport from North America [9].

Forest IAS have a huge and potentially devastating impact on native plants due to the absence of their specific natural predators, competitors, and pathogens, and the lack of a co-evolutionary process with the hosts, that would limit their invasion [10,11].

Protecting forests from IAS is essential, but it remains a major challenge because effective management strategies are difficult to develop. Therefore, actions, implemented mainly through regulatory measures, to prevent introduction and spread of invasive species, are of special relevance.

One of the major forest destructive pests is the pine wood nematode (PWN—*Bursaphelenchus xylophilus*), which was introduced to Portugal, in the Setùbal Peninsula, during the late 1990s and

early 2000s [12]. Its introduction in new non-native areas has resulted in serious ecological and economic damage to pine forests. Despite the emergency measures implemented by the Portuguese authorities and the European Union to prevent its further spread, the nematode established in other regions of Portugal [13–16]. Moreover, Finland, Spain, and Sweden received the nematode in wood materials imported from Portugal [17]. If no regular control measures are applied against the PWN, the economic impact of lost forestry stock is estimated to reach €22 billion for Europe by 2030 [18]. The probability of successful eradication of PWN in a new non-native area is reliably low, and could require impractical emergency measures [19]. Moreover, eradication treatments, when applicable, are very expensive. Eradication efforts against sudden oak death (SOD), caused by *Phytophthora ramorum*, introduced via live plants [20,21] on approximately 560 ha of forest land in Oregon, resulted in a cost of 2.6 million US$ for the United States [22]. The eradication programme for *Anoplophora glabripennis* was 373 million US$ for the United States. In Europe, the cost ranged from €48,000 to €464,000, according to the number of outbreaks and the type and schedule of treatments applied [23]. The success of the eradication programme can also be compromised by the ecology of the pathogen. The presence of *Fusarium circinatum* as a symptomless endophyte on herbaceous plants could affect the occurrence of the disease in pine nurseries and forest and, consequently, the management costs [24,25]. On the other hand, eradication programmes allow for a significant reduction of the damage and the protection of ecosystem services provided by trees.

Policy and management should also take into account the interactive effects of climate change and IAS on forest health. Pests and pathogens have the capacity to respond faster to environmental changes compared to their forest hosts. This may influence changes in spread, establishment, and impact of the diseases they cause [26–28].

The awareness of the risk of invasive species is reflected in a suite of international, European, and national policy legislation developed at different scales to prevent the introduction and spread of IAS within and among countries, regions, or areas. Over the past 120 years, the existing international regulation and management of non-native plant pests have continuously evolved [29]. Most countries base their phytosanitary regulations on the International Plant Protection Convention (IPPC) and the World Trade Organisation's Agreement on Sanitary and Phytosanitary Measures [30]. Nevertheless, approaches with different phytosanitary regulations are applied for managing the risk of introducing invasive alien species through international plant trade [31]. This paper aims to provide an overview of the current main European information sources on plant health for forestry in general with a focus on *Fusarium circinatum* Nirenberg, O'Donnell.

2. Current European Plant Health Legislation

The IPPC is the framework that determines the phytosanitary barriers to international trade. A total of 183 countries are currently under contract with the IPPC [32], including all member states of the EU. The IPPC provides International Standards for Phytosanitary Measures (ISPMs), that can be used by member states to achieve international agreement of phytosanitary measures. Examples of ISPMs relevant to forest pests and pathogens include ISPM 15 (Regulation of wood packaging material in international trade), ISPM 38 (International movement of seeds), and ISPM 39 (International movement of wood) [33–35]. National Plant Protection Organizations (NPPOs) follow the IPPC (Figure 1) and implement ISPMs in legislative and administrative procedures, to prevent plant pests from entering and spreading within their territories [36]. This is often referred to as plant health or phytosanitary legislation. In international plant trade, NPPOs interact with exporting and importing countries by agreeing on phytosanitary requirements. In this respect, the NPPO of the exporting country guarantees that exported plant material fulfils the phytosanitary requirements of the importing country. NPPOs often collaborate and harmonise phytosanitary measures at a regional level throughout the Regional Plant Protection Organizations (RPPOs). Regional standards for phytosanitary measures, developed in a RPPO, can be adopted by the IPPC in the form of ISPMs, which have a global reach.

For example, ISPM 36 [37] was initiated as the North American Plant Protection Organization's Regional Standard for Phytosanitary Measures 24 [38].

The European and Mediterranean Plant Protection Organization [39] (EPPO) is the RPPO for Europe. Founded in 1951, EPPO now includes 51 member countries, with nearly every country in the European and Mediterranean region, and aims to:

- protect plant health in agriculture, forestry, and the uncultivated environment;
- develop an international strategy against the introduction and spread of pests (including invasive alien plants) that damage cultivated and wild plants, in agricultural and natural ecosystems and protect biodiversity;
- encourage harmonization of phytosanitary regulations and all other areas of official plant protection action;
- promote the use of modern, safe, and effective pest control methods;
- provide a documentation and information service on plant protection.

One of the missions of EPPO is to help its member countries to prevent entry or spread of dangerous pests (plant quarantine). According to this, the organization identifies threatening pests and proposes workable phytosanitary measures which can be taken. The list of documents produced by EPPO related to forest pests and commodities, reported in Table 1, include standards for commodity, diagnostic protocols for pests, and standards for pest risk assessment (Box 1).

Box 1. Glossary.

Pest Risk Analysis (PRA)

The PRA consists of the assessment of the probability of entry, establishment, spread, and impact of pests. Specific guidelines for pest risk analysis (PRA) are provided by the International Plant Protection Convention (IPPC) in International Standards for Phytosanitary Measures (ISPMs) No 2 [40] and No 11 [41]. The relevant terminology is included in ISPM No 5 [42].

In recent years, with the aim to improve its standards, EPPO has formalised the identification of risk and the justification of phytosanitary measures to be taken. Several EPPO Standards on PRA are now available [43]. EPPO has also developed a decision-support scheme for PRA, and a computer program (Computer Assisted Pest Risk Analysis—CAPRA) [44] to assist pest risk analysts in running the decision-support scheme. A new method for a quantitative PRA and the identification and evaluation of risk-reducing options is currently under development by the European Food Safety Authority (EFSA) Plant Health Panel [45]. The method has been applied to some case studies related to forest plants, including *Atropellis* spp. [46] and *Cryphonectria parasitica* [47].

Contingency Plan

The plan is defined to ensure a rapid and effective response to an outbreak of a pest which has been considered a threat with high economic and environmental impact. It contains information concerning the decision-making processes, procedures, and protocols to be followed. As specified in International Standards for Phytosanitary Measures (ISPMs) No. 9 [48], a contingency plan is needed for pests with a high potential of introduction and for which an eradication plan is deemed necessary. EPPO standards in series PM9- National regulatory control system provide procedures for control of specific pests with the aim of containing and eradicating them.

Demarcated Areas

Officially delimited area for the implementation of phytosanitary measures to eradicate a pest.

EPPO standards for commodities [49] contain recommendations about phytosanitary measures which should be used or required by EPPO member countries for certain commodities moving in trade, to prevent the introduction and spread of quarantine pests. The EPPO list of forest commodities is provided in Table 1. Additional pest-specific information produced or collected by EPPO is available in the EPPO Global Database [50].

Table 1. Documents produced by the European and Mediterranean Plant Protection Organization (EPPO) related to forest pests and commodity [43].

EPPO	Documents	Commodity/Pests
Standards	PM 8/2(2)	*Coniferae*
	PM 8/4(1)	*Castanea*
	PM 8/5(1)	*Quercus*
	PM 8/6(1)	*Betula*
	PM 8/7(1)	*Populus*
	PM 8/8(1)	*Salix*
Diagnostic Protocols	PM 7/14(2)	*Ceratocystis platani*
	PM 7/45(1)	*Cryphonectria parasitica*
	PM 7/46(3)	*Lecanosticta acicola*
	PM 7/73(1)	*Gymnosporangium* spp. *(non-European)*
	PM 7/91(1)	*Fusarium circinatum*
	PM7/119(1)	*Bursaphelenchus xylophilus* (nematode extraction)
	PM7/123(1)	*Phytophthora lateralis*
	PM7/112(1)	*P. kernoviae*
	PM7/66(1)	*P. ramorum*
Final Decision		
Pest Risk Analysis	A1-2011	*Agrilus anxius*
	A1-2013	*Apriona* spp.
	A1-2014	*Aromia bungii*
	A1-2013	*Oemona hirta*
	A2-2014	*Polygraphus proximus*
	A2-2015	*Geosmithia morbida*
	A2-2015	*Heterobasidion irregulare*
	A1—transferred to A2 in 2011	*Phytophthora lateralis*
	A2 in 2013	*P. kernoviae* and *P. ramorum*
	A2-2017	*Thekopsora minima*
	A1—transferred to A2 in 2010	*Bursaphelenchus xylophilus*

The Panel on Plant Health of the European Food Safety Authority (EFSA) provides the European Commission independent scientific advice on the risk posed by plant pests, which can cause harm to plants, plant products, or biodiversity in the EU. Several scientific opinions have been produced on forest pests, including *Atropellis* spp. [46], *Cryphonectria parasitica* [47], and many others [51]. The EFSA Panel carries out scientific evaluations of pest risk assessment or evaluates risk mitigating measures proposed by other parties. The EFSA opinions often form the basis for regulation of organisms considered harmful to plants or plant products under the Council Directive 2000/29/EC. This Directive specifies requirements for the trade in plant material (including wood) into and within the European Union.

A scheme of the relationship between phytosanitary organisations is reported in Figure 1.

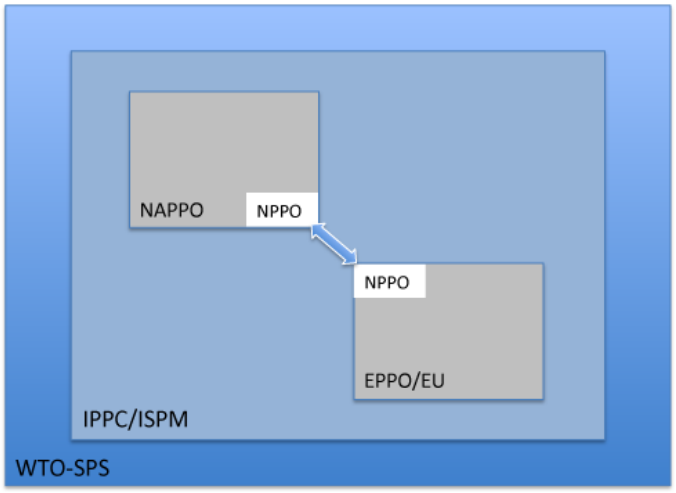

Figure 1. Relationship between phytosanitary organisations as indicated by different coloured boxes; figure adapted from Klapwijk et al., 2016 [52]. Abbreviations. WTO: World Trade Organization, SPS: Agreement on the Application of Sanitary and Phytosanitary Measures, IPPC: International Plant Protection Convention, ISPM: International Standards for Phytosanitary Measures, NAPPO: North American Plant Protection Organisation, NPPO: National Plant Protection Organisation, EPPO: European and Mediterranean Plant Protection Organization.

Within the European Community, plant health was initially a national responsibility. In 1977, member states started to work together to regulate imported plant material and restrict imports where necessary (Plant Health Directive 77/93/EC).

At present, the 28 member states of the European Union (EU) have harmonised phytosanitary legislation as specified by Plant Health Directive 2000/29/EC. This Directive lists about 300 harmful organisms, some of them subjected to specific quarantine requirements, whose introduction into or spread within the EU is prohibited. It establishes control checks to be carried out at the place of origin on plants and plant products destined for the EU, or to be moved within the EU. It also defines the control measures to be carried out at the border of the Community upon arrival of plants and plant products (including wood). Nevertheless, member states can be authorised to provide derogations from certain provision of Council Directive 2000/29/EC regarding plants or plant products listed in Annex III part A and B.

Directive 2000/29/EC is supported by further legislation in the form of a number of Control Directives and Emergency Measures against organisms, which could be introduced into or spread within the Community. Currently, there are five emergency measures in place for pests and diseases endangering European forests (Table 2).

Table 2. Geographic distribution and status of pests threatening European forests for which emergency measures have been implemented.

Pest/Pathogen	Group	Outbreak Areas		Description	EU Decision
		Present	Transient, under Eradication		
Anoplophora chinensis	Insect	China (Anhui, Aomen (Macau), Fujian, Gansu, Guangdong, Guizhou, Hebei, Hubei, Hunan, Jiangsu, Jiangxi, Liaoning, Shaanxi, Sichuan, Xinjiang, Xizhang, Yunnan, Zhejiang), EU (Italy), Indonesia, Japan (Hokkaido, Honshu, Japan Kyushu, Ryukyu Archipelago, Shikoku), Korea Dem. People's Republic, Malaysia, Myanmar, Philippines, Taiwan, Vietnam.	EU (Croatia, Germany), Switzerland, Turkey	The life cycle can be one or two generations per year, depending on the climatic and feeding conditions. Adults feed on leaves, petioles, and young bark of various tree species. The eggs are deposited under the bark. In international trade, these insects are most likely to move as eggs, larvae, or pupae hidden in woody plants and packing material. Larvae and adults of *A. glabripennis* have been intercepted in the United Kingdom on packaging material, while individuals of *A. chinensis* entered Europe on bonsai plants. Damage to fruit, and ornamental and amenity trees, results in serious economic loss. Moreover, attacks on urban plants poses hazards to pedestrians and vehicles from structural weakening and falling branches [53,54].	2012/138/EU
Anoplophora glabripennis	Insect	China (Anhui, Fujian, Gansu, Guangdong, Guangxi, Guizhou, Hebei, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Jiangxi, Jilin, Liaoning, Neimenggu, Ningxia, Qinghai, Shaanxi, Shandong, Shanxi, Sichuan, Xinjiang, Xizhang, Yunnan, Zhejiang), EU (France—Corsica, Finland) Korea Dem. People's Republic, Lebanon, Russia Far East, United States of America (Ohio, New York).	EU (Austria, France, Germany, Italy), Canada (Ontario), Montenegro, Switzerland, United Kingdom (England)		2015/893/EU
Bursaphelenchus xylophilus (Pine Wood Nematode—PWN)	Nematode	Canada (Alberta, British Columbia, Manitoba, New Brunswick, Newfoundland, Northwest Territories, Nova Scotia, Nunavut, Ontario, Québec, Saskatchewan, Yukon Territory), China (Anhui, Chongqing, Fujian, Gansu, Guangdong, Guangxi, Guizhou, Hubei, Hunan, Jiangxi, Liaoning, Shandong, Sichuan, Yunnan, Zhejiang, Xianggang), EU (Portugal), Japan (Honshu, Kyushu, Ryukyu Archipelago, Shaanxi, Shikoku, Jiangsu), Korea Republic, Mexico, Taiwan, USA (Alabama, Arizona, Arkansas, California, Colorado, Connecticut, Delaware, Florida, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Nebraska, New Jersey, New York, North Carolina, Ohio, Oklahoma, Oregon, Pennsylvania, South Carolina, Tennessee, Texas, Vermont, Virginia, West Virginia, Wisconsin).	EU (Portugal, Spain)	*Bursaphelenchus xylophilus* is the causal agent of the pine wilt disease. It is transmitted from one host to the next by insect vectors, mainly belonging to the genus *Monochamus*. It enters the tree through wounds caused by the insect feeding on the twig bark or wounds by the vector to lay its eggs. Once inside the tree, nematodes feed on the hyphae of fungi (usually *Ceratocystis* spp.) also transmitted to the wood by ovipositing beetles. They rapidly multiple in the resin canals leading to tree death within a few months [55,56].	

Table 2. *Cont.*

Pest/Pathogen	Group	Outbreak Areas		Description	EU Decision
		Present	Transient, under Eradication		
Fusarium circinatum	Fungus	Chile, EU (Portugal, Spain), Haiti, Japan (Kyushu, Ryukyu Archipelago), Korea Republic, Mexico, South Africa, Uruguay, USA (Alabama, Arkansas, California, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas, Virginia).	EU (Portugal, Spain)	See section "The case of *Fusarium circinatum*".	2007/433/EC
Phytophtora ramorum	Chromista	EU (Denmark, Germany, Greece, Poland, Portugal, Serbia, Spain, Belgium, Croatia, France, Ireland, Netherlands, Norway, Sweden, United Kingdom—Channel Islands, England, Scotland) Switzerland, Canada—British Columbia, USA (Florida, Georgia, Louisiana, South Carolina, Tennessee, Washington, Virginia, California, Oregon).	EU (Czech Republic, Finland, Italy, Slovenia).	*Phytophthora ramorum* is an oomycete pathogen known as responsible agent of sudden oak disease (SOD). The disease causes extensive damage and death to a wide range of trees and ornamental plants. It resulted in significant losses of trees, mainly oaks in California and Oregon. By contrast, in Europe, the pathogen affects mainly ornamental shrubs. However, recently, *P. ramorum* was unexpectedly detected on Japanese larches (*Larix kaempferi*), causing widespread tree mortality in England. *P. ramorum* produces several types of structures (zoospores, sporangia, and chlamydospores) specialised for survival, dispersal, or infection. Movement of infected ornamental shrubs is a significant mode of dispersal. The disease can be transmitted by infected plants and soil, and dispersal through vectors and air/water is still poorly understood [57–59].	2002/757/EC

In 2019, a new Plant Health Regulation (Directive 2016/2031) will be implemented. The new regulation focuses particularly on the prevention of entry or spread of plant pests within the EU territory. According to this Directive, a list of priority pests, with significant severe economic, social, and environmental effects will be defined. For these priority pests, member states are obliged to perform annual detection surveys and to develop contingency plans that contain detailed descriptions of the actions to be taken in case of an outbreak.

2.1. The Case of Fusarium circinatum

Fusarium circinatum causes pine pitch canker (PPC) disease, one of the most devastating diseases in *Pinus* spp. in several countries worldwide (Figure 2) [60].

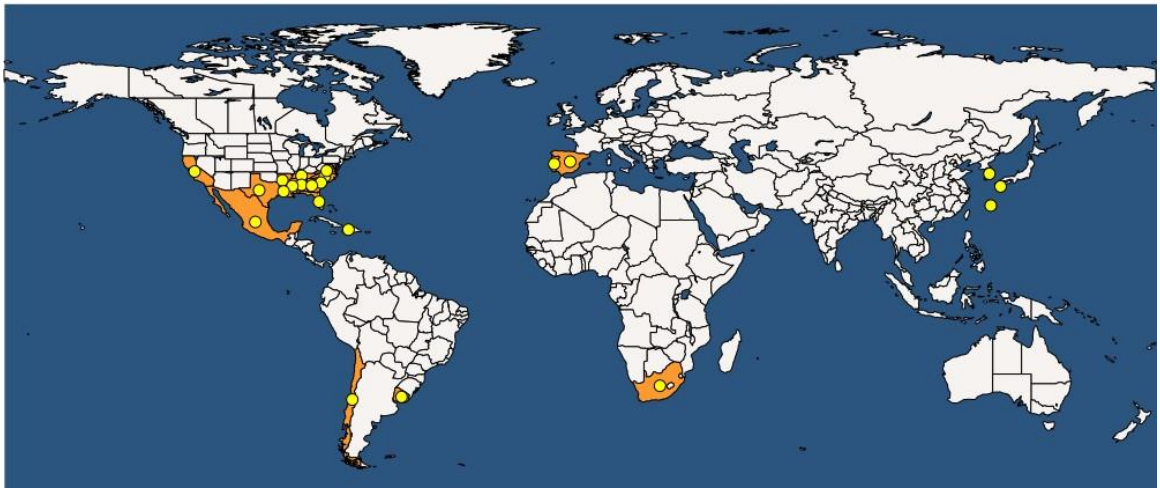

Figure 2. World map of the current distribution of *Fusarium circinatum* represented by yellow dots [50].

PPC disease shows characteristic sunken cankers that produce abundant resin in branches and main stem (Figure 3).

(**a**) (**b**) (**c**)

Figure 3. Symptoms of pine pitch canker disease on mature trees: (**a**) infected tree showing branch symptoms and resin flow at on the stem, (**b**) resinous canker on the main stem, (**c**) canker section.

Above the infection point, needles are brown and necrotic, causing partial discoloration and defoliation of branches which appears as dieback. There are usually multiple infection points in a

tree that may cause severe canopy defoliation. In seedlings, the pathogen causes damping-off in pre- and post-emergence. All *Pinus* species and *Pseudotsuga menziesii* can be affected by the disease, but these species vary widely in susceptibility. The most susceptible species are *P. radiata* [61,62] and *P. patula* [63], and the least susceptible species are *P. thunbergii*, *P. canariensis*, and *P. pinea* [60]. In Europe, the pathogen has been found in forest stands of *P. pinaster* and *P. radiata* in Spain [64,65], and *P. radiata* in Portugal [66], and in association with different *Pinus* species in nurseries [64,66]. The pathogen was eradicated in urban parks on *P. halepensis* and *P. pinea* [67] in Italy, and on *P. menziesii* and *Pinus* spp. trees in French nurseries [68].

In 2005, PPC disease was reported in *P. radiata* in Spain, as the first detection in Europe [69]. Hereafter, there were other disease occurrences reported in Italy [67] and France (NPPO, 2011) that were eradicated. Today, the disease is established in several new areas in Spain and Portugal [70] (Figure 4).

Figure 4. Year and location of first reports of *Fusarium circinatum* in countries within the European Union according to EPPO [70]. White = no information available, Light grey = pest absent, eradicated; grey = pest absent, confirmed by survey, black = pest present.

The occurrence of PPC is in agreement with suitable areas defined by the species distribution model CLIMEX for potential PPC disease establishment, that include zones within Europe in Portugal, Spain, France, Italy, and Greece [71]. *Fusarium circinatum* spreads via spores disseminated by air and insects, which are produced throughout the year [72]. Successful natural infections are associated with wounds (mechanical, weather-related, and insect-mediated activity) under favourable environmental conditions. The relative importance of dispersing the pathogen by insects and spores is variable. Insects are considered the most important means of dissemination in California [60]. In Spain, fungal spores have been detected both in the air throughout the year and associated with bark beetles such as *Tomycus piniperda* and *Pityophthorus pubescens* [73,74]. The pathogen can be brought to new areas mainly by seeds, seedlings, soil, and plant material. Pine seeds and seedlings are considered the major pathways of introduction into new countries.

Fusarium circinatum may infest seeds superficially, and internally colonise the embryo and the gametophyte tissues. Proportions of infested *P. radiata* seeds in California and Spain are 83% and 0.73%, respectively. However, these infections appear to be superficial [75]. In forest nurseries, *F. circinatum* causes damping-off of seedlings, but under certain unknown conditions, seedlings can be asymptomatic, and then become an important means of dispersion. *Fusarium circinatum* can also be disseminated by movement of soil. The pathogen survives in infested debris on the soil surface for up two years, but not in soil [76]. This is more likely due to the lack of survival structures and low inoculum potential. Serrano et al. (2017) indicated that the number of surviving *F. circinatum* spores in soil is high for a short time. This finding provides additional evidence that the pathogen may persist in soil long enough to be regarded as a vehicle for spreading to new areas [76]. In addition, *F. circinatum* can overwinter in infected branches and logs from which insect vectors can emerge and spread the pathogen. The association of the pathogen with insects is particularly worrying when firewood or infested plant material are moved to new areas [60].

2.1.1. EU Legislation

Fusarium circinatum is included in the EPPO A2 list (pests locally present in the EPPO region) and is regulated as a quarantine pest in the EU, as specified in the emergency measures (Commission Decision 2007/433/EC). Although not specific to *F. circinatum*, some provisions of the EU plant Health Directive are also relevant in order to prevent the introduction and spread of *F. circinatum* in the EU, in particular:

- Annex III (A), prohibits the introduction of plants or plant parts of *Pinus* spp. and *Pseudotsuga menziesii* (host plants) other than fruit and seed from non-European countries in all member states. Annex III (A) also prohibits the introduction of soil and growing medium as such in all member states;
- Annex II (A) and IV(A) specify import requirements for growing media attached to plants and coniferous wood;
- Wood packaging material must comply with the requirements as specified in ISPM 15.

Requirements for marketing of pine reproductive material (seeds, parts of plants, and planting stock) are also included in the Council Directive 1999/105/EC11, issued for marketing of forest reproductive material and its implementing measures.

2.1.2. Emergency Measures and Contingency Plans

Since the reported outbreaks in Spain, there are now emergency measures in place to prevent the introduction into and the spread within the EU of *F. circinatum* (Commission Decision 2007/433/EC). This EU decision imposes requirements on the import and internal movement of plants of *Pinus* spp. and *P. menziesii* intended for planting, including seeds and cones for propagation purposes (see Box 2 for details). The EU decision also sets survey obligations to EU member states and indicates which measures should be taken by member states when the organism is found. It is worth noting that, at the time that the EU measures were instituted, it was not yet known that the fungus could infect herbaceous plants. Natural infection of grasses (*Briza maxima*, *Ehrharta erecta* var.

erecta, *Pentameris pallida*, and one unidentified species) was published for the first time in 2012 [24]. Recently, *F. circinatum* has been isolated from non-symptomatic plant species belonging to the *Asteraceae*, *Lamiaceae*, *Rosaceae*, and *Poaceae* families, and from *Hypochaeris radicata* seeds [25]. The role these herbaceous plants may have in the general life cycle of the pathogen still needs to be elucidated. Preliminary results suggest that these plants become infected from airborne spores released from pine cankers. Knowledge regarding the relative contribution of this potential inoculum source, as well as its survival time once trees are felled, requires further studies.

Box 2. Outline of European Unit Emergency Measures against *Fusarium circinatum* as specified in 2007/433/EC.

(A) Specific Import Requirements for Specified Plants

The movement of specified plants originating in third countries has to be accompanied by a certificate stating that the specified plants originate in a place of production which is registered and supervised by the national plant protection organisation in the country of origin, and

(i) they have been grown throughout their life in countries where the specified organism is not known to occur, or
(ii) they have been grown throughout their life in a pest-free area, established by the national plant protection organisation in the country of origin in accordance with relevant International Standards for Phytosanitary Measures. The name of the pest-free area shall be mentioned under the rubric "place of origin", or
(iii) they originate in a place of production where no signs of the specified organism have been observed during official inspections within a period of two years prior to export, and have been tested immediately prior to export.

(B) Conditions for EU Internal Movement of Specified Plants

All specified plants either originating in the Community or imported into the Community may be moved within the Community only if they are accompanied by a plant passport, and

(i) they have been grown throughout their life or since their introduction into the Community in a place of production of a Member State where the organism is not known to occur, or
(ii) they have been grown throughout their life or since their introduction into the Community, in a place of production in a pest-free area, established by the responsible official body in a Member State, in accordance with relevant International Standards for Phytosanitary Measures, or
(iii) they originate in a place of production where no signs of the specified organism have been observed during official inspections within a period of two years prior to movement and have been tested immediately prior to movement.

(C) Establishment of Demarcated Areas (Box 1)

The Commission Decision 2007/433/EC further requires the establishment of demarcated areas following introduction of the pathogen. The demarcated areas consist of the following parts:

(i) an infected zone where the presence of the specified organism has been confirmed and which includes all specified plants showing symptoms caused by the specified organism, and
(ii) a buffer zone with a boundary at least 1 km beyond the infected zone. In cases where several buffer zones overlap or are geographically close, a wider demarcated area shall be defined which includes the relevant demarcated areas and the areas between them.

The official measures to be taken in the demarcated areas must include at least

(i) appropriate measures aimed at eradicating the specified organism;
(ii) intensive monitoring (surveillance) for the presence of the specified organism through appropriate inspections.

(D) Surveys and Notifications

Member states shall conduct official annual surveys for the presence of the specified organism or evidence of infection by this organism in their territory. The results of these surveys must be reported each year. If the pathogen is detected, control measures involve setting up a buffer zone of at least 1 km around the contamination point, and carrying out an intensive survey and extermination measures within the demarcated area. If the organism is no longer found for two consecutive years, the measures may be discontinued.

Note: "specified plants" means plants of the genus *Pinus* L. and the species *P. menziesii*, intended for planting, including seeds and cones for propagation purposes.

A strategy successful in controlling and eradicating *F. circinatum* should be developed at an international level. It should include contingency plans and clear governance to minimise/eradicate the impact when outbreaks occur. From 2019, the development of contingency plans will be mandatory for all member states with the application of the Directive 2016/2031. According to this Directive, each contingency plan shall include the following:

(a) the roles and responsibilities of the bodies involved in the execution of the plan in the event of an outbreak;
(b) access of competent authorities to premises of operators, laboratories, equipment, personnel, external expertise and resources necessary for the rapid and effective eradication or containment of the priority pest;
(c) official publication and communication of findings and measures taken against the priority pest;
(d) a pest risk assessment regarding the risk of the priority pest concerned for its territory and the risk management measures to be taken;
(e) principles for the geographical demarcation of demarcated areas;
(f) protocols describing the methods of visual examinations, sampling and laboratory testing, and principles concerning the training of personnel.

Contingency plans may be combined for multiple priority pests with similar biology and range of host species.

Recently, EPPO developed the standard generic elements for contingency plans and new standards for important pests in the series PM 9 National Regulatory Control Systems. This should facilitate EPPO members to draft their own pest-specific contingency plans and harmonizing the strategies for control and eradication of dangerous pests in Europe.

Presently few European countries have designed a strategy to help government agencies to anticipate, assess, prepare for, prevent, or respond to and recover from *F. circinatum* outbreaks, regardless of the presence of positive records of the pathogen. In the United Kingdom, *F. circinatum* is not known to be present. However, it is listed on the UK Plant Health Risk Register with a high unmitigated risk rating of 75/125, and a low mitigated risk rating of 50/125. In 2016, a contingency plan was prepared by the Forestry Commission's cross-border Plant Health Service to be used at country and national levels [77]. This contingency plan contains information on official actions following presumptive diagnosis and outbreak and background information about the pest. In addition, as required by EC decision 2007/433/EC, an annual survey of *P. radiata* (considered to be the most susceptible pine species) is carried out in England and Wales. The survey is not conducted in Scotland because there are no *P. radiata* stands there, and the climate is not as suitable as in other British regions. Moreover, the Forestry Commission in England has also published a pest alert and a field guide to identifying the symptoms of pine pitch canker.

In Spain, the disease still represents a serious threat to pine forests and nurseries. It is under eradication in some areas. The law RD 637/2006, partially modified in RD65/2010, regulates the eradication and control of *F. circinatum* in Spain. The directive contains essential elements of a contingency plan, as recommended by ISPM No. 9 [9]. A detailed comparison for contingency plans defined in UK (with no positive records of disease) and Spain is given in Table 3. Both plans address practically the same cases and situations, although the Spanish laws are more detailed, probably because they were enacted when PPC disease was already present in the country.

Table 3. Comparison of contingency plans of *Fusarium circinatum* as defined in United Kingdom [77] and Spain [a].

United Kingdom	Spain
Obligations within Demarcated Areas	
Trees felled to eradicate *F. circinatum* should be destroyed in situ.	All susceptible plants in the infected zone should be destroyed in situ.
For nurseries in the area, authorization for *Pinus* and *Douglas* fir plants suspended until the presence of *F. circinatum* within the nursery and within the demarcated area is determined.	For forest reproductive material, all fields and facilities that use this material will be declared as possibly contaminated and, therefore, susceptible plant material is to be eliminated and facilities decontaminated. Particularly for seeds, the affected batch will be destroyed, and all other batches that share facilities will be declared as possibly contaminated and immobilised until presence of *F. circinatum* is determined.
After immediate measures taken, possible preventive measures to be applied are described.	
Tracing Backwards	
If the infected trees have been planted within the previous two years, the source of the plants must be traced back to the supplying nursery, and the nursery inspected for the presence of *F. circinatum*.	The origin of affected plants within a planted forest will be investigated to determine the possible source of plants. Suppliers of infected forest reproductive material will provide a list with users of that material in the last two years. Material will be immobilised and analysis will be done to determine the presence of *F. circinatum*.
If the infected trees have been planted within the previous two years, the source of the plants must be traced back to the supplying nursery, and the nursery inspected for the presence of *F. circinatum*.	Origin of affected plants within a planted forest will be investigated to determine the possible source of plants. Suppliers of infected forest reproductive material will provide a list with users of that material in the last two years. Material will be immobilised and analysis will be done to determine the presence of *F. circinatum*.
Disposal of Felled Trees (Including Branches and Round Wood)	
By chipping, composting or burning. Regulations for burning are explained	By burning or any other accepted method.
Plant material for decorative purposes, particularly material used for Christmas trees, should be preferably buried or composted. In nurseries, infected plants and seedlings should be uprooted and burned.	Infected plants and seedlings have to be eliminated; way not specified.
Movement of Plant Material from Demarcated Areas	
It is not recommended that logs and firewood cut in infested areas be moved from the demarcated area.	It is forbidden to move plants and plant material (including wood) out from the demarcated areas.
If logs must be moved, debarking is recommended. They should be transported, with a protective covering ensuring that all material is contained, to a licensed incinerator. Merchantable logs may be sold to an authorised processing plant within the demarcated area for conversion to products such as pulp or fibreboard. Their use as saw logs is not allowed.	An exception is made for wood and wood products (first transformation) if it is completely debarked, a heat treatment is applied in a way that inner wood reaches at least 56 °C for 30 min, and it has its phytosanitary passport. If the wood requires transportation because there are no facilities to treat it within the demarcated area, it has to be done under supervision.

[a] Spanish laws RD 65/2010 and RD637/2006 for eradication and control of *F. circinatum*.

3. Conclusions

Forest ecosystems can be seriously affected by both intentional and unintentional invasions. In the last decade, along with rising global awareness of the impact of invasive forest pathogens, there has been growing recognition within the international community for the need to develop actions required for prevention and control, including legislation frameworks. To date, the European Union's response to the problems of alien species has been developed within international agreements, such as the World Trade Organization Agreement on the Application of Sanitary and Phytosanitary Measures (SPS), and the Convention on Biological Diversity (CBD). Nevertheless, the number of IAS' establishment in Europe has progressively increased over the last century [2–4]. Current legislations are based on the consensus amongst scientists and policy-makers that prevention is better than cure. However, there are gaps in the international regulatory framework that weaken the system. The new Directive 2016/2031 provides a solid legislative basis for the EU response to IAS. It also puts forward several concrete measures to tackle them as trade bans, restrictions on intentional release and contingency

plans. Nevertheless, several aspects still need to be optimised in addressing the IAS problem. Some of them are particularly noteworthy. The core instrument of the EU regulation is the European Union "blacklist", based on already-known pests [78]. Currently, the EPPO and the EFSA carry out pathway risk analyses for some of them. Nonetheless, many new non-native pests were previously unknown to be harmful, or even to science, and were therefore not regulated before they invaded. To address this issue, monitoring of sentinel plants in exporting countries has been proposed as a valuable tool to identify harmful organisms prior to their arrival [79–81]. Although several European projects (e.g., ISEFOR, COST Action FP1401, EUPHRESCO, IPSN, PRATIQUE) highlight the use of sentinel plantations, arboreta, and botanical gardens as an effective method for the identification of potential plant threats, as of now, no EU regulations are specifically defined for their implementation. This can lead to a discouraging complex bureaucracy which, in turn, discourages sentinel plantations. It is worth noting that the list of the pests regulated in the EU contains a different number and different types of organisms than those of other countries [31].

Under the new Directive, priority pests will be subjected to enhanced measures, including surveys, eradication action plans, and contingency plans. According to the new EU Plant Health Directive (article 42) import bans can be introduced for high-risk plants and plant products based on a preliminary assessment to be followed by a full risk assessment. The specific list of high-risk plants is scheduled to be published in December 2018. Another issue that is still poorly considered is the discrepancy between regulations and inspection practices in EU importing countries. In the European Union, all incoming consignments must be inspected at the first "point of entry", but the large differences in the volume of imported plants in member states, the intensity of sampling methods used for inspections, and the generally limited number of inspectors may result in differences in the way inspections are carried out [82]. In conclusion, better regional cooperation and consistency of prevention and mitigation attempts between neighbouring countries are necessary.

International collaboration may contribute to determining likely points of system failures and how to monitor and mitigate such failures.

Concerning specifically *F. circinatum*, there is still a lack of knowledge regarding potential pathways that need to be addressed. Branches for decorative purposes, bark for gardening, and timber, are common items in international trade for which it is unknown how long the pathogen can survive for during transportation and movement. It is also important to raise public awareness of the full consequences of their actions as, for example, the import of pine seeds via the internet, is currently not well regulated by the EU Directive. Moreover, the regional cooperation between Spain and Portugal, highly experienced member states concerning pitch canker disease, and other European countries should be strengthened, increasing exchanges and networking activities between scientific institutions and relevant authorities.

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