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and Technical Research
- COST -**

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COST 100/14

MEMORANDUM OF UNDERSTANDING

Subject : Memorandum of Understanding for the implementation of a European Concerted Research Action designated as COST Action FP1406: Pine pitch canker - strategies for management of *Gibberella Circinata* in greenhouses and forests (PINESTRENGTH)

Delegations will find attached the Memorandum of Understanding for COST Action FP1406 as approved by the COST Committee of Senior Officials (CSO) at its 191th meeting on 12-13 November 2014.

MEMORANDUM OF UNDERSTANDING

For the implementation of a European Concerted Research Action designated as

COST Action FP1406

PINE PITCH CANKER - STRATEGIES FOR MANAGEMENT OF GIBBERELLA CIRCINATA IN GREENHOUSES AND FORESTS (PINESTRENGTH)

The Parties to this Memorandum of Understanding, declaring their common intention to participate in the concerted Action referred to above and described in the technical Annex to the Memorandum, have reached the following understanding:

1. The Action will be carried out in accordance with the provisions of document COST 4114/13 “COST Action Management” and document 4112/13 “Rules for Participation in and Implementation of COST Activities”, or in any new document amending or replacing them, the contents of which the Parties are fully aware of.
2. The main objective of this Action is to increase understanding of pine pitch canker caused by *Gibberella circinata* to formulate plans for integrated management and reduce the probability of further introductions into currently disease-free countries in Europe.
3. The economic dimension of the activities carried out under the Action has been estimated, on the basis of information available during the planning of the Action, at EUR 84 million in 2014 prices.
4. The Memorandum of Understanding will take effect on being accepted by at least five Parties.
5. The Memorandum of Understanding will remain in force for a period of 4 years, calculated from the date of the first meeting of the Management Committee, unless the duration of the Action is modified according to the provisions of Section 2. *Changes to a COST Action* in the document COST 4114/13.

A. ABSTRACT AND KEYWORDS

Gibberella circinata is a highly virulent pathogen damaging pines, causing damping-off in nurseries and pitch canker in forests. It was first detected in North America, since when the pathogen has spread into Central and South America, South Africa, Asia and, more recently, Europe. *G. circinata* is now considered the most important pathogen affecting *Pinus* seedlings and mature trees in many countries globally; asymptomatic seedlings may be planted out, resulting in very serious losses in forests. Nevertheless, there has been little research on *G. circinata* in Europe to date and little information is available overall on host range in Europe, pathogen spread and disease control. The main aim of this Action is to establish a European-focused network to increase knowledge of the biology, ecology and pathways of spread of *G. circinata*, to examine the potential for the development of effective and environmentally-friendly prevention and mitigation strategies and to deliver these outcomes to stakeholders and policy makers. To that end, a multidisciplinary approach will be taken, including researchers, forest managers and policy makers from (initially) 27 countries focused on the common problem of pitch canker, making PINESTRENGTH highly innovative.

Keywords: *Fusarium circinatum*, pine forests, nurseries, biological control, silvicultural management, forest diseases.

B. BACKGROUND

B.1 General background

Gibberella circinata (anamorph: *Fusarium circinatum*) is a highly virulent pathogen affecting pines, causing damping-off in nurseries and pitch canker in forests. In Europe *G. circinata* is currently included in the A2 list (present in the EPPO region but not widely distributed) of pests recommended for regulation as quarantine pathogens. In adult trees the most common symptom of pitch canker is a bleeding, resinous canker on the main stem, terminals or large branches. Cankers on the main stem are lethal when the stem is girdled. The pathogen also causes damping-off, shoot die-back and death of seedlings in nurseries. It was first described in 1945 in the southeastern United States, where it was thought to be endemic; subsequent work suggested that the pathogen may be native in Mexico. Since then, *G. circinata* has spread widely and now occurs in Haiti, South Africa, Japan, Korea, Chile, Uruguay and Spain, the first European country where the disease was detected over nine years ago; more recently the disease has established in Portugal and also been

reported in France and Italy.

Pines forests and plantations are important not only for timber production, but also in soil protection, carbon sequestration, biodiversity, for ornamental purposes and for production of numerous other non-timber products. Trees susceptible to pitch canker include at least 57 species of *Pinus* along with *Pseudotsuga menziesii*. Currently, *G. circinata* is considered the most important pathogen of *Pinus* seedlings in several countries around the world. The European Food Safety Authority (EFSA) has recently established that under the current host distribution and climatic conditions, the potentially endangered areas cover over 10 million hectares, out of approximately 50 million hectares of pine forests in Europe (excluding European Russia). Nevertheless, several studies have already highlighted that climate change will lead to increased suitability of currently disease-free areas for *G. circinata*, based partly on the fact that the frequency of climatic extremes, such as drought, floods, high temperature fluctuations and storms, will increase in the near- to mid-term.

Beyond the ecological benefits, the socio-economic benefits derived from European forests and, in particular, pine forests are unquestionable. Rural development is an important policy area in Europe, covering industries such as farming and forestry. The European rural development programme foresees the economic growth of forest areas through support to innovative solutions, environmentally friendly management approaches and quality products as a source of new job opportunities. Increasing the availability of employment opportunities is particularly important for European countries, where 112.1 million people live in rural areas, which is suffering both depopulation and an ageing population as a result of reductions in agricultural and forestry activities and associated employment. In addition, the increasing threats posed to European forests by invasive pests and pathogens, such as pine pitch canker substantially amplify these problems, both ecologically and socially. In Spain, for example, the presence of *G. circinata* in forest plantations and nurseries has resulted in severe crop and yield losses, reduced revenues due to the ban on planting susceptible species (*Pinus* spp. and *Pseudotsuga menziesii*) in infected areas (Spanish Royal Decree 637/2006 and 65/2010), the high costs invested in monitoring and control, and bans on the export of timber and other products.

Gibberella circinata invaded Europe relatively recently, and has shown a very high potential for establishment. Although *G. circinata* has not yet been detected in most European countries, and therefore little funding is allocated to investigating this pathogen in currently disease-free European countries, the threat posed by the pathogen is enormous. PINESTRENGTH will establish a new network for collaboration between researchers, forest managers (and associated industries) and policy makers throughout Europe for collaboration and knowledge sharing. The multidisciplinary

vision offered will avoid unnecessary repetition. Moreover, as very little research is carried out on *G. circinata* in Europe, other non-COST countries with extensive practical experience in this pathogen and other phytosanitary risks, such as Chile, New Zealand, Republic of Korea, South Africa and USA, will contribute their knowledge and skills. These collaborations will increase awareness of the importance of this pathogen, to improve procedures for the identification of *G. circinata*, minimizing the risk of new introductions into disease-free European countries, as well as launching new research projects in the near future. The most effective mechanism for creating such networks is through COST Actions.

B.2 Current state of knowledge

Although very little research has been carried out on *G. circinata* in Europe, this pathogen has been more widely studied in other continents where severe losses have already occurred and are ongoing. The few European publications are mainly centered on characterization of Spanish populations of the pathogen, its pathogenicity and, very recently, the finding of two mitoviruses in isolates of *G. circinata*, and one pine endophyte with antagonistic characteristics against this pathogen. As far as interactions with other pests and pathogens are concerned, little is known beyond certain associations, such as with *Tomicus* spp. or *Leptoglossus* spp. and *Diplodia pinea* or *Dothistroma* spp., respectively.

At least 57 species of *Pinus* along with *Pseudotsuga menziesii* are susceptible to pitch canker. In contrast, some pine species appear to be resistant and quantitative differences in susceptibility have been documented within species that are susceptible. Research on the susceptibility of provenances of several European pine species to *G. circinata* has already commenced in Spain and jointly between Spain and the UK, and will be very useful in identifying pine genotypes to provide a base for a future European breeding programme.

Several pathways for entry from areas of establishment have been identified, such as plant material for propagation purposes (seeds, seedlings and scions), timber, plant material for decorative purposes (Christmas trees branches, cones), soil and growing substrates, natural means (insects, wind) and other human activities (travellers, machinery, silvicultural practices). The fact that international trade, both live plant material and plant products, is increasing enormously amplifies the already high risk of spreading of *G. circinata* to disease-free regions of Europe.

Contamination of pine seeds and seedlings by *G. circinata* is well documented and several possible solutions have been examined in attempts to cope with this problem. Several fungicides have been used to control seed-borne *G. circinata*. Nevertheless, as the utilization of chemicals in the forest is

very restricted, other methods, such as biological control, must be tested against the disease. A preliminary study has demonstrated that hot water treatment, at 51-52°C for 30 min, can be used to reduce *G. circinata* contamination on *Pinus radiata* seeds. A plant defence inducer, chitosan stimulated resistance in pine seedlings, reducing and delaying pitch canker development. Moreover, endophytic fungi (*Trichoderma* spp.; *Clonostachys* spp.) and bacteria (*Bacillus subtilis*; *Burkholderia* spp.) have been identified as potential biocontrol agents against *G. circinata*. In addition, essential oils of *Myrtaceae* and their components have shown antifungal activity against *G. circinata*.

PINESTRENGTH will coordinate the research efforts on pine pitch canker in Europe, prioritizing work on biological control and other techniques (silvicultural management, screening for relative resistance between provenances of various European pine species, control of vectors) for the establishment of integrated management protocols for *G. circinata* as the pathogen spreads in Europe. The Action will be highly innovative as it will increase understanding of this forest disease new to Europe and will address the problem with a multidisciplinary vision (forest pathologists, breeders, forest managers, policy makers) in an international network.

B.3 Reasons for the Action

Invasive alien species are estimated to have cost the EU at least €12 billion per year over the past 20 years, yet the damage and costs continue to increase, according to the executive summary of the European Commission impact assessment. Currently European forests face increasing numbers of alien pests and pathogens entering the region, of which *G. circinata* is amongst several attacking pines. Increasing alien invasions result from globalization of trade and free market policies. The introduction of *G. circinata* into Europe threatens economic, environmental and ecological sustainability of pine forests and plantations. The lack of knowledge on disease epidemiology, interactions with other endemic or already established pine pathogens and risk to European disease-free areas make the impact unpredictable particularly in fragile pine ecosystems with important ecological and socio-cultural values (e.g. *Pinus leucodermis* relict forests in Southern Italy).

Combined with climate change challenges, invasives pose an extremely serious risk to the future of forest ecosystems throughout the continent. Europe must establish multidisciplinary, international networks to address these varied problems in a coordinated way, sharing knowledge, avoiding unnecessary overlaps and promoting new European research projects to increase knowledge on the gaps identified. The risks associated with the spread of *G. circinata* are immense: within Europe there are some 50 million hectares of pine forests, and it is essential that greater understanding of

the *G. circinata* problem is gained, in order to better protect disease-free areas and mitigate against future losses.

The ecological, industrial and socio-economic importance of European pine forests, combined with the fact that very little research is conducted on *G. circinata* in Europe strongly supports the need for the PINESTRENGTH COST Action. Action participants will include not only researchers, but also stakeholders and a wide range of interested parties, including policy makers, regulators and forest managers, maximizing the benefits of the work.

B.4 Complementarity with other research programmes

Many substantial EU and national research programmes focused on invasive alien pests and pathogens have a synergy with and components relevant to PINESTRENGTH. These include several ongoing COST Actions, such as FP1401: *A global network of nurseries as early warning system against alien tree pests (Global Warning)*, TD1209: *European information system for alien species (Alien challenge)*, FP1103: *Fraxinus dieback in Europe: elaborating guidelines and strategies for sustainable management (FRAXBACK)*, FP1102: *Determining invasiveness and risk of Dothistroma (DIAROD)* and FP1002: *Pathway evaluation and pest risk management in transport (PERMIT)*. Other EU research projects include FP7 *Responses of European forests and society to invasive pathogens (RESIPATH)*, FP7 *European phytosanitary research coordination (EUPHRESCO-Gibcir-Diagseed)*, FP7 *Increasing sustainability of European forests against invasive pests and pathogens (ISEFOR)*. National research projects include *Mycoviruses for biological control of pitch canker (BIOFUS)* (Spanish Ministry funding, AGL2012-39912), *Etiology, epidemiology and control of Fusarium circinatum in Spain* (Special Action Project, Spanish Ministry-INIA funding) and a research programme funded by The Biology and Biotechnology Science Research Council in the UK *Promoting resilience of UK tree species to novel pests and pathogens: ecological and evolutionary solutions*, which includes a substantial subsection on variations in susceptibility of Scots pine provenances to the pitch canker pathogen, jointly between the Universities of Aberdeen and Valladolid. Further proposals for parallel work are being considered in the UK. Authorities in France and Italy are also well aware of the potential problems posed by this organism. Moreover, several Horizon 2020 proposals have been submitted in which *G. circinata* is a main focus, in particular Marie Skłodowska-Curie Action: Innovative Training Networks (ETN-DOCTORS) and Societal Challenge 2: Sustainable Food Security SFS-03a (SONATA).

C. OBJECTIVES AND BENEFITS

C.1 Aim

The aim of the PINESTRENGTH Action is to collect and collate the current state-of-art knowledge on pitch pine canker caused by *Gibberella circinata*, in order to increase understanding of the problem and the pathogen so that plans for the integrated management of pine pitch canker and to reduce the probability of further introductions into currently disease-free countries, can be established in Europe.

C.2 Objectives

This aim is addressed through the following four objectives:

Objective 1: to develop and recommend suitable, practical tools, techniques and methodologies for rapid and sensitive detection and efficient monitoring of G. circinata in plant materials and in pathways of potential spread.

State-of-art of methods will be collated to (i) determine suitable approaches, timing, frequency and methodology for surveys and sampling, (ii) identify and evaluate the best available biological/molecular techniques for *G. circinata* diagnostics.

Objective 2: to collect and collate published information on the biology and ecology of G. circinata and other pine pests and pathogens with high potential to interact with pitch canker.

Knowledge of the biology and ecology of *G. circinata* will be collated and information on abiotic and biotic factors influencing disease development synthesized. The implications of other pine pests and pathogens and their potential interactions with *G. circinata* will be also examined to implement this knowledge into strategies for integrated disease management. Furthermore, this knowledge will serve to delineate the pathways of pitch canker disease spread from nurseries to the field and assess the utility of the current Pest Risk Analysis for *G. circinata* under present and future climate change scenarios.

Objective 3: to develop effective and environmentally-friendly control strategies for pitch canker.

Host responses to pathogen infection will be examined in order to improve knowledge on and to develop morphological markers for pitch canker-resistant genotypes and provenances. An assessment of current control methods used worldwide and novel methods for management explored, with emphasis on the use of biological control agents in the nursery, and on individual tree and landscape scales. Along with the silvicultural methods, these data will enable sustainable integrated management for pitch canker to be established.

Objective 4: to raise awareness of pine pitch canker and disseminate the outcomes of these activities to stakeholders, policy makers and other interested parties.

The ecological, economic and social impacts of pitch canker will be investigated, detailed and summarized to raise awareness of the importance of this pathogen in forestry for forest managers and policy makers. Combined results from the work will enable future research needs to be assessed, in order to fill knowledge gaps. Finally, dissemination of results will be a priority commitment of the PINESTRENGTH partners.

C.3 How networking within the Action will yield the objectives?

Sharing experiences between COST Action participants, particularly in conjunction with both reciprocal country participants, and invited speakers from countries that already have serious pitch canker problems will enable rapid advances in achieving the objectives. A combination of literature searches and experimental work funded outside the Action, along with STSM work will also facilitate the prompt achievement of Action objectives. PINESTRENGTH will establish a network involving many countries and assemble a multidisciplinary team. The Action Chair will coordinate the management of PINESTRENGTH in conjunction with the Management Committee (MC) and Core Group (Vice Chair, Working Group (WGs) leaders, STSM manager, Early Stage Researcher Representative) using the timetable agreed by the MC at the kick-off meeting. Meetings of the MC will be held annually to enable future planning, formal monitoring of deliverables and demonstration of the milestones achieved. Whenever possible, MC meetings will be held in parallel with WG meetings, to reduce overall costs and promote as full attendance as practical.

Work in PINESTRENGTH is divided amongst six Working Groups, the Leaders and Deputies of which (elected at the kick-off meeting) will be in charge of encouraging and channelling the work of WG members. Furthermore, WG leaders will also collaborate together to avoid unnecessary overlaps and relay relevant feedback to WG members. Meetings of WGs will be held at least annually; initial meetings will assign specific tasks to the WG members on the basis of experience and to a realistic timetable. WGs will also propose to the MC ideas for workshops and training schools for each WG, identify knowledge gaps and, encourage new European research projects to increase understanding of the pitch canker problem in Europe.

STSMs will have an essential role in PINESTRENGTH. An STSM Manager will be in charge of collecting applications and offers from COST participants, seeking approval from the Core Group and disseminate STSM reports amongst the partners. The aim is to fund 7-10 STSMs per year, with a major focus on the participation of early-stage researchers (ESRs). Three training schools will be

organized within the PINESTRENGTH timeframe, to increase knowledge of pine pitch canker amongst early-stage researchers, focusing on monitoring and detection methods, integrated pest management (including host resistance, biological control possibilities; management of disease) and pest risk analysis for *G. circinata*.

C.4 Potential impact of the Action

Scientific knowledge. Tackling a new problem on an international scale, such as the inadvertent introduction of a new pathogen, requires, initially, the compilation of all available information. PINESTRENGTH will provide a fluid flow of information and bring together experts with extensive practical experience in *G. circinata* from various International Partner Countries such as Chile, New Zealand, Republic of Korea, South Africa and the USA to share their knowledge. Thus, specific training by means workshops and training schools and the establishment of an integrated management will allow the European scientific community and stakeholders to become highly familiarized with the problems caused by *G. circinata*, facilitating rapid detection of the pathogen, avoiding spread and, where it does establish, rapidly implementing appropriate management and control protocols.

Social and economic impact. As indicated above (B1), the benefits derived from forests and, in particular locations, pine forests, are unquestionable. The forestry sector represents a low percentage of the European economy, but its importance from the social and ecological perspectives is beyond economic analyses. Forests are located in rural areas and, in many cases, represent the only source of permanent regular income in those areas. The establishment of a new pathogen, therefore, such as *G. circinata*, will lead to loss in income and, hence, higher rates of depopulation of these areas. Furthermore, the seed-borne characteristic of this pathogen and the devastating effects on pine seedlings seriously threaten forest nursery production systems in all European countries. The socio-cultural value of pine forests in Europe is unquestionable and is related to the use of timber for traditional construction and tools, production of non-timber products, such as pine nuts and mushrooms, for typical regional recipes, and the unique landscape signatures that characterize many areas.

C.5 Target groups/end users

PINESTRENGTH will impact on society as a whole, which is becoming ever more conscious that natural resources are limited and sustainability of forests and other ecosystems is, on one hand

essential, whilst on the other under threat. More specifically, stakeholders/end users of this COST Action, many of whom were involved in the preparation of the proposal, will include: forest policy makers, plant health/quarantine organizations (e.g. EPPO, NPPOs of EU Member, IPPC), forest owners and managers, forestry industry (e.g. nurseries, timber industry, chemical and biological control industries [SEM]), the scientific community and citizen associations (e.g. conservation organisations focused on traditions or cultural heritage). Furthermore, outcomes of the Action will may be implemented in regulations on the prevention and management of the introduction and spread of invasive alien species. Relevant to this point, the European Commission has recently published a preliminary proposal 2013/0307 (COD), which is likely to come into effect in 2016.

D. SCIENTIFIC PROGRAMME

D.1 Scientific focus

PINESTRENGTH will tackle this invasive disease problem from a multidisciplinary approach, compiling current knowledge of *G. circinata* from global sources in order to answer fundamental questions, co-ordinating ongoing research projects, identifying knowledge gaps, acting as a platform to foster new research programmes that deal with these gaps and elaborating guidelines for integrated management of the disease. The primary tasks covered in the PINESTRENGTH Action are:

Task 1: Determining suitable approaches, timing, frequency and methodology for surveys and sampling.

EU Member States conduct annual surveys for the presence of *G. circinata* in compliance with Commission Decision 2007/433/EC, which has been transposed into national and even regional laws, resulting in the use of different methodologies according to region. Thus, it is essential to bring the current knowledge and experience from COST participants and to establish a common methodology to monitor forest stands, nurseries and seed orchards.

*Task 2: Identifying and evaluating the best available molecular techniques for *G. circinata* diagnostics.*

Since the publication of Commission Decision 2007/433/EC, trade in plant material between EU states requires a phytosanitary passport that certifies by means of reliable laboratory tests the absence of *G. circinata*. EPPO diagnostic protocol PM 7/91 describes several methods currently available to detect the presence of *G. circinata* in seeds or *in planta*. Included are morphological identification in pure culture and molecular techniques, such as PCR-RFLP, SyBr green real-time

PCR, dual-labelled probe real-time PCR or conventional PCR. In this respect, a European project (Gibcir-Diagseed – EUPHRESKO) was launched to test the viability of three different methods to detect *G. circinata* in seeds. However, identification, evaluation and harmonization of the best techniques for *G. circinata* diagnostic *in planta* are lacking.

Task 3: Assessing the potential interactions between other pine pathogens and G. circinata.

Numerous pathogens are currently impacting negatively on European pine forests, which could interact with *G. circinata* in a synergistic manner, producing an even a higher threat. In this regard, PINESTRENGTH will collate information on the problems posed by other pathogens already established in Europe and their potential interactions with *G. circinata* in order to assess the implications towards an integrated disease management.

Task 4: Assessing the potential interactions of other forest pests with G. circinata.

Interactions between forest pathogens and pests are well-known. PINESTRENGTH will collate information about pests acting as potential vectors of *G. circinata* and any other interaction between these organisms with implications for the integrated disease management.

Task 5: Synthesizing environmental data on pitch canker epidemiology and spread on a Europe-wide scale.

Previous studies demonstrated that climatic factors, such as temperature and moisture conditions, can be used to delineate risk of infection and establishment of *G. circinata*. PINESTRENGTH will collate a highly informative dataset from COST participants to establish a proper level of understanding of the effect of environmental conditions on pitch canker epidemiology and spread. These models will allow outbreaks to be predicted under, for example, changing climatic conditions or inappropriate silvicultural treatments (thinning, pruning), which could modify stand conditions favouring the establishment and spread of *G. circinata*.

Task 6: Assessing the pathways of pitch canker disease spread, with emphasis on nurseries to the field.

The best way to prevent the establishment of new pathogens is strict pathway management. In this regard, several pathways for entry of *G. circinata* from infested areas have been identified (see B2). Nevertheless, contaminated seeds almost certainly represent the route through which *G. circinata* was first introduced into Europe (via Spain) and the same route was likely to have been responsible for subsequent introductions to Portugal, Italy and France. Thus, it is essential to bring together current knowledge on seed contamination, with a particular focus on the endophytic status of the pathogen. Any progress in this area will significantly minimize the risk of spread from nurseries to the field via latent, asymptomatic infections.

Task 7: Pest Risk Analysis for G. circinata.

EFSA recently carried out a pest risk assessment on *G. circinata*, concluding that under current conditions the potentially endangered areas with massive consequences from infection cover over 10 million hectares in Europe. Nevertheless, several studies have highlighted that climate change will lead to increased incidence of several tree diseases, including pitch canker in Australasia. Data collated by the Action participants and its implementation in climate-based models, such as CLIMEX, will enable detailed predictions of the impact of pitch canker, with emphasis on disease-free European countries, based on future climate change scenarios established by the Intergovernmental Panel on Climate Change (IPCC, 2013). The development of risk maps will be very useful to European authorities and forest managers, so that sampling efforts will be devoted to higher-risk areas.

Task 8: Estimating the economic and social impacts of pitch canker.

As the socio-economic benefits arising from pine forests are enormous, PINESTRENGTH, based on pest risk assessment, will evaluate the potential economic, social and cultural impact of *G. circinata* in affected countries and the potential impact on disease-free states. The estimation of economic losses and its direct consequences on employment will further raise public awareness of pitch canker, particularly amongst authorities, forest managers, stakeholders and society at large.

Task 9: Determining host responses to pathogen infection, acquiring knowledge on pitch canker-resistant genotypes and provenances.

Several papers report variations in pitch canker susceptibility both between and within species. Breeding programmes are innocuous tools to overcome the susceptibility of sensitive pine species to *G. circinata*. PINESTRENGTH will, therefore, bring together the current state of knowledge on research carried out in Europe and beyond, to provide stakeholders and all interested parties with valuable information to select those species, provenances and/or genotypes more resistant to pitch canker.

Task 10: Assessment of current control methods used worldwide and exploring the utilization of novel management methods, with emphasis on application of biological controls at the nursery, individual tree and landscape scale.

As the utilization of chemicals in the forest is highly restricted, alternative, more environmental-friendly methods are required to assist in the management of forest diseases. Biological control methods overcome the tendency of pathogens to become resistant through repeated use of xenobiotic chemicals targeting a single active site in the organism. PINESTRENGTH will compile all relevant information from ongoing research on biological control methods, with emphasis on hot water treatment of seed, resistance inducers, endophytic fungi and bacteria, mitoviruses and natural components from plants with antifungal activity.

Task 11: Coordination of the Working groups.

PINESTRENGTH will ensure efficient coordination and management of the Working groups (1), avoiding unnecessary duplication and, therefore, optimizing resources, and (2) reviewing and assessing the project results and progress towards the objectives, with regard to deviations, timing and resources consumed.

Task 12: Identification of future research needs - coping with knowledge gaps.

The network established in PINESTRENGTH will share all available information from Tasks 1-10, allowing the identification of knowledge gaps, co-ordinating ongoing research and launching future projects aimed at filling those knowledge gaps, whilst optimizing resources.

Task 13: Dissemination of results - establishing communication mechanisms to stakeholders and other target audiences.

Dissemination is one of the main aims of PINESTRENGTH, ensuring rapid transfer of knowledge to stakeholders and other target audiences. The PINESTRENGTH website will be key to achieving this work, with regular updates, acting as a primary communication channel. Furthermore, outcomes from the Action will be presented at annual workshops with basic proceedings, an international conference in the last project year, and at forestry (e.g. International Union of Forest Research Organizations (IUFRO)) and relevant plant pathology meetings (International Congress of Plant Pathology (ICPP)). The most noteworthy results will be published in a proceedings of the final conference, or in a special issue of a scientific journal such as *Forest Pathology*. Management information derived from work in the Action will be summarized in a practice guide (illustrated pamphlets in several languages) on integrated management of *G. circinata* that is easily understandable by practitioners.

D.2 Scientific work plan methods and means

The PINESTRENGTH Action will be based around thirteen main tasks (see D1), supported by six WGs. These WGs will interact in developing knowledge and ensuring that all Tasks are fulfilled. The structure of the work plan is as follows:

Working Group 1. The pathogen: diagnosis	
<i>Task 1: Determining suitable approaches, timing, frequency and</i>	Target 1. To review data, including unpublished results and grey literature, to obtain consensus on the most suitable methodologies for surveying in nurseries, seed orchards and forest stands

<i>methodology for surveys and sampling</i>	Target 2. Data will be collated from different studies (completed and ongoing research) to determine the probability of detecting <i>G. circinata</i> in an infested area according to type of sampling used.
Task 2: Identifying and evaluating the best available molecular techniques for <i>G. circinata</i> diagnostics	Target 1. To review data, including unpublished results and grey literature, to obtain consensus on the best available molecular techniques for <i>G. circinata</i> diagnosis in seeds and in planta
	Target 2. Data will be compiled to validate the available and widely used detection methods
<i>Deliverable 1. Illustrated pamphlets on Pitch Canker Disease, in several European languages, showing symptomatology on different pine species (month 18)</i>	
<i>Deliverable 2. Review article assessing and standardising survey methodologies and molecular diagnostic methods (month 36)</i>	
Working Group 2. Interactions with other forest pests and pathogens	
Task 3: Assessing the potential interactions of other pine pathogens with <i>G. circinata</i>	Target 1. To review data, including unpublished results and grey literature, on interactions with other stem pathogens, with an initial emphasis on Diplodia shoot blight
	Target 2. To review data, including unpublished results and grey literature, on interactions with foliar pathogens, with emphasis on Dothistroma needle blight
Task 4: Assessing the potential interactions of other forest pests with <i>G. circinata</i>	Target 1. To review data, including unpublished results and grey literature, on interactions with forest pests of pines, with emphasis on their implications as vectors of <i>G. circinata</i>
	Target 2. To review data, including unpublished results and grey literature, on interactions with forest pests of pines, with emphasis on their implications as immediate cause of outbreaks
<i>Deliverable 3. Review article on interactions of forests pests and other pathogens with <i>G. circinata</i> and their potential implications for integrated disease management (month 36)</i>	
Working Group 3. Pathway of disease spread	
Task 5: Synthesizing environmental data on pitch canker	Target 1. To review data, including unpublished results and grey literature, on disease distribution and environmental factors that influence development and spread of the disease

<i>epidemiology and spread on a Europe-wide scale</i>	Target 2. To review data, including unpublished results and grey literature, on forest management that influence development and spread of the disease
Task 6: Assessing the pathways of pitch canker disease spread, with emphasis on nurseries to the field	Target 1. To review data, including unpublished results and grey literature, to assess the risk of <i>G. circinata</i> spread associated with plant material for propagation purposes, timber or for pine materials for decorative purposes
	Target 2. To review data, including unpublished results and grey literature, to assess the risk of <i>G. circinata</i> spread associated with soil and growing substrates
	Target 3. To review data, including unpublished results and grey literature, to assess the risk of <i>G. circinata</i> spread associated with natural means, with emphasis on insects
	Target 4. To review data, including unpublished results and grey literature, to assess the risk of <i>G. circinata</i> spread associated with human activities, with emphasis on silvicultural practices
	Target 5. To review and collate data to clarify the risk of spreading <i>G. circinata</i> as a latent pathogen during its endophytic stage in seedlings from nurseries to the field
<i>Deliverable 4. Illustrated pamphlets on Pitch Canker Disease, in several European languages, synthesizing pathways of disease spread and preventive measures (month 18)</i>	
<i>Deliverable 5. Review article on the importance of environmental factors and forest management on disease spread (month 36)</i>	
Working Group 4. Pest risk analyses	
Task 7: Pest Risk Analysis for <i>G. circinata</i>	Target 1. To review data, including unpublished results and grey literature, on current pest risk analysis for <i>G. circinata</i>
	Target 2. Generation of risk maps for <i>G. circinata</i> based on future climate change scenarios
Task 8: Estimating the economic and social impacts of pitch canker	Target 1. To review data, including unpublished results and grey literature, on current economic losses and their impacts on employment, caused by <i>G. circinata</i> in the affected countries
	Target 2. To estimate the potential economic losses and their consequences on employment caused when <i>G. circinata</i> invades

	currently disease-free countries
<i>Deliverable 6. Risk maps for G. circinata on current and future climate change scenarios (month 42)</i>	
<i>Deliverable 7. Report on the economic and social impacts of pitch canker in Europe (month 36)</i>	
Working Group 5. Management of the disease in forest and nurseries	
<i>Task 9: Determining host responses to pathogen infection, acquiring knowledge on pitch canker-resistant genotypes and provenances</i>	Target 1. Collation of data to establish the degree of susceptibility of European pines to <i>G. circinata</i> , with emphasis on differences between results under laboratory and field conditions
	Target 2. To review data, including unpublished results and grey literature, on resistant genotypes and provenances of pine species of interest in Europe
	Target 3. To review data, including unpublished results and grey literature, on mechanisms that contribute to host resistance
	Target 4. Data will be compiled to summarize results from breeding programmes, pine silvicultural trials and from monitored regeneration plots
<i>Task 10: Assessment of current control methods used worldwide and exploring the utilization of novel methods, with emphasis on application of biological controls at the nursery, individual tree and landscape scale</i>	Target 1. To review data, including unpublished results and grey literature, on biological control methods of potential value in managing pitch canker, with emphasis on hot water treatment of seed, resistance inducers, endophytic fungi and bacteria, mitoviruses and natural components from plants with antifungal activity
	Target 2. To co-ordinate the ongoing research in control to maximize the available resources and implement the most valuable techniques in a simple integrated management tool
<i>Deliverable 8. European database of pitch canker-resistant Pinus species/genotypes/provenances and established or planned breeding programmes (month 38)</i>	
<i>Deliverable 9. Review article on host resistance mechanisms against G. circinata (month 42)</i>	

<i>Deliverable 10. Review article on application of biological controls against G. circinata(month42)</i>	
Working Group 6. Coordination, identifying research gaps and dissemination	
Task 11: Coordination of the Working groups	Target 1. Avoid unnecessary duplications, optimizing resources
	Target 2. Review and assess the project results and progress towards the objectives, with regard to deviations, timing and resources consumed
Task 12: Identification of future research needs - coping with knowledge gaps	Target 1. Undertake an annual, web based questionnaire and feedback review process within PINESTRENGTH, in which researchers, stakeholders and other interested parties can raise research questions and needs
	Target 2. Establish capabilities with the WGs to facilitate collaborative research to cope with identified knowledge gaps. If this is not possible directly through ongoing projects, consider applications for new funding and launch a new European project
Task 13: Dissemination of results - establishing communication mechanisms to stakeholders and other target audiences	Target 1. Identify target audiences, stakeholders and research parties for both external and internal communication
	Target 2. Establish communication mechanisms and link appropriate information to target audiences
<i>Deliverable 11. PINESTRENGTH website with regular updates, including feedback, links with the different websites of ongoing related projects, electronic outputs and a database of peer reviewed and grey literature (month 3)</i>	
<i>Deliverable 12. Final report in several European languages, including hard copy and electronic versions of the knowledge compiled through conference proceedings/book/peer reviewed papers and of best practice guidelines for integrated management of G. circinata in Europe (month 48)</i>	

E. ORGANISATION

E.1 Coordination and organisation

PINESTRENGTH will be coordinated through the Management Committee, which will be established as set out in “Rules and Procedures for Implementing COST Actions”. MC Members, including the Chair, Vice-Chair, WG Leaders and Deputies, and the STSM Manager, will be formally nominated at the kick-off meeting of the Action. The MC will be in charge of overseeing the planning, execution and delivery of this Action, including liaison with local organisers involved in workshops, training schools and meetings. The PINESTRENGTH website will act as a communication channel not only amongst members of the Action but also as a dissemination tool for all other interested parties.

Although the number of European research programmes funded is still limited because of the recent establishment of *G. circinata* in this continent, numerous research projects are currently being undertaken in Australasia, North and South America and South Africa. Thus, both European and non-European researchers will be involved in the COST Action, participating in meetings, workshops and training schools in order to collate and disseminate the full extent of available knowledge. Experts with common research interests from a multidisciplinary approach will become members of each WG. The MC will identify research institutions with similar research interests, however WG members will also be encouraged to suggest the inclusion of further experts from outside the currently identified membership. WGs will propose, plan and organise the workshops and training schools considered by consensus most interesting. Furthermore, the STSM Manager will be collaborating closely with all WGs to foster research collaboration among research institutes.

The following milestones will be achieved through the WGs: 1) Kick-off meeting (month 1), 2) establishment and maintenance of the PINESTRENGTH website with open and restricted access areas (month 3), 3) state-of-art methods for rapid and sensitive detection of the pathogen along pathways of dispersal including seeds, infected seedlings and mature trees (month 18), 4) standardisation of the molecular diagnostic methods (month 20), 5) recognition and production of a comprehensive listing of known and potential pathways for spread at all levels (month 24), 6) production of disease distribution maps (month 24), 7) production of potentially diseased areas maps under different climate change scenarios (month 36), 8) estimation of current and potential economic losses and social implications (month 36), 9) gaining knowledge on pitch canker-resistant *Pinus* species/genotypes/provenances and established or planned breeding programmes (month 38), 10) feedback on knowledge gaps to the MC and recommendations for facilitating research

outcomes and identification of new funding streams to address those research gaps (month 42), 11) training schools, workshops, STSMs and final conference (month 6-42), 12) dissemination of scientific findings, non-technical publications and final report (month 18-48).

E.2 Working Groups

Working Group 1. Diagnosis will address Tasks 1 and 2 aimed at harmonizing a common methodology to monitor the presence of *G. circinata* in Europe, so reference laboratories and mandated diagnostic laboratories will have a tool to carry out rapid and sensitive detection of the pathogen along pathways of dispersal.

Working Group 2. Interactions with other forest pests and pathogens will address Tasks 3 and 4, collating information concerning potential synergic effects with other pathogens and pests and the role of the latter as potential vectors of *G. circinata*.

Working Group 3. Pathway of disease spread will address Tasks 5 and 6 aimed at shedding light on factors determining epidemiology and spread of pine pitch canker, including environmental conditions that favour outbreaks once established and potential pathways that favour the dispersal towards free-disease regions.

Working Group 4. Pest Risk Analyses will address Tasks 7 and 8, assessing the current and potential European risk for *G. circinata* based on future climate change scenarios. Furthermore, this pest risk assessment will result in estimations of economic and social impacts of Pitch Canker.

Working Group 5. Management of pine pitch canker in forests and nurseries will address Tasks 9 and 10, synthesizing information concerning host resistance and utilization of biological control methods as alternatives to chemical treatments.

Working Group 6. Coordination, identifying research gaps and dissemination will address Tasks 11, 12 and 13, coordinate WGs 1-5 and compile their outcomes, identify knowledge gaps and acting as a platform for prioritising research areas and formulate new projects. Furthermore, it is aimed at providing timely dissemination of information from PINESTRENGTH, with emphasis on stakeholders and other target audiences beyond COST participants.

E.3 Liaison and interaction with other research programmes

Researchers involved in PINESTRENGTH are already participating and/or coordinating the research projects and COST Actions listed in section B.4, which will ensure a better integration of activities and avoid overlaps. Other experts taking part in these research initiatives will be invited to

workshops of the Action in order to facilitate interactions. In particular, experience gained from other related COST Actions and research projects dealing with phytosanitary risk and movement of invasive alien species (e.g. Global Warming, DIAROD, FRAXBACK, PERMIT, ISEFOR) will be integrated in this COST Action.

E.4 Gender balance and involvement of early-stage researchers

PINESTRENGTH will aim at an appropriate gender balance in all activities and the MC will place this as a standard agenda item. The Action is also committed to involve ESRs in management, as well as in STSMs. The Core Group will include an ESR representative. ESRs will also be placed as a standard item on all MC agendas.

The people who have expressed interest in this COST Action include 32 % women, however further efforts will be made to bring more female scientists into PINESTRENGTH to exceed the EU target of 40 %. Furthermore, election of female members to the MC and to lead WGs will also be given high priority. PINESTRENGTH will take on the COST family friendly policy (COST 295/09) whenever feasible, planning meetings outside major school holidays, providing information on venues with family rooms and collecting requests from participants on whether childcare is needed. The Action will support the development of ESRs, based on the COST ESR policy (COST 295/09), in order to transfer knowledge and skills between generations. ESRs, both postgraduate students and postdoctoral scientists, will be responsible for the generation of primary data, playing a key role in the Action. They will be encouraged to take part as national MC delegates and leaders or deputies of Working Groups whenever feasible. They will also be encouraged to take up STSMs, and to attend training schools and workshops (at least 80% of participants are likely to be ESRs), opportunities that will widen their experience. They will also be invited to present their research and ideas at meetings and workshops of the Action, receiving feedback from senior researchers, which helps in producing high quality research papers of benefit to the ESRs' scientific careers. Furthermore, ESRs will be integrated in a network, facilitating participation in other European schemes, such as EU Marie Skłodowska-Curie programmes, in the near future.

F. TIMETABLE

PINESTRENGTH will plan activities as indicated in the Table below. The progress of the Action towards the objectives will be assessed in the form of assigned milestones and deliverables (see D2

and E1)

	Year 1			Year 2			Year 3			Year 4				
MC Meeting	X			X			X			X		X		
WG 1 Meeting			X	X		X		X		X		X		
WG 2 Meeting			X	X		X		X		X		X		
WG 3 Meeting			X	X		X		X		X		X		
WG 4 Meeting			X	X		X		X		X		X		
WG 5 Meeting			X	X		X		X		X		X		
WG 6 Meeting			X	X		X		X		X		X		
STSM		X	X	X	X	X	X	X	X	X	X	X	X	X
Workshops			X		X			X			X			
Training Schools				X		X			X					
International Conference													X	
Publication of Proceedings														X
Web site set up and maintenance		X	X	X	X	X	X	X	X	X	X	X	X	X

G. ECONOMIC DIMENSION

The following COST countries have actively participated in the preparation of the Action or otherwise indicated their interest: BG, CH, CZ, EE, EL, ES, FI, FR, IT, LT, MK, NL, NO, PL, PT, RO, SE, SI, SK, TR, UK. On the basis of national estimates, the economic dimension of the activities to be carried out under the Action has been estimated at 84 Million € for the total duration of the Action. This estimate is valid under the assumption that all the countries mentioned above but no other countries will participate in the Action. Any departure from this will change the total cost accordingly.

H. DISSEMINATION PLAN

H.1 Who?

Information derived from work within PINESTRENGTH, including data, synthesis and

recommendations of relevance, will be aimed at a wide range of stakeholders and interested parties involved in forest management and, particularly, ecosystem health. Target audiences will, therefore, include:

- Forestry and plant health/quarantine policy makers (including EPPO and NPPOs of EU Member states) and regulators at the local, regional, national and EU levels
- Land owners
- Forest and landscape managers
- Nursery industry
- Forest product industry
- Biotechnology industry, including companies focused on chemical and biological control of plant pathogens
- Scientists from research institutes and universities involved in forest pathology
- Members of the public who utilize and enjoy forest recreation
- Health and landscape benefits

H.2 What?

Dissemination of the findings from PINESTRENGTH will be carried out through a different media as appropriate to each audience, covering the full range of interested parties:

- The PINESTRENGTH website will be regularly updated acting as a primary communication channel with both open and restricted areas for working documents. The website will include background information on the Action and its members, with links to and from other partner institution web sites. Furthermore, the web site will include documentation of Working Group progress reports, state-of-the-art reports, proceedings from workshops, minutes from Management Committee and Working Groups meetings, discussion forums, FAQs, experimental methodologies, field guides,

reference lists of peer reviewed papers and grey literature, and advertisements of upcoming events. Maintenance of databases and relevant outcomes will be ensured beyond project duration by uploading this information to the partner institutional websites.

- Workshops in PINESTRENGTH will enable dialogue between participants and end-users not directly involved in the Action, with emphasis on land owners, forest managers and industry. This debate will contribute to establishing knowledge gaps and the following phases of the Action.
- Non-technical publications, such as illustrated pamphlets on pine pitch canker disease (available as a PDF download from the Action website), in several European languages, will be aimed at raising awareness of the disease and pathways of spread among stakeholders and the general public.
- Scientific findings resulting from collaborations within PINESTRENGTH will be published in peer reviewed journals, scientific books and conference proceedings.
- Final reports, in several European languages, will be aimed at synthesizing the knowledge compiled through conference proceedings/book/peer-reviewed papers in a popular format easily accessible for stakeholders and other interested parties.
- Best practice guidelines for integrated management of *G. circinata* in Europe, including stand management, host selection and control biological methods, will be produced, as will advisory papers for Plant Health Regulation.

H.3 How?

Dissemination of the results from PINESTRENGTH is a priority commitment of the project partners. Hence, PINESTRENGTH will devote a specific WG to establishing a suitable dissemination strategy and supporting other WGs in this task, confirming that progress is timely and establishing the mechanisms needed to address any deviations. An awareness-raising campaign will be launched to highlight the problems and challenges posed by *G. circinata* at different levels.

At each member institution: seminars held in institutions and European Researchers' Night in

order to explain the work to colleagues and ESRs. Technical meetings with stakeholder during the first months of the Action to give an overview to awareness about Pitch Canker Disease and associated problems, and the importance of prevention strategies. Local seminars with Forestry and plant health/quarantine policy makers in outreach from the Action.

Within the COST Action: WG members will be encouraged to present their research results and future plans during WG meetings and other events organized by the COST Action. The PINESTRENGTH website and a mailing list will be used to promote the feedback between researchers. Other means of communication, such as email and Skype, and where required, telephone or video conferencing will also be used.

National and International level: a wide spectrum of tools, including the PINESTRENGTH website, workshops and conferences, scientific publications, pamphlets and non-technical publications in several European languages, will ensure that all target audiences are reached. Other information and communication technologies (ICT) will be also used to increase the impact of the Action.